Report

Firlough Wind Farm
Telecommunications Impact Study

Document Number:

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Approved for Release: Rev 2.1 KH **Date:** 24/02/22

Document Filename: *Firlough Wind Farm Telecommunications Impact Study Report*

Executive Summary

Following consultations between Jennings O'Donovan & Partners Ltd and ESB Services it was found that ESB have one UHF Point-to-Point (PMP) telemetry radio link that passes through the proposed wind farm at Firlough Co Mayo. Ai Bridges Ltd were subsequently commissioned to assess the potential impact of the proposed wind turbines on the ESB radio link and to proposed possible mitigation measures.

The scope of work included field surveys and a detailed network 3D analysis. Both ends of the radio link were surveyed to assess/verify the accuracy of the radio link details (antenna co-ordinates, antenna installation heights, etc). The findings of the field surveys can be found in Section 4 of this report.

The network analysis was carried out to model the radio link in 3D and to show the link relative to the proposed turbines. The findings of the network analysis indicate that one of the proposed Firlough turbines, T02, would causes an Interference Condition of 8.47m to the 2nd Fresnel of the ESB radio link. The findings of the network analysis can be found in Section 5 of this report.

Extensive consultation with ESB Networks was carried out to discuss the findings of the report prepared by their consultants that identified potential impacts from T01, T02 and T11on the UHF link. Following a series of conference calls to discuss and compare the findings of ESB consultants and Ai Bridges it was agreed that only the impact of T02 should be considered and it was accepted by ESB that T01 and T11 did not constitute a risk to the UFF radio link.

A number of possible mitigation measures were discussed with ESB Networks to offset the possible impact of Turbine T02 on the ESB UHF radio link these mitigation measure are outlined in Section 6. It was agreed with ESB that a relay mast site to the south of T02 would offer the most appropriate mitigation measure. The associated costs were discussed and it was agreed that should the relay mast site be constructed that the wind farm developer would cover these costs. ESB provided a consultation response on October 1st 2021 with confirmation that this proposed mitigation measure was acceptable.

Sections

Appendix

Section 1 - Wind Farm Site Information

1. Introduction

In this section a brief summary of the wind farm site is provided. Details regarding the site's geographic location and the proposed wind turbine dimensions are presented.

1.1 Wind Farm Site Information

The wind farm development is located in County Mayo approximately 4km northeast of the town of Bonniconlon. The wind farm proposal consists of 13 turbines with a maximum turbine tip-height of 185 meters and a maximum rotor diameter of 155 meters. The proposed turbine co-ordinates are provided in Appendix A.

Wind Farm	Number of Turbines	Max Turbine Tip-Height	Max Turbine Rotor Diameter
Furlough	13	185 m	155m

Table 1. Firlough Wind Farm Turbine Details

The location of the proposed Firlough wind farm development is shown below in Figure 1.

Figure 1. Location of Firlough Wind Farm, County Mayo.

Section 2 - Methodology

2. Introduction

In this section a brief summary of the Telecommunication Impact Study Methodology is provided.

2.1 Methodology

There are four primary stages in preparing and compiling a communication impact study:

- Telecom Operator Consultations
- Field Surveys
- Desktop Survey Network Modelling and Analysis
- Mitigation Measures
- Report Generation

A summary of each of these stages is provided below:

Telecom Operator Consultations

Consultations are commenced with telecom operators who are requested to raise any concerns they have regarding the impact of the proposed wind farm on their networks. The consultation process is used to assist in identifying telecoms infrastructure that could be impacted by the proposed wind farm development.

Field Surveys

Field surveys are undertaken and the co-ordinates of communication masts are recorded. During the field surveys of the communication sites, approximations of antenna size, bearing and height are made for the antennas installed on each of the masts surveyed.

Desktop Survey and Network Analysis

A desktop survey is carried out to plot and model the proposed wind turbines in a radio planning tool. The radio planning tool uses GIS and terrain mapping databases to enable accurate modelling. This provides a means of graphically showing the turbines in 3D relative to the existing radio link(s). The radio planning tool is then used to calculate the Clearance or Interference Condition distance between the relevant radio link and the nearest turbine(s).

Mitigation Measures

A range of Mitigation Measures are assessed and proposed to offset the potential impact of the proposed turbines on existing radio link(s).

Report Generation

The final stage of the communications impact study process is to collate the data and present the findings & analysis into a report for submission.

Section 3 - Telecom Operator Consultations

3. Introduction

In this section the consultation process undertaken with the relevant telecom operator(s) is described. The response received from each operator is also provided.

3.1 Telecom Operator Consultations

Consultations beginning in April 2021 were undertaken by the EIAR consultants (Jennings O'Donovan & Partners Ltd) with relevant telecom network operators. Following the round of consultations, ESB Services raises concerns regarding one of their Point-to-Point (PMP) radio links. Ai Bridges Ltd were subsequently requested assess the potential impact of the proposed wind farm on the ESB PMP link and additional consultations with ESB were undertaken by Ai Bridges.

