MWP

Appendix 15A

Aviation Report

Report

Ballycar Wind Farm

Aviation Impact Assessment

& Mitigation Report

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Executive Summary

Ai Bridges Ltd was commissioned by the Environmental Planning Consultants, Malachy Walsh and Partners (hereafter referred to as MWP) to review a consultation response from the Irish Aviation Authority (hereafter referred to as IAA) received in November 2022 in relation to the possible interference impacts of the proposed Ballycar wind farm on the Surveillance Radar equipment at Shannon Airport and Woodcock Hill.

In their response the IAA noted that there was:

> *"… no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections, reflections and shadowing from the proposed turbines…"*

The IAA also noted that:

> *"… the proposed development would introduce false primary targets or clutter on the Shannon Primary radar. Mitigation for the primary clutter would degrade the performance of the Shannon primary radar…"*

Ai Bridges subsequently conducted a full review of all correspondence between MWP and the IAA and recommended a further detailed technical assessment to be carried out by a third party IAA Approved Procedure Designer, Cyrrus Limited, to investigate all possible Mitigation Measure options to remediate the impacts on surveillance radar systems. It was also recommended to engage with the manufacturers of the Surveillance Radar equipment being used by the IAA to confirm if said equipment supported wind farm mitigation features.

The findings from the Mitigation Options Study included the following recommendation that states that the radar technical documentation provides assurance that mitigation for proposed the Ballycar Wind Farm is possible subject to an on-site condition survey to ascertain if updates or upgrades would be required :

> *" … The technical documentation provided by the manufacturer (Thales) of the two systems provides assurance that mitigation for the Ballycar Windfarm is possible. Cyrrus would recommend that an onsite condition survey is carried out by Thales on both the Shannon Airport and Woodcock Hill systems to confirm their current operational state and ascertain whether updates or upgrades would be required …"*

IAA Consultations

1. In January 2022, MWP engaged and submitted a scoping report to the IAA with a request for comments in relation to a proposed wind farm on lands at and near Ballycar, Co. Clare.

2. There were further rounds of consultations in January 2022 with the Airspace and Navigation Team at the IAA where it was highlighted that there are a number of

aviation surfaces under the responsibility of the IAA Air Navigation Service Provider (ANSP) regarding safeguarding around Shannon Airport. These were referred internally within the IAA and the Shannon Airport Operator for further response on potential impacts to the following:

- Navigational Aids
- Surveillance Radar
- Instrument Flight Procedures (IFPs)

The MWP consultation engagements with the IAA from January 2022 to May 2022 served to:

i) Identify the main concerns of the IAA in relation to the potential impacts on aviation surfaces.

ii) Present the findings of the detailed Aviation Technical Assessments to the IAA in relation to Instrument Flight Procedures, showing a ***"No Impact"*** condition.

iii) Present the findings of the detailed Aviation Technical Assessments to the IAA in relation to Navigational/Flight Calibration Impact Assessments , demonstrating a **"No Impact"** condition.

iv) Present the findings of the detailed Aviation Technical Assessments to the IAA in relation to Radar Surveillance including the Primary Surveillance Radar (PSR) at Shannon Airport and the Monopulse Secondary Radar (MSR) at Woodcock Hill, showing a **"Potential Impact"** condition which can be appropriately mitigated.

IAA Consultation Reponses

The IAA has welcomed and accepted the findings presented within the detailed Aviation Technical Assessments and in a consultation response to MWP on February 28th 2022 responded as follows:

1. *In relation to the IFP Opinion (Attachment 1) I'm happy to accept that the proposed turbines will not affect the Shannon Airport Instrument Flight Procedures and nothing further is required from this perspective.*

   Note: If planning is granted and the construction goes ahead, these turbines will need to be notified to the IAA Aviation Safety Regulator, each being higher than 100m elevation.
2. *Technical Assessment Report:*
   - *Building Restricted Areas: SAA's Paul Hennessy copied for information.*
   - *NAVAIDs: The report conforms no issues for Airport NAVAIDs: Fergal Doyle copied to confirm this.*
   - *Surveillance: The report notes that mitigations are required for the Shannon PSR and the Woodcock Hill MSSR most particularly not prevent false targets and ghost signals respectively. While the report outlines how these mitigations could be applied, this must be assessed by our surveillance team*

On November 29th 2022 there was a response from the IAA Surveillance M&E Division following their review of the detailed Technical Assessment Report by Cyrrus. The response stated as follows:

> *"… The IAA Surveillance Domain conclusion is that this proposed Ballycar Wind Farm development, would degrade the performance of the Woodcock Hill Radar. As a consequence the IAA would object to a Ballycar Wind Farm development planning application …"*

Wind Farm Mitigation Measures

It was identified through the consultation process with the IAA that there were no impacts on Instrument Flight Procedures, Navigational Aids or Flight Inspection Procedures and that no mitigation measures were required.

In their detailed technical aviation assessment report Cyrrus, did identify potential surveillance radar impacts stating that:

> " a form of mitigation for Shannon PSR over the proposed Ballycar development may be required … "
>
> " .. It is recommended that mitigation options are discussed with the Irish Aviation Authority (IAA), specifically Air Traffic Services. It is the surveillance network and operational use that will largely influence a suitable mitigation.."

Ai Bridges commissioned Cyrrus to review the possible Mitigation Measures and undertake a Mitigation Options Study Report that would address the ten concerns identified by the IAA in their final consultation response on November 28th 2022. Cyrrus were requested to engage with the manufacturer of the radar equipment in use at Shannon Airport and Woodcock Hill to provide supporting evidence of "wind farm mitigation" features including upgrade availability.

Cyrrus produced a "Mitigations Options Study" report following research conducted over a three-month period with references to other wind farm mitigation projects as well as reliance on data provided by the radar equipment manufacturer. The report addressed all of the IAA concerns on radar performance degradation and provides viable mitigation measures. The report has been provided with supporting evidence of workable mitigation measures with references to third-party Wind Farm Mitigation Projects.

Summary

Following the investigation of the mitigation options along with discussions with the manufacturer of the radar equipment, it has been shown that there are viable options available for the mitigation / remediation of the ten concerns raised by the IAA . The Mitigation Options Study report concludes that:

- The development of the Windfarm at Ballycar would require minimal optimization of the Woodcock Hill and Shannon Airport radars.
- The systems in place have the capacity to provide a service even if a large number of turbines were developed in the coverage area.
- The manufacturer can also provide upgrades and enhancements to both systems should they be required in future.

Sections

Appendices

1. Introduction

Malachy Walsh and Partners (MWP) commissioned an independent aviation assessment in reponse to concerns raised by the IAA in relation to a Scoping Report consultation request in January 2022 concerning the proposed Ballycar Wind Farm development. The IAA raised concerns in relation to:

- Instrument Flight Procedures (IFP) surfaces
- Navigational Aids\ ISL Flight Inspection surfaces
- Surveillance Systems

MWP commenced the consultation process with the IAA in January 2022 with the final response from the IAA being received in November 2022. The consultations and communications are detailed in Appendix A of this report.

A series of technical aviation assessment reports were submitted by MWP to the IAA Air Navigation Service Provider which satisfied the concerns raised in relation to Instrument Flight Procedures detailing that there is no impact to the IFP surfaces. This report, prepared by Cyrrus, is included in Appendix B (Ballycar Wind Farm IFP Opinion). MWP also commissioned FCSL Ltd., a certified flight inspection company retained by the IAA for bi-annual flight inspection services, to prepare a study to assess the impacts on ILS Inspection flights. The study findings reported that there were no impacts to ILS flight inspections. The full details of the report are included in Appendix D (Ballycar Wind Farm Impact on ILS Inspection Report).

MWP commissioned Cyrrus to undertake a further Technical Aviation Assessment Study to assess the impacts of the proposed wind farm development on surveillance radar systems. The study reported that there would be an impact on the surveillance radar and outlined some mitigation options. The IAA Airspace Navigation Team referred the report to their Surveillance M&E Systems Team. A response from the IAA in November in 2022 to MWP noted that the proposed Ballycar Wind Farm development would degrade the performance of the radar at Woodcock Hill and also introduce false targets or clutter on the Shannon Airport primary surveillance radar.

Ai Bridges conducted a full review of all the consultations and the aviation assessment reports and then engaged with Cyrrus to undertake a review of the IAA consultation response and undertake further research into the concerns raised by the IAA. Ai Bridges also requested Cyrrus to engage with the manufacturer to further investigate the capabilities of the radar equipment at Woodcock Hill and Shannon Airport for possible service upgrades and/or feature upgrades to mitigate the impacts. Cyrrus produced a Mitigations Options Study, shown in Appendix E, that addressed each of the concerns raised by the IAA and provided mitigation measure proposals that would allow the development of the Ballycar Wind Farm, without any residual impact on the radar systems.

Sections 1.1 to 1.3 below provides a more detailed description of the concerns raised by the IAA Air Navigation Service Provider in relation to IFP, Navigational Aid surfaces and Surveillance Radar systems.

1.1 Instrument Flight Procedures (IFP)

The Ballycar Wind Farm IFP Opinion Report, in Appendix B, identifies that the proposed wind farm does impact the current published procedures at Shannon airport. This is however limited to the ATC Surveillance Minimum Altitude Chart (ATC SMAC). Although a full IFP assessment is normally required to identify an impact, it is normally recommended to submit the opinion report to the IAA Air Service Navigation Provider for consideration as to whether a full assessment is required. Following a review of the IFP Opinion, the IAA deemed that a full IFP Assessment is not required and that there would be a No Impact condition on IFP surfaces and that no mitigation is required.

Aviation Impact Assessment	Mitigation Measure Action	Residual Impact
Instrument Flight Procedures surfaces	No action	None

1.2 Flight Inspection Procedures

The Ballycar Wind Farm Impact on ILS Inspection Report, in Appendix D shows that there is no impact on the Airport Navigational Aids at Shannon Airport. The IAA requested that an assessment be performed to establish any adverse effect the proposed wind farm may have on flight inspection procedures and profiles associated with the Shannon Airport Runway 24 Instrument Landing System (ILS). This report provides an assessment of the impact of terrain and obstacles on ILS flight inspection procedures. The assessment presented within the report outlines that the flight inspection aircraft flying centreline, part orbit and bottom edge flight profiles associated with the Shannon Airport Runway 24 ILS will remain sufficiently clear of the proposed Ballycar Wind Farm site and therefore there would be no impacts.

Aviation Impact Assessment	Mitigation Measure Action	Residual Impact
Runway 24 ILS Flight Inspection Procedures	No action	None

1.3 Surveillance Radar Systems

The Aviation Technical Assessment, in Appendix C conducted by Cyrrus identified that there would be wind farm impact degradation on the PSR at Shannon Airport which would require some form of mitigation.

Ai Bridges then engaged with Cyrrus, to undertake a Mitigations Options Study, included in Appendix E, that would investigate and address all of the concerns of the IAA in radar performance degradation, false targets and clutter raised by the IAA Surveillance M&E Systems Division.This Mitigations Options Study by Cyrrus provides a constructive technical view on how both the Woodcock Hill **Thales RSM970** Monopulse Secondary Surveillance Radar (MSSR), and the Shannon Airport **Thales STAR 2000** Primary Surveillance Radar (PSR) with co-mounted MSSR can operate without disruption to the controlled airspace and allow the development of Ballycar Windfarm. Below is an extract from this Mitigation Options Study:

"..Cyrrus have engaged with the manufacturer of both radar systems to confirm their capability to operate in the presence of Wind Turbines with minimal intervention. The RSM970 MSSR at Woodcock Hill and STAR 2000 PSR with co-mounted MSSR at Shannon Airport have been developed to allow this capability. The STAR 2000 PSR was designed to work in areas with wind turbines, a continual development cycle has been carried out by Thales to ensure the systems performance is not impacted by Wind Turbines. If required upgrades and enhancements for the STAR 2000 are available. Thales have provided evidence that they are confident that with minor optimisation the proposed wind turbines at Ballycar should have minimal effect on the coverage provided by the radars. This evidence is provided as commercial in confidence. Cyrrus have permission from Thales to reference relevant parts but not provide the Thales documents in full.."

"..Table 1 below highlights the IAAs concerns, and the expected impacts should the windfarm be permitted to be developed. Thales have provided evidence that each of their systems has the capability of handling multiple windfarms within the coverage area. Examples include the Star 2000 sited at Schiphol Airport and the STAR 2000 based at Newcastle. The Aeronautical Information Service (AIS) for Newcastle Airport, Reference [9], has been provided for reference. The UK MoD has contracted NATS / AQUILA under project Marshall to provide a large number of these systems due to their inbuilt capability. Reference [10] gives some detail of project Marshall. Thales have also provided a structured list of upgrades, Reference [6] within the Mitigations Options Study, available to ensure the systems can continue to provide this service into the future.."

1.3.1 IAA Concerns in relation to Surveillance Radar Systems

The IAA have raised ten concerns in relation to impacts on the Surveillance Radar Systems. Each of these concerns is individually addressed below by referencing the evidence-based material identified in the Mitigation Options Study.

1.3.1.1 IAA Concern #1 :

This concern relates to the false returns from deflected targets which are known as FRUIT (False Returns Un-correlated in Time). The Thales Monopulse Secondary Surveillance Radar (MSSR) operated at Woodcock Hill can use one of its own specific inbuilt processing techniques within its Surveillance Data Processor (SDP) to remove these false targets. This technique is used within most MSSR radars and is called a DE-FRUITER.

The Mitigation Measure solution to eliminate the radar beam deflections is highlighted within the radar manufacturer's documentation under section 3.1.3.1.1 of Reference [3] in the Mitigation Options Study and is shown in Figure 1 below.

3.1.3.1.1 MSSR/Mode S beam management

The MRP_SBM function manages all activities that must be performed within the main beam of the antenna and regulates the use of the RF channel. Its main functions are the followings:

- it prepares all information necessary to process All-Call and Roll-Call periods,
- it processes all SSR and Mode S replies received during All-Call periods,
- it manages the real-time scheduling of Mode S surveillance and data link transactions within the Roll-Call periods.

The MRP_SBM function is composed of the following sub-functions:

- Mode S Modulator and eXtractor Control (SBM_MMXC), which manages the interface between MRP CSCI and MMXC,
- Roll Call Period Processing (SBM_RCPP), which manages activities within the Roll Call periods,
- Mode S All Call Period Processing (SBM_MACPP), which manages Mode S activities within the All Call periods,
- SSR All Call Period Processing (SBM_SACPP), which manages SSR activities within the All Call periods. It includes the defruitor function.

Figure 1: Evidence of the Mitigation Measure Solution for Radar beam deflections

Additional supporting evidence within the radar manufacturer's documentation in relation to the concern of false returns is highlighted in Figure 2 below from the radar manufacturer's documentation in section 1.3.1 of Reference [3] in the Mitigation Options Study :

1.3.1 General

The RSM 970S Mode S ensures a high quality and reliable coverage to contribute to radar operational separation of 3 NM, 5 NM and 10 NM according to EUROCONTROL standard.

The radar is capable of determining range, azimuth and height positional data, along with the identity, on each target detected, during each revolution of the antenna.

Since the MSSR systems are used in an environment which often includes multiple SSR coverage, the system has been designed in order to cope with a high fruit density (MSSR and/or Mode S fruit). Therefore, the performance will be optimised such that the output of the false data is minimised, while meeting the guaranteed parameters.

The MSSR RSM 970 S Mode S is designed to meet all the guaranteed performance in the presence of a fruit rate of 11,000 replies per second.

The performance of the RSM 970 S MODE S equipment have been confirmed through the various fields and validated by Eurocontrol and French DSNA in the frame of the POEMS pre-operational European Mode S programme. Significant breakthroughs have been achieved in the fields of:

- Discrimination,
- Phantom processing,
- Reflection processing.

Typical performance characteristics are summarised below :

GENERAL	
Modes	1; 2; 3/A; C; S
Output transmitter peak power	2570 W
Transmitter frequency	1030 ± 0.01 MHz
Range	Up to 256 NM
Scan rate	Up to 15 rpm
Antenna:	
- Azimuth beamwidth	2.4°
- Maximum gain	27 dBi
Fruit density	11,000 fruit/sec in the main lobe

Figure 2: Evidence of the Mitigation Measure Solution for Radar beam deflections

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below. Based on the inbuilt DE-FRUITER capability of the MSSR, no residual impact is envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
1	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. **Reference 3 –3.1.3.1.1**Thales description of how the system automatically deals with deflections (FRUIT).	None

1.3.1.2 IAA Concern #2 :

This concern relates to the reflections that will caused by the proposed turbines. The Surveillance Data Processor (SDP) in Thales RSM970 Monopulse Secondary Surveillance Radar (MSSR) can use a two-stage reflection removal process to eliminate this problem of reflections.

The Mitigation Measure solution to eliminate the radar beam deflections is highlighted within the radar manufacturer's documentation under section 1.2.2.3 of Reference [3] in the Mitigation Options Study and is shown in Figure 3 below.

1.2.2.3 Signal and Data Processor

The signal and data processing chain performs:

1. MSSR/Mode S Processor (MMXC)
   - MSSR/Mode S scheduling,
   - MSSR/Mode S signal processing,
2. Data Processor Computer (DPC)
   - MSSR/Mode S extractor and
   - PSR/MSSR/Mode S plot combination and tracking.

The MMXC and DPC cope with garbling situations in dense surveillance areas. The Off Boresight Angle measure on each code pulse is associated to the reply message with specific flags and is routed to the monopulse post-processing. The monopulse post-processing performs plot extraction and solves conflict conditions such as garbling, phantoms, saturated presences and specifically processes emergency and distress codes.

Reflections which are common phenomena in SSR systems, are detected and processed using the monopulse information. This reflection may be found either at track level or at plot level. At track level, this function is based on an auto-adaptive process : the reflections are identified as permanent or temporary. This Thales unique feature provides automatic site environment adaptation. At plot level (prior to scan-to-scan correlation), the site environment is taken into account by windows programming.

Figure 3: Evidence of the Mitigation Measure Solution for reflections

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting the Concern versus Residual Impact condition. Based on the inbuilt two stage reflection processing capability to eliminate reflections, no residual impact is envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
2	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar reflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None

1.3.1.3 IAA Concern #3 :

This concern relates to the volumes of the Woodcock Hill MSSR shadow regions that may be created by the proposed turbines. The concern relating to shadowing has been addressed within the Aviation Technical Assessment Report prepared by Cyrrus which concluded that the effects of shadowing would be minimal and should be operational tolerable.

As shadowing from the proposed wind farm development at Ballycar will be below the Air Traffic Control (ATC) surveillance minimum altitudes and should be operationally tolerable then no Mitigation Measure solutions are required. This is addressed under section 5.9.5 of Reference [1], the CL-5715-RPT-002 V1.0 Ballycar Wind Farm Aviation Technical Assessment, and is shown in Figure 4 below

5.9.5. The maximum heights of shadow regions from the turbines will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable.

Figure 4: Evidence showing Shadowing is operationally tolerable

Further evidence from Reference [1], sections 5.8.24 – 5.8.28 as shown below in Figure 5, provides the technical calculation of the shadow regions based on the EUROCONTROL Guidelines. The volumes of the shadow regions created by each of the turbines have been calculated and tabulated. In the Aviation Technical Assessment, the proposed turbines have been overlaid on the Air Traffic Control Surveillance Minimum Altitude Chart (ATC SMAC) with a maximum height of 352m or 1,155 feet AMSL for turbine T1 which is located within Sector 1 where the minimum altitude is 2,300 feet AMSL . Also, turbines T11 and T12 are in Sector 2 where the minimum altitude is 3,000 feet AMSL . Any aircraft flying at these minimum altitudes will not be flying low enough to be impacted by the shadow regions of the turbines and therefore the shadow regions should be operationally tolerable

5.8.24. An array of turbines can create a radar shadow in the space beyond it from the radar. The EUROCONTROL Guidelines provides a means of calculating the dimensions of this shadow region.

$$Dwr = Dtw/[\lambda.\frac{Dtw}{S^2}\left(1-\sqrt{PL}\right)^2 - 1]$$

- *Dwr* = depth of the shadow region.
- *Dtw* = distance of turbines
- λ = wavelength (0.29m)
- S = diameter of support structures (6m)
- PL = acceptable power loss (0.5/3dB as per guidelines)

5.8.25. The EUROCONTROL Guidelines also provide equations for calculating the width and height of the shadow regions.

5.8.26. The volumes of the Woodcock Hill MSSR shadow regions created by each of the Ballycar turbines are shown in Table 7.

5.8.27. The depth of the shadow regions beyond the Ballycar turbines will vary between 2.3km and 3.6km for Woodcock Hill MSSR, with widths of up to 65m and with a maximum height of 352m or 1,155 feet AMSL.

5.8.28. Figure 26 shows an extract of Shannon Airport's ATC Surveillance Minimum Altitude Chart, as published by the Irish Aviation Authority in the current Integrated Aeronautical Information Publication[5]. The Ballycar turbine locations are overlaid on the chart, which shows that turbines T1 to T10 are within Sector 1 where the minimum altitude is 2,300 feet AMSL. Turbines T11 and T12 are in Sector 2 where the minimum altitude is 3,000 feet AMSL. Aircraft at these minimum altitudes will not be low enough for the shadow regions to have any impact, and therefore the shadow regions that may be generated beyond the proposed turbines should be operationally tolerable.

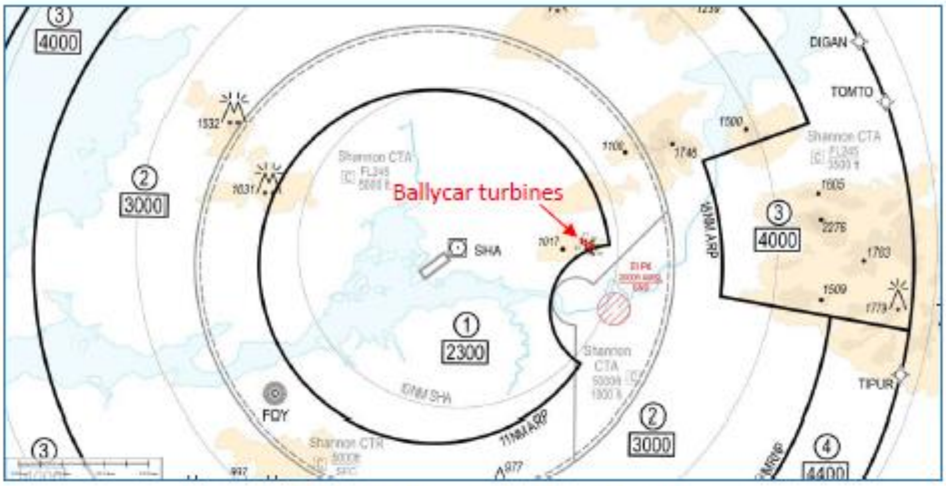

Figure 26: Shannon Airport ATC Surveillance Minimum Altitude Chart

Figure 5: Calculation of the shadow regions

The Concern versus Residual Impact condition has been extracted from Table 1 of the Mitigation Options Study showing no Mitigation Measure Solution is required as the shadowing from the proposed Ballycar windfarm will be below the published ATC SMAC altitudes and should therefore be operationally tolerable. The effect of shadowing will be minimal and of no consequence to Air Traffic Control, therefore there is no residual impact.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
3	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar shadowing from the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. **Reference 1 – 5.9.5**	None

1.3.1.4 IAA Concern #4 :

This concern relates to the false primary targets or clutter on the Primary Radar (Thales STAR 2000) at Shannon Airport. To address the concern relating to clutter, the Mitigation Options Study by Cyrrus concluded that the effects of shadowing would be minimal and should be operational tolerable. The STAR 2000 radar is quite advanced with a number of existing in-built capabilities for mitigating the effects of wind turbines. The STAR 2000 is an S-band solid-state approach radar. The current data sheet, Reference [2] of the Mitigation Options Study, for the STAR 2000 radar addresses wind farm mitigation:

> *"Windfarms: dedicated impact studies and implementation of optimal mitigation, among a large panel of solutions"*

Thales, as stated on its website, offers upgrades for its radars including a feature enabling a proper windfarm mitigation. The Windfarm Filter is a dedicated algorithm that uses a specific adaptive Constant False Alarm Rate (CFAR) mechanism designed to minimize track loss and reduce false alarms above and around windfarms. It can be integrated to address both civil and military needs and, as a software capability, can also be activated into other Thales ATC radars already in service. Based on the fact that the Thales STAR 2000 uses an advanced SDP to prevent wind turbines causing clutter to be displayed on the controllers display and the availability of the Windfarm Filter upgrade , no residual impact is envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
4	*Ballycar Wind Farm development would introduce false primary targets or clutter on the Shannon Primary radar*	Thales STAR 2000 uses an advanced SDP to prevent wind turbines causing clutter to be displayed on the controllers display. Windfarms : dedicated impact studies and implementation of optimal mitigation, among a large panel of solutions **Reference 2**	None

1.3.1.5 IAA Concern #5 :

This concern relates to the possible performance degradation of the PSR radar at Shannon Airport that may occur if mitigation measures for the impact of primary radar clutter were to be implemented.

The Thales STAR 2000 was designed to work in areas of wind farms without degradation of coverage. The Thales STAR 2000 would be able to process out the clutter by the processing capability of the Surveillance Data Processor (SDP). In the Mitigation Option Study prepared by Cyrrus, Reference [6], they highlight that Thales can provide upgrade options. The STAR 2000 has the processing capabilities to deal with wind turbines to ensure that the radar system performance is not impacted.

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting that the Surveillance Data Processor (SDP) within the existing Shannon Airport Primary radar together with minimal optimisation will result in minimal impact, and therefore no significant residual impact is envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
5	*Mitigation for the primary clutter would degrade the performance of the Shannon primary radar*	Thales STAR 2000 was designed to work in areas with wind turbines without degradation of coverage. If required upgrade options are available from Thales. A list of upgrade options has been provided. **Reference 6**	None

1.3.1.6 IAA Concern #6 :

This concern states that a non-mitigation approach relating to clutter would be operationally un-acceptable for Air Traffic Control.

The STAR 2000 would be able to process out the clutter by the Surveillance Data Processor. In the Mitigation Option Study prepared by Cyrrus, Reference [6], they highlight that Thales can provide upgrade options. The STAR 2000 has the processing capabilities to deal with wind turbines to ensure that the radar system performance is not impacted.

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting that the clutter would be processed out by the Surveillance Data Processor (SDP) in the STAR 2000 radar and upgrade options are available if required to mitigate out clutter impacts and therefore no significant residual impact is envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
6	*Not mitigating for the clutter would be operationally unacceptable and unsafe for Air traffic control*	Clutter would be processed out by the Thales STAR 2000 SDP. If required upgrade options are available from Thales. A list of upgrade options has been provided. **Reference 6**	None

1.3.1.7 IAA Concern #7 :

This concern relates to a maintenance service outage that may be required to mitigate reflections. A significant outage period would not be acceptable to the IAA and would compromise the safety of Air Traffic in Irish airspace.

The Thales RSM970 MMSR radar at Woodcock Hill has inbuilt two-stage processing to eliminate reflections and the radar would not have to be taken out of service for any significant period if optimisation was carried out. Only minor optimization would be required and Thales have completed successful upgrades based on a proven upgrade plan which would not require any operational downtime of the radar. In the Mitigation Option Study prepared by Cyrrus they conclude in Figure 6 below that :

> The development of the Windfarm at Ballycar would require minimal optimisation of the Woodcock Hill and Shannon Airport radars. The systems in place have the capacity to provide a service even if a large number of turbines were developed in the coverage area. Thales can also provide upgrades and enhancements to both systems should they be required in future.

Figure 6: Minimal Optimization Requirement

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting that the existing Woodcock Hill RSM970 MSSR radar will use its inbuilt two stage reflection processing to eliminate against reflections. Therefore, the radar would not be taken out of service for a significant period. The radar in question has a modular architecture and in the event that upgrades are required any downtime would be minimal. As Thales have completed many projects involving similar upgrades they have upgrade implementation plans to allow radars to remain operational throughout. Based on the inbuilt capabilities and potentially minor optimisation, a residual impact is not envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
7	*Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace.*	The Woodcock Hill radar would not require to be taken out of service for any significant periods. Only minor optimisation should be required. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None

1.3.1.7 IAA Concern #8 :

This concern relates to the potential that radar reflection mitigations may be bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.

The Thales RSM970 MMSR radar at Woodcock Hill has inbuilt two-stage processing to eliminate reflections.

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting that the Surveillance Data Processor (SDP) within the existing radars will mitigate against reflections. Based on the inbuilt capabilities, a residual impact is not envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
8	*Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.*	This is not correct. The radars SDP will still mitigate against reflections. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None

1.3.1.7 IAA Concern #9 :

This concern relates to the possible reduction of radar coverage and the scale of the non-initialisation area that would be required to mitigate deflections generated by the proposed wind turbines, with a reduction in radar performance below mandated requirements.

In the Mitigation Options Study, Cyrrus investigated the processing used to prevent deflected targets being displayed. The false returns from deflected targets are known as False Returns Uncorrelated in Time (FRUIT). The Surveillance Data Processor (SDP) within the Woodcock Hill MSSR will use a DE-FRUITER to remove these false targets. This technique is used in most MSSR systems.

Any deflections generated by the proposed wind turbines will be eliminated by the DE-FRUITER and a non-initialisation area should not be required. The Thales RSM970 MSSR radar at Woodcock Hill has an inbuilt DE-FRUITER to eliminate deflected targets. The Mitigation Options Study highlights, in Reference [3], the manufacturer's description of how the Woodcock Hill radar surveillance system automatically deals with deflections (FRUIT) as part of the MSSR/Mode S beam management of the Radar Processing hardware function (shown below in Figure 7).

3.1.3.1.1 MSSR/Mode S beam management

The MRP_SBM function manages all activities that must be performed within the main beam of the antenna and regulates the use of the RF channel. Its main functions are the followings:

- it prepares all information necessary to process All-Call and Roll-Call periods,
- it processes all SSR and Mode S replies received during All-Call periods,
- it manages the real-time scheduling of Mode S surveillance and data link transactions within the Roll-Call periods.

The MRP_SBM function is composed of the following sub-functions:

- Mode S Modulator and eXtractor Control (SBM_MMXC), which manages the interface between MRP CSCI and MMXC,
- Roll Call Period Processing (SBM_RCPP), which manages activities within the Roll Call periods,
- Mode S All Call Period Processing (SBM_MACPP), which manages Mode S activities within the All Call periods,
- SSR All Call Period Processing (SBM_SACPP), which manages SSR activities within the All Call periods. It includes the defruitor function.

Figure 7: MSSR/Mode S beam management DE-FRUITER function.

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting that the Surveillance Data Processor (SDP) within the existing Woodcock Hill MSSR radar will use a DE-FRUITER to mitigate deflected targets. Based on this inbuilt capability, no residual impact in envisaged in relation to a reduction in radar coverage and performance below mandated requirements.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
9	*Due to the proximity of the proposed Ballycar wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Ballycar generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements*	This is not correct, any deflections generated by the Ballycar wind turbines will be eliminated by the DE-FRUITER. A non-initialisation area should not be required. Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. **Reference 3 – 3.1.3.1**.**1**, Thales description of how the system automatically deals with deflections (FRUIT).	None

1.3.1.7 IAA Concern #10 :

This concern relates to the volumes of the Woodcock Hill MSSR shadow regions that may be created by the proposed turbines. The concern relating to shadowing has been addressed within the Aviation Technical Assessment Report prepared by Cyrrus which concluded that the effects of shadowing would be minimal and should be operational tolerable.

As shadowing from the proposed wind farm development at Ballycar will be below the Air Traffic Control (ATC) surveillance minimum altitudes and should be operationally tolerable then no Mitigation Measure solutions are required. This is addressed under section 5.9.5 of Reference [1], the CL-5715-RPT-002 V1.0 Ballycar Wind Farm Aviation Technical Assessment, and is shown in Figure 8 below.

5.9.5. The maximum heights of shadow regions from the turbines will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable.

Figure 8: Evidence showing Shadowing is operationally tolerable

Further evidence from Reference [1], sections 5.8.24 – 5.8.28 as shown below, provides the technical calculation of the shadow regions based on the EUROCONTROL Guidelines. The volumes of the shadow regions created by the proposed turbines have been calculated and tabulated. In the Aviation Technical Assessment, the proposed turbines have been overlaid on the Air Traffic Control Surveillance Minimum Altitude Chart (ATC SMAC) with a maximum height of 352m or 1,155 feet AMSL for turbine T1 which is located within Sector 1 where the minimum altitude of 2,300 feet. Also, turbines T11 and T12 are in Sector 2 where the minimum altitude is 3,000 feet for this sector. These minimum altitudes for each of these sectors can be seen below in the ATC Surveillance Minimum Altitude Chart excerpt in Figure 9 below. Any aircraft flying at these minimum altitudes within these sectors will not be flying low enough to be impacted by the shadow regions of the turbines and therefore the shadow regions should be operationally tolerable. The calculation methods are shown below in Figure 9 below.

5.8.24. An array of turbines can create a radar shadow in the space beyond it from the radar. The EUROCONTROL Guidelines provides a means of calculating the dimensions of this shadow region.

$$Dwr = Dtw/[\lambda.\frac{Dtw}{S^2}(1-\sqrt{PL})^2 - 1]$$

- *Dwr* = depth of the shadow region.
- *Dtw* = distance of turbines
- λ = wavelength (0.29m)
- S = diameter of support structures (6m)
- PL = acceptable power loss (0.5/3dB as per guidelines)

5.8.25. The EUROCONTROL Guidelines also provide equations for calculating the width and height of the shadow regions.

5.8.26. The volumes of the Woodcock Hill MSSR shadow regions created by each of the Ballycar turbines are shown in Table 7.

5.8.27. The depth of the shadow regions beyond the Ballycar turbines will vary between 2.3km and 3.6km for Woodcock Hill MSSR, with widths of up to 65m and with a maximum height of 352m or 1,155 feet AMSL.

5.8.28. Figure 26 shows an extract of Shannon Airport's ATC Surveillance Minimum Altitude Chart, as published by the Irish Aviation Authority in the current Integrated Aeronautical Information Publication[5]. The Ballycar turbine locations are overlaid on the chart, which shows that turbines T1 to T10 are within Sector 1 where the minimum altitude is 2,300 feet AMSL. Turbines T11 and T12 are in Sector 2 where the minimum altitude is 3,000 feet AMSL. Aircraft at these minimum altitudes will not be low enough for the shadow regions to have any impact, and therefore the shadow regions that may be generated beyond the proposed turbines should be operationally tolerable.

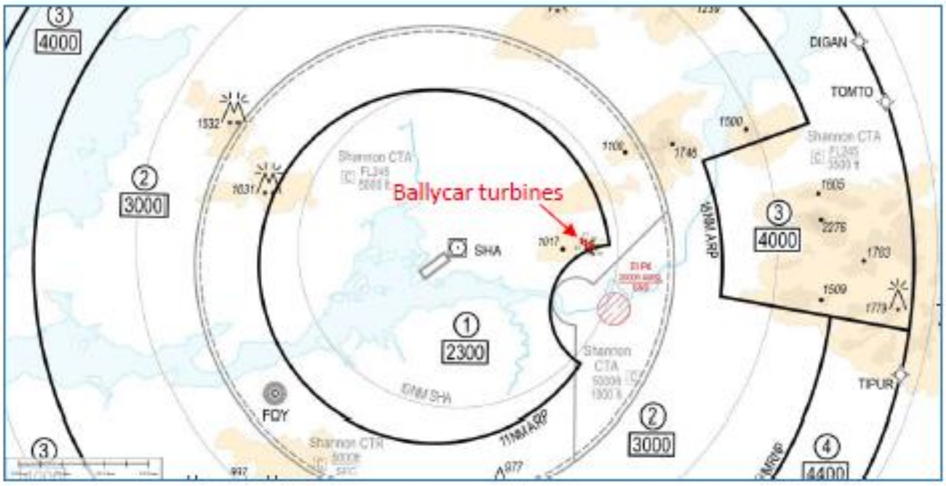

Figure 26: Shannon Airport ATC Surveillance Minimum Altitude Chart

Figure 9: Calculation of the Shadow Regions

The Concern versus Residual Impact condition has been extracted from Table 1 of the Mitigation Options Study showing no Mitigation Measure Solution is required as the shadowing from the proposed Ballycar windfarm will be below the published ATC SMAC altitudes and should therefore be operationally tolerable. The effect of shadowing will be minimal and of no consequence to Air Traffic Control and therefore, there is no residual impact.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
10	*Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. **Reference 1 – 5.9.5**	None

2. Summary

Table 1 (taken from the Mitigation Options Study) shows the concerns raised by the IAA and the likely impact on the Woodcock Hill and Shannon Airport systems. Based on the below it is apparent that the proposed Ballycar wind farm will not result in any residual impact on the systems due to the inbuilt systems capabilities and minor optimisation opportunities.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
1	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. **Reference 3 – 3.1.3.1.1,** Thales description of how the system automatically deals with deflections (FRUIT).	None
2	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar reflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None
3	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar shadowing from the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. **Reference 1 – 5.9.5**	None
4	*Ballycar Wind Farm development would introduce false primary targets or clutter on the Shannon Primary radar*	Thales STAR 2000 uses an advanced SDP to prevent wind turbines causing clutter to be displayed on the controllers display. Windfarms: dedicated impact studies and implementation of optimal mitigation, among a large panel of solutions **Reference 2**	None
5	*Mitigation for the primary clutter would degrade the performance of the Shannon primary radar*	Thales STAR 2000 was designed to work in areas with wind turbines without degradation of coverage. If required upgrade options are available from Thales. A list of upgrade options has been provided. **Reference 6**	None
6	*Not mitigating for the clutter would be operationally unacceptable and unsafe for Air traffic control*	Clutter would be processed out by the Thales STAR 2000 SDP. If required upgrade options are available from Thales. A list of upgrade options has been provided. **Reference 6**	None
7	*Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace.*	The Woodcock Hill radar would not require to be taken out of service for any significant periods. Only minor optimisation should be required. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None
8	*Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.*	This is not correct. The radars SDP will still mitigate against reflections. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None
9	*Due to the proximity of the proposed Ballycar wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Ballycar generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements*	This is not correct, any deflections generated by the Ballycar wind turbines will be eliminated by the DE-FRUITER. A non-initialisation area should not be required. Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. **Reference 3 – 3.1.3.1.1**, Thales description of how the system automatically deals with deflections (FRUIT).	None
10	*Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. **Reference 1 – 5.9.5**	None

Table 1: IAA Concerns v Residual Impact

3. Recommendations

From the findings of the Mitigations Options Study Report prepared by Cyrrus the following recommendations have been made to remediate the concerns raised by the IAA ANSP in relation to surveillance radar impacts on the Woodcock Hill MSSR and the Shannon Airport PSR. Below is an extract from this Mitigation Options Study:

i) The technical documentation provided by the manufacturer (Thales) of the two systems provides assurance that mitigation for the Ballycar Windfarm is possible. Cyrrus would recommend that an onsite condition survey is carried out by Thales on both the Shannon Airport and Woodcock Hill systems to confirm their current operational state and ascertain whether updates or upgrades would be required.

ii) A limited operational flight trial may also be prudent at this stage to provide a baseline of the current systems coverage over the area of the proposed Windfarm.

iii) Once the windfarm is built, the systems may require minor optimisation by Thales. Once completed, a further Flight Check would be recommended to confirm the systems performance was acceptable over the Windfarm area

Appendix A – IAA Consultations

APPENDIX A - IAA Consultations

The consultations between Malachy Walsh & Partners (MWP) and the Irish Aviation Authority (IAA) in relation to Ballycar wind farm are presented below.

IAA Email to MWP - 05 January 2022

From: *O'LEARY Geraldine <Geraldine.O'LEARY@IAA.ie>*
Sent: *Wednesday 5 January 2022 14:04*
Subject: *Proposed Ballycar Wind Farm [Filed 07 Jan 2022 11:03]*

Dear Mr. Barry,

Thank you for your letter and scoping report and request for comments in relation to a proposed wind farm on lands at and near Ballycar, Co. Clare.

As the blade tip height proposed is not included, nor specific turbine positions and the ground elevation of each site is not provided, Safety Regulation Division - Aerodromes cannot make any specific comments at this time.

The development appears to be approximately 16km East of Shannon Airport, as such, the applicant should engage with Shannon Airport Authority and the IAA's Air Navigation Service Provider (ANSP) as a matter of urgency to undertake a preliminary screening assessment to confirm that the proposed wind farm and the associated cranes that would be utilised during its construction would have no impact on instrument flight procedures, communication and navigation aids or flight checking at Shannon Airport. Contact details are as below:

Aerodrome Operator – Shannon Airport:	IAA-ANSP:	Shannon Tower Business Unit
Mr. Paul Hennessy Safety Compliance and Environment Manager Shannon Airport Authority DAC t: +353-61-712471 m: +87-2382453 e: paul.hennessy@shannonairport.ie	Mr. Cathal Mac Criostail Airspace & Navigation Manager Údarás Eitlíochta na hÉireann / Irish Aviation Authority The Times Building, 11-12 D'Olier Street, Dublin 2, D02 T449, Ireland cathal.maccriostail@iaa.ie +353 (0)1 6031173 +353 (0)86 0527130	Mr. Jonathan Byrne Operations Manager STBU/CTBU Air Traffic Control Irish Aviation Authority jonathan.byrne@iaa.ie +353 61 703704 +353 87 9375486

Subject to any study noting a potential impact on the safety of operations at Shannon Airport, during the formal planning process, the Safety Regulation Division – Aerodromes would likely make the following general observation:

In the event of planning consent being granted, the applicant should be conditioned to contact the Irish Aviation Authority to: (1) agree an aeronautical obstacle warning light scheme for the wind farm development, (2) provide as-constructed coordinates in WGS84 format together with ground and tip height elevations at each wind turbine location and (3) notify the Authority of intention to commence crane operations with at least 30 days prior notification of their erection.

Yours sincerely

Deirdre Forrest
Corporate Affairs

MWP Email to IAA - 13 January 2022

From: *Peter Barry <Peter.Barry@mwp.ie>*
Sent: *Thursday 13 January 2022 10:35*
Subject: *RE: Proposed Ballycar Wind Farm*

Hi Geraldine,

Please find attached the turbine coordinates, hub height, rotor diameter and ground elevation as requested (email thread below).

If you need any more information, please let me know.
I would appreciate if you would acknowledge receipt of this email.

Peter Barry
BSc MSc CEnv
Principal Environmental Scientist

IAA Email to MWP - 13 January 2022

From: *MACCRIOSTAIL Cathal <Cathal.MacCriostail@IAA.ie>*
Sent: *Thursday 13 January 2022 13:41*
Subject: *220112 Proposed Ballycar Wind Farm*
Importance: *High*

Dear Peter,

Happy New Year and many thanks for the data supplied in the attached file.

There are a number of surfaces that the IAA Air Navigation Service Provider (ANSP) are responsible for safeguarding around Shannon Airport, including Navigation Aids, Surveillance Radar and Instrument Flight Procedures (IFPs).

In regard to the IFP surfaces, I am responsible for safeguarding here and we have a safeguarding grid to guide as to whether there is a potential impact on the IFP surfaces, generated by new obstacles, such as the proposed (12) wind turbines.

Below is a depiction of this safeguarding grid with a pin at Ballycar:

The values each grid cell represent an Above Mean Sea Level (AMSL: Site elevation + Height of obstacle) elevation value, above which, an IFP impact assessment will be required. In the case of the Ballycar area and taking the highest turbine height supplied, 254m added to an approximate site elevation of 240m, gives an AMSL elevation of in excess of 400m, which is above the safeguarding values in this area.

Separately, the heights proposed will likely impact the Surveillance Radar at Woodcock Hill and navigation aids for approaches to Shannon Airport. I've copied colleagues from the ANSP in these areas, for information.

This is not the only wind turbine proposal for this area and to be completely upfront, nearly all are creating issues for the surfaces referenced.

If you could supply confirmation of the AMSL elevations of the turbines and give co-ordinates in WGS 84 format (Latitude and Longitude), this would be appreciated and will allow me to give greater clarity on requirements for the ANSP and indeed SAA. If I have picked up on information incorrectly, please do correct me.

Kind regards,

Cathal
Cathal Mac Criostail
Údarás Eitlíochta na hÉireann / Irish Aviation Authority

MWP Email to IAA - 13 January 2022

From: *Peter Barry <Peter.Barry@mwp.ie>*
Sent: *Thursday 13 January 2022 15:16*
Subject: *RE: 220112 Proposed Ballycar Wind Farm*

Hi Cathal,

Attached table with Lat/ Long coordinates included. Also, to clarify the column rotor diameter was labelled wrong in the earlier table I emailed, it should have been labelled blade length, rotor diameter is then double. Corrected table attached with AMSL as requested.

We are happy to discuss findings once you have had a chance to carry out your internal studies. We are still in the design and assessment stage. Let me know if I can do anything else.

Peter

IAA Email to MWP - 14 January 2022

From: *MACCRIOSTAIL Cathal <Cathal.MacCriostail@IAA.ie>*
Sent: *Monday 14 February 2022 17:44*
Subject: *220214 Proposed Ballycar Wind Farm ANSP Update*
Importance: *High*

Dear Peter,

Many thanks for the email and the attached detailed outline of the proposed Turbine co-ordinates and AMSL elevations. Thanks also for the phone-call by way of reminder on this.

As I outlined there are three areas of concern for us the IAA Air Navigation Service Provider:

1. ***Instrument Flight Procedures (IFPs) surfaces:*** *Below is a Google Earth outline of the turbines with our IFP safeguarding girds overlayed:*

As you can see the guide (IFP) elevation which does not affect the IFPs, is exceeded for many of the proposed turbines. This does not mean that this is not acceptable. It does however require an IF assessment to be carried out by a certified IFP designer to assess possible impacts. When you're ready to engage on this I can advise on which companies are certified for this work. The result should confirm no impact, or recommend mitigations, e.g. lowering of some turbines elevations possibly

2. ***Navigation Aids:*** *The nearest turbine proposed is c. 16.5 km from Shannon Airport and as such should be outside area of concern for our ground-based navigation aids. This may need to be confirmed by the company who carry out flight checking if these systems. Fergal Arthurs and Fergal Doyle, Could you review and provide an opinion please?*

3. ***Surveillance:*** *The turbines as proposed are close to our surveillance systems at Woodcock Hill and will need to be considered for an effect on these systems. Attached is some guidance material and I'll refer this element to my colleague Charlie O'Loughlin for a view on this.*

If you are proceeding to planning application, could you advise all copied please and we can assess where we are at that point?

I hope this all makes sense.

Kind regards,
Cathal

Cathal Mac Criostail
Údarás Eitlíochta na hÉireann / Irish Aviation Authority

MWP Email to IAA – 25 February 2022

From: *Peter Barry <Peter.Barry@mwp.ie>*
Sent: *Friday 25 February 2022 14:47*
Subject: *RE: 220214 Proposed Ballycar Wind Farm ANSP Update*

Hi Cathal,

Thank you for below. We are proceeding with the application.

I attached a couple of reports which we commissioned by Cyrrus. You might review and we could discuss the findings and recommended mitigation. There have been a couple of iterations of the layout since, but the mitigation measures should be the same.

Do we need to have a meeting to discuss the attached?

IAA Email to MWP - 28 February 2022

From: *MACCRIOSTAIL Cathal <Cathal.MacCriostail@IAA.ie>*
Sent: *Monday 28 February 2022 12:50*
Subject: *220228 Proposed Ballycar Wind Farm ANSP Update (2)*
Importance: *High*

Dear Peter,

Many thanks for the attached reports.

1. *In relation to the IFP Opinion (Attachment 1) I'm happy to accept that the proposed turbines will not affect the Shannon Airport Instrument Flight Procedures and nothing further is required from this perspective.*

   Note: If planning is granted and the construction goes ahead, these turbines will need to be notified to the IAA Aviation Safety Regulator, each being higher than 100m elevation

2. *Technical Assessment Report:*

   - *Building Restricted Areas: SAA's Paul Hennessy copied for information*
   - *NAVAIDs: The report conforms no issues for Airport NAVAIDs: Fergal Doyle copied to confirm this*
   - ***Surveillance:*** *The report notes that mitigations are required for the Shannon PSR and the Woodcock Hill MSSR most particularly not prevent false targets and ghost signals respectively. While the report outlines how these mitigations could be applied, this must be assessed by our surveillance team (Charlie O'Loughlin and his team copied).*

This last item will be the main issue for then IAA ANSP in my experience. This proposed development is one of multiple application in the same general area which is all cases is leading to an assessment of Surveillance impacts. While in isolation "filtering" of PSR and /or updates to the reflector file for Woodcock Hill MSSR may seem straightforward, it may be of significant cost to the ANSP and if required for multiple developments, lead to a realistically unusable radar system for aircraft targets between 3500 and 10000 feet, which would be the altitude band serving Shannon Airport. Added to this, such system upgrades have not been planned for in the Surveillance work programme.

I suggest that Charlie and his team will need to assess and revert with their position. Please follow up with me in a week's time and I'll in turn check with Surveillance.

Best regards,
Cathal

Cathal Mac Criostail
Údarás Eitlíochta na hÉireann / Irish Aviation Authority

MWP Email to IAA – 09 March 2022

From: *Peter Barry <Peter.Barry@mwp.ie>*
Sent: *Wednesday 9 March 2022 09:46*
Subject: *RE: 220228 Proposed Ballycar Wind Farm ANSP Update (2)*

Hi Cathal,

Just following up on below, as you advised.

FYI, I have emailed FCSL and am waiting to hear back.

IAA Email to MWP - 09 March 2022

From: *MACCRIOSTAIL Cathal <Cathal.MacCriostail@IAA.ie>*
Sent: *09 March 2022 10:28*
Subject: *RE: 220228 Proposed Ballycar Wind Farm ANSP Update (2)*

Many thanks for all this Peter.

I appreciate your proactive engagement on this.

Kind regards,

Cathal

Cathal Mac Criostail
Údarás Eitlíochta na hÉireann / Irish Aviation Authority

IAA Email to MWP - 29 November 2022

From: *OLOUGHLIN Charlie <Charlie.OLOUGHLIN@IAA.ie>*
Sent: *Tuesday 29 November 2022 13:47*
Subject: *[Pending]RE: 220516 Proposed Ballycar Wind Farm ANSP Update-Surveillance Request*

Hi Peter,

My apologies for not replying to you sooner with a response from the IAA's Surveillance Domain in relation to the proposed Ballycar Wind Farm and our review of the Cyrrus Technical Assessment Report.
We assessed the Cyrrus report back in the summer but neglected to close the circle by replying with our comments and conclusions.

Our assessment is that the proposed Ballycar Wind Farm development would introduce Woodcock hill radar reflections, deflections and shadowing.

The IAA Surveillance Domain conclusion is that this proposed Ballycar Wind Farm development, would degrade the performance of the Woodcock Hill Radar.

As a consequence the IAA would object to a Ballycar Wind Farm development planning application.

I have outlined below a brief summary of Woodcock Hill radar impact concern. Reflections and shadowing are also identified in the CYRRUS report but the deflection issue is not.

IAA Radars must now meet EU mandated (EU 1207/2011) performance criteria in order to support 5 nautical Mile separation of aircraft in IAA airspace. Radar performance is assessed on an ongoing periodic basis as well as prior to implementation of any Radar configuration change. From our assessment Woodcock hill radar, without mitigation would not meet the mandated surveillance performance required relating to False Target reports and positional accuracy. The implementation of mitigations for the false target reports will compromise the radars probability of detection requirements and the testing of the mitigations will compromise our availability requirements. We believe there are no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections, reflections and shadowing from the proposed turbines.
We also note the proposed Ballycar Wind Farm development would introduce false primary targets or clutter on the Shannon Primary radar. Mitigation for the primary clutter would degrade the performance of the Shannon primary radar. Not mitigating for the clutter would be operationally unacceptable and unsafe for Air traffic control.

> *Reflections generate dual aircraft tracks which set off IAA automation system (COOPANS) safety-net alarms such as Short-Term Conflict Alert (STCA) and Duplicate (DUPE) alerts. These alerts distract Air Traffic controllers who may attempt to deconflicting real Air traffic tracks from tracks that do not physically exist.*
> *Each Safety Net Alarm initiates a safety occurrence report.*
> *Reflections occur when an aircraft replies to both a radar interrogation directly and to an interrogation reflected by the Turbine tower or rotor blade; the radar generates both a real aircraft track and a false reflected track in the direction of the turbine.*
> *It is possible to reduce the probability of reflections through mitigation. This is normally done at the commissioning phase, where reflection mitigations for existing structures are implemented and tested prior to the operational use of the radar. Mitigating for multiple changing reflections during the construction and operation of wind Turbines within 4km of the woodcock radar, may require the radar to be taken out of service for the duration of the construction phase to implement and test the reflection mitigations. Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace.*
> *Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.*
>
> *Deflections also generate dual aircraft tracks which set off COOPANS safety-net alarms such as Short-Term Conflict Alert (STCA) and Duplicate (DUPE) alerts. These alerts distract Air Traffic controllers who may attempt to deconflicting real Air traffic tracks from tracks that do not physically exist.*
> *Each Safety Net Alarm initiates a safety occurrence report.*
> *Deflections occur when a Radar interrogation signal is deflected by the Wind Turbine introducing an error in the measured bearing of the Aircraft. This bearing error increases with range of the aircraft from the radar, becoming significant at ranges beyond 100Nautical miles. The radar bearing errors become an issue when the deflected Radar tracks are fused with the track data from other radars which calculate a different position for the aircraft track, and the deflected track is not associated with the true track position and a new Duplicate track is generated.*
> *We have mitigated for deflections from individual masts by implementing non-initialisation-areas in our Tracking systems (ARTAS). However, this non-initialisation-area mitigation must be kept to a minimum to avoid introducing holes in radar coverage. Due to the proximity of the proposed Ballycar wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Ballycar generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements.*

> *Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines. This may result in the Woodcock hill radar not meeting its mandated Surveillance performance requirements.*

Regards,
Charlie O'Loughlin.
Manager Surveillance M&E Systems,
Irish Aviation Authority,
Shannon Area Control Centre,
Ballycasey Cross, Shannon, Co. Clare, Ireland.

Appendix B CL-5715-RPT-002 V1.0 Ballycar Windfarm IFP Opinion

IFP Opinion

Ballycar Wind Farm

Shannon Airport

05 November 2021

CL-5715-RPT-002 V1.0

www.cyrrus.co.uk

info@cyrrus.co.uk

Executive Summary

MWP (hereafter referred to as the Client) has requested an Instrument Flight Procedure (IFP) review in respect of a proposed windfarm development (Ballycar) near Shannon Airport.

The process of providing an 'opinion' still requires a review of the applicable IFP lateral and horizontal surfaces. This process only determines whether there is a 'surface penetration' and not whether the obstacle impacts the IFP. If there is a penetration a full IFP assessment will be noted.

The proposed development is approximately 10NM north-east of Shannon Airport, as shown in Figure 1.

The windfarm does impact to the current published IFPs for Shannon Airport but is only limited to the ATC Surveillance Minimum Altitude Chart. Although a full IFP assessment is normally required for any identified impact, it is recommended to submit this report to the IAA for consideration whether a full assessment is required.

Figure 1: Wind Farm Position from Threshold 24

IFP's Assessed

The following IFPs, as published in the IAA Aeronautical Information Publication (AIP) were assessed.

- RNAV STANDARD INSTRUMENT DEPARTURES RWY06
- RNAV STANDARD INSTRUMENT DEPARTURE RWY24
- RNAV STANDARD ARRIVALS RWY06
- RNAV STANDARD ARRIVALS RWY24
- INSTRUMENT APPROACH ILS OR LOC RWY06
- INSTRUMENT APPROACH VOR RWY06
- INSTRUMENT APPROACH ILS CAT I & II OR LOC RWY24
- INSTRUMENT APPROACH VOR RWY24
- ATC SURVEILLANCE MINIMUM ALTITUDE

Data

The assessment undertaken by Cyrrus has been based upon the latest promulgated aeronautical information for Shannon contained in the Ireland AIP, reference EINN AD Section 2.

The following data was used for the assessment:

- Irish AIP – AIRAC 10/2021 effective 26 August 2021
- Email titled "RE_CYB1329 –Ballycar Wind Farm Aviation Studied.msg"

Table 1 below provides the base co-ordinates of the Turbines, the co-ordinates were provided in Irish Transverse Mercator (ITM) and converted to World Geodetic System 84 (WGS84) using the ordinates survey's GridInQuestII conversion tool.

Turbine No	Easting (ITM)	Northing (ITM)	Lat (UTM29N)	Long (UTM29N)
1	554531	664275	522072.59	5842025.21
2	554605	663847	522152.51	5841598.38
3	555030	664044	522574.63	5841801.22
4	555027	663611	522577.64	5841368.32
5	555476	663804	523023.81	5841567.49
6	555805	664104	523348.54	5841871.96
7	555886	663643	523435.91	5841412.23
8	555547	663267	523102.25	5841031.65
9	555090	663180	522646.61	5840938.34
10	555990	663191	523546.15	5840961.83
11	555582	662837	523143.2	5840602.28
12	555912	662521	523477.48	5840290.97

Table 1: Positional Data

Turbine dimensions as indicated in Table 2 were used.

In the absence of surveyed ground elevations, a vertical tolerance of 10 m was added.

Turbine No	Hub Height (m)	Rotor (m)	Ground Elevation (m)	Vertical Tolerance (m)	Max Tip Height
1	90	66.5	234	10	400.5
2	90	66.5	207	10	373.5
3	90	66.5	238	10	404.5
4	90	66.5	198	10	364.5
5	90	66.5	243	10	409.5
6	90	66.5	254	10	420.5
7	90	66.5	198	10	364.5
8	90	66.5	160	10	326.5
9	90	66.5	166	10	332.5
10	83	66.5	124	10	283.5
11	90	66.5	113	10	279.5
12	90	66.5	77	10	243.5

Table 2: Data used for the Assessment

Conclusion

The proposed wind farm does impact the current published procedures at Shannon airport. This is however limited to the ATC Surveillance Minimum Altitude Chart.

Although a full IFP assessment is normally required for any identified impact, it is recommended to submit this report to the IAA for consideration whether a full assessment is required.

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Appendix C – CL-5715-RPT-002 V1.0 Ballycar Wind Farm Aviation Technical Assessment

Ballycar Wind Farm Aviation Technical Assessment

Greensource Limited

05 November 2021

CL-5715-RPT-002 V1.0

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Executive Summary

Cyrrus Limited has been engaged by Malachy Walsh and Partners to undertake an Aviation Study for the proposed Ballycar Wind Farm development in County Clare in the West of Ireland. The proposal comprises 12 wind turbines with a maximum tip height of up to 156.5m Above Ground Level.

An assessment of the Building Restricted Areas associated with the Instrument Landing Systems and Distance Measuring Equipment installed at Shannon Airport shows that the proposed turbines will have no impact on these navigation facilities.

Detailed radar modelling of the indicative layout against the combined Primary Surveillance Radar/Monopulse Secondary Surveillance Radar (PSR/MSSR) facility at Shannon Airport shows the following:

- Radar Line of Sight (RLoS) exists between Shannon PSR and 11 of the 12 proposed turbines;
- There is a high probability that Shannon PSR will detect turbines T1 to T9 and turbines T11 and T12, leading to turbine-induced clutter and false targets, and track seduction of aircraft targets;
- It is unlikely that Shannon PSR will detect turbine T10;
- Mitigation for Shannon PSR may be required;
- The proposed turbine sites are outside the Eurocontrol recommended 16km turbine assessment zone for Shannon MSSR, therefore an impact assessment for the facility was not required;
- No mitigation measures are necessary for Shannon MSSR.

Detailed radar modelling of the indicative layout against the MSSR at Woodcock Hill shows the following:

- RLoS exists between Woodcock Hill MSSR and all 12 proposed turbine towers;
- Aircraft between 5,250m and 10,536m from the proposed turbines may respond to bistatic reflections from these turbine towers, resulting in false targets on the bearings of the turbines;
- Provided the MSSR reflector file is updated with the turbine positions, the MSSR should be able to process out false targets caused by reflections from the turbine towers;
- The maximum heights of shadow regions from the turbines will be below published Air Traffic Control surveillance minimum altitudes and should therefore be operationally tolerable.

It is recommended that mitigation options are discussed with the Irish Aviation Authority (IAA), specifically Air Traffic Services. It is the surveillance network and operational use that will largely influence a suitable mitigation.

Possible mitigation solutions for Shannon PSR include blanking of PSR transmissions over the wind farm. This can be combined with the application of a Transponder Mandatory Zone in the affected airspace, or with in-fill data from a remote radar source.

Existing remote PSR data can be used as in-fill provided it has suitable airspace coverage and does not have visibility of the turbines. This relies on suitable terrain screening and can be problematic in terms of synchronisation and slant range errors.

In-fill mitigation can be provided using a dedicated 2D radar from a company such as Terma. The mitigation radar must be located in close proximity to the airport PSR and be synchronised with it. Terma radars filter out turbines while continuing to track aircraft.

The Aveillant Holographic Radar™ offers a 3D radar mitigation solution that can discriminate turbines from aircraft without the need for masking. It does not require locating close to the airport PSR and its target output can be coordinate transformed to the PSR origin without slant range errors.

Abbreviations

AGL	Above Ground Level
AMSL	Above Mean Sea Level
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
BRA	Building Restricted Area
CFAR	Constant False Alarm Rate
DME	Distance Measuring Equipment
DOC	Designated Operational Coverage
DTM	Digital Terrain Model
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
MSSR	Monopulse Secondary Surveillance Radar
MWP	Malachy Walsh and Partners
NM	Nautical Miles
PD	Probability of Detection
PSR	Primary Surveillance Radar
RCS	Radar Cross Section
RLoS	Radar Line of Sight
RPM	Revolutions Per Minute
TMZ	Transponder Mandatory Zone
VPD	Vertical Polar Diagram

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1. Introduction

1.1. Overview

1.1.1. A new wind farm development, Ballycar Wind Farm, is being proposed in County Clare in the West of Ireland. The proposed development is planned to comprise 12 wind turbines with a maximum tip height of up to 156.5m Above Ground Level (AGL).

1.2. Aviation Study

1.2.1. Cyrrus Limited has been engaged by Malachy Walsh and Partners (MWP), on behalf of Greensource Limited, to undertake an Aviation Study for the development.

1.2.2. This report is concerned with the possible impacts the turbines may have on aviation navigation and surveillance facilities and includes an assessment of the Instrument Landing System (ILS) and combined Primary Surveillance Radar/Monopulse Secondary Surveillance Radar (PSR/MSSR) installations at Shannon Airport, and the MSSR at Woodcock Hill.

1.2.3. A review of the Building Restricted Areas (BRAs) that safeguard the ILS Localiser, Glidepath and Distance Measuring Equipment (DME) facilities at Shannon Airport will be used to determine the likelihood of any impact from the turbines.

1.2.4. Radar Line of Sight (RLoS) assessments will determine the degree of visibility of the proposed turbines to each of the radars and detailed Probability of Detection (PD) calculations will assess the likelihood of an impact on radar caused by signal reflections from the turbine blades and towers.

2. Evaluation Tools Used

2.1. Software

- ATDI HTZ communications v23.4.2 x64;
- Global Mapper v21.1;
- ZWCAD+ 2015 SP1 Pro v2014.11.27(26199).

2.2. Terrain Data

- ATDI 20m Digital Terrain Model (DTM), 2020, Irish Grid projection.

2.3. Data Provided by the Client

- 22156-MWP-00-00-SK-C-0003-P01 Site Location.pdf;
- Turbine Layout 2021-09-29.xls.

3. Development

3.1. Location

3.1.1. The indicative 12 turbine layout used for the modelling is shown in Figure 1.

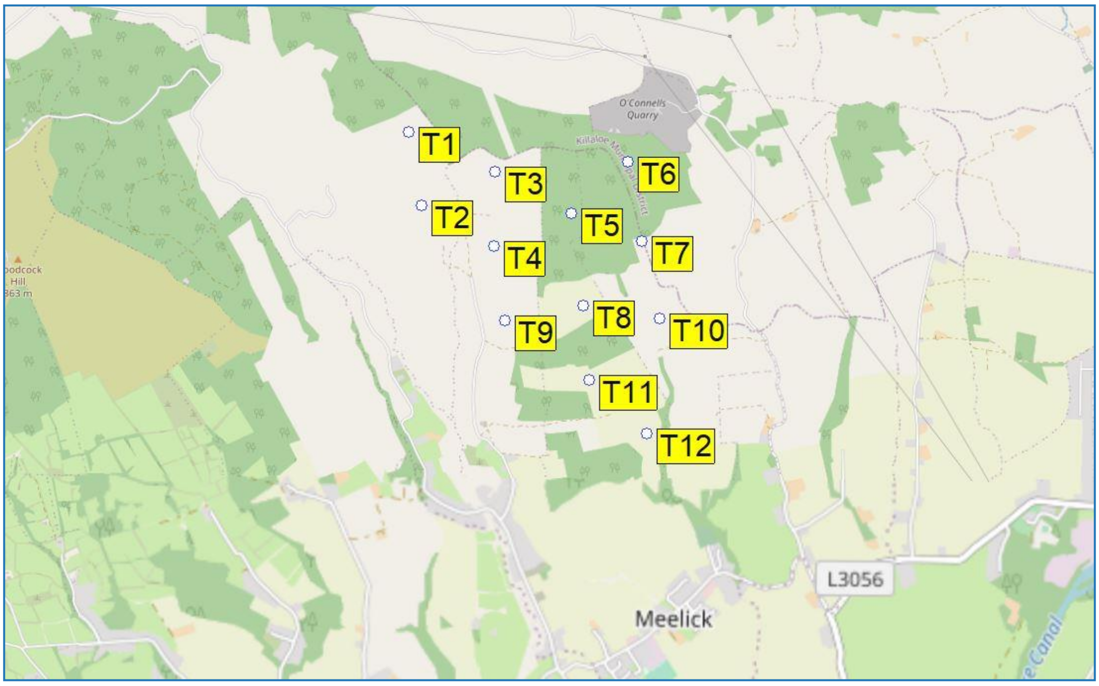

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Figure 1: Indicative turbine layout

3.2. Turbine Data

3.2.1. Turbine T10 has a planned hub height of 83m AGL and blade length of 66.5m, to give a tip height of 149.5m AGL.

3.2.2. The other turbines have a planned hub height of 90m AGL and blade length of 66.5m, to give a tip height of 156.5m AGL.

3.2.3. Location data for the 12 proposed turbines has been supplied by MWP. The Irish Transverse Mercator grid coordinates for each turbine are presented in Table 1, together with each site elevation Above Mean Sea Level (AMSL).

Turbine ID	Easting (m)	Northing (m)	Site Elevation AMSL (m)
T01	554531.3	664275.1	234
T02	554604.7	663847.3	207
T03	555029.9	664043.7	238
T04	555027.2	663611.2	198

Turbine ID	Easting (m)	Northing (m)	Site Elevation AMSL (m)
T05	555475.6	663803.6	243
T06	555804.8	664103.9	254
T07	555885.7	663643.1	198
T08	555546.9	663267.0	160
T09	555090.4	663180.2	166
T10	555989.9	663191.0	124
T11	555582.0	662836.6	113
T12	555912.5	662520.8	77

Table 1: Turbine location data

4. ILS Assessment

4.1. Locations of Turbines and Shannon Airport

4.1.1. The closest turbine within the proposed development lies approximately 17.3km east of the centre of the main runway at Shannon Airport, as shown in Figure 2.

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Figure 2: Locations of turbines and Shannon Airport

4.2. Building Restricted Areas

4.2.1. The navigation facilities under consideration at Shannon Airport are the ILS Localisers, Glidepaths and DMEs that provide guidance for aircraft landing on runways 06 and 24. The minimum safeguarded areas for these facilities are defined by the International Civil Aviation Organisation (ICAO) in the document ICAO EUR DOC 015[1].

[1] ICAO EUR DOC 015 European Guidance Material on Managing Building Restricted Areas, Third Edition 2015

4.2.2. Figure 3 shows an example of the BRA shape for directional facilities such as ILS Localisers, Glidepaths and DMEs, as depicted in ICAO EUR DOC 015 Figures 3.1, 3.2, 3.3 and 3.4.