Section 3.1.1 provides the response that ESB provided to the EIAR consultants. Section 3.1.2 that follows, provides the subsequent correspondences between Ai Bridges and ESB Services.

3.1.1 Consultations between ESB Services and EIAR Consultant

The ESB response to the initial EIAR Consultation request is provided below.

23/04/21 – ESB response to EIAR Consultations

"Hi Sean,

I have carried out an impact analysis of the proposed windfarm.

We have 1 Point to Multipoint link that I expect will be affected:

Point A: FIDDANDARRY 38KV/ 54.13304917765282, -8.953129739546501 / Height 6m / Frequency 458MHz
Point B: Ballina AO / 54.11388778862945, -9.159387861674759 / Height 30m / Frequency 458MHz

I will have to submit this to a third party Radio consultant to review and determine what buffer area may be required and also if turbines may need to be moved to ensure service isn't impacted. This process will take 8-12 weeks for their report.

If you have any questions, please let me know.

Regards,
Myles"

3.1.2 Consultations between ESB Services and Ai Bridges Ltd

The consultations between ESB Services and Ai Bridges Ltd are provided below.

05/07/21 – Consultation Request sent by Ai Bridges to ESB

Hello Myles,

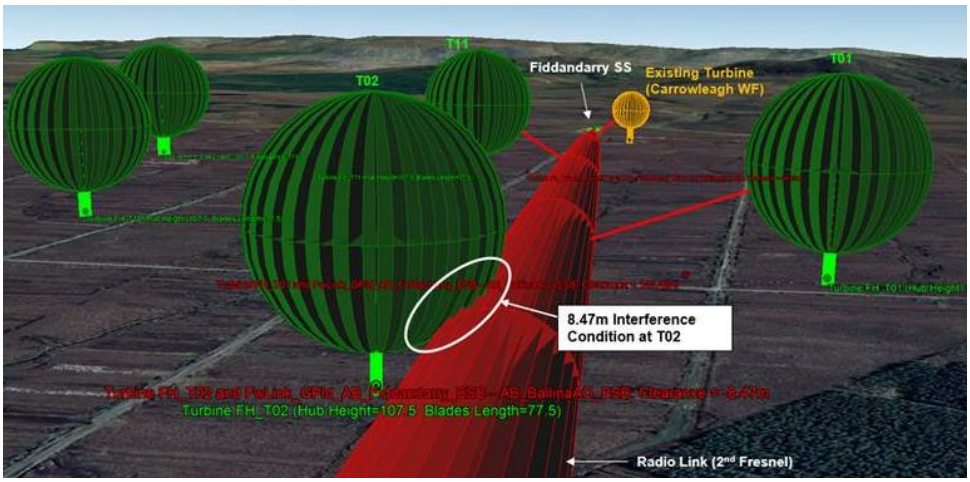
We are following up in relation to Firlough Wind Farm. We have been requested by the EIAR Consultants responsible for this project to carry out a technical analysis of the possible impact of the proposed turbines on an ESB Services UHF telemetry link.

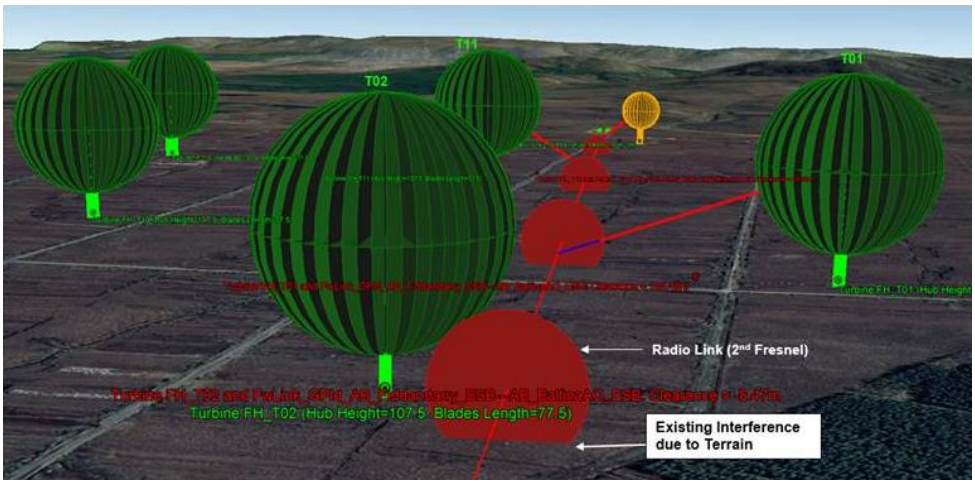
The proposed turbines have been modelled in 3D below and are shown relative to the ESB UHF radio link from Ballina to Fiddandarry Sub-station. Network analysis calculations indicate that (in its current location) turbine T02 would obstruct the 2nd Fresnel Zone of ESB radio link by 8.47m. The analysis also shows that the 2nd Fresnel Zone of the radio link is already is subject to terrain obstruction.