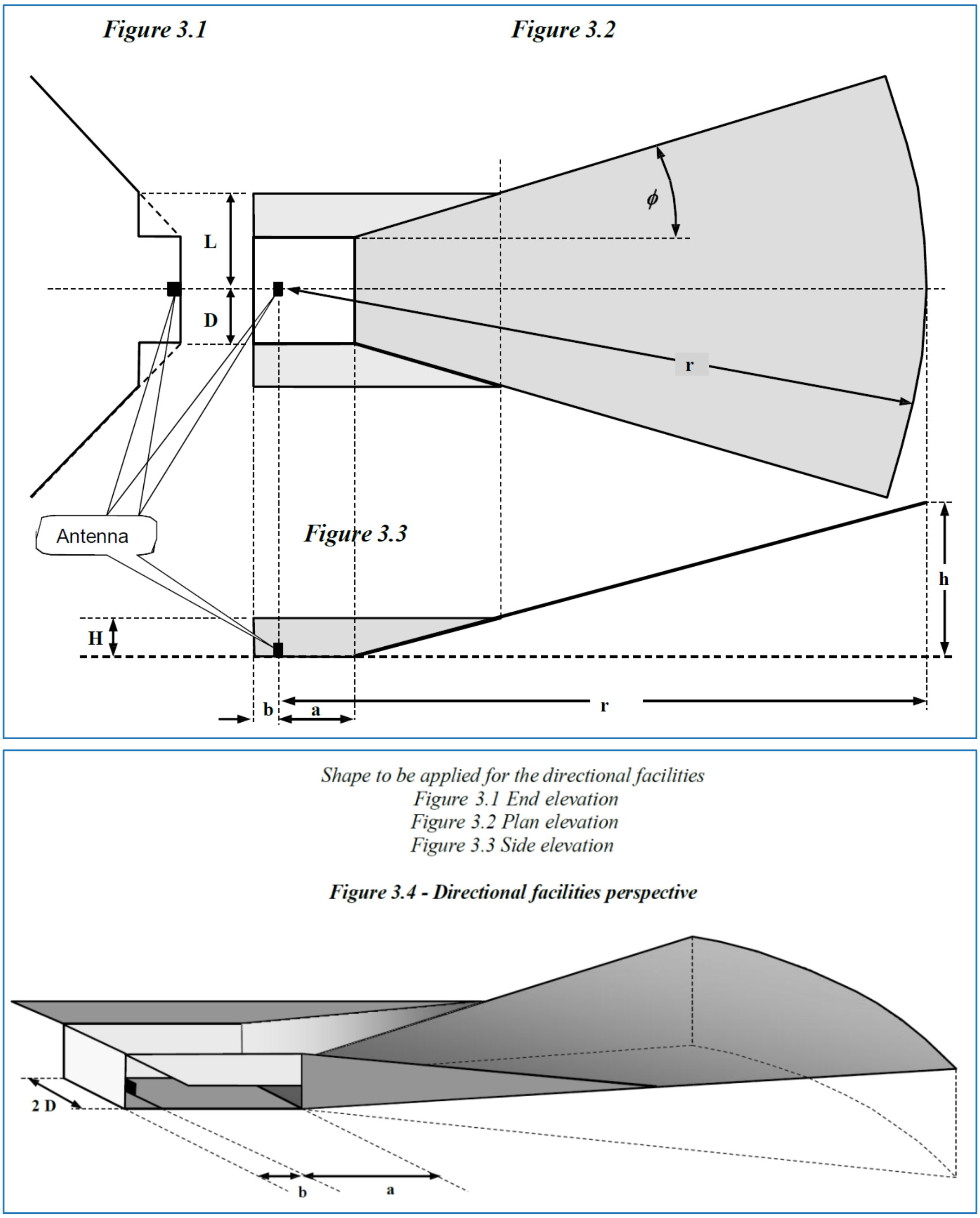


Figure 3: ICAO EUR DOC 015 Figures 3.1-3.4 – BRA shape for directional facilities

4.2.3. Applicable dimensions to be applied for the various directional navigation facilities are reproduced in Figure 4.

Type of ***navigation*** *facilities*	***A*** *(m)*	***b*** *(m)*	***h****(m)*	***r*** *(m)*	***D*** *(m)*	***H*** *(m)*	***L*** *(m)*	***ϕ*** *(°)*
ILS LLZ (medium aperture single frequency)	Distance to threshold	500	70	a+6000	500	10	2300	30
ILS LLZ (medium aperture dual frequency)	Distance to threshold	500	70	a+6000	500	20	1500	20
ILS GP M–Type (dual frequency)	800	50	70	6000	250	5	325	10
MLS AZ	Distance to threshold	20	70	a+6000	600	20	1500	40
MLS EL	300	20	70	6000	200	20	1500	40
DME (directional antennas)	Distance to threshold	20	70	a+6000	600	20	1500	40

Figure 4: ICAO EUR DOC 015 Table 2 – Harmonised guidance figures for directional navigation facilities

4.2.4. The purpose of the safeguarded areas is to identify developments with the potential for causing unacceptable interference to navigation facilities. Developments that infringe a safeguarded area must undergo technical assessments to determine the degree of interference, if any, and whether the interference will be acceptable to the Airport operator.

4.2.5. The ILS Localiser, Glidepath and DME safeguarded areas for runways 06 and 24 are shown in Figure 5 and Table 2.

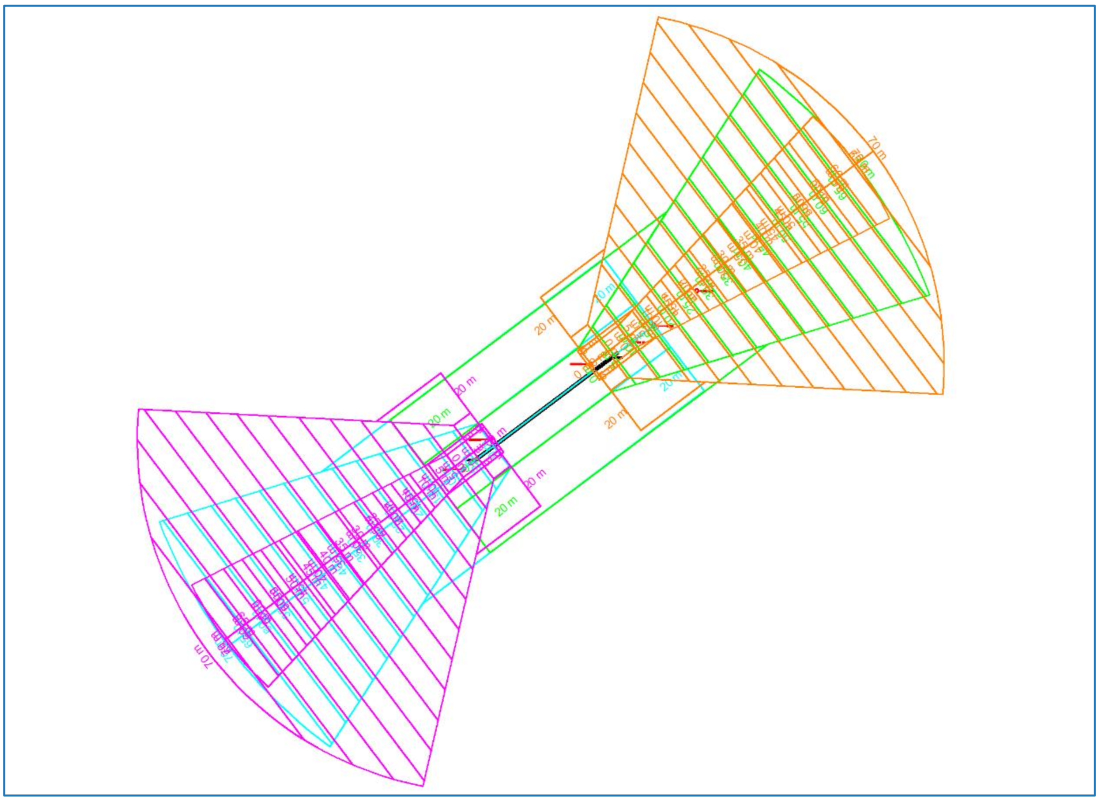


Figure 5: ILS safeguarded areas at Shannon Airport

Area Colour	Description
Magenta	Glidepath/DME 06
Orange	Glidepath/DME 24
Cyan	Localiser 06
Green	Localiser 24

Table 2 - Safeguarded areas colour reference

4.2.6. The same safeguarded areas are shown in Figure 6 relative to the proposed turbines.

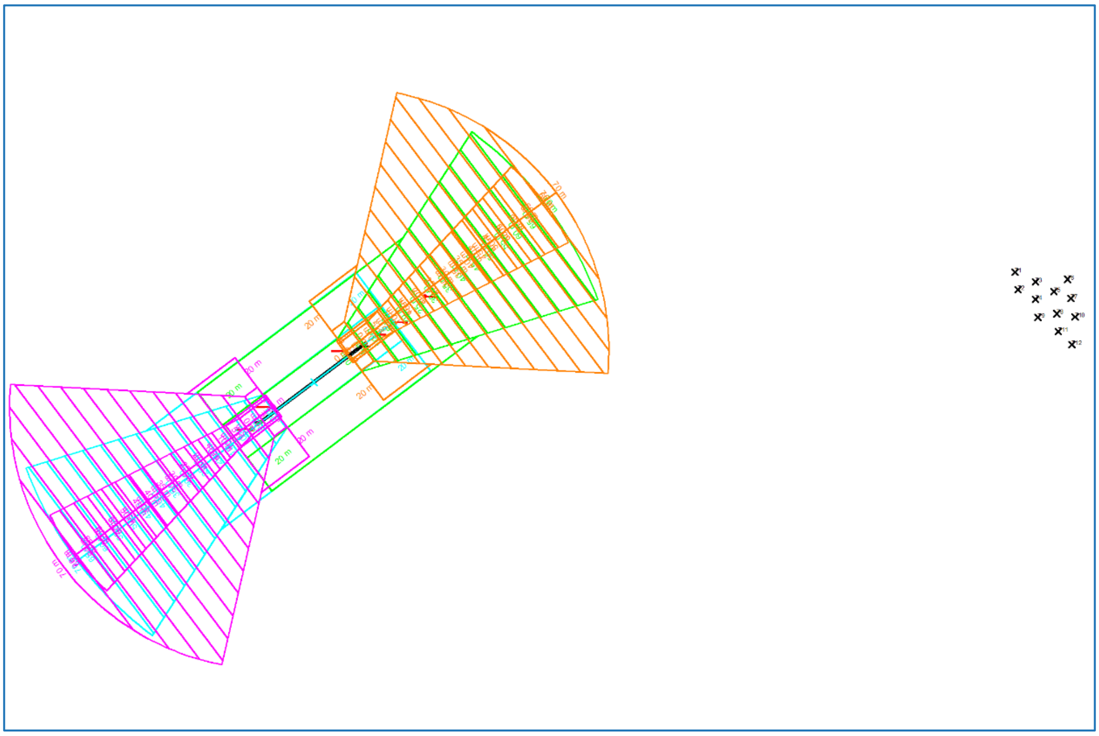


Figure 6: ILS safeguarded areas relative to proposed turbines

4.2.7. The proposed turbines lie outside the ILS safeguarded areas and will have no impact on ILS signals. No further technical assessment for the ILS facilities at Shannon Airport is required.

5. Radar Assessment

5.1. Potential Impact of Wind Turbines on PSR

5.1.1. A PSR transmits pulses of energy that are reflected back to the radar's receiver by objects that are within RLoS. Wind turbines can act as reflectors presenting a static target to the radar system. This phenomenon is no different to any other reflection received from ground obstacles (buildings, electricity pylons etc) except that each turbine structure reflects an amount of energy several orders of magnitude larger than that caused by an aircraft. This has the potential effect of causing a shadow behind the obstacle rendering the receiver blind to wanted targets in the immediate area beyond the turbine. It is thus not possible to reduce the gain of the radar in this range cell and still see the wanted targets.

5.1.2. PSRs will 'see' any reflecting object that the radar energy illuminates. To discriminate wanted targets (aircraft) from the unwanted clutter, the radar ignores static objects and only displays moving targets. The rotating blades of a wind turbine impart a Doppler frequency shift to the reflected radar pulse, which the radar receiver 'sees' as a moving target; these targets are then presented on the Air Traffic Control Officers (ATCOs) radar display as primary radar returns, indistinguishable from those returns originating from aircraft. This is not a steady effect but has dependency on the axis of rotation of the turbine in relation to the radar. Such unwanted radar returns are known as 'clutter'.

5.1.3. PSRs are usually designed to manage the amount of clutter within defined cells using Constant False Alarm Rate (CFAR) algorithms. In areas of high clutter returns, as experienced from wind turbines, the CFAR action is to reduce the sensitivity of the receiver. Whilst this has the positive benefit of keeping the displayed data usable by the ATCOs rather than being totally swamped with clutter returns, it does have the adverse effect of reducing the PD of aircraft within the affected cells.

5.1.4. A consequence of these effects is that the tracking mechanism in the radar processing is no longer able to reliably report the aircraft's passage in the vicinity of the turbines. The aircraft's track is liable to either be lost or 'seduced' by the turbine returns to create an erratic course.

5.1.5. If the radar cannot distinguish a wanted target (aircraft) amongst the returns originated by the turbines it can result in an undecipherable data display to the ATCO. In the worst case, the presence of a real aircraft, possibly in confliction with another aircraft under control, may be hidden by turbine-induced clutter or a desensitized receiver thereby increasing the risk of collision. Furthermore, false targets when presented on the ATCO's radar screen may appear as conflicting traffic to other real aircraft, resulting in the issuance of unnecessary avoiding action. In addition, the establishment by the ATCO of aircraft identity may be delayed or subsequently lost altogether in the vicinity of a wind farm.

5.2. Potential Impact of Wind Turbines on MSSR

5.2.1. Unlike PSR, MSSR is an 'active' system. It operates by the radar transmitting a coded pulse sequence which is received and decoded by suitably equipped aircraft. The aircraft responds with a coded pulse sequence on a different frequency which is received by the MSSR. Range and azimuth information is derived in the same way as PSR, but additional information in the coded reply allows the identification of a particular aircraft and its height. Other data may also be made available dependant on the mode of operation.

5.2.2. MSSR is immune to direct reflections (monostatic back scatter) from large objects such as wind turbines because the transmitted and received frequencies differ and the message structure is different for transmit and receive paths.

5.2.3. Bistatic reflection is where the signal transmitted by the radar is 'forward' reflected to an aircraft, and the aircraft reply is also reflected back to the radar. The effect of this is best understood by considering the following diagrams.

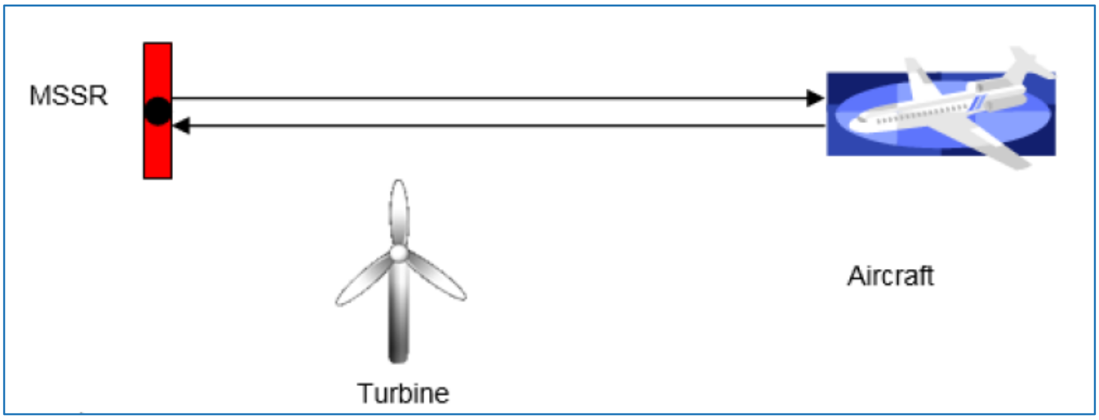


Figure 7: Direct interrogation and reply pulses

5.2.4. In Figure 7, the MSSR transmits an interrogation pulse sequence and the aircraft, on receiving the interrogation sequence, replies with a coded pulse sequence. The time delay between interrogation and receipt of reply is proportional to the distance of the aircraft from the radar. The bearing of the aircraft is the physical bearing of the radar antenna.

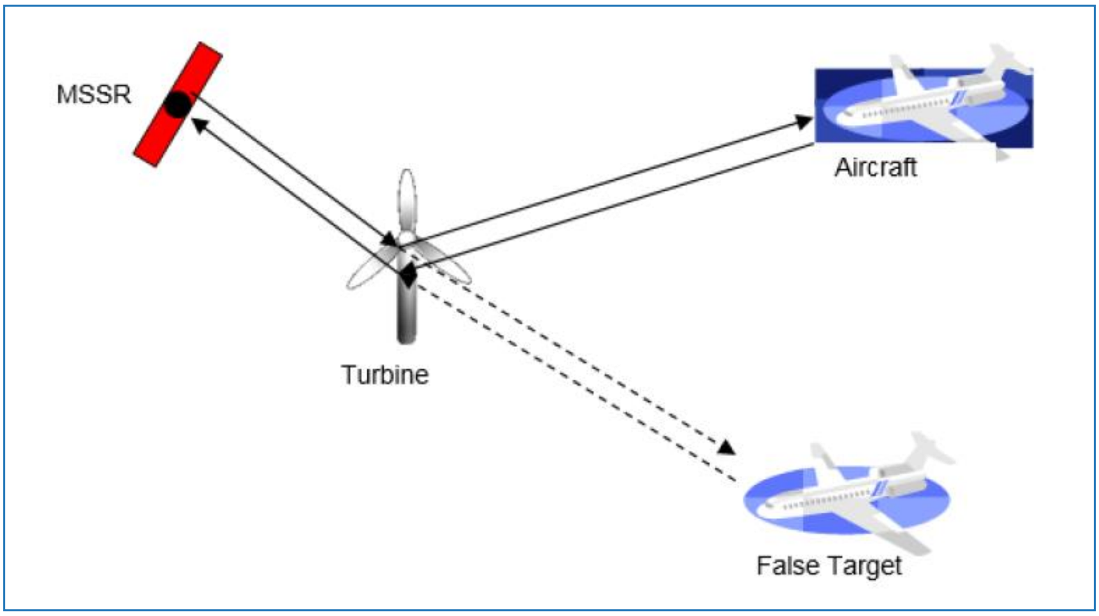


Figure 8: Reflected interrogation and reply pulse

5.2.5. In Figure 8, the MSSR beam illuminates a wind turbine which reflects the interrogation to an aircraft on a different bearing. The aircraft transponder replies, and this is received by the radar via the turbine. The radar processes this as a false target on the bearing of the wind turbine and at a distance proportional to the path length, which is slightly longer than the direct path length.

5.2.6. Objects can produce a radar shadow in the airspace behind the object. As a wind turbine is narrow compared to the radar beam width, assuming the turbine is >2km from the radar, the shadow will be relatively small, and will reduce with increasing distance behind the turbine. Shadowing effects are likely to be insignificant but, due to diffraction of the beam around the turbine tower, small azimuth angular errors may be introduced. Aircraft targets in this area can potentially be subject to track jitter causing the returns to meander from side to side. This can only occur where the turbine is in the direct RLoS between the radar and the aircraft target.

5.3. Shannon Airport Radar

5.3.1. The radar at Shannon Airport is a combined head with co-mounted PSR and MSSR antennas.

5.3.2. The PSR model is a Thales Star 2000, operating in the S-Band frequency, turning at 15 Revolutions Per Minute (RPM) and with an instrumented range of 60 Nautical Miles (NM). As with all PSRs of this type, it is vulnerable to the adverse effects of wind turbines, however, Thales claim to have newer processing capabilities which are more turbine tolerant.

5.3.3. The MSSR model is a Thales RSM 970 S. It meets the current standard of MSSR capability to the European Mode S Functional Specification[2] and has an instrumented range of 256NM.

Image © 2021 Google © 2021 Europa Technologies

Figure 9: Shannon PSR/MSSR

5.3.4. The WGS84 coordinates for the radar are: 52° 42' 05.03'' N, 08° 56' 11.74'' W

5.3.5. The PSR antenna height is 16m AGL, the MSSR antenna height is 18m AGL.

[2] EUROCONTROL European Mode S Station Functional Specification v3.11, May 2005

5.3.6. The location of Shannon PSR/MSSR is shown in Figure 10.

© OpenStreetMap contributors

Figure 10: Location of Shannon PSR/MSSR

5.4. Woodcock Hill Radar

5.4.1. The radar at Woodcock Hill is a Thales RSM 970 S MSSR and is housed in a polycarbonate radome.

Image © 2021 Google

Figure 11: Woodcock Hill MSSR

5.4.2. The WGS84 coordinates for the radar are: 52° 43' 15.77'' N, 08° 42' 26.78'' W

5.4.3. The MSSR antenna height is 10m AGL.

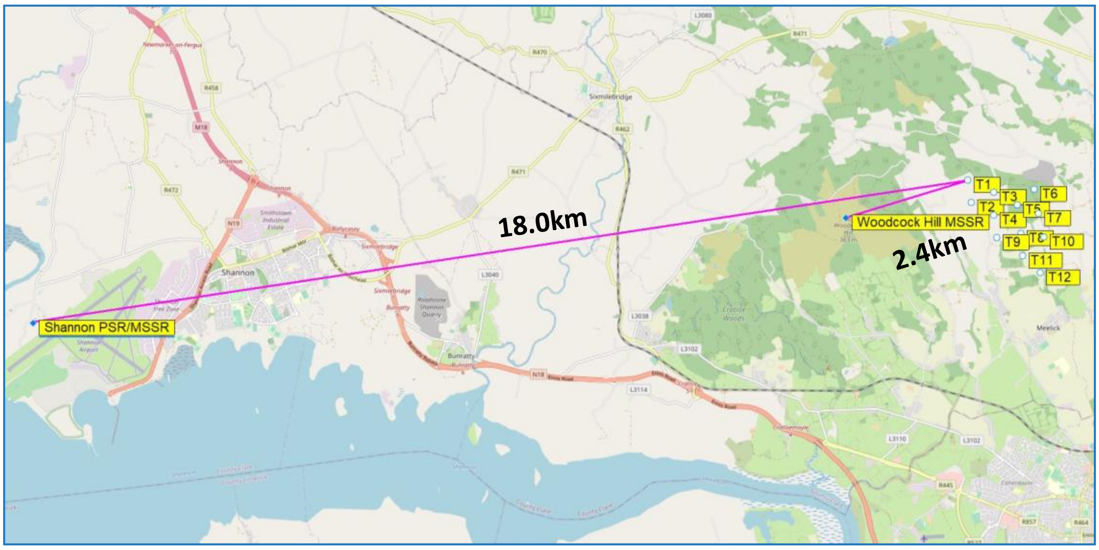
5.4.4. The location of Woodcock Hill MSSR is shown in Figure 12.

© OpenStreetMap contributors

Figure 12: Location of Woodcock Hill MSSR

5.5. Locations of Turbines and Radars

5.5.1. The relative locations of the proposed turbines and the radars at Shannon Airport and Woodcock Hill are shown in Figure 13.



© OpenStreetMap contributors

Figure 13: Locations of radars and proposed turbines

5.5.2. The closest proposed turbine within Ballycar Wind Farm (T1) is 18.0km from the Shannon PSR/MSSR, and 2.4km from Woodcock Hill MSSR.

5.5.3. In accordance with Eurocontrol Guidelines[3], the wind turbine assessment zone for MSSR facilities extends to 16km. Beyond this range the impact of a wind turbine is considered to be tolerable. Therefore, an assessment of the impact on the Shannon MSSR is not required.

5.6. Radar Line of Sight Modelling

5.6.1. RLoS is determined from a radar propagation model (ATDI HTZ communications) using 3D DTM data with a 20m horizontal resolution. Radar data is entered into the model and RLoS to the turbines from the radars is calculated.

5.6.2. Note that by using 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.

5.6.3. For PSR, the principal sources of adverse wind farm effects are the turbine blades, so for Shannon PSR RLoS is calculated for the maximum tip height of the turbines, i.e. 156.5m AGL.

5.6.4. In the case of MSSR, adverse effects are generated by the turbine towers, so for Woodcock Hill MSSR RLoS is calculated for the maximum hub height of the turbines, i.e. 90m AGL.

5.6.5. A 3D view of the turbines and the terrain model, as viewed from Shannon PSR/MSSR, is shown in Figure 14.

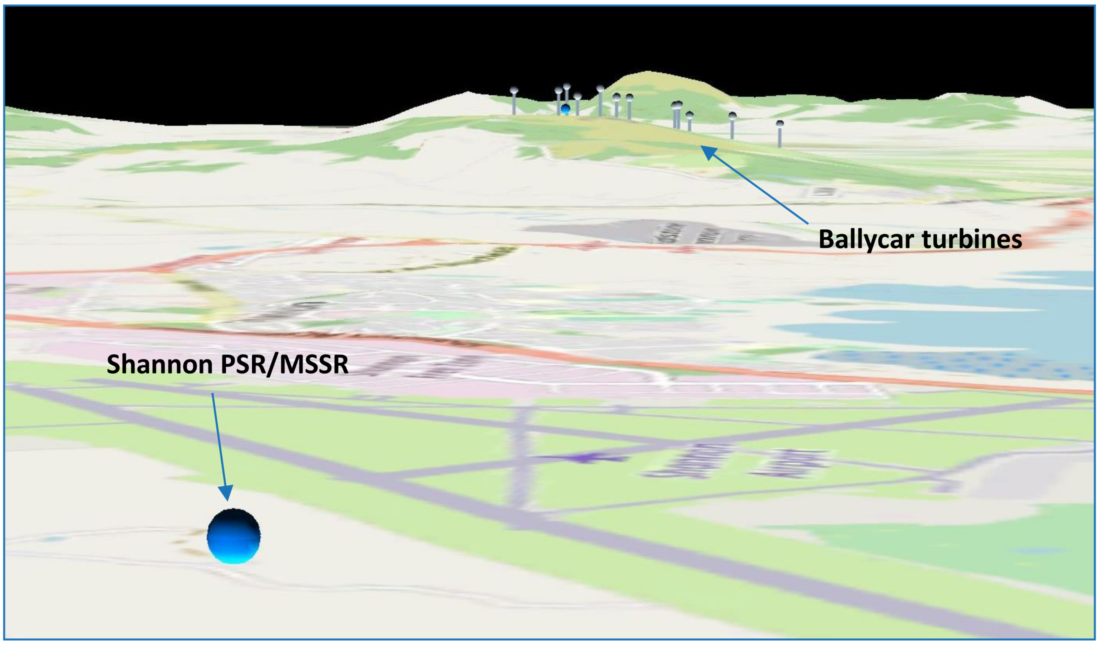


Figure 14: 3D view from Shannon PSR/MSSR towards turbines

[3] EUROCONTROL Guidelines for Assessing the Potential Impact of Wind Turbines on Surveillance Sensors, EUROCONTROL-GUID-0130 Edition Number 1.2, September 2014

5.6.6. The magenta shading in Figure 15 illustrates the RLoS coverage from Shannon PSR to turbines with a blade tip height of 156.5m AGL.

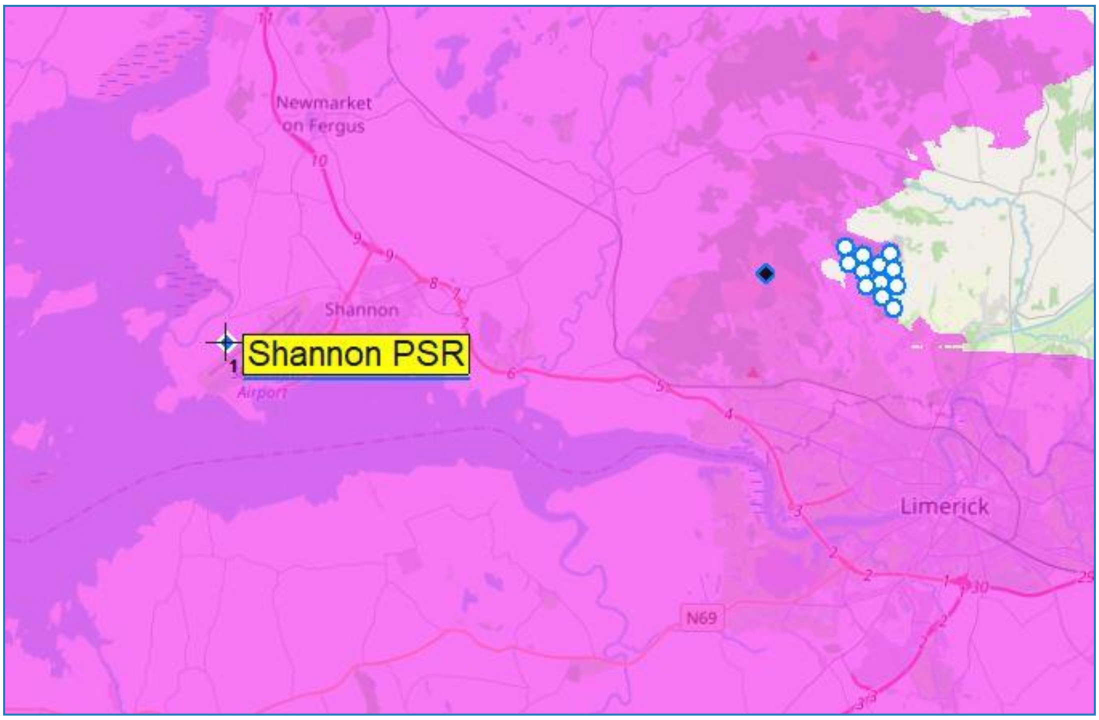


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Figure 15: Shannon PSR RLoS to 156.5m AGL

5.6.7. A zoomed view of the RLoS coverage in the vicinity of the proposed turbines is shown in Figure 16.

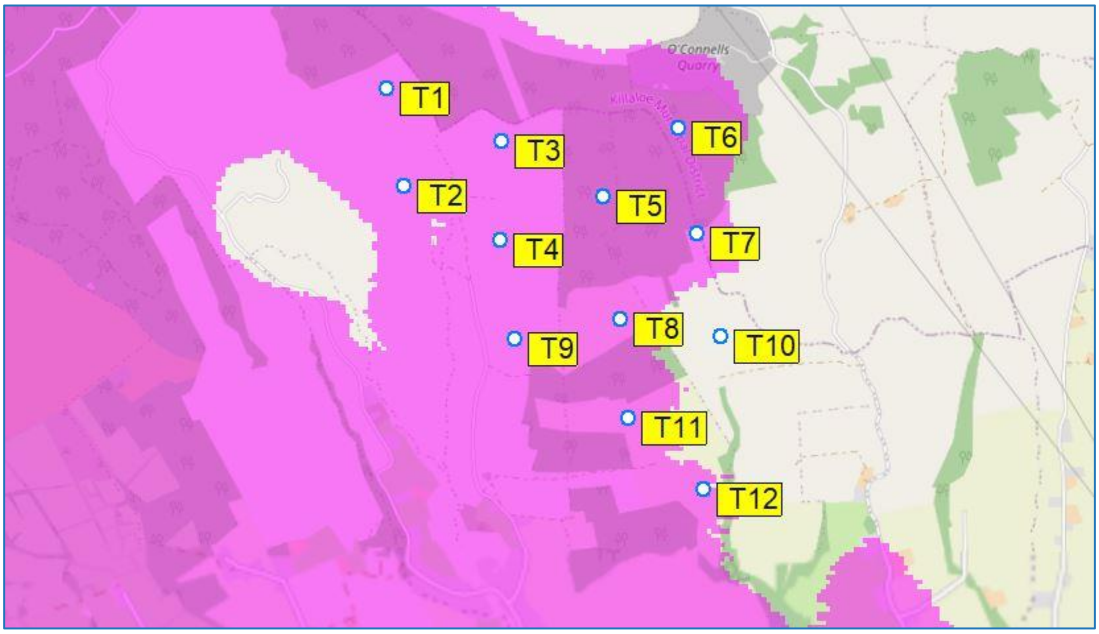

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Figure 16: Shannon PSR RLoS to 156.5m AGL – zoomed

5.6.8. The magenta shading indicates that RLoS exists between Shannon PSR and all the turbines except turbine T10 in the indicative layout. The planned turbine T10 tip height is 149.5m AGL. RLoS will not exist between Shannon PSR and turbine T10 at the lower tip height.

5.6.9. Where RLoS exists it can be assumed that the PSR will detect the turbines, and where there is no RLoS it can generally be assumed that the turbine will not be detected. However, this can only be confirmed by analysing the path profiles between the PSR and each turbine and calculating the PD using known PSR parameters. This is undertaken in Section 5.7.

5.6.10. A 3D view of the turbines and the terrain model, as viewed from Woodcock Hill MSSR, is shown in Figure 17.

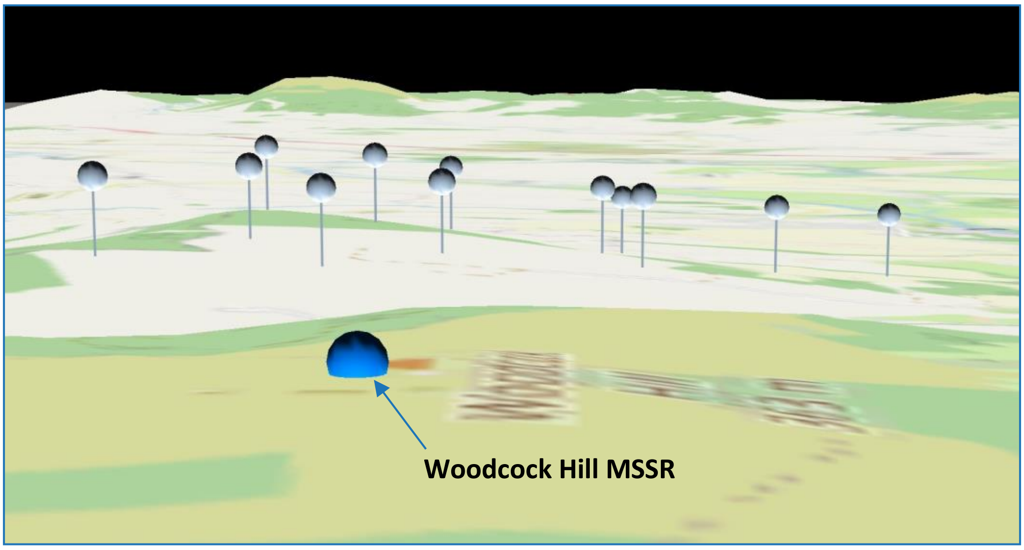

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Figure 17: 3D view from Woodcock Hill MSSR towards turbines

5.6.11. The magenta shading in Figure 18 illustrates the RLoS coverage from Woodcock Hill MSSR to turbines with a tower hub height of 90m AGL.

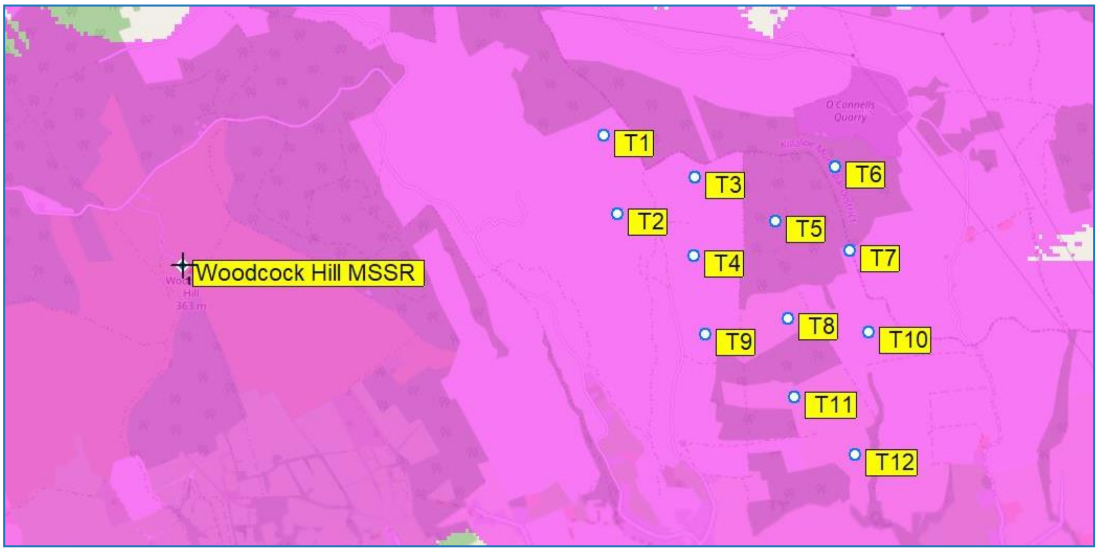

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Figure 18: Woodcock Hill MSSR RLoS to 90m AGL

5.6.12. RLoS at 90m AGL exists between Woodcock Hill MSSR and all the turbines in the indicative layout.

5.6.13. To account for the reduced T10 hub height, RLoS coverage at 83m AGL is shown in Figure 19.

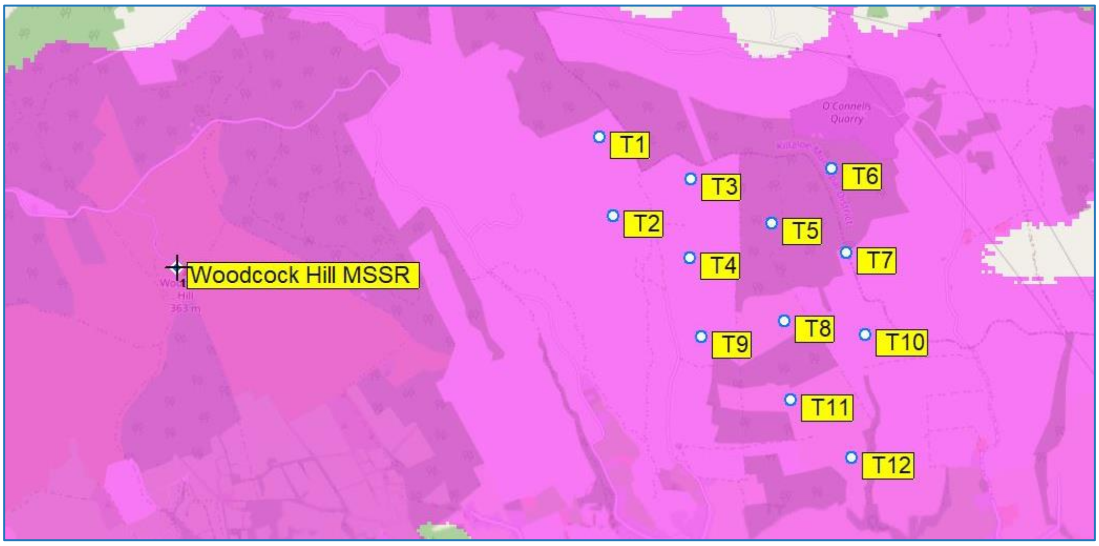

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Figure 19: Woodcock Hill MSSR RLoS to 83m AGL

5.6.14. RLoS between Woodcock Hill MSSR and turbine T10 still exists at the reduced hub height of 83m AGL.

5.7. Shannon PSR Path Loss and Probability of Detection

5.7.1. Using the radar propagation model the actual path loss between Shannon PSR and various parts of each turbine can be determined.

5.7.2. An illustration of the path loss profile between Shannon PSR and the tip of turbine T1 is shown in Figure 20. Shannon PSR has uninterrupted RLoS to the turbine tip.

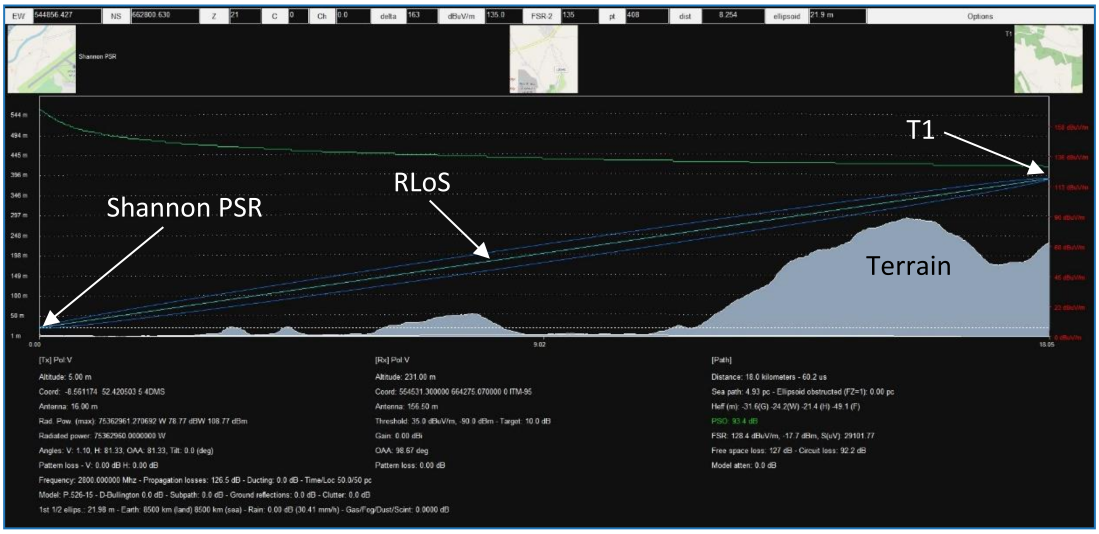


Figure 20: Path loss profile between Shannon PSR and tip of turbine T1

5.7.3. The path loss profile between Shannon PSR and the tip of turbine T10 is shown in Figure 21. In this case there is intervening terrain which blocks RLoS.

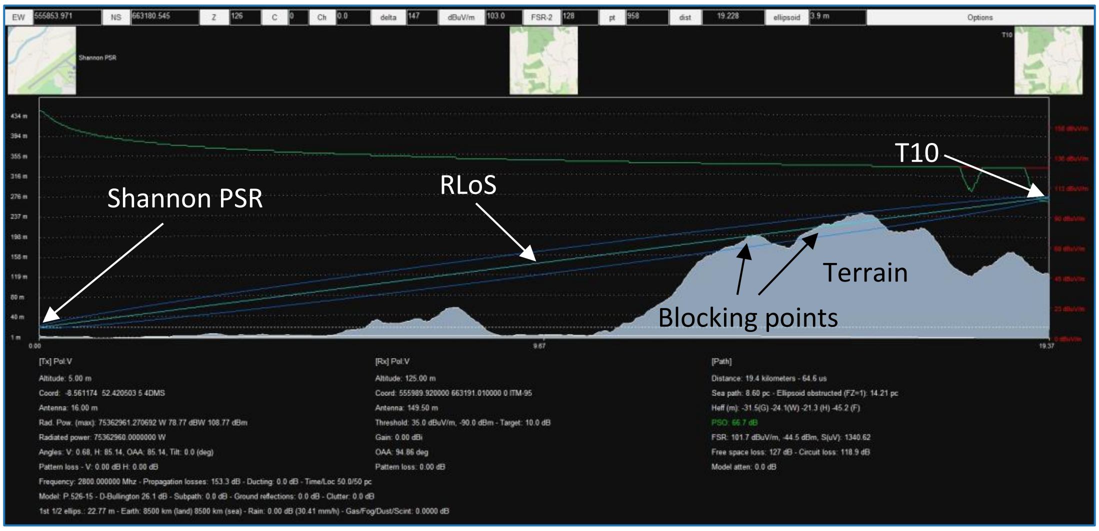


Figure 21: Path loss profile between Shannon PSR and tip of turbine T10

5.7.4. All the path profiles between Shannon PSR and the 12 Ballycar turbines are shown in Annex A of this report.

5.7.5. Even with no intervening terrain between the PSR and the turbines, the probability that a 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 turbine.

5.7.6. 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.

5.7.7. 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 $50m^2$ based on a blade length of 66.5m. 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.

5.7.8. 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 ($60m^2$ ~ +47dB)
-	Path Loss	dB
+	Antenna Gain	dB
=	Received Signal	dBm

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

5.7.10. An example of the calculation from Shannon PSR to turbine T1 is shown in Figure 22.

Radar 2-Way Path Loss Calculator

Data		
Tx Frequency	2800	MHz
Tx Power	28000	Watts
Antenna Gain	34	dBi
Rx Sensitivity	-125	dBm
Target		
RCS	50	m^2
Path Loss (1-way)	126.5	dB
Calculations		
Tx Wavelength	0.11	m
Tx power	74.47158	dBm
EIRP	108.4716	dBm
Power at Target	-18.02842	dBm
RCS Gain	47.39	dB
Power at Rx	-63.14	dBm
dB over Rx Threshold	61.86	dB

Figure 22: Example path loss calculation

5.7.11. 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.

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

5.7.13. The results of the Shannon PSR PD calculations for each turbine are shown in Table 3.

Initial data from '2-Way'				KEY:
A	126.5	Path Loss		Unlikely to be detected
B	61.86	dB over Rx Thr		Small possibility of detection
C	50.00	RCS (m^2)		Possibility of detection
				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	152.2	126.5	126.5	64.87
2	161.4	151.1	126.5	61.86
3	155.1	130.2	126.7	62.25
4	160.1	148.3	126.7	61.46
5	154.5	130.0	126.9	62.00
6	152.6	127.1	127.1	63.67
7	160.6	152.0	127.1	60.66
8	160.5	150.6	126.9	61.06
9	158.0	139.9	126.7	61.47
10	165.5	161.3	153.3	8.39
11	161.6	152.7	126.9	61.06
12	162.5	155.5	137.0	40.86

Table 3: Shannon PSR PD results

5.7.14. From Table 3 it appears that there is a high probability that Shannon PSR will detect all the Ballycar turbines.

5.7.15. 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.

5.7.16. The Star 2000 PSR has a dual beam antenna. At short ranges the radar uses a high beam to reduce the effects of close-in ground clutter. Beyond these ranges a low beam is used. It is likely that the proposed wind farm lies in Shannon PSR's high beam area.

5.7.17. The maximum high beam gain for a Star 2000 antenna usually occurs at an elevation angle of 6.5° above the horizontal and the maximum low beam gain at about 3°. If the mechanical tilt of the antenna is altered, then the angles 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 Vertical Polar Diagram (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.

5.7.18. The Star 2000 VPD data gives the graph shown in Figure 23.

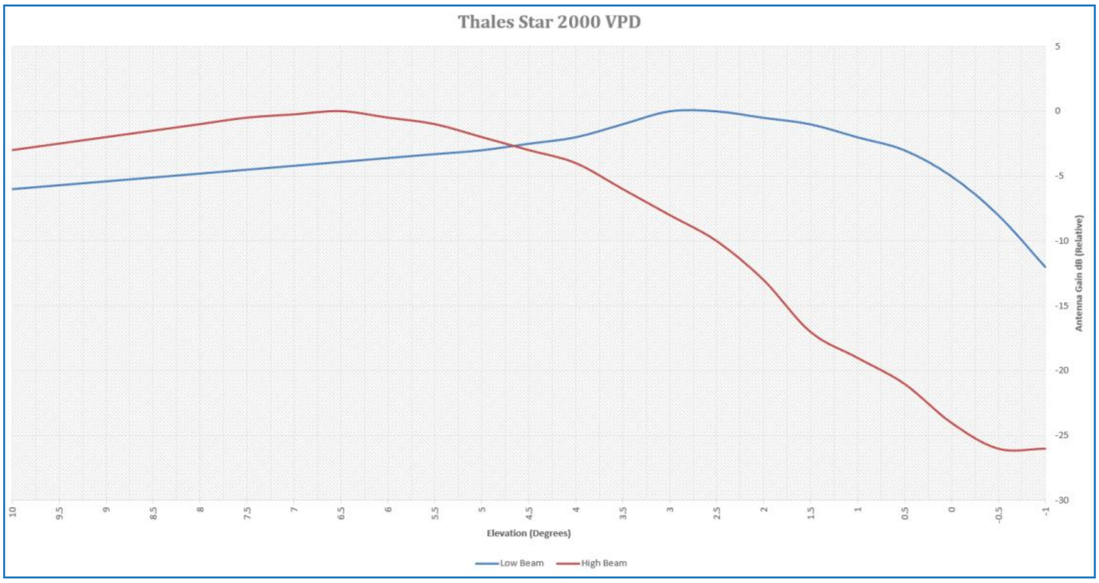


Figure 23: Thales Star 2000 VPD

5.7.19. The vertical angle from Shannon PSR to the tips of the turbines varies between 0.57° (turbine T12) and 1.10° (turbine T1). If a 0° mechanical antenna tilt is assumed, this means a high beam gain reduction of approximately -20dB and a low beam gain reduction of approximately -3dB at these elevations. Table 4 shows the results of the PD calculations incorporating the reduction in antenna gain.

Initial data from '2-Way'			KEY:	Unlikely to be detected
A	126.5	Path Loss		Small possibility of detection
B	38.86	dB over Rx Thr		Possibility of detection
C	50.00	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	152.2	126.5	126.5	41.87
2	161.4	151.1	126.5	38.86
3	155.1	130.2	126.7	39.25
4	160.1	148.3	126.7	38.46
5	154.5	130.0	126.9	39.00
6	152.6	127.1	127.1	40.67
7	160.6	152.0	127.1	37.66
8	160.5	150.6	126.9	38.06
9	158.0	139.9	126.7	38.47
10	165.5	161.3	153.3	-14.61
11	161.6	152.7	126.9	38.06
12	162.5	155.5	137.0	17.86

Table 4: Shannon PSR PD results – corrected for VPD

5.7.20. With the gain reduction, it is unlikely that Shannon PSR will detect turbine T10. However, there is still a high probability that Shannon PSR will detect the rest of the Ballycar turbines.

5.8. Woodcock Hill MSSR Path Loss

5.8.1. Using the radar propagation model the actual path loss between Woodcock Hill MSSR and the tops of the Ballycar turbine towers can be determined.

5.8.2. An illustration of the path loss profile between Woodcock Hill MSSR and turbine T1 is shown in Figure 24. As with all the other Ballycar turbines, Woodcock Hill MSSR has uninterrupted RLoS to the top of the turbine tower.

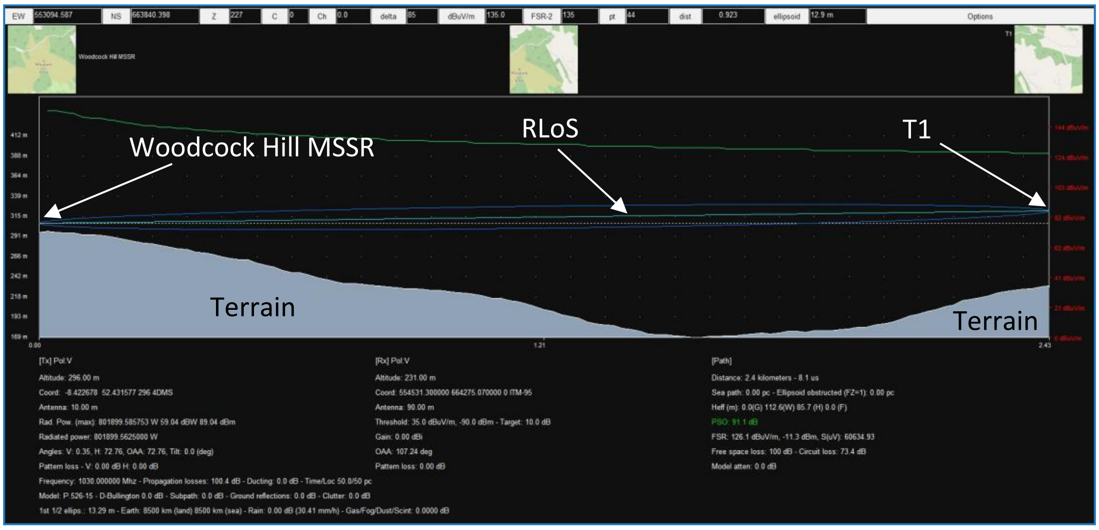


Figure 24: Path loss profile between Woodcock Hill MSSR and top of turbine tower T1

5.8.3. All the path profiles between Woodcock Hill MSSR and the 12 Ballycar turbines are shown in Annex B of this report.

5.8.4. As explained in Section 5.2, multipath, or bistatic, reflections from turbine towers can potentially cause 'ghost' targets on MSSR. This occurs when an aircraft replies through a signal reflected from an obstruction; the radar attributes the response to the original signal and outputs a false target in the direction of the obstruction, which can lead to ATCOs deconflicting real traffic from targets that do not physically exist.

5.8.5. The likelihood of bistatic reflections can be determined by knowing the MSSR transmitter power, antenna gain, path loss to the turbine tower, RCS gain and aircraft receiver sensitivity.

5.8.6. The amount of signal reflected by a turbine tower is a function of the tower's RCS. A typical RCS value for a 100m steel tower of 8m diameter is 3,000,000m^2. However, a 0.5° taper of the tower can reduce this figure from millions to hundreds of square metres.

5.8.7. EUROCONTROL Guidelines[4] recommend an RCS value of $10^{3.5}m^2$ or 35dBm^2 for a turbine tower which equates to an RCS gain of 57dB at the MSSR uplink frequency of 1030MHz.

[4] EUROCONTROL Guidelines for Assessing the Potential Impact of Wind Turbines on Surveillance Sensors, EUROCONTROL-GUID-0130 Edition Number 1.2, September 2014

5.8.8. The following calculation can be used to determine the power of a radar signal reflected by a wind turbine tower:

	Tx Power	dBm
+	Antenna Gain	dB
-	Path Loss	dB
+	RCS Gain	dB (35dBm^2 ~ +57dB)
=	Reflected Power	dBm

5.8.9. Free Space Path Loss can be used to calculate the maximum distance from the reflecting obstacle an aircraft can be in order for the reflected signal to trigger a response from the aircraft transponder.

5.8.10. The maximum range at which a reflection can trigger a response is proportional to the reflected power of the signal. From the above calculation, reflected power is greatest when the path loss between the MSSR and a turbine is the least.

5.8.11. Using the radar propagation model the actual path loss between Woodcock Hill MSSR and the tops of the Ballycar turbine towers can be determined.

5.8.12. The path loss results between Woodcock Hill MSSR and the tops of the 12 Ballycar turbine towers are shown in Table 5.

Turbine	Path Loss (dB)
T1	100.4
T2	100.4
T3	101.8
T4	101.7
T5	103.0
T6	103.9
T7	104.0
T8	103.2
T9	102.0
T10	104.3
T11	103.4
T12	104.4

Table 5: Woodcock Hill MSSR path loss results

5.8.13. From Table 5 the worst-case or smallest path loss is 100.4dB to turbines T1 and T2.

5.8.14. The Tx Power for a Thales RSM 970 S MSSR is 60.35dBm at the antenna input. As with the PSR, MSSR antenna gain varies with elevation angle, with peak gain of 27dB at an elevation of between 8° and 9° above the horizontal, as shown in Figure 25.

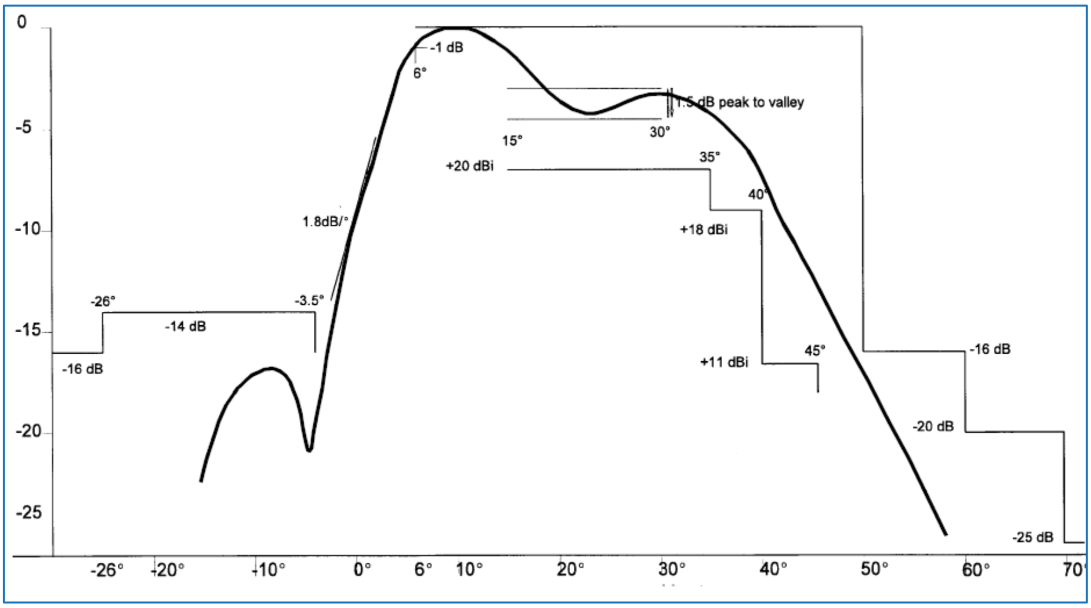


Figure 25: Thales RSM 970 S VPD

5.8.15. The vertical angle from Woodcock Hill MSSR to the hub of turbine T1 is 0.35° and to the hub of turbine T2 is -0.27°. If a mechanical tilt of 0° is assumed this means a reduction in gain of -7.5dB for T1 and -8.5dB for T2 at these elevations.

5.8.16. The T1 reduction in gain will be worst-case, and results in a reflected power of 36.2dBm from turbine T1.

5.8.17. If an aircraft receiver sensitivity of -77dBm is assumed, the reflected signal will not trigger a response if the Free Space Path Loss from the turbine to the aircraft is more than 77+36.2=113.2dB.

5.8.18. The Free Space Path Length for an MSSR frequency of 1030MHz and path loss of 113.2dB is 10,536m. This means that aircraft beyond this distance from the turbine will not detect a reflected signal. Reflected signals from other Ballycar turbines will only be detected at ranges less than 10,536m.

5.8.19. Annex D of the EUROCONTROL Guidelines states that an airborne transponder will be insensitive for 35µs following reception of a radar interrogation through radar sidelobes. Thus, an aircraft closer than 5,250m (half of the distance corresponding to 35µs) to the source of a reflected interrogation will not reply to reflected interrogations because the path length between the direct and reflected signals will always be smaller than 35µs.

5.8.20. Aircraft between 5,250m and 10,536m from the proposed turbines may respond to reflected Woodcock Hill MSSR interrogations, potentially resulting in MSSR 'ghost' targets.

5.8.21. The calculations can be repeated to determine the maximum reflection ranges for all the Ballycar turbines, as shown in Table 6.

Turbine	Maximum Reflection Range (m)
T1	10,536
T2	9,390
T3	8,967
T4	8,085
T5	7,810
T6	7,041
T7	6,204
T8	5,724
T9	6,571
T10	4,243
T11	4,443
T12	3,738

Table 6: Woodcock Hill MSSR maximum reflection ranges

5.8.22. Table 6 shows that for turbines T1 to T9 the maximum reflection range is more than 5,250m. Reflections from these turbines may result in MSSR 'ghost' targets.

5.8.23. The maximum reflection ranges for turbines T10 to T12 are less than 5,250m. An aircraft will not respond to reflected Woodcock Hill MSSR interrogations from these turbines as they will only be detected when the aircraft is within 5,250m of the turbines.

5.8.24. An array of turbines can create a radar shadow in the space beyond it from the radar. The EUROCONTROL Guidelines provides a means of calculating the dimensions of this shadow region.

$$Dwr = Dtw/[\lambda.\frac{Dtw}{S^2}\left(1-\sqrt{PL}\right)^2 - 1]$$

- *Dwr* = depth of the shadow region.
- *Dtw* = distance of turbines
- λ = wavelength (0.29m)
- S = diameter of support structures (6m)
- PL = acceptable power loss (0.5/3dB as per guidelines)

5.8.25. The EUROCONTROL Guidelines also provide equations for calculating the width and height of the shadow regions.

5.8.26. The volumes of the Woodcock Hill MSSR shadow regions created by each of the Ballycar turbines are shown in Table 7.

Turbine	Depth of shadow region (km)	Width of shadow region (m)	Height of shadow region AMSL (m)
T1	3.6	65	352
T2	3.6	65	285
T3	2.9	58	351
T4	3.0	59	270
T5	2.6	55	355
T6	2.4	53	370
T7	2.3	52	277
T8	2.5	54	210
T9	2.9	58	208
T10	2.3	52	147
T11	2.5	54	128
T12	2.3	52	83

Table 7: Woodcock Hill MSSR shadow regions

5.8.27. The depth of the shadow regions beyond the Ballycar turbines will vary between 2.3km and 3.6km for Woodcock Hill MSSR, with widths of up to 65m and with a maximum height of 352m or 1,155 feet AMSL.

5.8.28. Figure 26 shows an extract of Shannon Airport's ATC Surveillance Minimum Altitude Chart, as published by the Irish Aviation Authority in the current Integrated Aeronautical Information Publication[5]. The Ballycar turbine locations are overlaid on the chart, which shows that turbines T1 to T10 are within Sector 1 where the minimum altitude is 2,300 feet AMSL. Turbines T11 and T12 are in Sector 2 where the minimum altitude is 3,000 feet AMSL. Aircraft at these minimum altitudes will not be low enough for the shadow regions to have any impact, and therefore the shadow regions that may be generated beyond the proposed turbines should be operationally tolerable.

[5] ATC SURVEILLANCE MINIMUM ALTITUDE CHART – ICAO, EINN AD 2.24-16.1, 17 JUN 2021

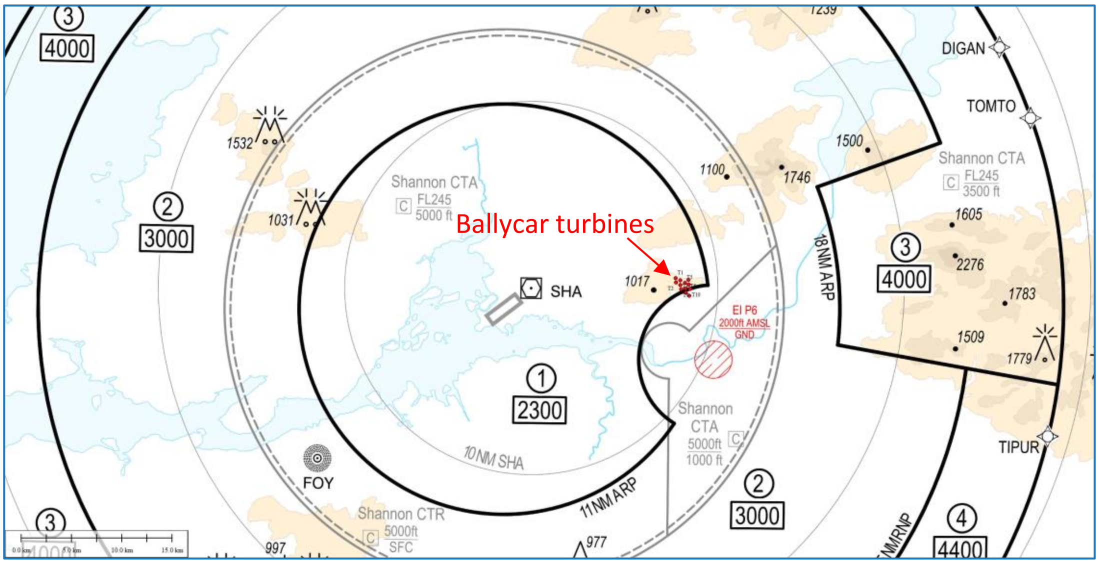


Figure 26: Shannon Airport ATC Surveillance Minimum Altitude Chart

5.9. Conclusions

5.9.1. All the proposed Ballycar turbines except turbine T10 are likely to be detected by Shannon PSR. This can result in turbine-induced clutter and false targets. In such areas of high clutter, the radar receiver sensitivity is reduced which can lead to track seduction of genuine aircraft targets in the vicinity of the turbines. A form of mitigation for Shannon PSR over the proposed Ballycar development may be required and this is discussed in Section 6.

5.9.2. All the proposed sites for the Ballycar turbines are outside the Eurocontrol recommended 16km turbine assessment zone for Shannon MSSR, therefore an impact assessment on this facility was not required. No mitigation measures are therefore necessary for Shannon MSSR.

5.9.3. Calculations have shown that false targets due to bistatic reflections from the turbine towers may occur for Woodcock Hill MSSR. Aircraft between 5,250m and 10,536m from the proposed turbines may respond to reflected Woodcock Hill MSSR interrogations, potentially resulting in MSSR ‘ghost’ targets appearing on the bearings of the turbines.

5.9.4. The Woodcock Hill MSSR has a reflection processing capability which enables the positions of permanent reflecting objects, such as the turbine towers, to be stored in a ‘reflector file’. Once the reflector file is updated it should eliminate any false targets caused by reflections from the turbine towers.

5.9.5. The maximum heights of shadow regions from the turbines will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable.

6. Shannon PSR Mitigation

6.1. Mitigation Strategy

6.1.1. It is generally not tolerable for an airport to have to cope with a variety of mitigation solutions, each tailored for individual wind farm developments. Ideally, an airport is best served by a single coherent strategy which will cope with the turbine developments foreseen within its designated operational coverage (DOC). New development applications can then be assessed on whether they will be covered by that strategy. Terms of inclusion within the strategy can then be negotiated with the developer as part of the planning approval process. This approach keeps the airport in control of its destiny and able to work positively with the renewables industry, rather than reacting against each application on the grounds that it will cause interference.

6.1.2. It is recommended that mitigation options are discussed with the Irish Aviation Authority (IAA), specifically Air Traffic Services. It is the surveillance network and operational use that will largely influence a suitable mitigation.

6.2. Mitigation Solutions

6.2.1. Physical PSR mitigation options include blanking of PSR transmissions in the azimuth sector over the proposed wind farm, or suppressing radar returns in the wind farm range azimuth sector. Both of these options may need to be combined with in-fill of the blanked sector from another source of radar information.

6.2.2. An operational PSR mitigation solution could involve the application of a Transponder Mandatory Zone (TMZ) in the airspace over the PSR blanked area. A TMZ means detecting aircraft using MSSR facilities only and requires aircraft within the TMZ to be equipped with a functioning transponder.

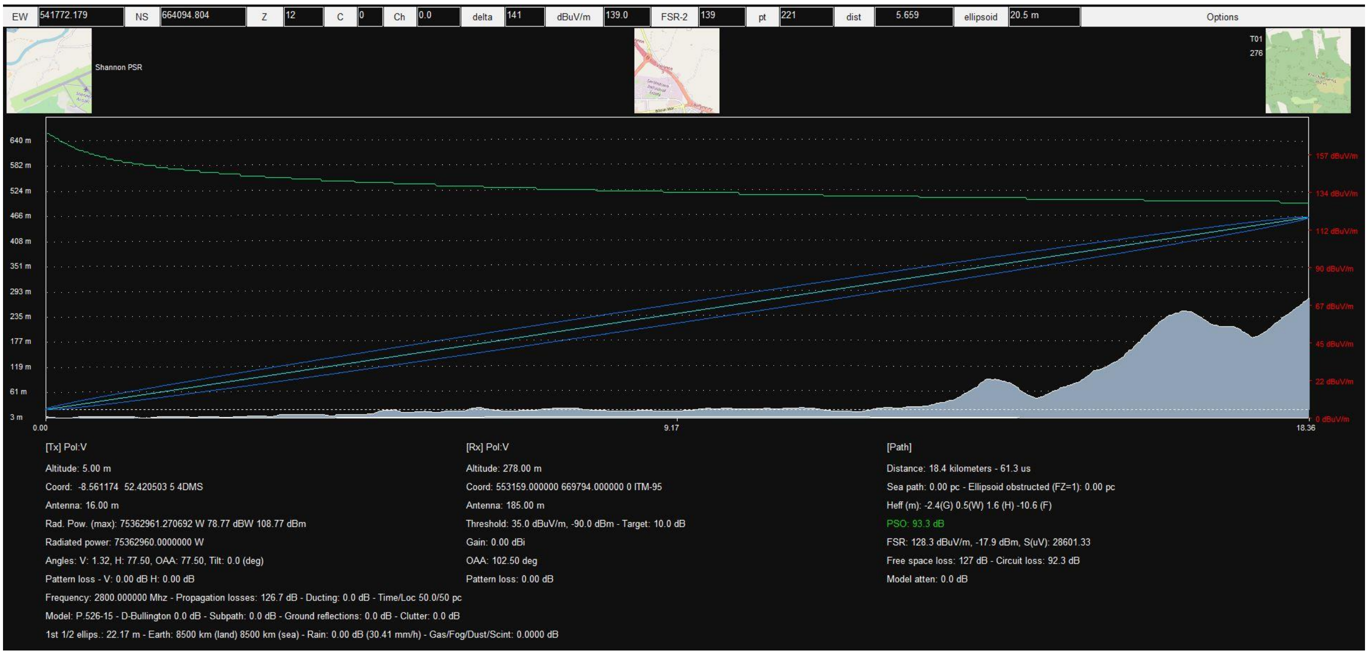
6.2.3. In-fill solutions using existing remote PSR data rely on the remote radar having suitable airspace coverage in the blanked area without having visibility of the turbines and depends on suitable terrain screening. A remote in-fill radar may also introduce problems of synchronisation with Shannon PSR and slant range errors.