Also shown below there is an existing wind farm (Carrowleagh) adjacent to Fiddandarry sub-station and these wind farm turbines are also modelled and it can be seen that there is a clearance to the nearest wind turbine of 45m indicating that a 150m clearance buffer is not required for operation of the link.

The wind farm developer has requested that we revert to you with proposals for Mitigation Measures. We have prepared a series of mitigation proposals that we have proposed on other wind farm developments and some of which have been adopted by telecommunications operators. These are attached for your review

Can you please confirm your availability later this week for a call to discuss,





05/07/21 – ESB Response

"Hi Kevin,

Thank you for your mail. I have several emails and reports to process for AI Bridges, I will aim to process these and get back to you later in the week.

Regards,
Myles"

19/07/21 – Ai Bridges Response to ESB

Hello Myles,

I am following up from our correspondence that we sent to you earlier this month in relation to Firlough Wind Farm

Have you been able to progress the report on your end and to review our proposed mitigation measures

Would you be available for a brief call later today? Alternatively would you be available for a Teams session later this week to discuss our mitigation measure proposals?

Our client is very keen progress this matter and are looking to finalise their submissions by the close of business this week

I look forward to hearing from you.

Best Regards,
Kevin Hayes,

09/08/21 – Ai Bridges Response to ESB

Hello Myles,

I am following up in relation to your email response below in early July.

Can you please respond to our emails below in relation to the proposed mitigation measures.

Best Regards,
Kevin Hayes

13/08/21 – ESB Response

"Hi Kevin,

Please find attached document. This is an extract from a detailed report carried out by a Third party radio consultant. It has a summary of the impact of the turbines on the operational Point to Multipoint radio link and also a mitigation solution to ensure that there is no impact to services.

Can you please review this and check to see if the developer is happy to agree to the proposed mitigation solution. If not, we may look to object to the development as recommended by our radio consultants.

If you require further details on how this mitigation solution was designed or would like to have a meeting regarding this project, please let me know and I can arrange this with ESB Network Telecoms management and the Radio consultant.

Regards,
Myles"

13/08/21 – Ai Bridges Response to ESB

Hello Myles,

As there is a substantial body of the analysis missing from the attached report it is not possible to conduct a detailed technical analysis of the results provided therein.

There is a reference to " Section 7 " within the attached report and this section is missing.

Also there is no reference \ response within the report to

1. The interference levels due to the existing terrain blocking which has been omitted from the third-party analysis results. This should be mandatory as part of a baseline telecoms assessment.

2. The existing turbine at Carrowleagh Wind Farm which, based on the results in the attached report, should also have an impact on the existing link. The blade tip of the Carrowleagh turbine, identified in our analysis, clears the 2nd Fresnel of the ESB Services link by 45m. Based on the same analysis methods we have shown that there is 69m clearance from the blade tip of the proposed T11 to the 2nd Fresnel of the link , 144m clearance from the blade tip of the proposed T1 to the 2nd Fresnel of the link. So if there is no impact from the existing Carrowleagh turbine then a detailed analysis should be provided your third party consultant to show how the proposed T1 and T11 turbines could cause a greater interference impact.

3. What levels of interference levels are due to terrain blocking (which our engineers have shown to be detrimental and significantly greater that the impact of T2 and what levels are due to the proposed turbines.

4. How the wind turbine has been modelled and what surfaces areas have been used.

5. No methodology as how the interference levels are predicted for each turbine

6. The proposed mitigation measure options that we have presented and their suitability.

Best Regards,
Kevin Hayes,

23/08/21 – Ai Bridges Response to ESB

Hello Myles,

As discussed last week can you please provide a response to our email below and as requested can you please escalate a conference call with ESB Services Senior Management

We would like to discuss the mitigation measures that we have presented to mitigate the interference impacts of T02 on the ESB Services link.

In the meantime can you please forward a copy of the telecoms analysis report completed by your third-party consultants in advance of our call so that we can assess their analysis of the interference impacts that they are reporting.

If you are unavailable to deal with our request can you provide the contact details of your own Management Team or colleagues so that we can contact them directly and schedule this call.

Best Regards,
Kevin Hayes,

24/08/21 – Ai Bridges Response to ESB

Dear Derek,

I am following up in relation to the email correspondences below in relation to Firlough Wind Farm.

Our client has requested that we follow up directly with Senior Management at ESB Services on an effort to expedite this matter.

Can you confirm your availability later today for a brief call to discuss.

Our client has asked us to stress that they are very willing to co-operate in relation to finding a mitigation measure and would cover the costs of the proposed mitigation measures.

I am available all day for a call with you

I look forward to hearing from you

Best Regards,

Kevin Hayes,

24/08/21 – ESB Response

"Kevin

Thank you for your email.
I'm unavailable to discuss this issue today, earliest opportunity I'd have free is tomorrow afternoon.
Does sometime then suit you?