6.2.4. Companies such as Terma offer dedicated 2D in-fill radar solutions for wind turbines. The in-fill radar must be located in close proximity to the airport PSR and be synchronised to it, enabling the mitigation radar to be used instead of the Airport PSR in the wind farm area. Terma radars have a narrow beamwidth that enables them to filter out turbines while continuing to track aircraft and can provide mitigation to a range of up to approximately 40NM.

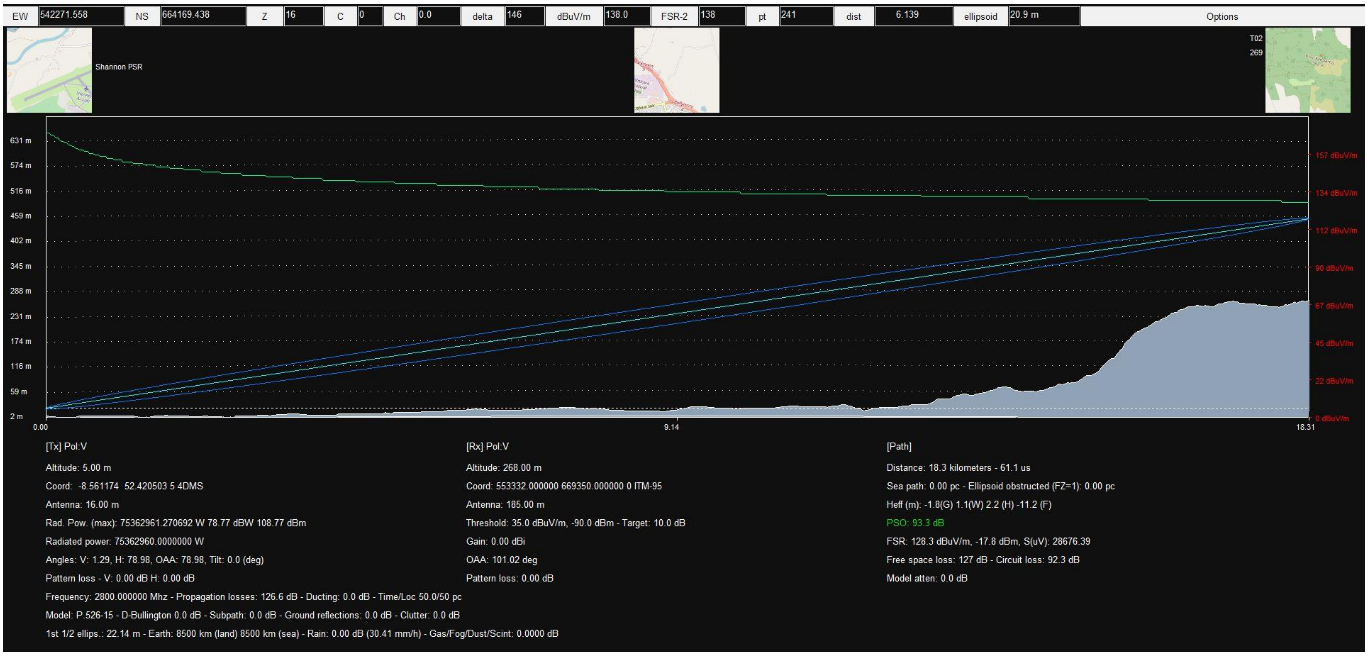
6.2.5. Aveillant offer a 3D radar mitigation solution with their Holographic Radar™. It is quite different to 2D mitigation radars as it has no rotating antenna and has continuous surveillance throughout its coverage volume. It can discriminate the distinct Doppler signatures of turbines from aircraft and as a result does not need to mask turbine returns to eliminate their false reports. The 3D output of this mitigation radar means that it does not need to be located in close proximity to the airport PSR and its target output can be coordinate transformed to the PSR origin without introducing slant range errors.

A. Annex A – Shannon PSR Path Profiles

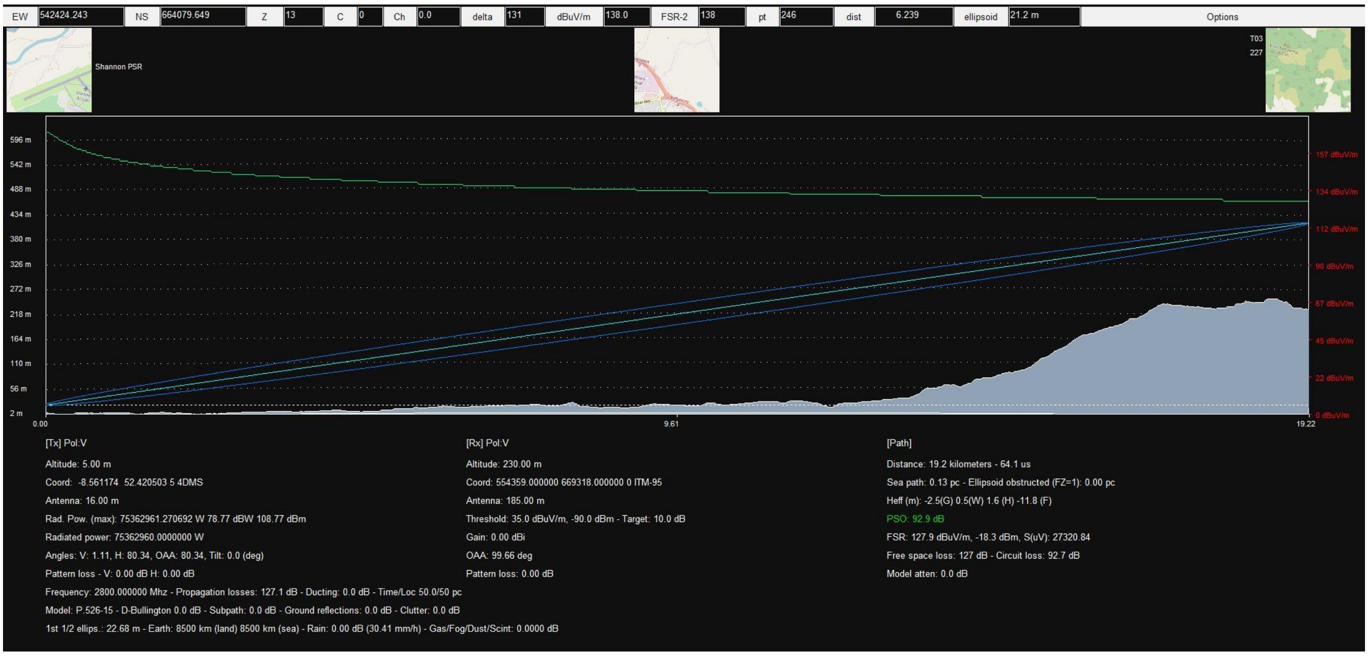
A.1. Turbine T1



A.2. Turbine T2



A.3. Turbine T3



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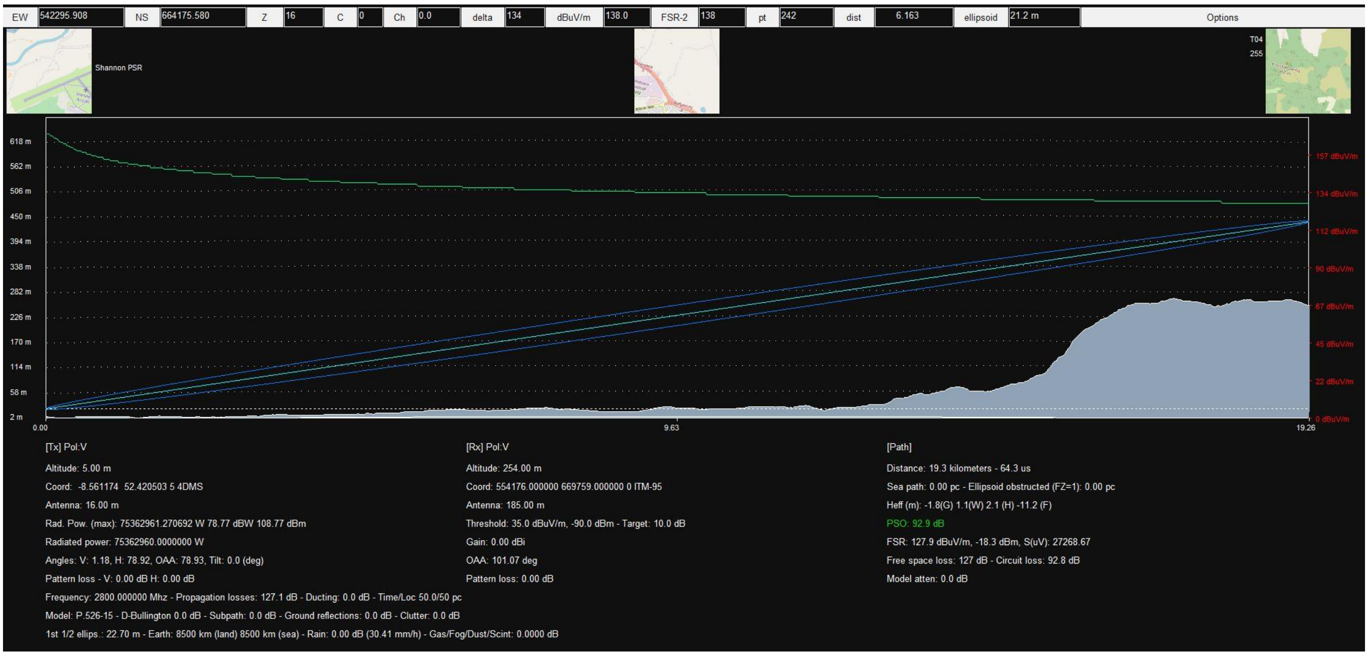
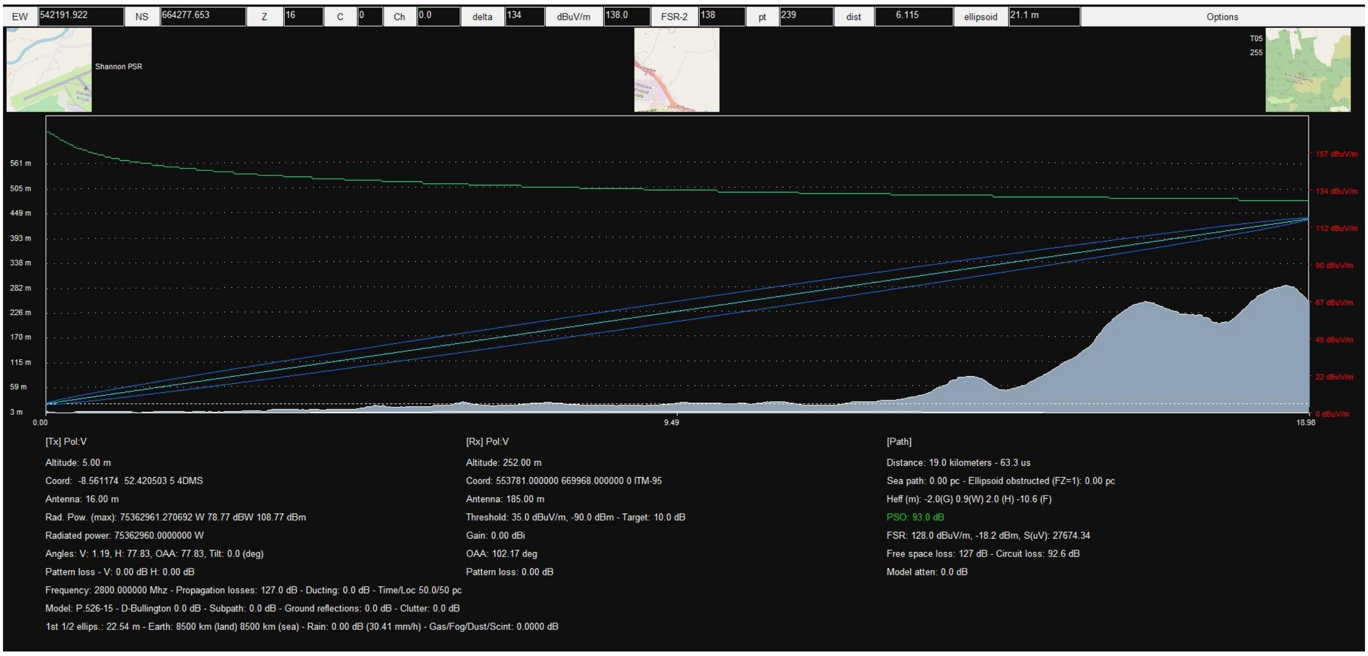
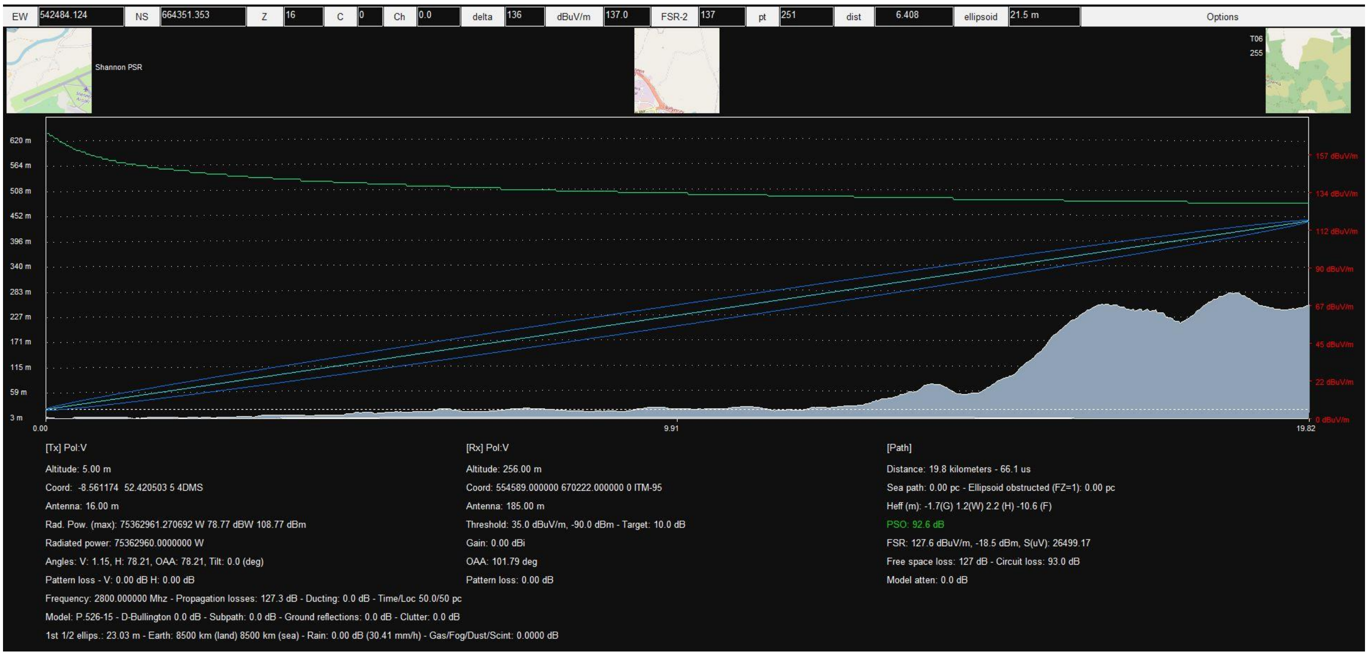


A.5. Turbine T5



A.6. Turbine T6



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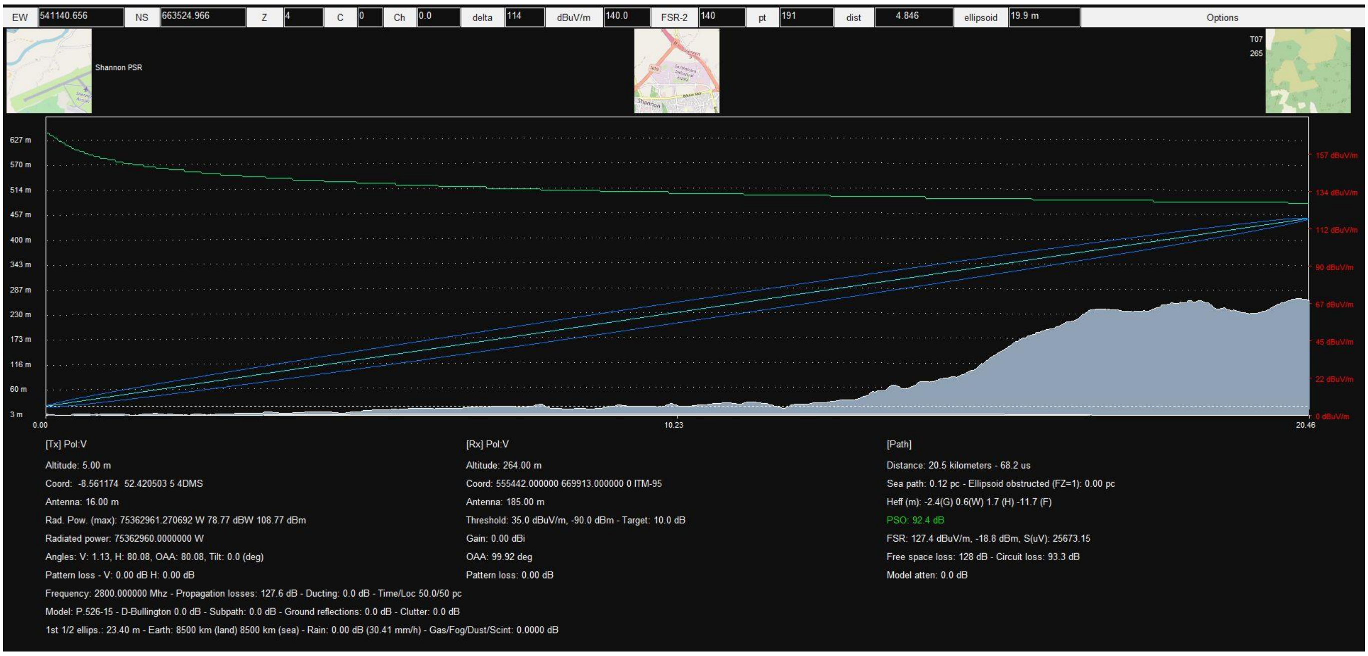
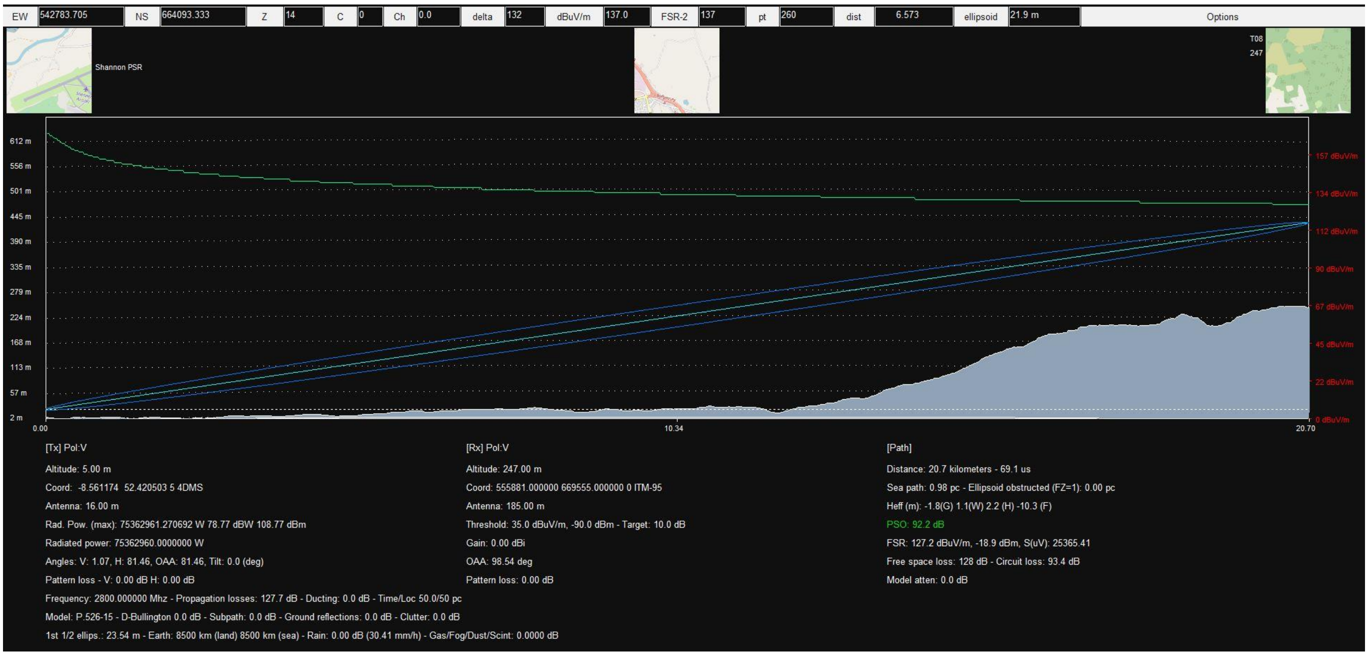
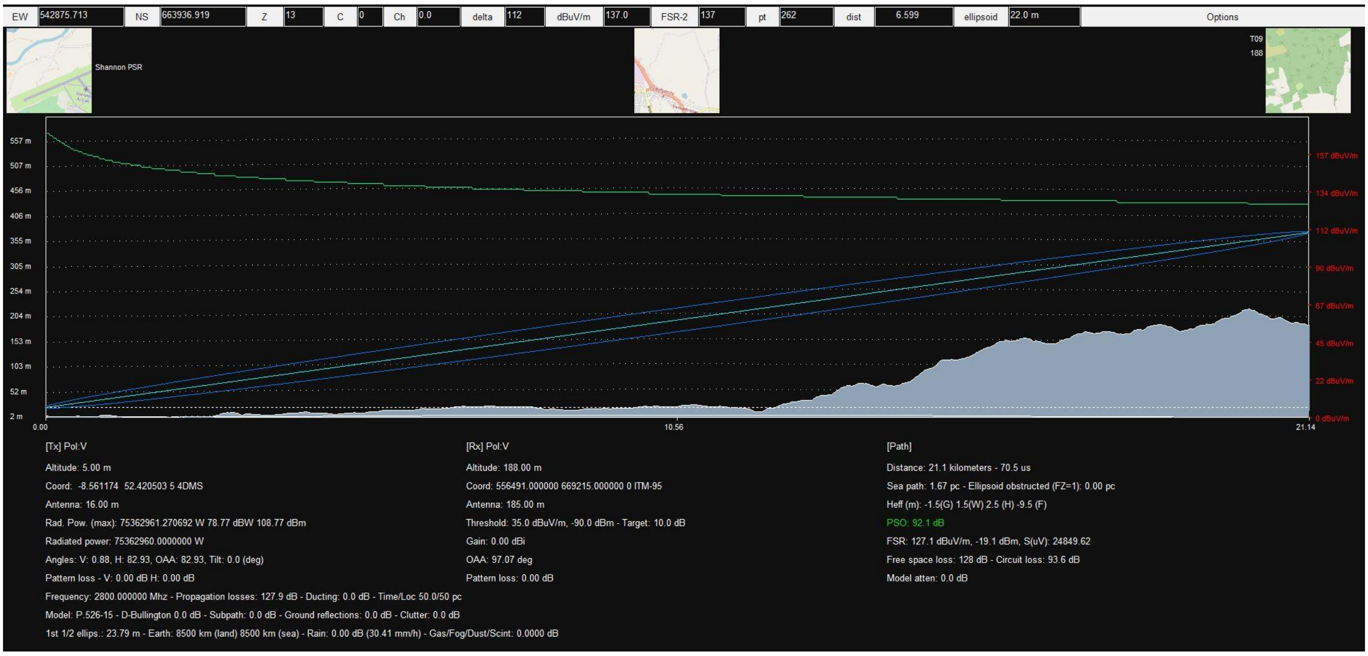


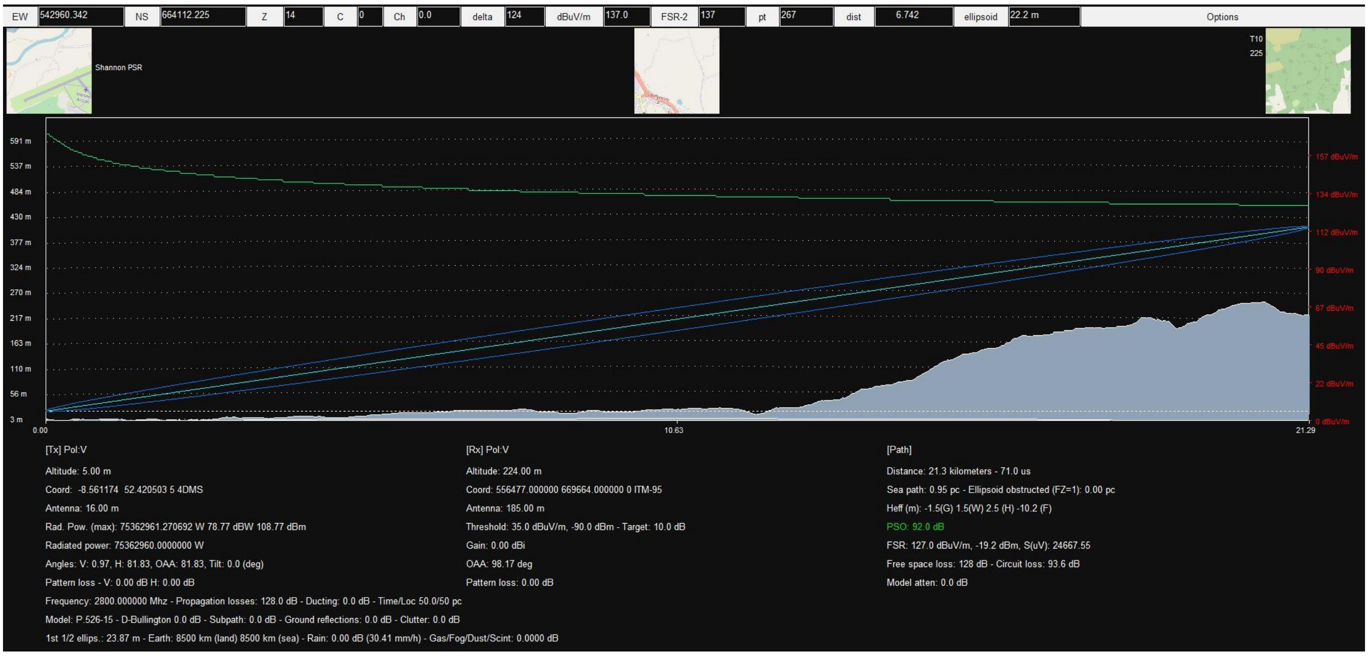
A.8. Turbine T8



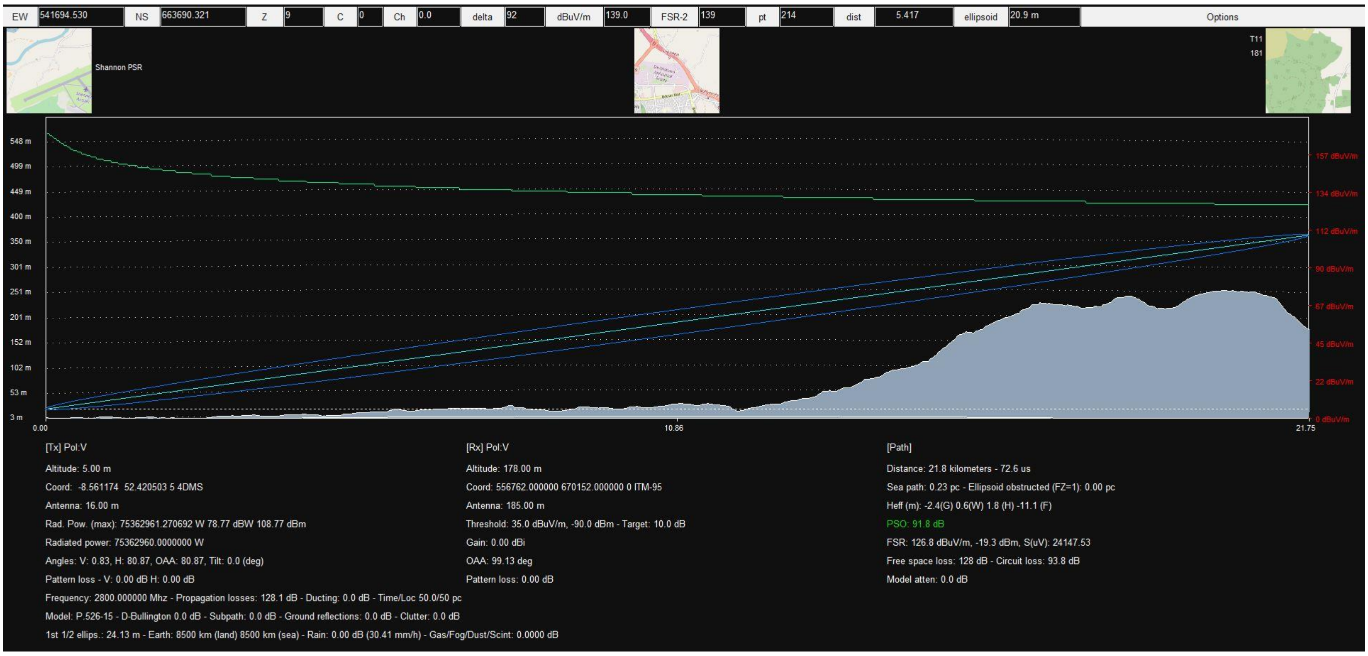
A.9. Turbine T9



A.10. Turbine T10



A.11. Turbine T11



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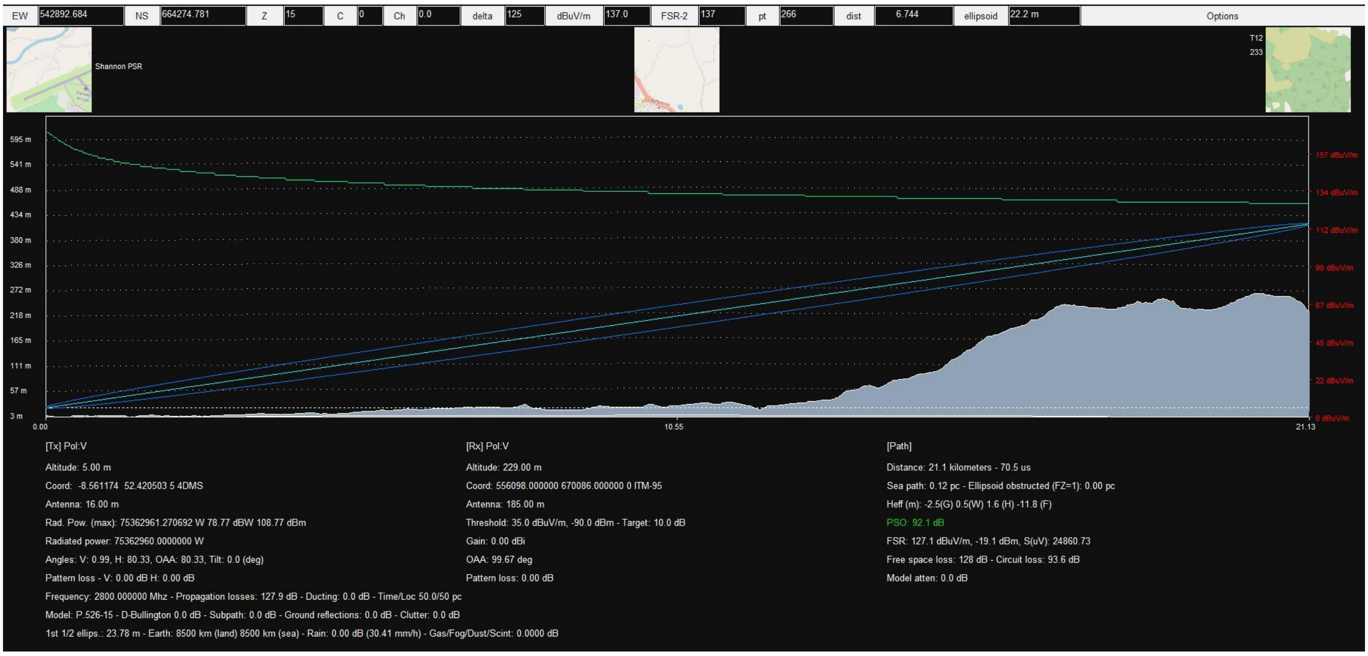
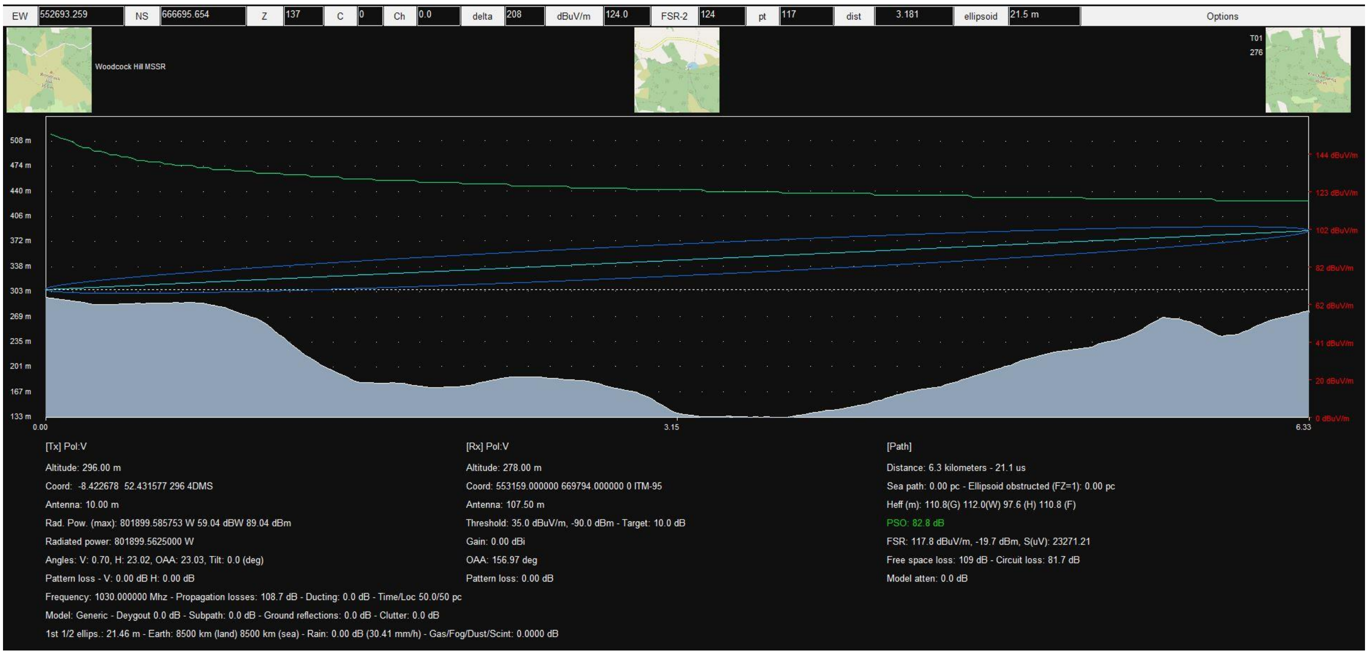