Regards
Derek,"

24/08/21 – Ai Bridges Response to ESB

Derek,

Thank you for your response. I can be available for a call anytime tomorrow afternoon.

If you can revert with a suitable time I can be available then.

When is the best number to contact you on.

Best Regards,
Kevin Hayes,

25/08/21 – ESB Response

"Kevin
I've meetings all day until 3.30pm and will be travelling from 3.30pm onwards in the car but happy to take a call while driving, so if you wanted to give me a call after 3.30pm I should be free.

Mobile number is in the auto signature below.
Regards
Derek"

25/08/21 – Ai Bridges Response to ESB

Hello Derek,

Thank you for getting back.
I can look to call you after 3:30pm

Best Regards,
Kevin Hayes,

25/08/21 – ESB Response

"Kevin
Thank you for taking the time this afternoon to discuss the issue outlined below.

I would welcome the opportunity to discuss the proposed mitigation measures in more detail with you with Donal and Myles also in attendance.

Would Friday the 27th August at 2pm be good for you?

Regards
Derek

25/08/21 – Ai Bridges Response to ESB

Derek,

Thanks for your time earlier

Yes, I can be available for a call at 2Pm on Friday this week

Best Regards,
Kevin Hayes,

26/08/21 – Ai Bridges Response to ESB

Derek,

Just to confirm that I have accepted a Team Meeting request from Donal earlier

As discussed on our call yesterday would it be possible that you could send through a copy of the analysis that you consultants have completed.

Our engineers are looking to plot a "hard surface" exclusion area in advance of our call tomorrow and the information that they require to do this would be based on the analysis that your consultants have completed.

Best Regards,
Kevin Hayes,

25/08/21 – ESB Response

"Kevin

Just for info, Myles reports to Donal who in turn reports to me. Donal was also the technical lead on our UHF telemetry project.

I've attached that report.
Talk tomorrow.

Regards
Derek"

Note: The report titled "*Joint Radio Company Ltd Detailed Coordination Report on the impact of Firlough WF on the radio infrastructure of ESB*" is provided in Appendix B.

29/09/21 – ESB Response

" Kevin
Apologies for missing your call yesterday, I was on site for most of the day at meetings.

I'll have an initial read of the attached and get back to you with my comments before COB on Friday but I should point out that anything that has the potential to incur a liability to ESB Networks will need to be reviewed by our legal department.

Regards
Derek "

30/09/21 – ESB Response

" Hello Kevin.
Thanks for your reply.

Are you free tomorrow about 12 midday for a call?
……

Regards
Derek "

01/10/21 – ESB Response

"Kevin

…….

In the meantime I'm satisfied that the proposed mitigation outlined in it with regard to Firlough, i.e. the construction of the relay site/antenna mounting structure, is sufficient to address our concerns on any impact to the UHF radio link to our high voltage station at Fiddandary.
Please let me know if any clarification on this specific issue is required.

Regards
Derek"

Section 4 - Field Surveys

4. Introduction

To assess/verify the accuracy of the radio link details (antenna co-ordinates, antenna installation heights, etc.), field surveys of both ends of the radio link were carried out.

Figure 2 below shows both ends of the ESB radio link (Fiddandarry 38kV Substation and Ballina ESB AO) relative to the proposed wind farm. A summary of the findings of the field surveys of these sites are provided in Section 4.1 and 4.2 that follow.

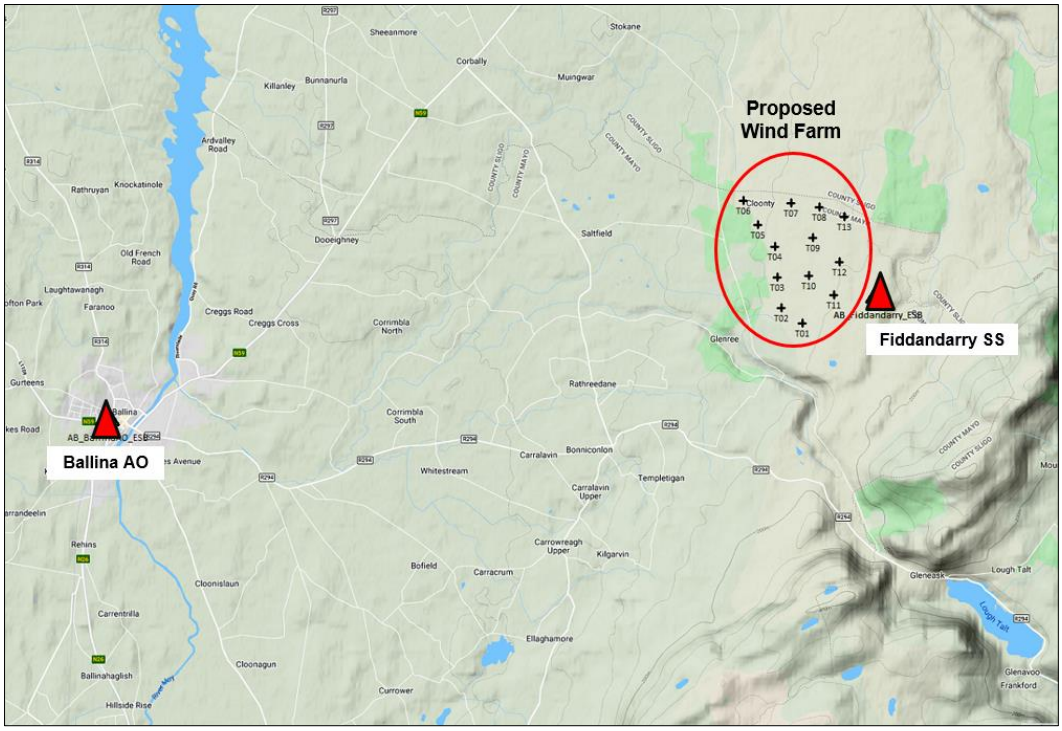


Figure 2. Telecom Mast-sites in the vicinity of Firlough Wind Farm

4.1 Fiddandarry 38kV Substation

The survey of this site found that the ESB antenna is installed on the apex of the Fiddandarry 38 kV Substation as shown below in Figure 3. The antenna is installed at an approximate height of 6m AGL. A summary of the Fiddandarry 38kV Substation Field Survey is provided below in Table 4

Figure 3. ESB Antenna at Fiddandarry Substation

Site	Operator	Co-ordinates	Antenna Type	Antenna Install Height (AGL) *
Fiddandarry Substation	ESB	54 07 58.97 N 08 57 11.24 W	*UHF Directional Yagi*	*6m*

Table 2. Fiddandarry SS – Field Survey Summary

** Approximate Height recorded from ground level during filed survey*.

4.2 ESB AO Ballina

The survey of this site found that the ESB antenna is installed on the telecoms mast outside ESB's Area Office in Ballina, Co Mayo as shown below in Figure 4. The antenna is installed at an approximate height of 14m AGL. A summary of the Ballina AO Field Survey is provided below in Table 4.

Figure 4. ESB Antenna at Ballina AO

Site	Operator	Co-ordinates	Antenna Type	Antenna Install Height (AGL) *
Ballina AO	ESB	54 06 49.87 N 09 09 33.93 W	UHF Directional Grid Dish	14m

Table 3. Ballina AO – Field Survey Summary

Section 5 - Radio Link Analysis

5. Introduction

Based on the findings obtained during field surveys and the telecom operator consultation process, an analysis* of the following links was carried out.

Link ID	Operator	Link Description
1	ESB	PMP radio link from Fiddandarry 38kV – Ballina Area Office (AO)

Table 4. Radio Links requiring Analysis

5.1 Link Analysis (Fiddandarry SS – Ballina AO)

Figure 5 below shows a Plan View of the ESB PMP radio link from Fiddandarry Substation to Ballina Area Office (AO).

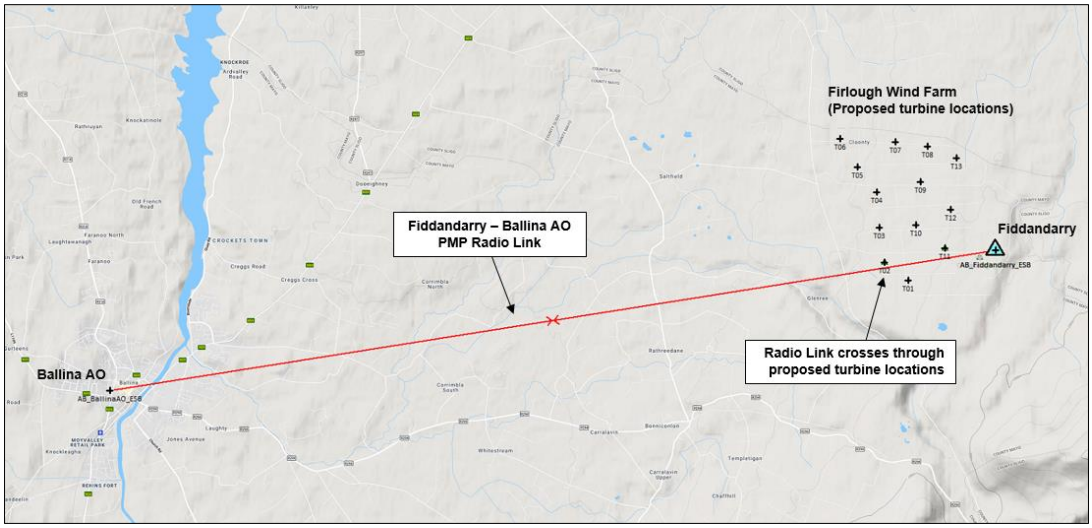


Figure 5. Plan View of ESB's PMP radio link between Fiddandarry Substation and Ballina AO.