B. Annex B – Woodcock Hill MSSR Path Profiles

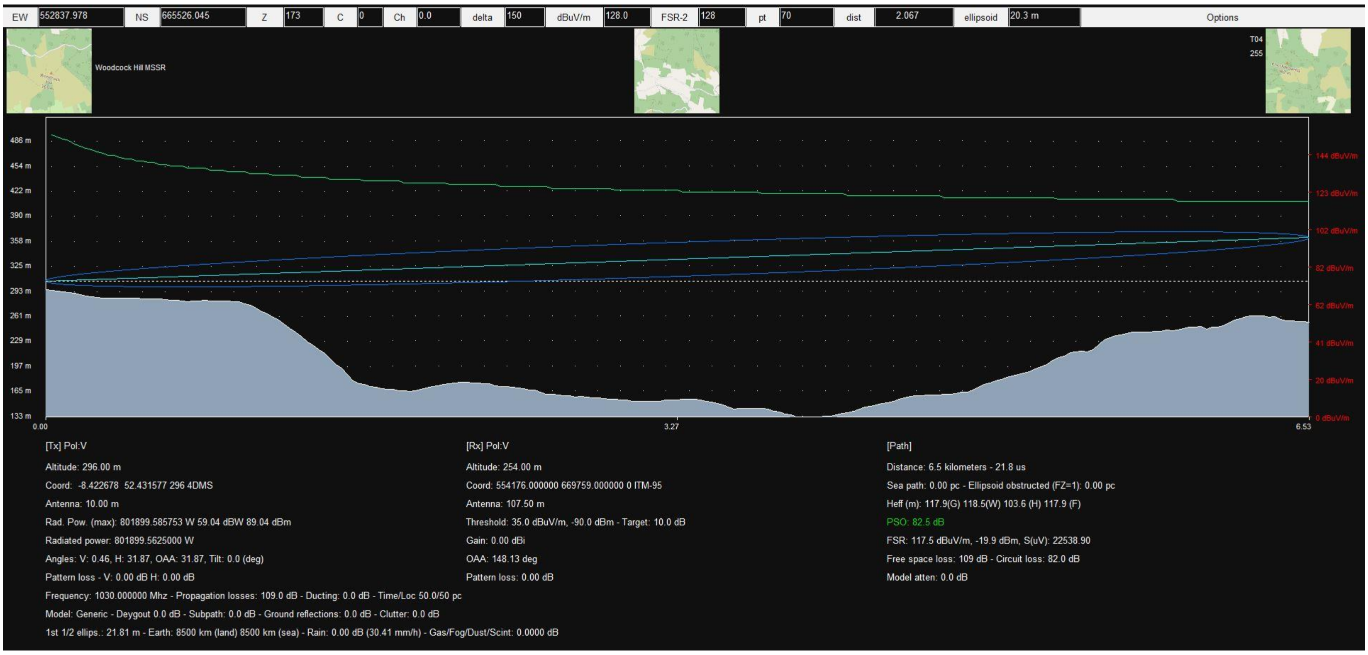
B.1. Turbine T1



B.2. Turbine T2

B.3. Turbine T3

B.4. Turbine T4



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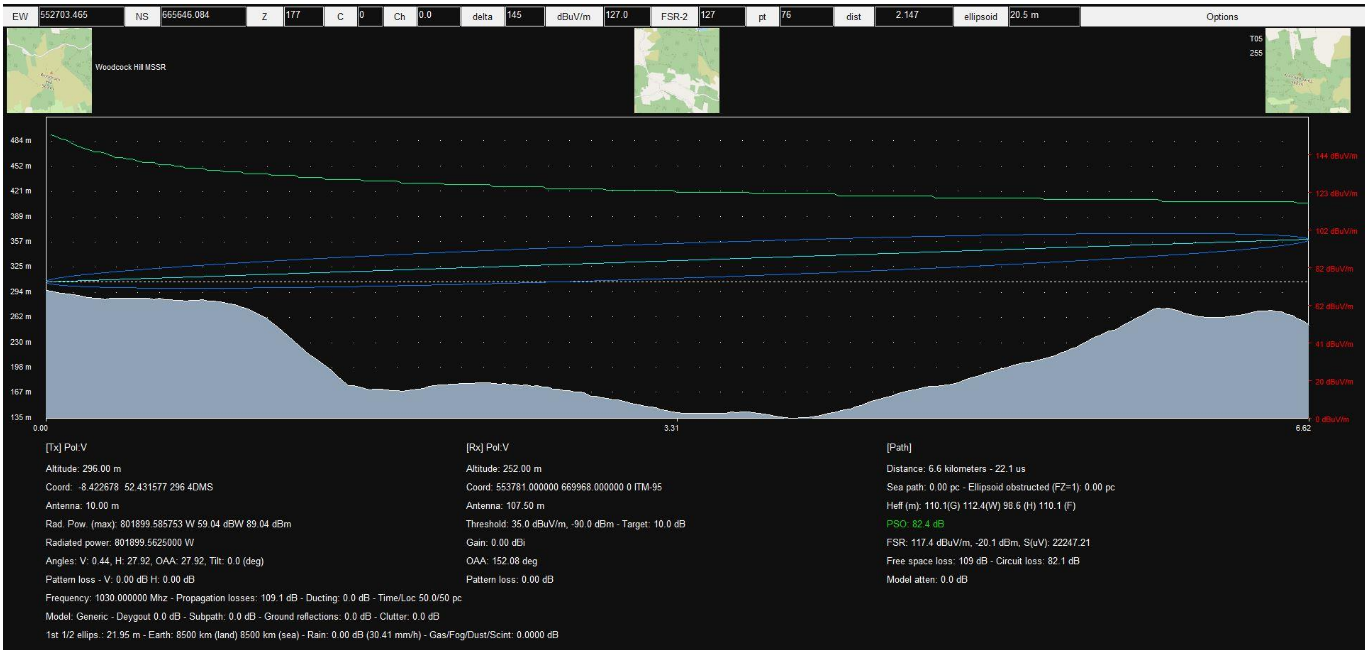
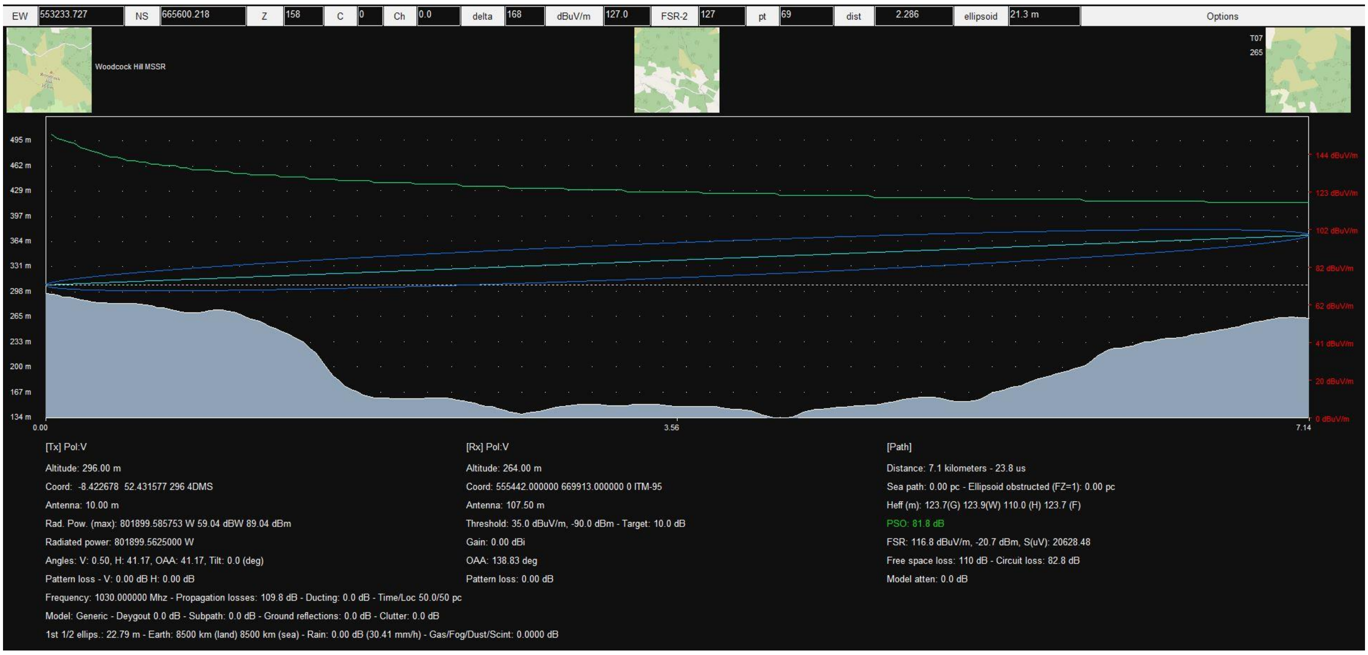
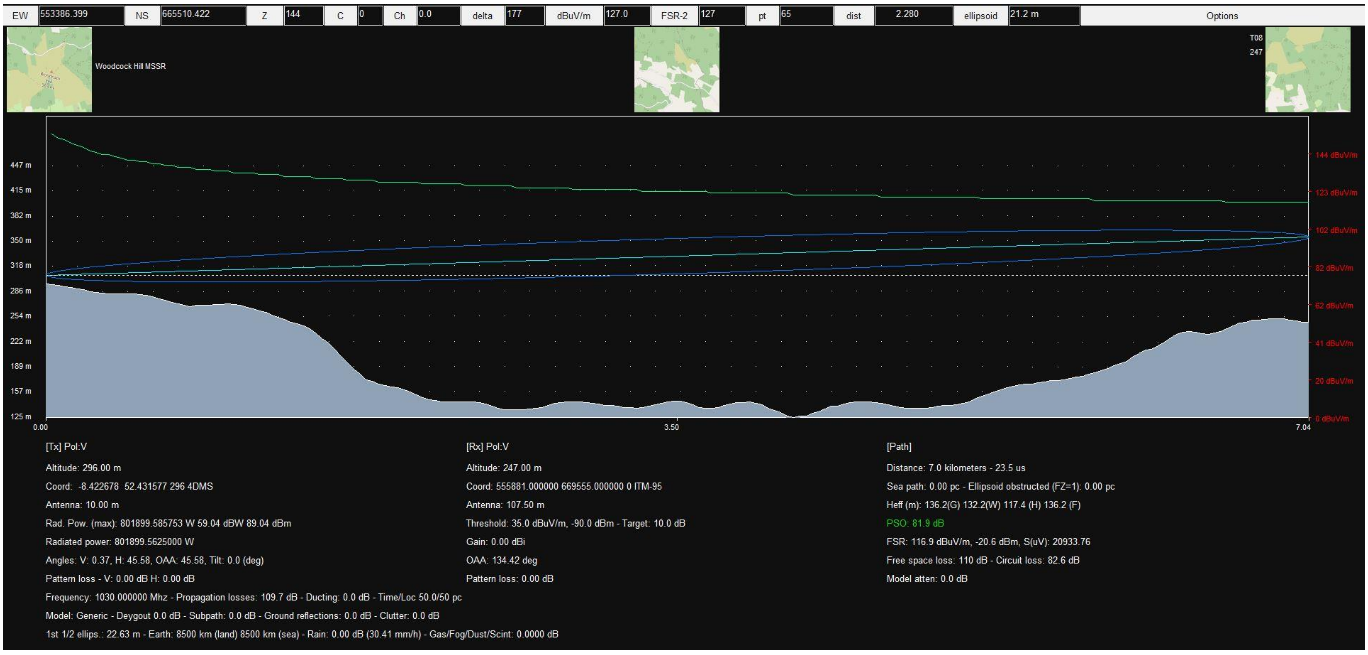


B.6. Turbine T6

B.7. Turbine T7

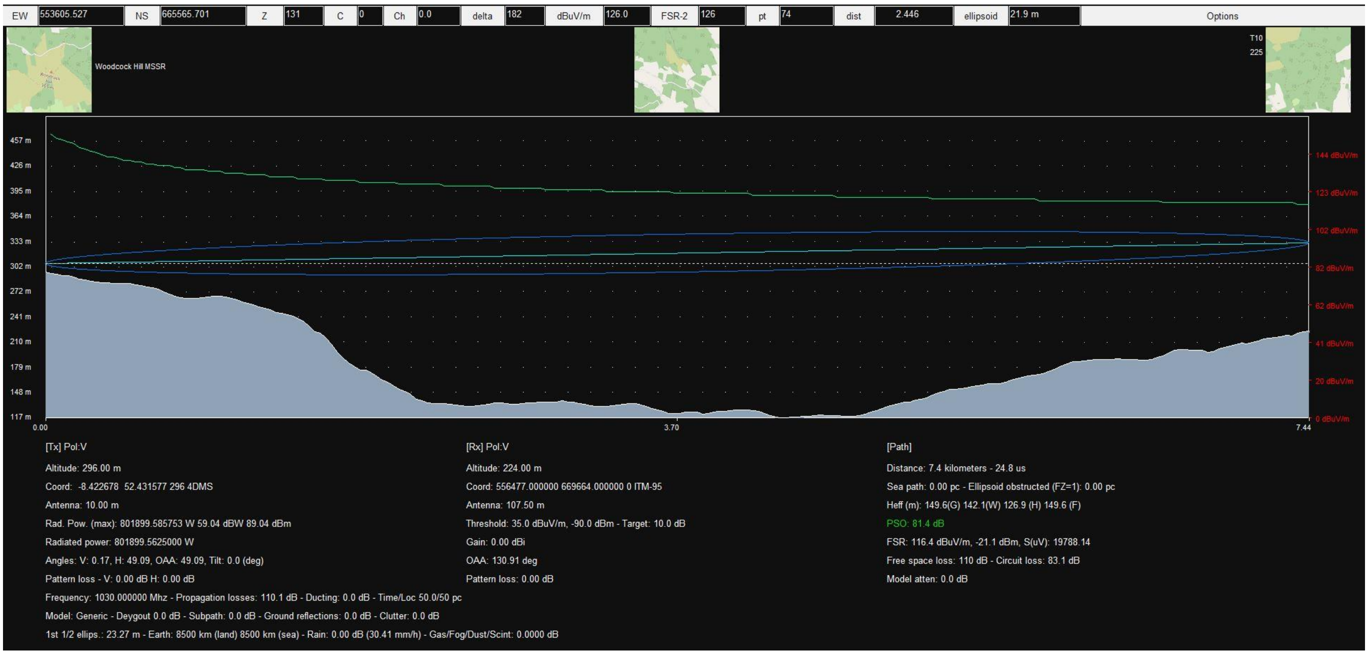


B.8. Turbine T8



B.9. Turbine T9

B.10. Turbine T10



B.11. Turbine T11

B.12. Turbine T12

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Appendix D – FCSL Ballycar Wind Farm Impact on ILS Inspection Report

FLIGHT CALIBRATION SERVICES LTD

BALLYCAR WIND FARM
IMPACT ON ILS FLIGHT INSPECTION

Prepared For:	Malachy Walsh & Co Ltd
Author:	John Wilson
Reviewed by:	David Bartlett
Reference:	FCSL 0140
Issue:	1
Date:	14 May 2022

BALLYCAR WIND FARM

Impact on ILS Flight Inspection

TABLE OF CONTENTS

ABBREVIATIONS

AIP	Aeronautical Information Publication
AMSL	Above Mean Sea Level
ARP	Aerodrome Reference Point
DME	Distance Measuring Equipment
FCSL	Flight Calibration Services Ltd
FIP	Flight Inspection Procedure
GP	Glide Path
GPS	Global Positioning System
ha	hectare
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
ITM	Irish Transverse Mercator
LOC	Localiser
NM	Nautical Mile
RF	Radio Frequency
VMC	Visual Meteorological Conditions
WGS	World Geodetic System

1 INTRODUCTION

Ballycar Wind Farm is a proposed renewable energy project in County Clare located approximately 16 km (8.6 NM) east of Shannon Airport.

The wind farm developer has requested that an assessment be performed to establish any adverse effect the proposed wind farm may have on flight inspection procedures and profiles associated with the Shannon Airport Runway 24 Instrument Landing System (ILS).

This report provides an assessment of the impact of terrain and obstacles on ILS flight inspection procedures. It does not provide an assessment of any impact the proposed wind farm may have on the integrity of the Runway 24 ILS guidance signals.

2 DETAILS OF PROPOSED WIND FARM

The proposed Ballycar Wind Farm comprises 12 wind turbines and associated infrastructure including turbine foundations, access tracks, an electricity substation and underground cabling located in an area of approximately 140 ha as shown in Figure 2.1 below. Figure 2.2 below shows the location of the wind farm in relation to Shannon Airport.

The proposed wind turbine coordinates are shown in Table 2.1 below.

The maximum height of the proposed wind turbines (to blade tip) is 158 m (518 ft) above ground level. Ground height at the highest turbine (T6) is 253 m (830 ft) AMSL.

The height of the highest turbine (to blade tip) is therefore 411 m (1,348 ft) AMSL.

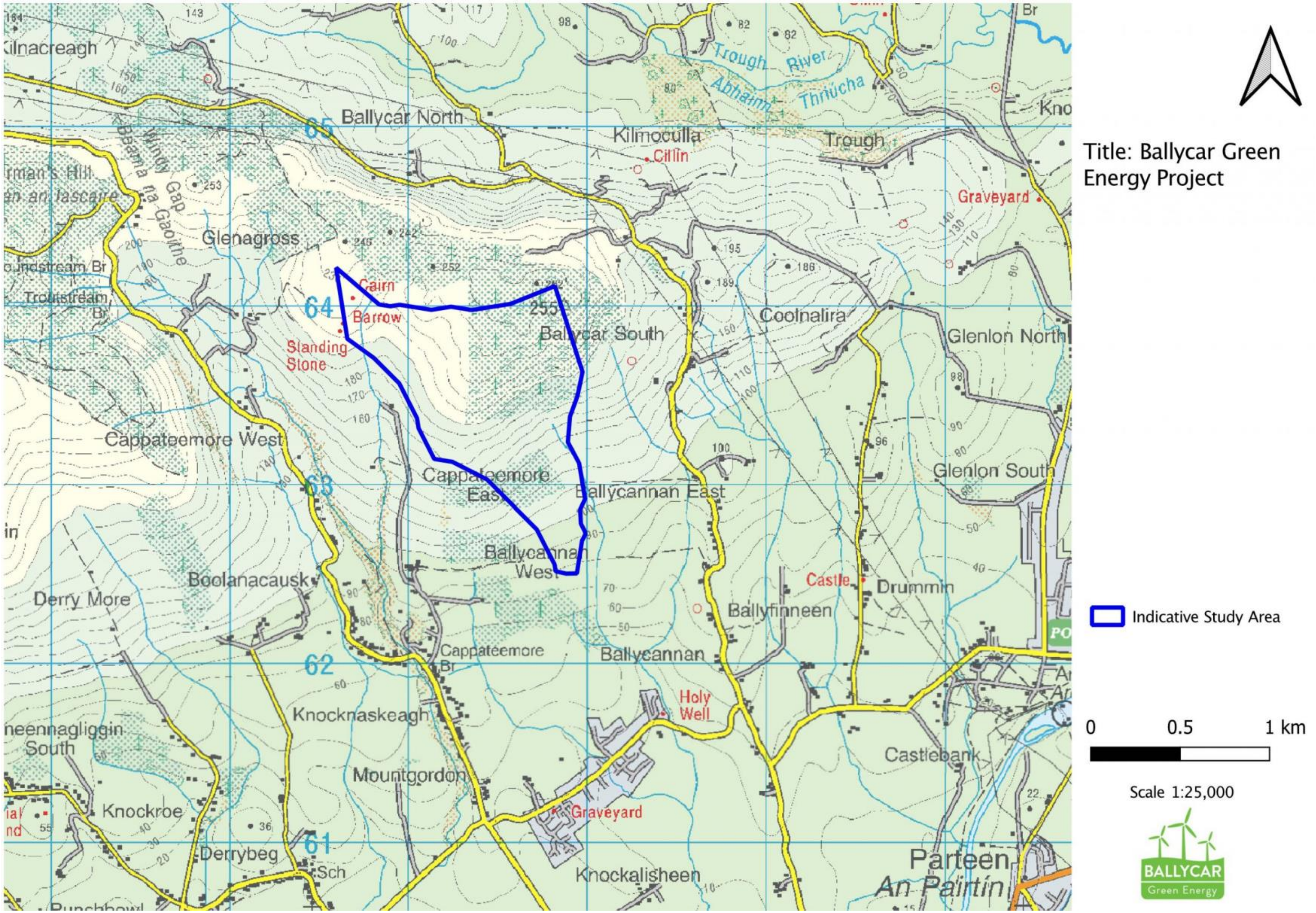


Figure 2.1 - Proposed Ballycar Wind Farm Site

Figure 2.2 – Location of Proposed Ballycar Wind Farm and Shannon Airport

Turbine	ITM Coordinates		WGS-84 Coordinates		Ground Level AMSL (m)
	X	Y	Latitude	Longitude	
T1	554589	664237	52.727317	-8.672287	234
T2	554609	663823	52.723595	-8.671932	205
T3	554964	664122	52.726317	-8.666729	232
T4	554981	663600	52.721624	-8.666394	193
T5	555405	663769	52.723181	-8.660152	241
T6	555821	664101	52.726198	-8.654033	253
T7	555913	663616	52.721845	-8.652613	192
T8	555503	663247	52.718497	-8.658624	160
T9	555084	663192	52.717965	-8.664818	166
T10	556023	663087	52.717097	-8.650911	115
T11	555645	662822	52.714689	-8.656465	107
T12	555899	662525	52.712041	-8.652666	236

Table 2.1 - Proposed Turbine Coordinates

3 ILS INFORMATION

3.1 ILS Site Information

The Runway 24 ILS provides radio navigation information to aircraft in the initial and final approach phases of flight towards Runway 24 within 25 NM of Shannon Airport. The ILS ground installation comprises:

- Localiser equipment (providing lateral guidance to the runway centreline) located on the extended runway centreline approximately 300 m from the stop end of Runway 24.
- Glide Path equipment (providing vertical guidance to a 3.0° glide path) located approximately 130 m offset from runway centreline and backset 360 m from Runway 24 threshold.
- Distance Measuring Equipment (DME) transponder (providing distance to runway threshold information). The DME antenna is mounted on the Glide Path mast.

ILS Localiser, Glide Path and DME antenna coordinates are shown in the extract from AIP Ireland shown in Figure 3.1 below.

3.2 ILS Coverage Information

International Standards and Recommended Practices (SARPS) for ILS are published by the International Civil Aviation Organization (ICAO). ICAO Annex 10 Chapter 3.1 defines ILS Localiser and Glide Path lateral coverage sectors as described below.

3.2.1 Localiser Coverage

The Localiser coverage sector shall extend from the centre of the localiser antenna system to distances of:

- 46.3 km (25 NM) within plus or minus 10 degrees from the front course line;
- 31.5 km (17 NM) between 10 degrees and 35 degrees from the front course line;
- 18.5 km (10 NM) outside of plus or minus 35 degrees from the front course line if coverage is provided.

Figure 3.2 below shows ILS Localiser lateral coverage sector as defined in ICAO Annex 10.

Figure 3.3 below shows the Runway 24 ILS Localiser lateral coverage sector in relation to the proposed Ballycar Wind Farm.

3.2.2 Glide Path Coverage

The Glide Path equipment shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation in sectors of 8 degrees in azimuth on each side of the centre line of the ILS glide path, to a distance of at least 18.5 km (10 NM).

ICAO Annex 10 Volume I states that ILS Glide Path coverage shall extend to a range of 10 NM, up to 1.75θ and down to 0.45θ above the horizontal, or to a lower angle, down to 0.3θ as required to safeguard the promulgated Glide Path intercept procedure (where θ is the nominal Glide Path angle).

Figure 3.4 below shows ILS Glide Path coverage as defined in ICAO Annex 10.

Figure 3.5 below shows the Runway 24 ILS Glide Path lateral coverage sector in relation to the proposed Ballycar Wind Farm.

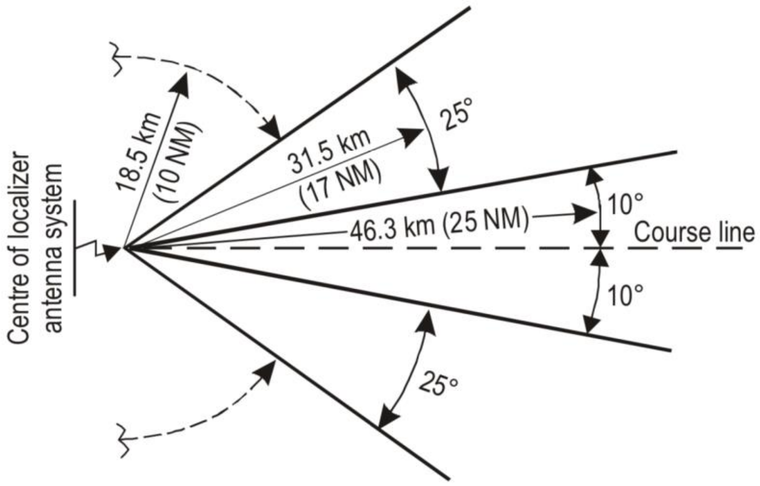
3.2.3 DME Coverage

The DME equipment shall provide aircraft with distance to threshold information throughout the Localiser coverage sector as defined in 3.2.1 above.

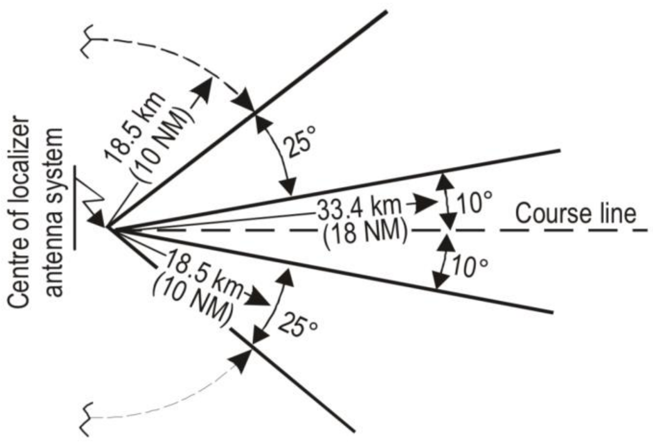
EINN AD 2.19 RADIO NAVIGATION AND LANDING AIDS

Type of aid, MAG VAR, Type of supported OP (for VOR/ILS/ MLS/GNSS/ SBAS and GBAS, give declination)	ID	Frequency	Hours of operation	Position of transmitting antenna coordinates	Elevation of DME transmitting antenna or SBAS: ellipsoid height of LTP/FTP	Service Volume Radius from the GBAS Reference Point	Remarks
1	2	3	4	5	6	7	8
DVOR/DME 4º W 2017	SHA	113.300 MHz	H24	524315.6N 0085306.8W	200ft		Designated Operational Coverage 300 NM/70,000ft 180ºTrue BRG to 360º True BRG. Designated Operational Coverage 100 NM/50,000ft.
NDB	FOY	395 kHz	H24	523358.5N 0091143.5W			Designated Operational Coverage 50 NM
ILS LOC RWY 06 CAT 1 4º W 2017	ISE	109.5 MHz	H24	524245.3N 0085408.2W			Coverage restricted to 35º either side of course line. Signals received outside coverage sector, (including back beam radiation), should be ignored.
ILS GP RWY 06		332.6MHz	H24	524147.2N 0085623.1W			GP Angle 3º RDH 55ft Full scale fly down indication may not be maintained when above GP sector. Full scale fly up indication may not be maintained when left of LOC sector and below GP.
ILS DME RWY 06	ISE	CH32X (109.5 MHz)	H24	524147.2N 0085623.1W	100ft		DME Zero ranged to THR 06. DME zero range is displaced from DME antenna by 445M.
ILS LOC RWY 24 CAT II 4º W 2017	ISW	110.95MHz	H24	524129.4N 0085649.6W *			Coverage restricted to 35° either side of the course line. Signals received outside coverage sector, (including back beam radiation), should be ignored. No LOC coverage below 3000ft MSL AT 25 NM EINN *Data whose accuracy has not been quality assured.
ILS GP RWY 24		330.65MHz	H24	524232.1N 0085447.7W			GP Angle 3° RDH 59ft
LO RWY 24	OL	339 kHz	H24	524456.4N 0084926.0W			Designated Operational Coverage 15NM
OM RWY 24	2 Dashes per sec	75 MHz	H24	524455.5N 0084927.0W			
MM RWY 24	Dots and Dashes	75 MHz	H24	524254.8N 0085347.9W			
ILS DME RWY 24	ISW	CH46Y (110.95 MHz)	H24	524232.1N 0085447.7W	100ft		DME Zero ranged to THR 24. DME zero range is displaced from DME antenna by 391M.

Figure 3.1 - AIP Ireland



When topographical features dictate or operational requirements and alternative navigation facilities permit, the following coverage may be provided:



Note.— If coverage as prescribed in Chapter 3, 3.1.3.3.1 is required outside the plus or minus 35-degree sector, this is provided to 18.5 km (10 NM), as indicated by the broken arc above.