To assess the potential impact of the proposed turbines on this radio link, a 3D analysis of the radio link was carried out. Topology and Morphology layers were modelled for the 3D analysis and the International Telecommunication Union - Radio Communication (ITU-R) Rec. 526-11/Cascade Knife Edge method was used for calculations.

Note: When assessing impacts on radio links the 2nd Fresnel Zone is used to provide a worse-case-scenario; however, most Telecom Operators including statutory bodies accept that low frequency links (< 1Ghz) will not be impacted if the obstruction (e.g. turbine or terrain) is outside the 0.6 Fresnel Zone of the radio link.

The analysis findings when considering the Worst-Case Scenario 2nd Fresnel Zone and the Critical 0.6 Fresnel Zone are provided in Sections 5.1.1 and 5.1.2 respectively.

** The Desktop Survey Analysis findings are subject to accuracy of the information (GPS co-ordinates, turbine dimensions, etc.) provided to Ai Bridges.*

5.1.1 2nd Fresnel Zone Analysis

Network analysis calculations indicate that (in its current location) turbine T02 would obstruct the 2nd Fresnel Zone of ESB radio link by a distance of 8.47m.

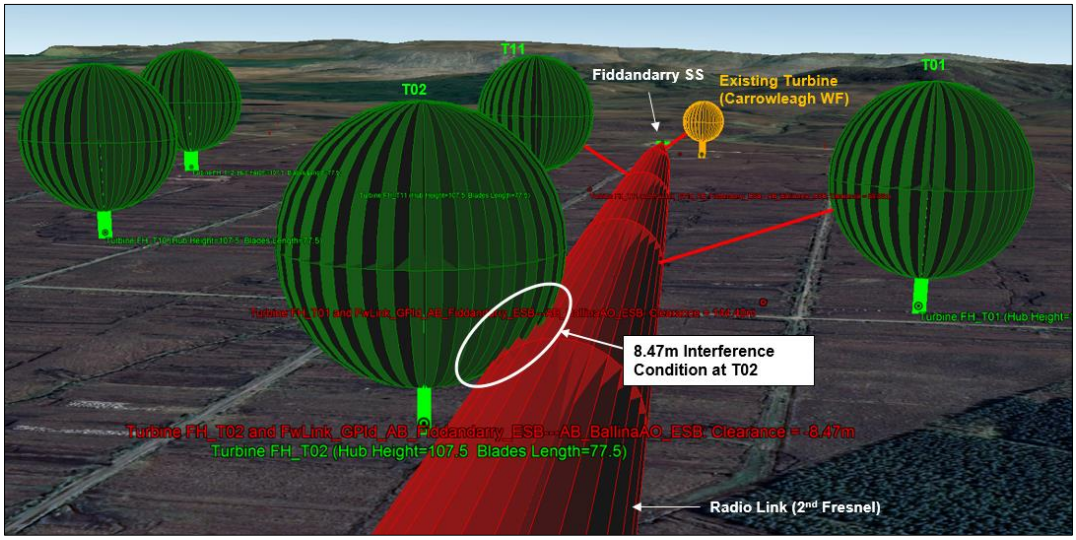


Figure 6. 3D Model showing proposed turbines relative to ESB radio link – 2nd Fresnel Zone

Although network analysis indicates that Turbine T02 will obstruct the 2nd Fresnel Zone of the ESB link by 8.47m, it should be noted that the 2nd Fresnel Zone of the radio link is already significantly impeded by existing terrain, as shown below in Figure 7.

The analysis indicates that any impact due to turbine T02 would be relatively small when compared the existing impact of the obstruction due to terrain.

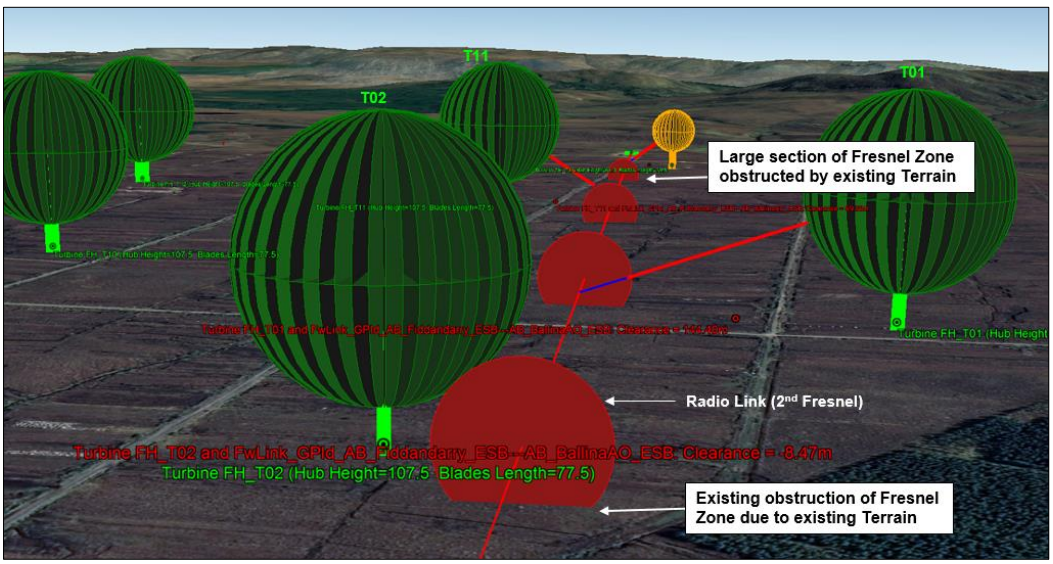


Figure 7. 3D Model showing 2nd Fresnel of ESB radio link is already obstructed by terrain.

5.1.2 0.6 Fresnel 1 Zone Analysis

As previously stated, most Telecom Operators, including statutory bodies accept that a link will not be impacted if the obstruction (e.g. turbine or terrain) is outside the 0.6 Fresnel Zone of the radio link. When considering a 0.6 Fresnel Zone there will be a Clearance Condition of 11.48 m to turbine blade-tip of T02.

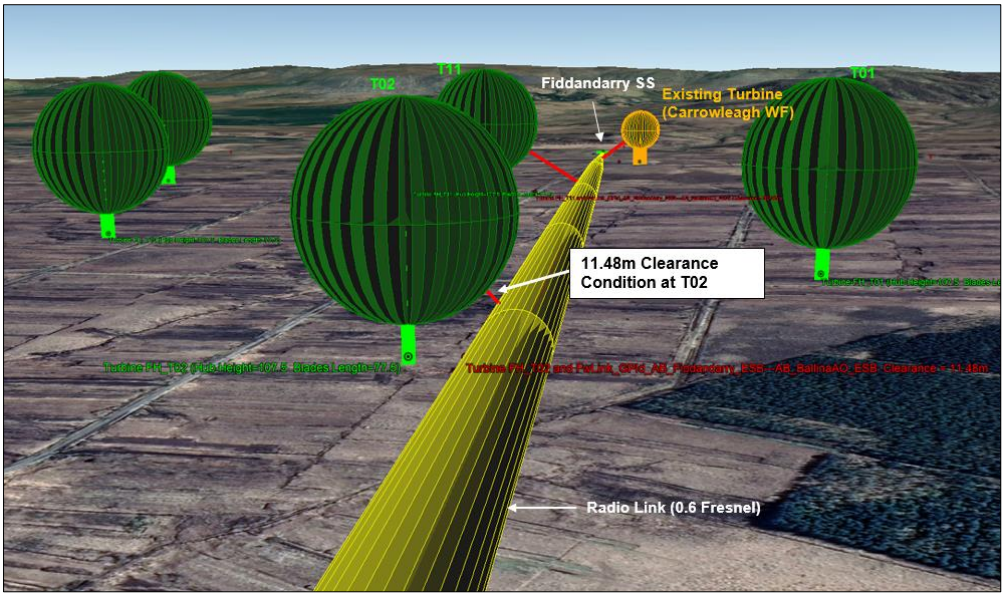


Figure 8. 3D Model showing proposed turbines relative to ESB radio link – 0.6 Fresnel Zone

When considering the 0.6 F1 (0.6 of the 1st Fresnel Zone) , the accepted industry standard model developed by Huygens\Kirchoff and adopted by Telecom Operators that there should be no obstructions inside this critical zone), the proposed turbines will have no impact on the ESB radio link. It should also be noted that while the proposed turbines will not obstruct the 0.6 Fresnel Zone, there is already some obstruction due to local terrain as shown in Figure 9.

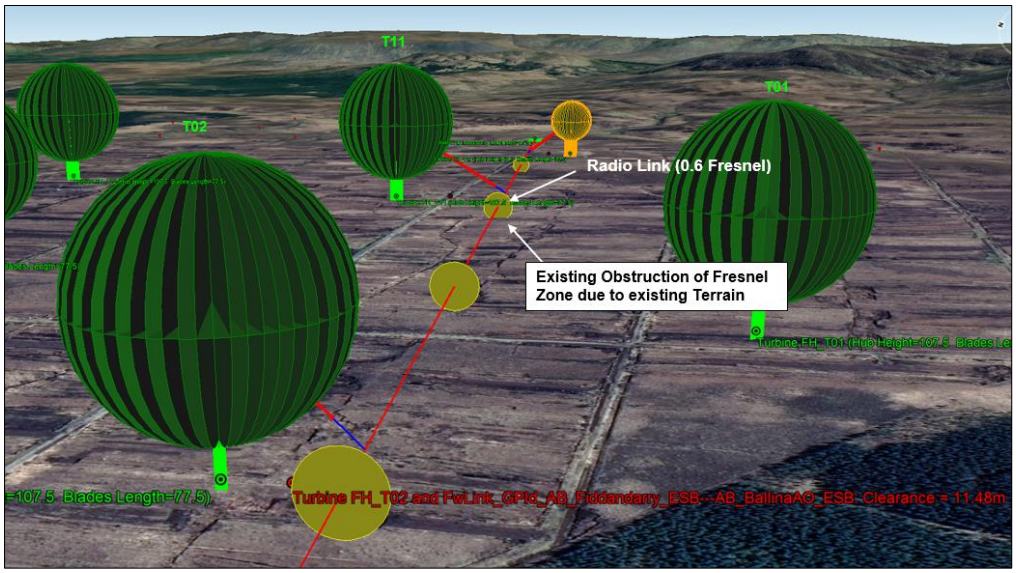


Figure 9. 3D Model showing 0.6 F1 of the ESB radio link is already obstructed by terrain.