Figure 3.2 - ILS Localiser Lateral Coverage Sector

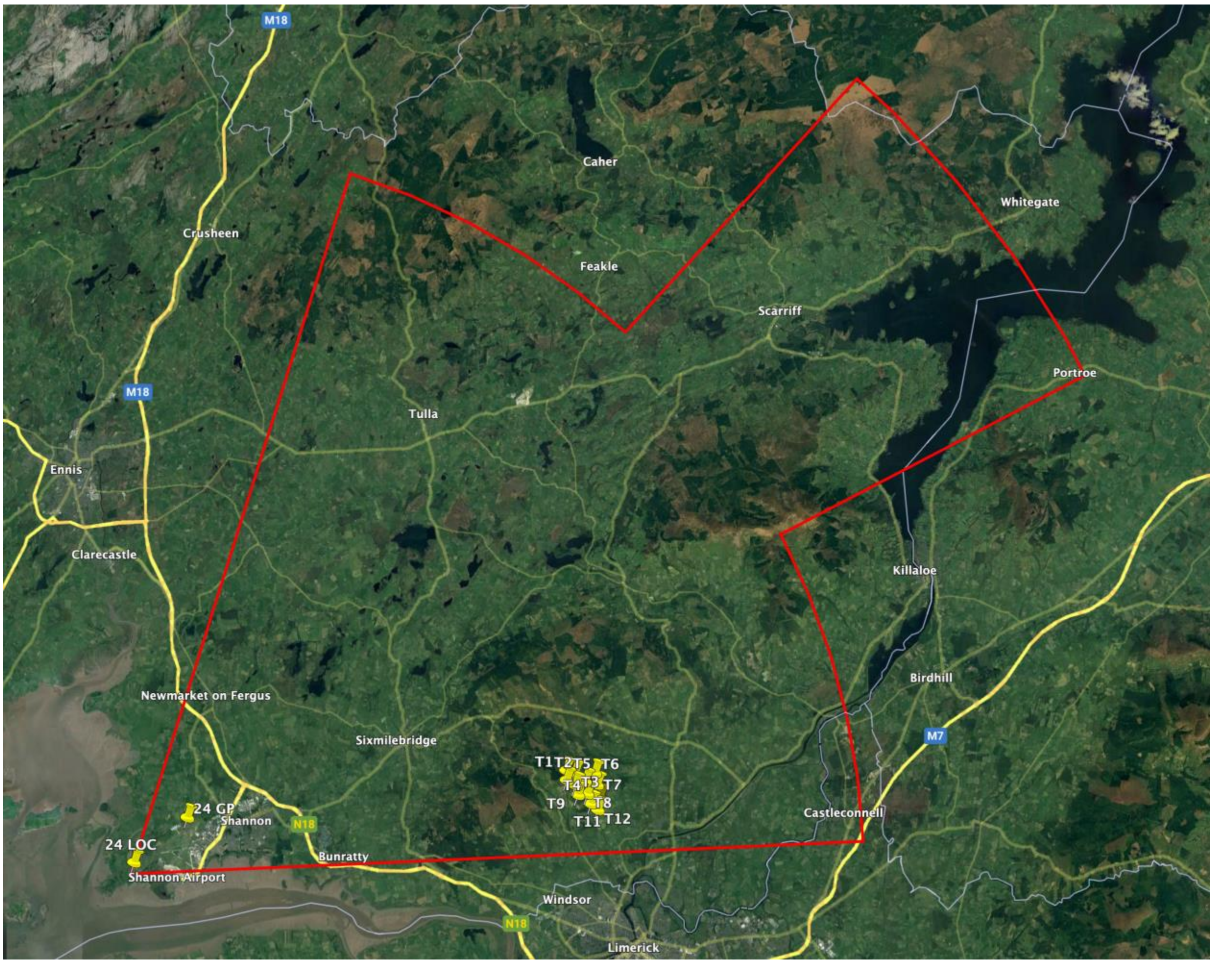


Figure 3.3 - Runway 24 ILS Localiser Lateral Coverage Sector

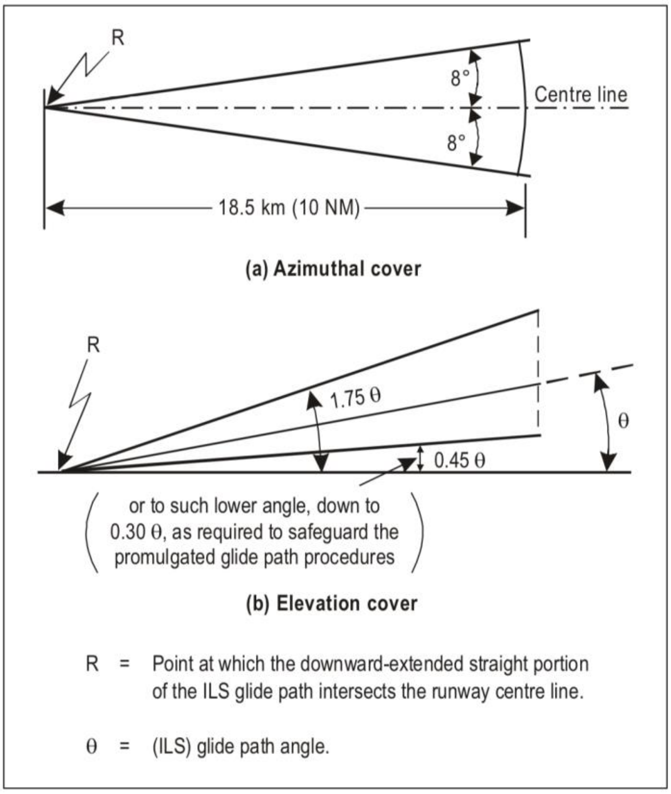


Figure 3.4 - ILS Glide Path Coverage

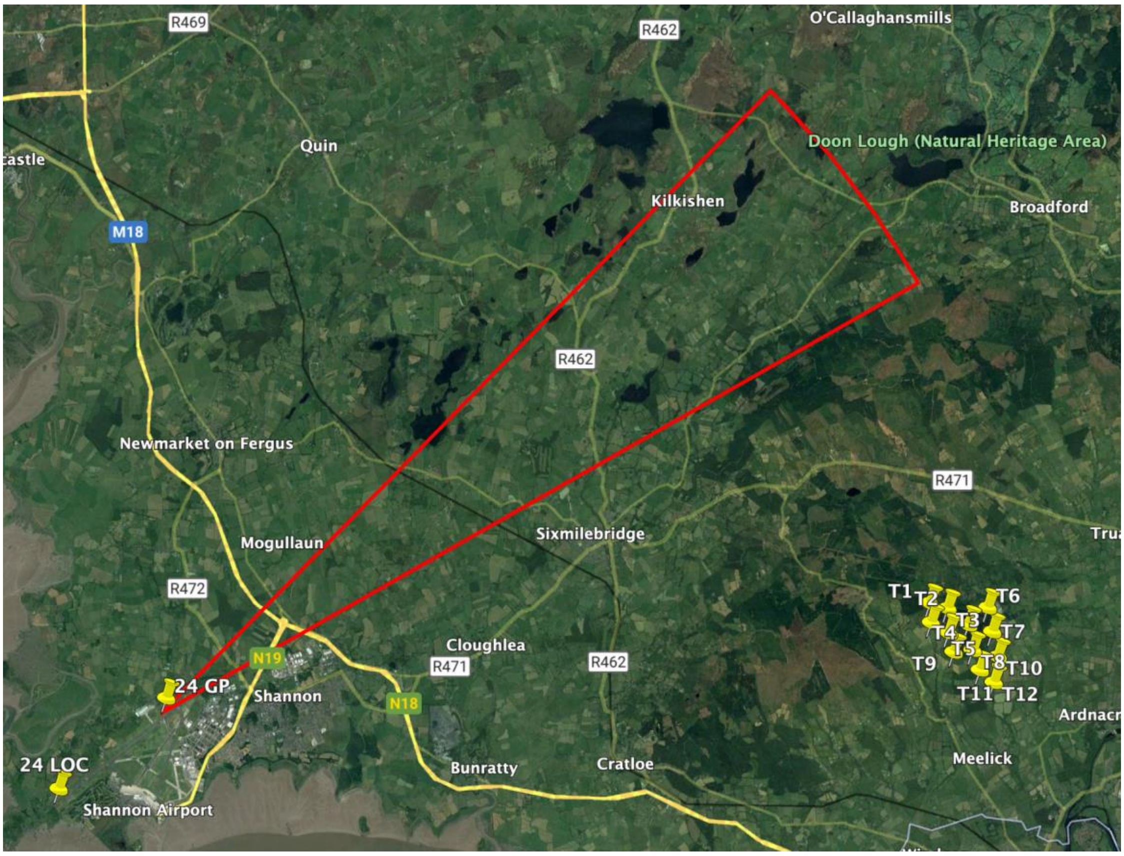


Figure 3.5 - Runway 24 ILS Glide Path Lateral Coverage Sector

4 ICAO ILS FLIGHT INSPECTION RECOMMENDATIONS

International Standards and Recommended Practices (SARPS) for ILS are published by the International Civil Aviation Organization (ICAO). Guidance material on factory, ground and flight testing of ILS installations is published in ICAO Doc 8071 Volume I. The purpose of ICAO Doc 8071 Volume I is to provide general guidance on the extent of testing and inspection normally carried out to ensure that radio navigation systems meet the SARPS published by ICAO.

To verify guidance signal accuracy within the ILS coverage volume, ICAO Doc 8071 recommends that a normal centreline approach should be flown, using the glide path, where available. For a Category II and III Localisers, the aircraft should cross the threshold at approximately the normal design height of the glide path and continue downward to normal touchdown point.

To verify that the ILS Localiser and Glide Path guidance signals provide the correct information to the user throughout the area of operational use, coverage checks should be performed. At periodic inspections, it is necessary to check coverage only at 31.5 km (17 NM) and 35 degrees either side of the course, unless use is made of the localiser outside of this area. Arc (part orbit) profiles may be flown at distances closer than this, provided an arc profile is flown at the same distance and altitude during the commissioning inspection to establish reference values.

To verify Glide Path displacement sensitivity, ICAO Doc 8071 recommends that approaches be made on centreline, 0.12θ below and 0.12θ above the nominal glide path angle (θ), where aircraft should receive 50% full-scale fly up (below path) and 50% full-scale fly down (above path) guidance indications.

The clearance of the Glide Path sector is verified by flying towards the facility on centreline at a constant height (level run) starting at a distance corresponding to an angle of 0.3θ (where θ is the nominal glide path angle) continuing to a point where twice the glide path angle (2θ) has been passed. Glide Path RF signal level is also measured during the level run to ensure the received signal level meets ICAO minimum requirements at the limits of coverage.

5 FCSL FLIGHT INSPECTION PROCEDURES

FCSL have developed company procedures for commissioning and routine flight inspection of ILS Localiser and Glide Path facilities. Customer flight inspection requirements are initially captured on a Client Facility Data Sheet (Form 101). Form 101 records the technical details of the navigation aid to be flight checked and the specified interval between flight checks. For the Runway 24 ILS, the interval between flight checks is 180 days.

In the case of the Runway 24 ILS, the ILS is flight checked in accordance with FCSL Flight Inspection Procedure (FIP) FIP 23 (ILS Flight Inspections GPS Southern Ireland).

FIP 23 specifies that the following flight profiles are flown as defined in FCSL Form 102 (Flight Profile Chart):

Profile No	Profile Description	See Figure
01	Centreline Approach	5.1
04	Part Orbit	5.2
12	Top Edge	5.3
13	Bottom Edge	5.4
14	Slice (Level run)	5.5
15	Left Slice 8° (Level run)	5.6
16	Right Slice 8° (Level run)	5.7

Figures 5.1 to 5.7 below show the flight profiles to be flown during ILS flight inspection.

The start points, heights and distances for each flight profile are decided by the FCSL Flight Inspector in conjunction with the pilots to ensure correct and sufficient data is recorded while taking into account local terrain and obstacle clearance requirements.

FCSL FIP 23 states that flight inspection pilots will not fly within 1,000 ft of the ground in IMC (unless on centreline and edge approaches) and commissioning flights should be carried out in sight of the surface at all times. FIP 23 also states that Inspection Pilots will not fly within 1,000 ft of the highest obstacle within 5 NM either side of track in IMC.

Glide Path flight inspection procedures include checks below the Glide Path sector to assure a safe flight path area between the bottom edge of the Glide Path sector and any obstacles on the approach path. The Glide Path slice and left slice 8° (level runs) flight profiles must therefore ensure that the flight inspection aircraft clears obstacles by at least 500 ft in VMC and by at least 1,000 ft in IMC.

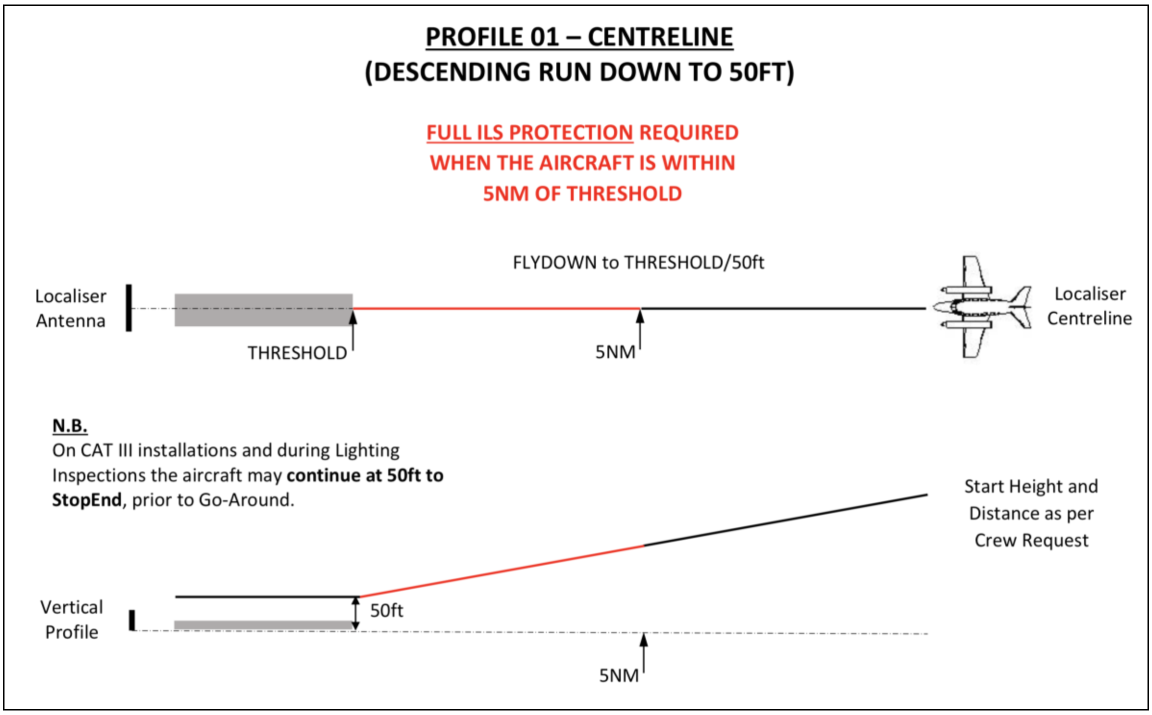


Figure 5.1 - Centreline Approach Flight Profile

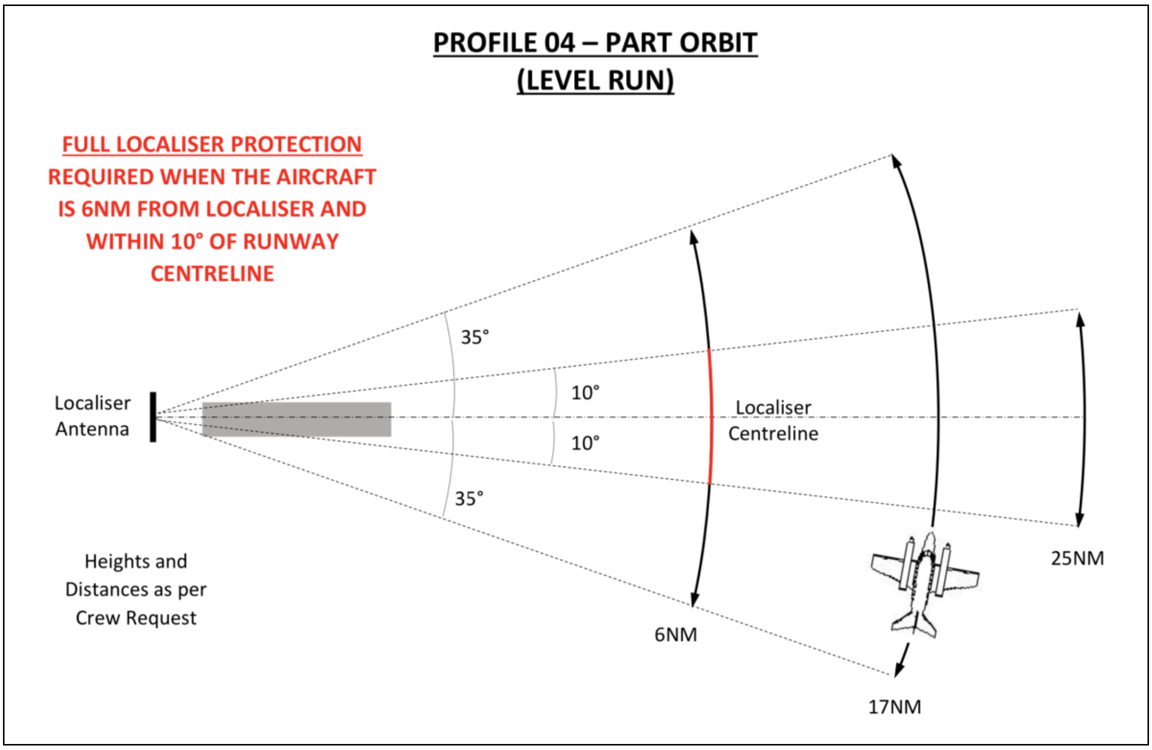


Figure 5.2 – Part Orbit Flight Profile

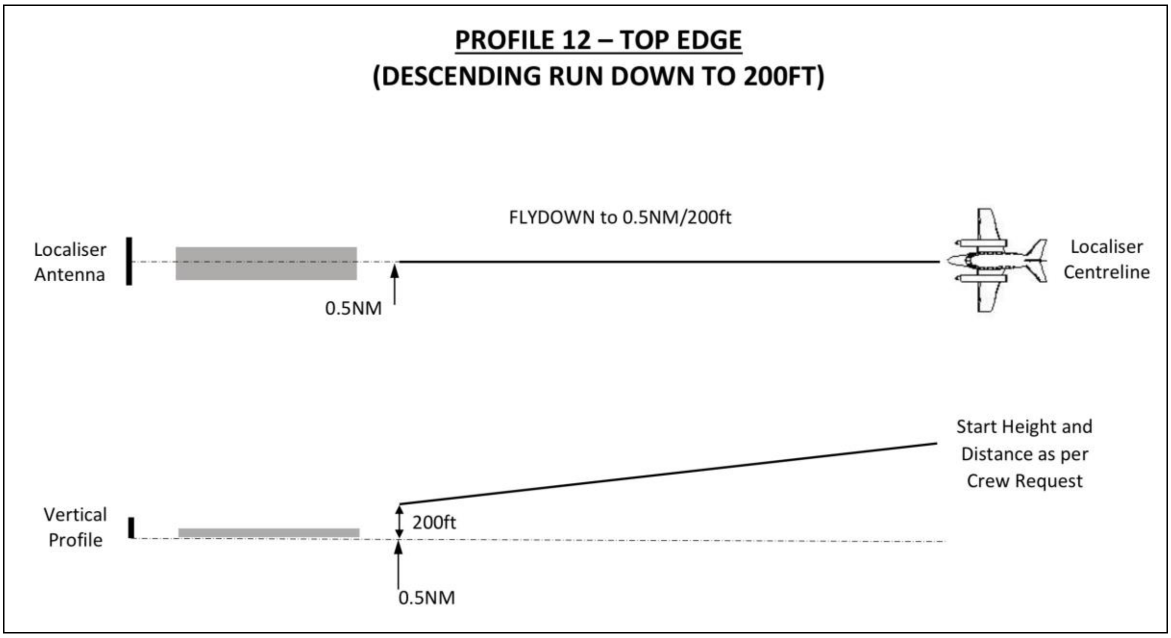


Figure 5.3 – Top Edge Flight Profile

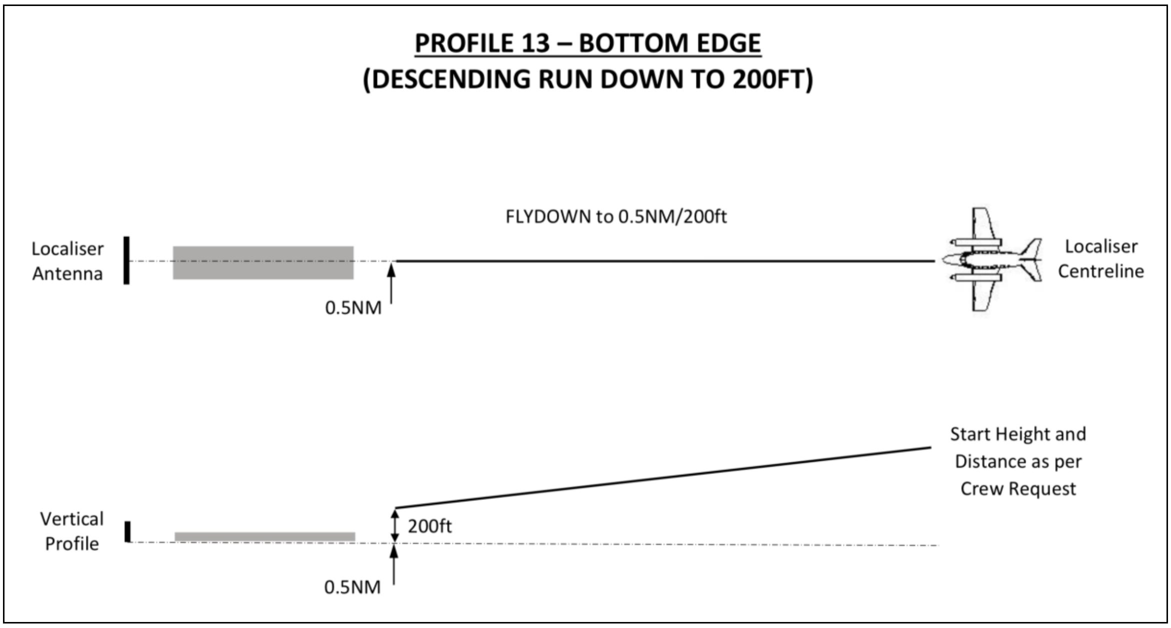


Figure 5.4 – Bottom Edge Flight Profile

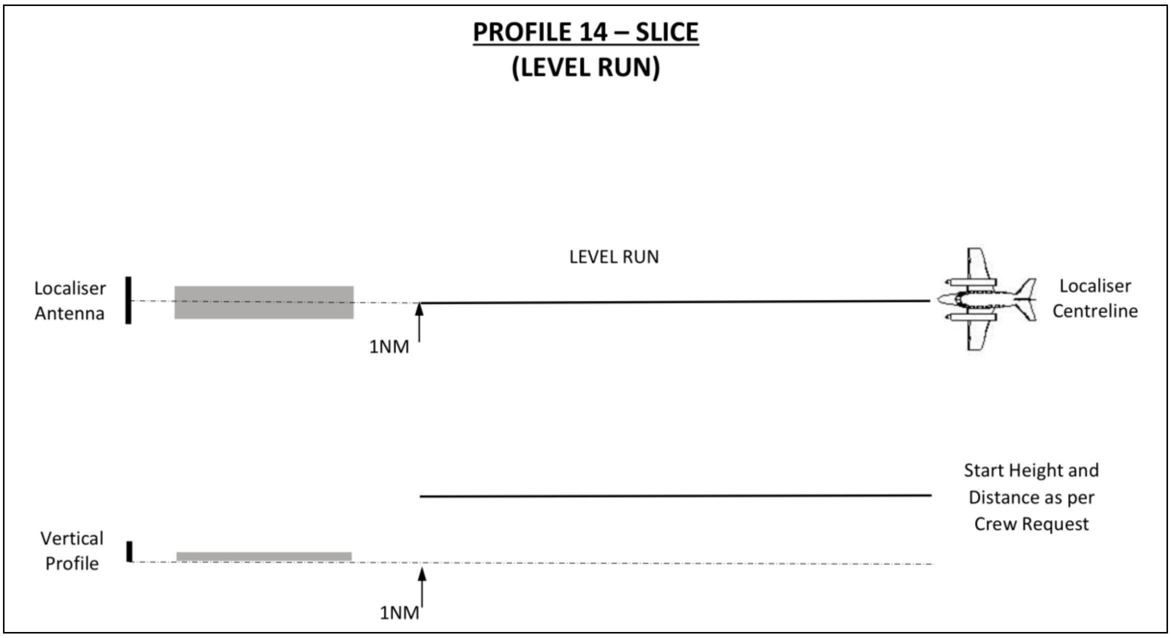


Figure 5.5 – Slice Flight Profile

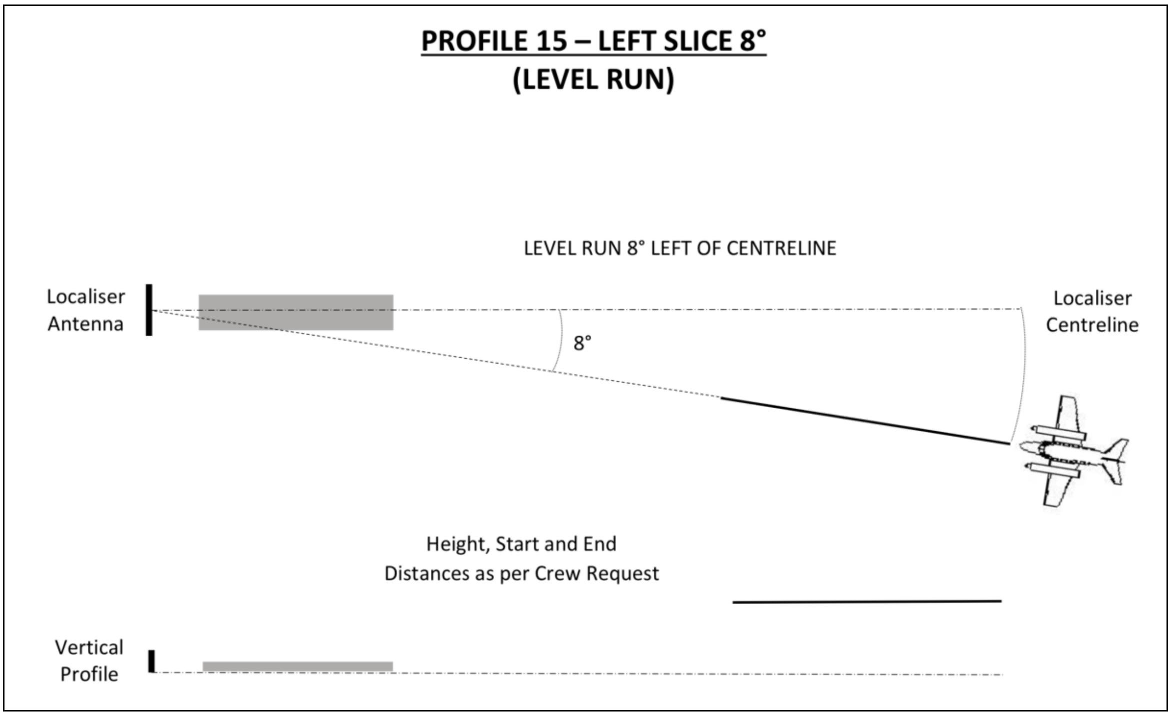


Figure 5.6 – Left Slice 8° Flight Profile

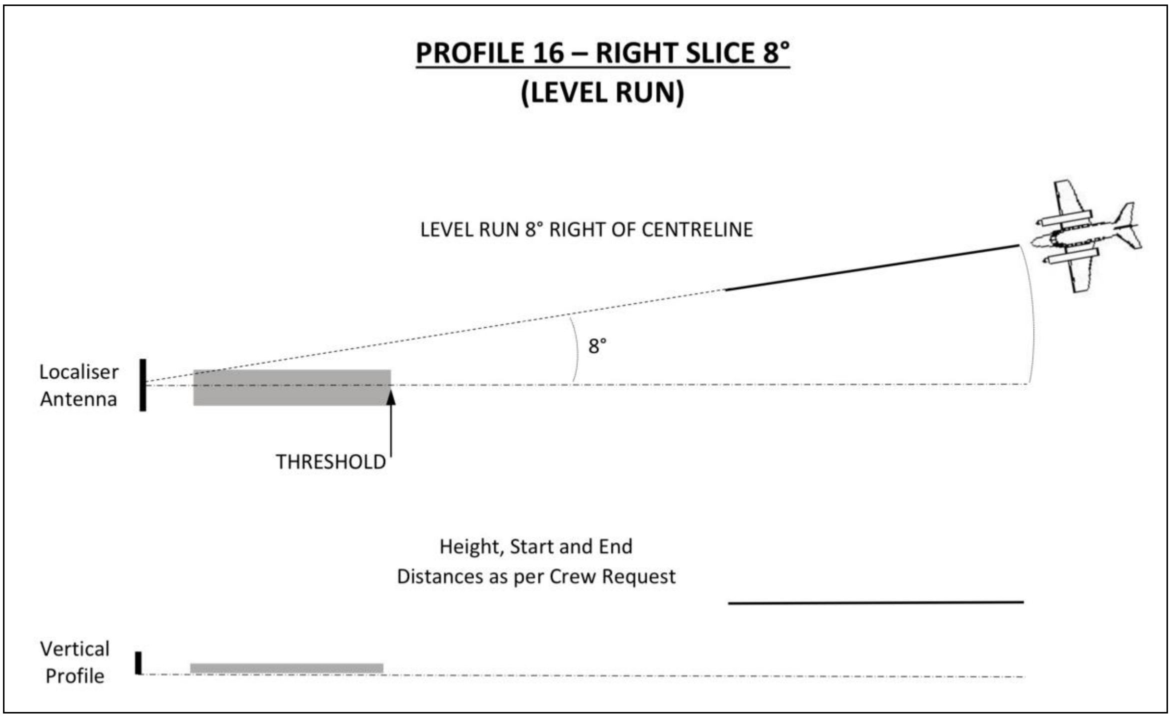


Figure 5.7 – Right Slice 8° Flight Profile

6 IMPACT ASSESSMENT

6.1 ILS Centreline Approach Flight Profile

For ILS centreline approach flight profiles, heights and distances are decided by the FCSL Flight Inspector in conjunction with the pilots to ensure correct and sufficient data is recorded while taking into account local terrain and obstacle clearance requirements.

For the most recent routine Runway 24 ILS flight inspections conducted by FCSL, centreline approaches were flown from a range of 25 NM.

6.1.1 Horizontal Obstacle Clearances

For a centreline approach profile, the flight inspection aircraft will be approximately 4.4 NM laterally from the nearest wind turbine (T1) at a point on the extended runway centreline closest to the wind farm. This distance is less than the minimum clearance required from any object in IMC, as defined in FIP 23.

6.1.2 Vertical Obstacle Clearances

For a centreline approach on a 3.0° glide path, the flight inspection aircraft will pass above, but 4.4 NM laterally distant from, the proposed Ballycar Wind Farm site. The flight inspection aircraft vertical clearance above the highest turbine (T6) can be estimated as follows (see Figure 6.1):

Horizontal distance from 24 Glide Path antenna (on boresight) to Turbine T6

= 15,208 m

Assume ground height at 24 Glide Path Antenna = ARP height = 46 ft = 14 m

Clearance (h) above highest turbine (T6)

$= (15{,}208\ m \times \tan 3.0°) - (253\ m - 14\ m) - 158\ m = 400\ m = 1{,}312\ ft$

This height exceeds the minimum clearance required above terrain and obstacles in IMC and VMC.

6.2 ILS Part Orbit Flight Profile

For ILS part orbit flight profiles, heights and distances are decided by the FCSL Flight Inspector in conjunction with the pilots to ensure correct and sufficient data is recorded while taking into account local terrain and obstacle clearance requirements.

For the six most recent routine Runway 24 ILS flight inspections conducted by FCSL, part orbits were flown at a range of 6 NM from the Localiser antenna and a height of 1,500 ft AMSL.

The tracks of the 6 NM and 17 NM part orbit profiles are shown in Figure 6.2 below. Figure 6.3 below shows the terrain elevation profile for the 17 NM part orbit.

6.2.1 Horizontal Obstacle Clearances

For a 6 NM part orbit flight profile, the flight inspection aircraft will be at least 4.2 NM from the nearest wind turbine (T2) at a point on the part orbit track closest to the wind farm site. This distance is less than the minimum clearance required from any object in IMC, as defined in FIP 23.

For a 17 NM part orbit flight profile, the flight inspection aircraft will be at least 6.1 NM from the nearest wind turbines (T6, T7 and T10) at a point on the part orbit track closest to the wind farm site. This distance is greater than the minimum clearance required from any object in IMC and VMC, as defined in FIP 23.

6.2.2 Vertical Obstacle Clearances

In accordance with FCSL FIP 23, pilots must not fly within 1,000 ft of the ground in IMC. The 17 NM part orbit flight must therefore be flown at a height of at least 1,000 ft above the highest obstacle to be encountered.

Figure 6.3 below shows that a flight inspection aircraft flying a 17 NM part orbit will pass overhead and close to the summit of Moylussa mountain (1,745 ft). The 17 NM part orbit must therefore be flown at a height of at least 2,745 ft AMSL to remain at least 1,000 ft clear of the summit of Moylussa mountain.

The maximum height of the highest wind turbine (T6) can be estimated as:

Ground height + maximum turbine height = 253 m + 158 m = 411 m (1,348 ft).

For an orbit height of 2,745 ft AMSL, a flight inspection aircraft will therefore have a clearance of 1,397 ft above the highest wind turbine. This height exceeds the minimum clearance required above terrain and obstacles in IMC and VMC.

6.3 ILS Bottom Edge Flight Profile

6.3.1 Horizontal Obstacle Clearances

For the bottom edge flight profile (flown on centreline), the flight inspection aircraft will be approximately 4.4 NM laterally from the nearest wind turbine (T1) at a point on the extended runway centreline closest to the wind farm. This distance is less than the minimum clearance required from any object in IMC, as defined in FIP 23.

6.3.2 Vertical Obstacle Clearances

For the bottom edge flight profile (flown on centreline), the flight inspection aircraft is flown at a glide path angle 0.12θ below the nominal glide path angle (θ).

Bottom edge glide path angle = $\theta - 0.12\theta = 3° - 0.36° = 2.64°$.

The flight inspection aircraft will pass above, but 4.4 NM laterally distant from, the proposed Ballycar Wind Farm site. The flight inspection aircraft vertical clearance above the highest turbine (T6) can be estimated as follows:

Horizontal distance from 24 Glide Path antenna (on boresight) to Turbine T6

= 15,208 m

Assume ground height at 24 Glide Path Antenna = ARP height = 46 ft = 14 m

Clearance (h) above highest turbine (T1)

$= (15{,}208\ m \times \tan 2.64°) - (253\ m - 14\ m) - 158\ m = 304\ m = 997\ ft$

This height exceeds the minimum clearance required above terrain and obstacles in VMC, but is less than the minimum clearance required in IMC.

6.4 ILS Slice Flight Profile

6.4.1 Horizontal Obstacle Clearances

For the slice flight profile (flown on centreline), the flight inspection aircraft will be approximately 4.4 NM laterally from the nearest wind turbine (T1) at a point on the extended runway centreline closest to the wind farm. This distance is less than the minimum clearance required from any object in IMC, as defined in FIP 23.

6.4.2 Vertical Obstacle Clearances

Figure 6.4 below shows the track of the ILS slice flight profile. The slice profile is normally flown at a height of 1,000 ft AMSL.

Figure 6.5 below shows the terrain elevation profile for the slice flight profile. The highest terrain on the slice profile from a range of 11 NM (12.7 miles) is approximately 150 ft AMSL. The 1,000 ft slice flight profile must therefore be flown within sight of the surface and not flown in IMC.

Figure 6.5 below shows that for a Runway 24 ILS Glide Path flight inspection slice profile (level run) at an altitude of 1,000 ft, clearance above the highest terrain will be adequate at approximately 850 ft. However, in IMC, Glide Path level runs will need to be flown at an altitude of at least 2,348 ft to remain 1,000 ft above the highest wind turbine. The altitude will be rounded up to the nearest 100 ft, so the ILS Glide Path slice profile will therefore have to be flown at 2,400 ft in IMC.

6.5 ILS Left Slice 8° Flight Profile

6.5.1 Horizontal Obstacle Clearances

For the left slice 8° flight profile (flown at an angle of 8° left of centreline with respect to the Localiser antenna), the flight inspection aircraft will be approximately 3.1 NM laterally from the nearest wind turbine (T1) at a point on the extended runway centreline closest to the wind farm. This distance is less than the minimum clearance required from any object in IMC, as defined in FIP 23.

6.5.2 Vertical Obstacle Clearances

Figure 6.4 below shows the track of the ILS left slice 8° flight profile. The slice profile is normally flown at a height of 1,000 ft AMSL.

Figure 6.6 below shows the terrain elevation profile for the left slice 8° flight profile.

The highest terrain on the left slice 8° profile from a range of 11 NM (12.7 miles) is approximately 900 ft AMSL. The 1,000 ft left slice 8° flight profile must therefore be flown within sight of the surface and not flown in IMC.

Figure 6.6 below shows that for a Runway 24 ILS Glide Path flight inspection level run (left slice 8°) at an altitude of 1,000 ft, clearance above the highest wind turbine will not be adequate. However, in IMC, Glide Path level runs will need to be flown at an altitude of at least 2,348 ft to remain 1,000 ft above the highest wind turbine. The altitude will be rounded up to the nearest 100 ft, so the ILS Glide Path left slice 8° (level run) will therefore have to be flown at 2,400 ft in IMC.

6.6 Analysis

If Glide Path flight inspection level runs (slice profiles) are to be flown at higher altitudes to provide sufficient clearance above obstacles, the length and duration of the runs, and distance from the runway will increase correspondingly. This could result in some increased flight inspection costs.

In addition, at increased ranges, there may not be sufficient Glide Path RF signal to ensure correct ILS receiver operation.

6.7 Runway 24 Glide Path Special Flight Inspection

As part of an impact assessment for another proposed wind farm, to be located approximately 9 NM north east of Shannon Airport, FCSL recently performed additional Runway 24 Glide Path level runs at an altitude of 2,600 ft AMSL. These additional level runs were flown on 20 April 2022, to verify that adequate RF signal level is achieved (to ensure correct ILS receiver operation) and to ensure that adequate fly-up guidance is obtained below the Glide Path sector.

The results of the additional Glide Path level runs are shown in Figures 6.7 and 6.8 below.

6.7.1 Slice 2,600 ft

Figure 6.7 below shows that for Glide Path left slice level run flown at an altitude of 2,600 ft AMSL, the minimum signal level of -95 dBW/m^2 is achieved at a range of approximately 20 NM from runway threshold. Figure 6.7 also shows that adequate fly-up guidance exists from this range.

6.7.2 Left Slice 2,600 ft

Figure 6.8 below shows that for Glide Path left slice level run flown at an altitude of 2,600 ft AMSL, the minimum signal level of -95 dBW/m^2 is achieved at a range of approximately 18.4 NM from runway threshold. Figure 6.8 also shows that adequate fly-up guidance exists from this range.

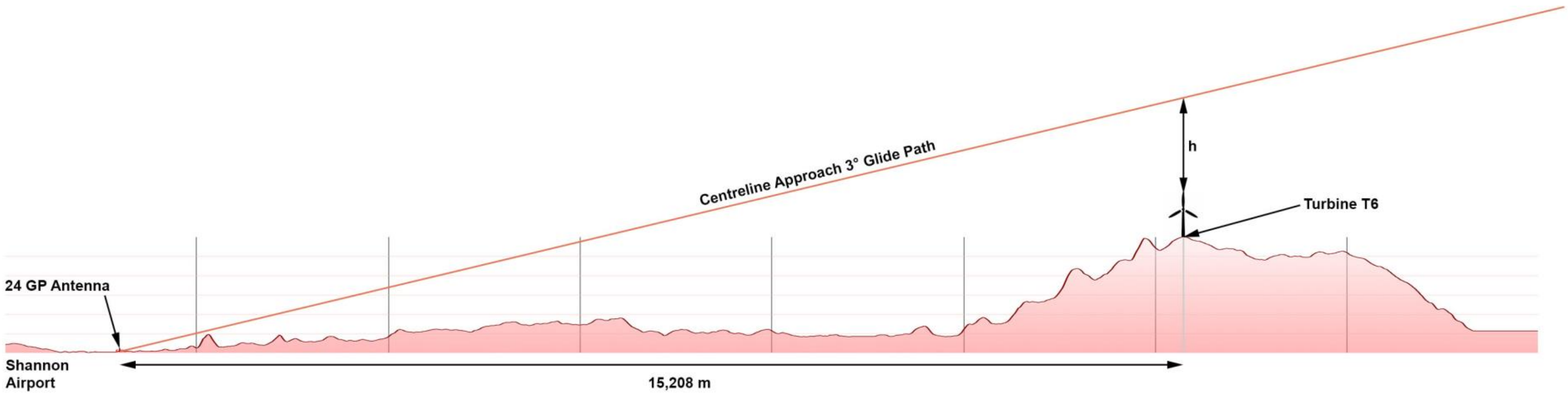


Figure 6.1 – ILS Centreline Approach Profile

(Not to scale)

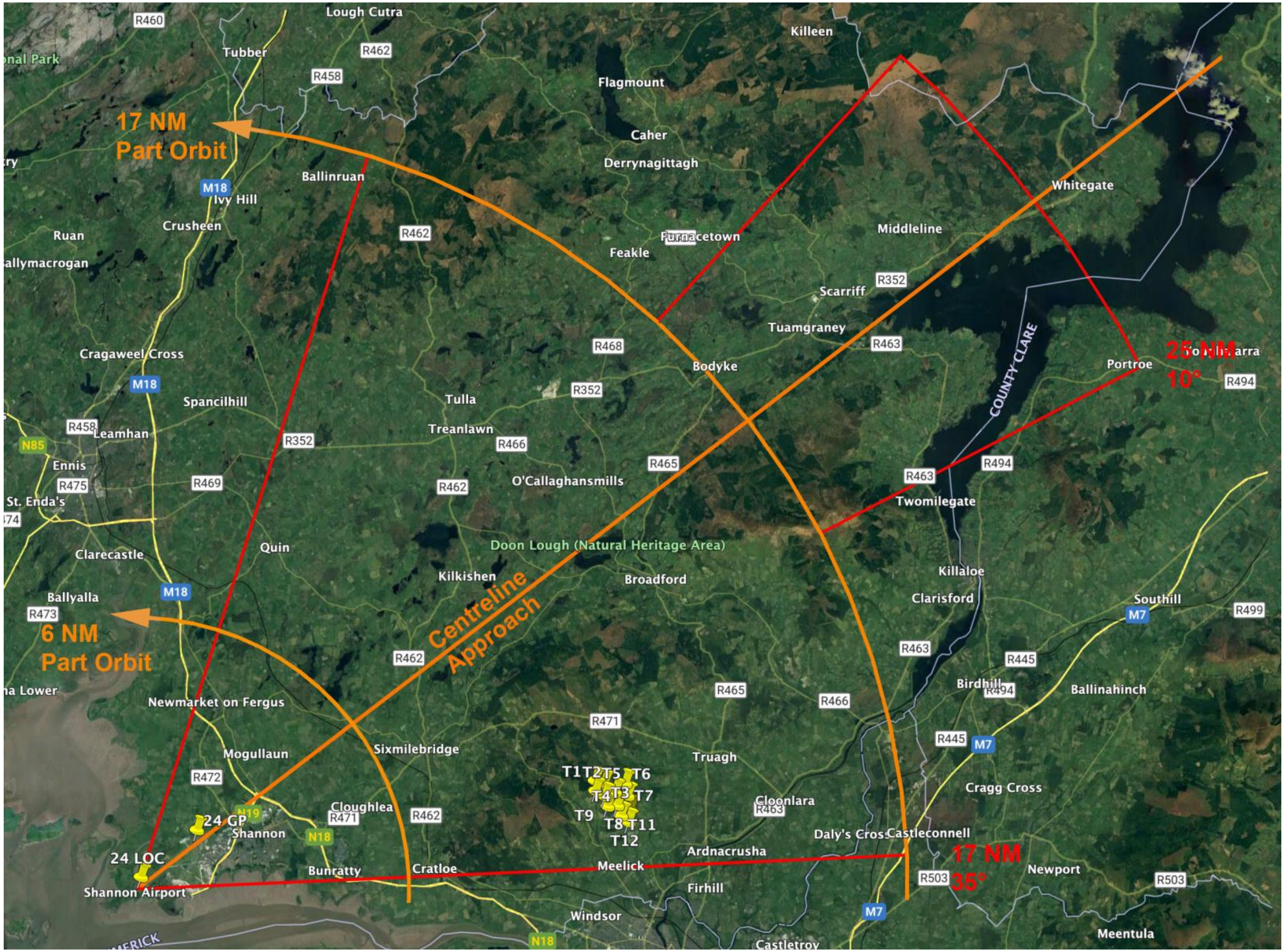


Figure 6.2 – ILS Centreline Approach and Part Orbit Tracks

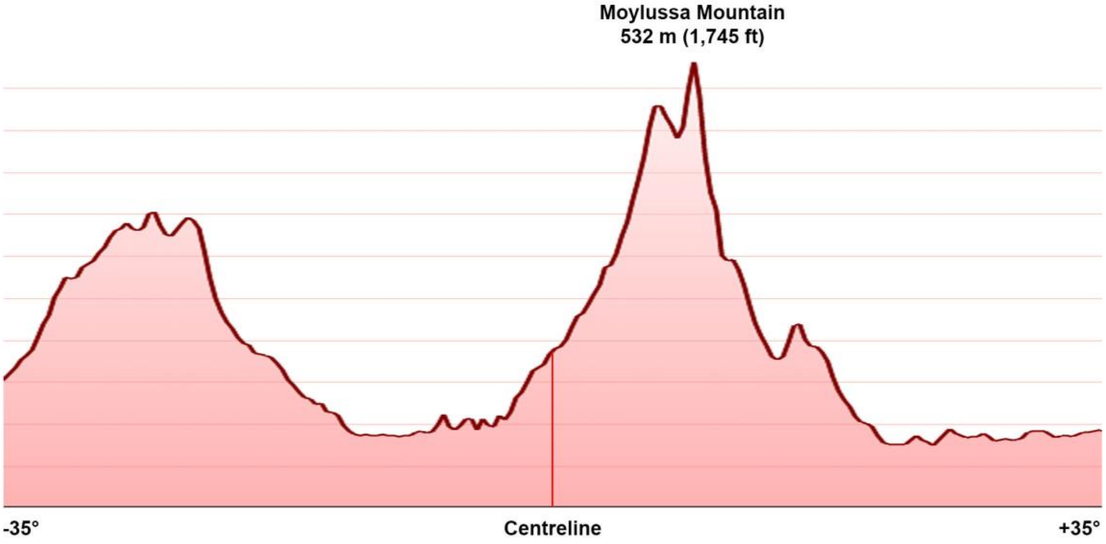


Figure 6.3 – 17 NM Part Orbit Terrain Elevation Profile

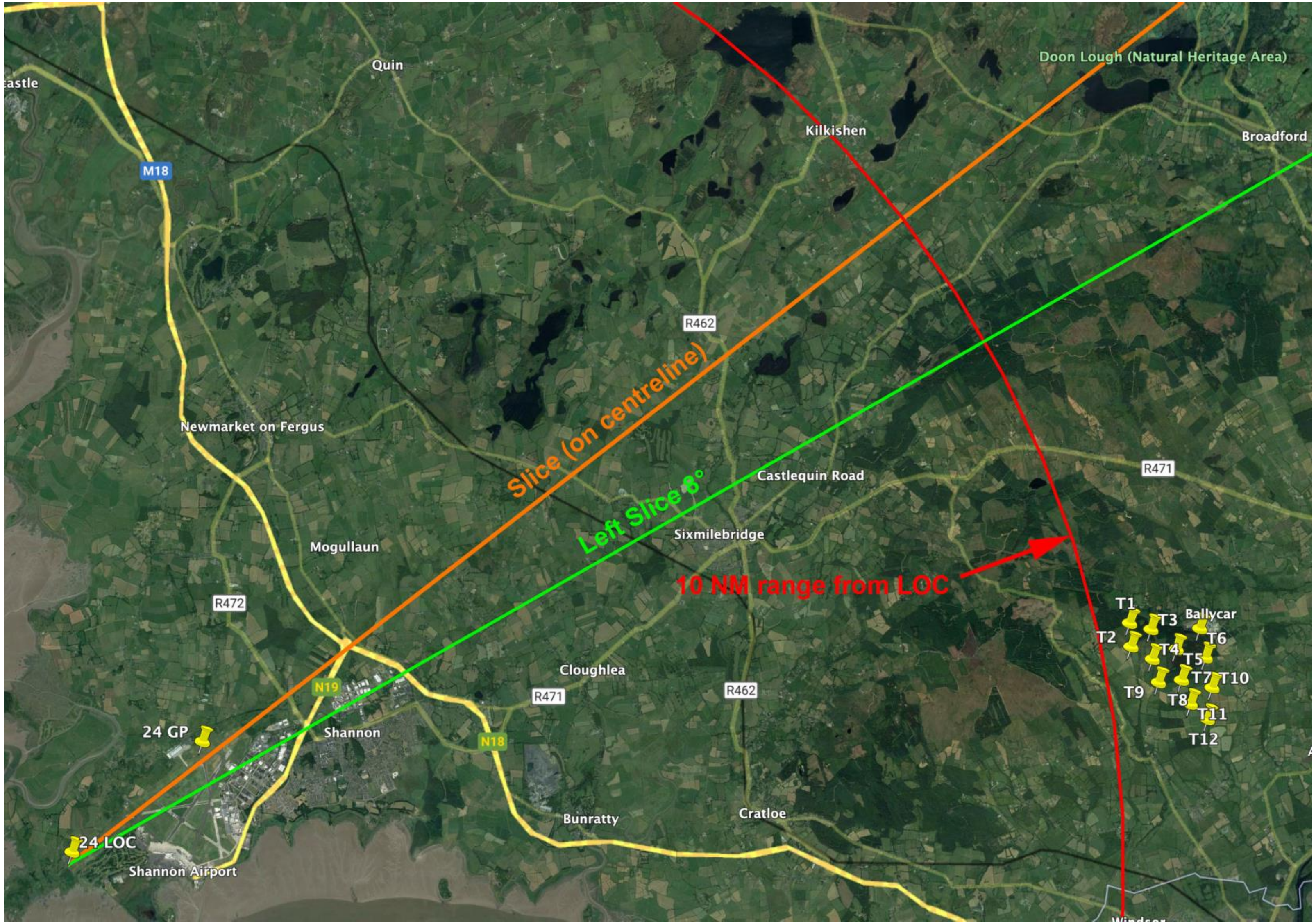


Figure 6.4 – Slice and Left Slice 8° Tracks

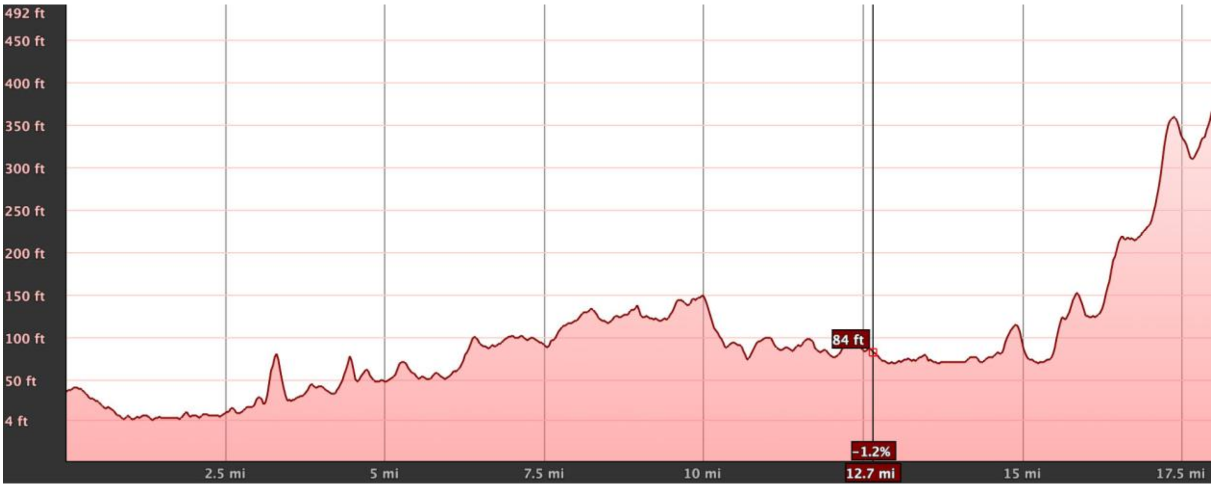


Figure 6.5 – Slice Terrain Elevation Profile

Figure 6.6 – Left Slice 8° Terrain Elevation Profile

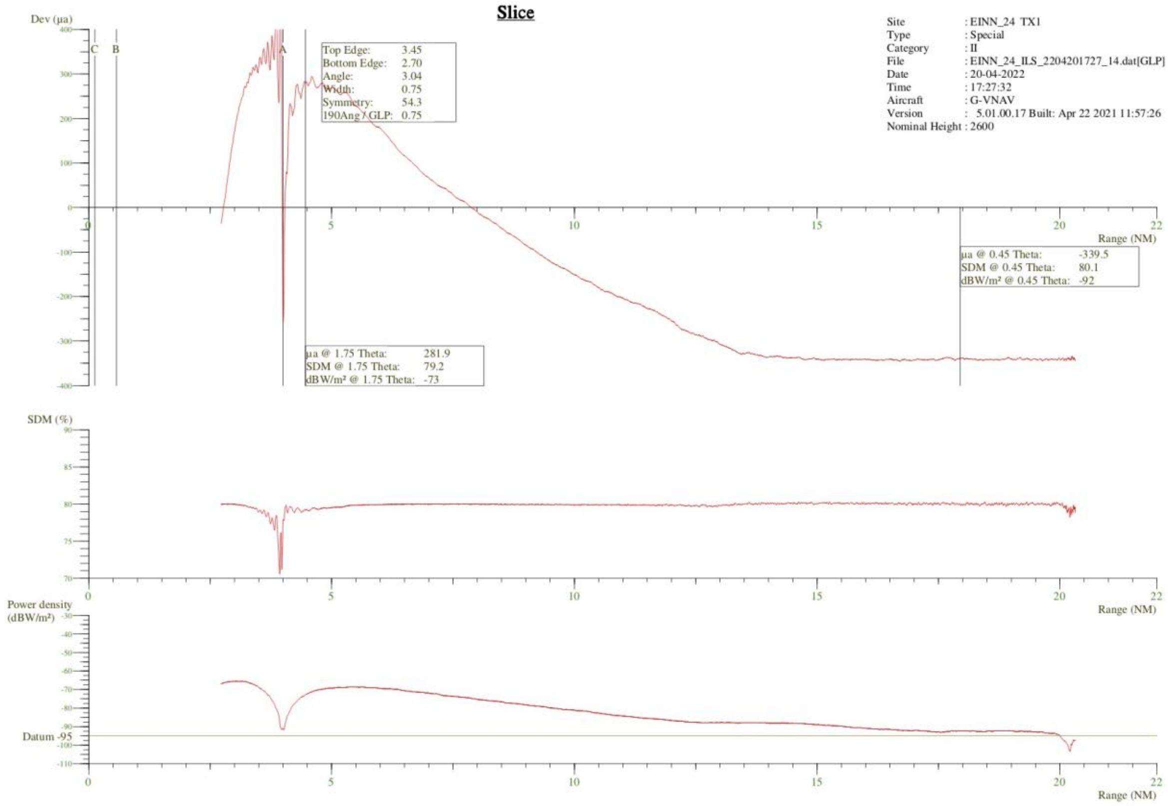


Figure 6.7 - Slice 2,600 ft

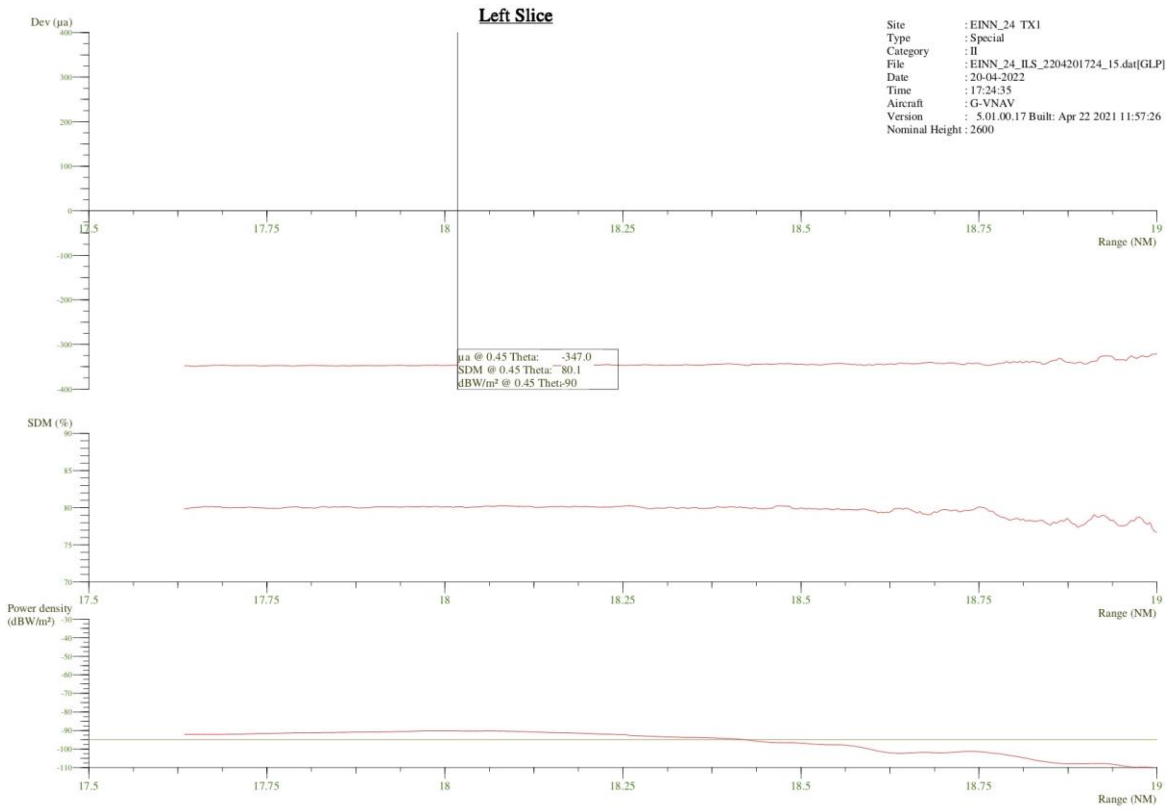


Figure 6.8 - Left Slice 2,600 ft

7 CONCLUSIONS

The assessment presented in Section 6 above has shown that a flight inspection aircraft flying centreline, part orbit and bottom edge flight profiles associated with the Shannon Airport Runway 24 ILS will remain sufficiently clear of the proposed Ballycar Wind Farm site.

However, for the slice and left slice 8° profiles, the proposed wind farm will require that these profiles are flown at higher altitudes to provide sufficient clearance above the proposed wind turbines. The flight inspection Glide Path slice and left slice 8° profiles (level runs) will have to be raised to an altitude of 2,400ft in IMC to provide the flight inspection aircraft adequate coverage over the proposed wind turbines.

Section 6.7 above shows that for level runs flown at an altitude of 2,600 ft, Glide Path RF signal levels exceed minimum level of -95 dBW/m^2 and sufficient fly-up guidance is achieved below the Glide Path sector.

The proposed Ballycar wind farm will therefore not have any adverse effect on Runway 24 ILS flight inspection procedures and flight profiles.

This report provides an assessment of the impact of terrain and obstacles on ILS flight inspection procedures. It does not provide an assessment of any impact the proposed wind farm may have on the integrity of the ILS guidance signals.

Appendix E – CL-5912-RPT-002 v1.0 Mitigation Options Study

Mitigation Options Study

Ballycar Windfarm

AI Bridges Ltd

16 May 2023

CL-5912-RPT-002 v1.0

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British Assessment Bureau UKAS Management Systems 8289 ISO 9001 Quality Management

British Assessment Bureau UKAS Management Systems 8289 ISO 14001 Environmental Management

Document Information

Document title	Mitigation Options Study
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Change History Record

Issue	Change Reference	Date	Details
1.0	Initial Issue	16 May 2023	Initial Issue

Executive Summary

Cyrrus have been requested by AI Bridges to provide a response to the Irish Aviation Authority email [6] which states *"**We believe there are no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections, reflections and shadowing from the proposed turbines.**"*

This report provides a constructive technical view on how both the Woodcock Hill **Thales RSM970** Monopulse Secondary Surveillance Radar (MSSR), and the Shannon Airport **Thales STAR 2000** Primary Surveillance Radar (PSR) with co-mounted MSSR can operate without disruption to the controlled airspace and allow the development of Ballycar Windfarm.

Cyrrus have engaged with the manufacturer of both radar systems to confirm their capability to operate in the presence of Wind Turbines with minimal intervention. The RSM970 MSSR at Woodcock Hill and STAR 2000 PSR with co-mounted MSSR at Shannon Airport have been developed to allow this capability. The STAR 2000 PSR was designed to work in areas with wind turbines, a continual development cycle has been carried out by Thales to ensure the systems performance is not impacted by Wind Turbines. If required upgrades and enhancements for the STAR 2000 are available. Thales have provided evidence that they are confident that with minor optimisation the proposed wind turbines at Ballycar should have minimal effect on the coverage provided by the radars. This evidence is provided as commercial in confidence. Cyrrus have permission from Thales to reference relevant parts but not provide the Thales documents in full.

Table 1 below highlights the IAAs concerns, and the expected impacts should the windfarm be permitted to be developed. Thales have provided evidence that each of their systems has the capability of handling multiple windfarms within the coverage area. Examples include the Star 2000 sited at Schiphol Airport and the STAR 2000 based at Newcastle. The Aeronautical Information Service (AIS) for Newcastle Airport[9] has been provided for reference. The UK MoD has contracted NATS / AQUILA under project Marshall to provide a large number of these systems due to their inbuilt capability. Reference [10] gives some detail of project Marshall. Thales have also provided a structured list of upgrades [6] available to ensure the systems can continue to provide this service into the future.

Table 1 shows the concerns raised by the IAA and the likely impact on the Woodcock Hill and Shannon Airport systems.

	Description of Concern	Mitigation Measure Solution	Residual Impact
1	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. Reference 3 – 3.1.3.1.1, Thales description of how the system automatically deals with deflections (FRUIT).	None

2	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar reflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None
3	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar shadowing from the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. Reference 1 – 5.9.5	None
4	*Ballycar Wind Farm development would introduce false primary targets or clutter on the Shannon Primary radar*	Thales STAR 2000 uses an advanced SDP to prevent wind turbines causing clutter to be displayed on the controllers display. Windfarms: dedicated impact studies and implementation of optimal mitigation, among a large panel of solutions Reference 2	None
5	*Mitigation for the primary clutter would degrade the performance of the Shannon primary radar*	Thales STAR 2000 was designed to work in areas with wind turbines without degradation of coverage. If required upgrade options are available from Thales. A list of upgrade options has been provided. Reference 6	None
6	*Not mitigating for the clutter would be operationally unacceptable and unsafe for Air traffic control*	Clutter would be processed out by the Thales STAR 2000 SDP. If required upgrade options are available from Thales. A list of upgrade options has been provided. Reference 6	None
7	*Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace.*	The Woodcock Hill radar would not require to be taken out of service for any significant periods. Only minor optimisation should be required. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None

8	*Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.*	This is not correct. The radars SDP will still mitigate against reflections. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None
9	*Due to the proximity of the proposed Ballycar wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Ballycar generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements*	This is not correct, any deflections generated by the Ballycar wind turbines will be eliminated by the DE-FRUITER. A non-initialisation area should not be required. Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. Reference 3 – 3.1.3.1.1, Thales description of how the system automatically deals with deflections (FRUIT).	None
10	*Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. Reference 1 – 5.9.5	None

Table 1: IAA Concerns v Impact

Conclusion

The development of the Windfarm at Ballycar would require minimal optimisation of the Woodcock Hill and Shannon Airport radars. The systems in place have the capacity to provide a service even if a large number of turbines were developed in the coverage area. Thales can also provide upgrades and enhancements to both systems should they be required in future.

Abbreviations

AIS	Aeronautical Information Service
AIP	Aeronautical Information Publication
IAA	Irish Aviation Authority
MSSR	Monopulse Secondary Surveillance Radar
PSR	Primary Surveillance Radar
SDP	Surveillance Data Processor

References

[1] CL-5715-RPT-002 V1.0 Ballycar Wind Farm Aviation Technical Assessment

[2] Thales Star 2000 Datasheet

[3] Thales RSM970 Technical Description

[4] Thales Windfarm Mitigation Presentation

[5] IAA email detailing their concerns

[6] Thales structured list of upgrades

[7] Eurocontrol Mode S station Functional Specification (EMS 3.1.1)

[8] ICAO annex 10 vol IV

[9] AIS AIP Newcastle Airport

[10] An in-depth look at Project Marshall | Thales Group

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1. Introduction

1.1. Overview

1.1.1. Cyrrus have been requested by AI Bridges to provide Aviation support for the Ballycar Windfarm proposal. Previously Cyrrus issued a report [1] which provided the technical evidence demonstrating that both the Shannon Airport and Woodcock Hill radars would have Radar Line of Sight with the Windfarm.

1.2. Aim

1.2.1. This report provides evidence that current systems at Woodcock Hill and Shannon Airport can mitigate the proposed Ballycar Windfarm with minimal intervention.

1.2.2. The following sections address the concerns raised by the IAA in email [5].

1.3. Woodcock Hill Radar

1.3.1. The Woodcock Hill RSM 970 Radar is a tried and tested system used throughout the UK and Europe. The Thales datasheet detailing the systems technical characteristics and ability to meet the Eurocontrol Mode S station Functional Specification (EMS 3.11)[7] and ICAO annex 10 vol IV latest edition standards[8] which have been included for reference.

1.3.2. The IAA have raised concerns that reflections, deflections, and shadowing will cause unacceptable issues. Evidence is provided to constructively address each of these concerns, including confirmation from Thales of the System's ability to address these issues with minimal intervention.

1.3.3. To address the issue of reflections, the Thales RSM970 technical submission details how the system can automatically process sporadic reflections, also known as dynamic reflections, to prevent degradation of the radar picture. The system utilises a second stage of reflection processing which is used to address repeated reflections from one area, these are placed in the static reflector file and automatically processed out by the system. A full explanation of how the radar does this is provided in the Thales RSM970 technical description [3].

1.3.4. The IAA's 2nd concern was that Beam deflection can take place on the Woodcock Hill MSSR. Cyrrus investigated the processing used to prevent deflected targets being displayed. The false returns from deflected targets are known as False Returns Uncorrelated in Time (FRUIT). The Surveillance Data Processor (SDP) within the Woodcock Hill MSSR will use a De-FRUITER to remove these false targets. This technique is used in most MSSR systems. A detailed explanation of how this is done is provided in reference [3].

1.3.5. The IAA's 3rd concern, that shadowing would degrade the area behind the windfarm. Cyrrus and Thales are confident that any effect would be minimal and have no impact on aeronautical operations.

1.4. Shannon Airport STAR 2000 Radar

1.4.1. The Shannon Airport radar is a Thales Star 2000 PSR with co-mounted MSSR.

1.4.2. Rotating wind turbine blades will be processed as moving targets by the PSR and will be displayed as clutter. Modern SDP systems can use advanced techniques prevent this clutter from the Wind turbines from being displayed.

1.4.3. The Thales datasheet [2], confirms the STAR 2000 was designed to operate in areas with wind turbines. Thales have confirmed that the STAR 2000 systems at both Schiphol Airport in the Netherlands and Newcastle Airport in the UK, both operate successfully with multiple windfarms within close proximity of the radars. The Aeronautical Information Service (AIS) for Newcastle Airport [9] has been provided for reference.

1.4.4. The UK MoD have under project Marshall contracted for the supply of a large number of these systems due to their inbuilt capability to operate alongside windfarms.

1.4.5. Thales have undertaken extensive trials documented in their Windfarm Mitigation presentation [4] which concludes the issue of false plots and desensitisation from wind turbines has been solved.

2. IAA Issue Summary

2.1. Table of Results

2.1.1. Table 2 contains a summary of the IAA concerns and if they can be addressed. A traffic Light system has been used to highlight the fact that currently there are no impacts with either the Woodcock Hill or Shannon Airport Radars which cannot be addressed.

	Description of Concern	Mitigation Measure Solution	Residual Impact
1	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. Reference 3 – 3.1.3.1.1, Thales description of how the system automatically deals with deflections (FRUIT).	None
2	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar reflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None
3	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar shadowing from the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. Reference 1 – 5.9.5	None
4	*Ballycar Wind Farm development would introduce false primary targets or clutter on the Shannon Primary radar*	Thales STAR 2000 uses an advanced SDP to prevent wind turbines causing clutter to be displayed on the controllers display. Windfarms: dedicated impact studies and implementation of optimal mitigation, among a large panel of solutions. Reference 2	None
5	*Mitigation for the primary clutter would degrade the performance of the Shannon primary radar*	Thales STAR 2000 was designed to work in areas with wind turbines without degradation of coverage. If required upgrade options are available from Thales. A list of upgrade	None

		options has been provided. Reference 6	
6	*Not mitigating for the clutter would be operationally unacceptable and unsafe for Air traffic control*	Clutter would be processed out by the Thales STAR 2000 SDP. If required upgrade options are available from Thales. A list of upgrade options has been provided. Reference 6	None
7	*Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace.*	The Woodcock Hill radar would not require to be taken out of service for any significant periods. Only minor optimisation should be required. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None
8	*Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.*	This is not correct. The radars SDP will still mitigate against reflections. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None
9	*Due to the proximity of the proposed Ballycar wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Ballycar generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements*	This is not correct, any deflections generated by the Ballycar wind turbines will be eliminated by the DE-FRUITER. A non-initialisation area should not be required. Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. Reference 3 – 3.1.3.1.1, Thales description of how the system automatically deals with deflections (FRUIT).	None
10	*Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. Reference 1 – 5.9.5	None

Table 2: IAA Concerns v Impact

2.2. Recommendations

2.2.1. The technical documentation provided by the manufacturer (Thales) of the two systems provides assurance that mitigation for the Ballycar Windfarm is possible. Cyrrus would recommend that an onsite condition survey is carried out by Thales on both the Shannon Airport and Woodcock Hill systems to confirm their current operational state and ascertain whether updates or upgrades would be required. A limited operational flight trial may also be prudent at this stage to provide a baseline of the current systems coverage over the area of the proposed Windfarm.

2.2.2. Once the windfarm is built, the systems may require minor optimisation by Thales. Once completed, a further Flight Check would be recommended to confirm the systems performance was acceptable over the Windfarm area.

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