The Radio Link Path Profile shown below in Figure 10 shows that there is an infringement of 5.387m into the 0.6 F1 Zone **due to existing terrain**. This infringement occurs at 13.01 km from the Ballina AO end of the link (or 0.63 km from Fiddandarry SS).

The Radio link Path Profile report is included in Appendix C

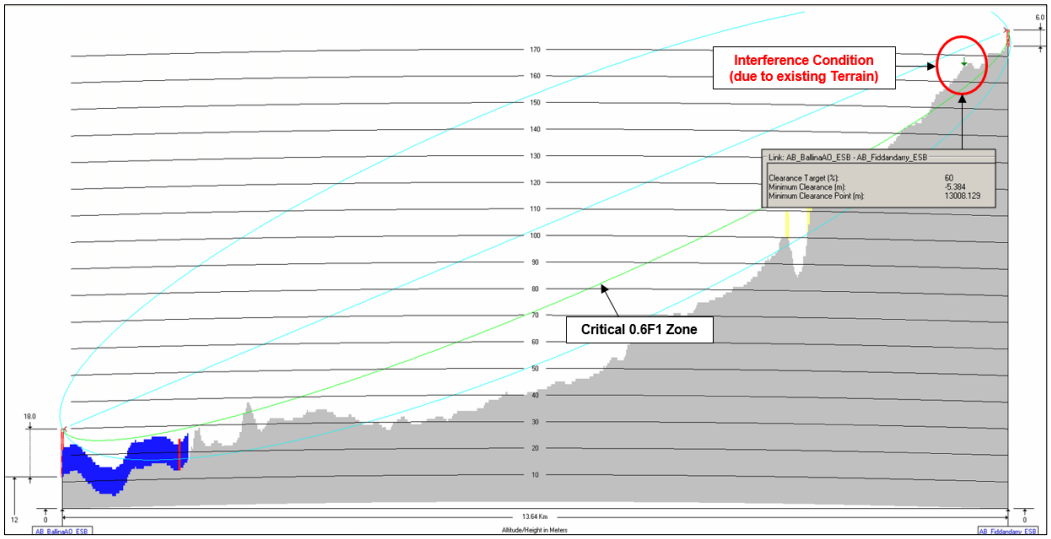
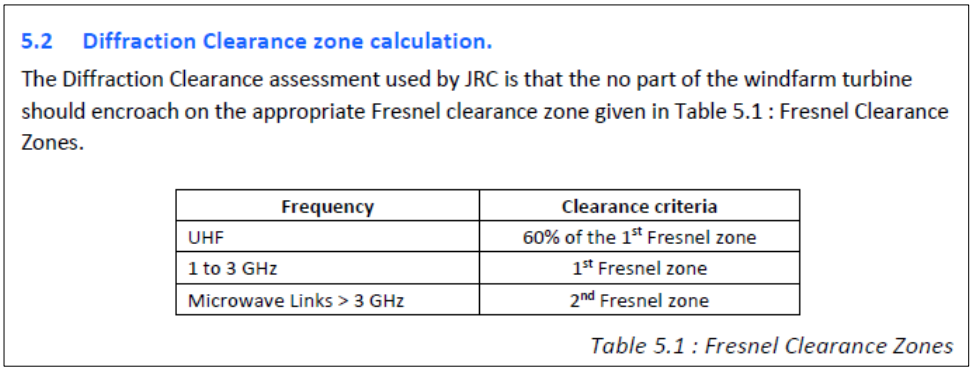


Figure 10. Path Profile showing 0.6 F1 of the ESB radio link is already obstructed by terrain

5.2 Radio Link Analysis Summary

A summary of the Baseline Telecommunications Impact Analysis is provided in Section 5.2.1 which summarizes the impact of the existing turbine at Carrowleagh wind farm and the impact of the terrain along the radio link. In Section 5.2.1 a summary of the Proposed Turbines Impact Analysis is provided. The results for the Worst-Case Scenario 2nd Fresnel Zone are presented along with the more generally accepted 0.6 F1 Fresnel Zone.

Note: The 0.6 F1 Fresnel Zone (or 60% of the 1st Fresnel Zone) has also been stated as being the assessment method used by JRC who provided an EMI assessment report to ESB (See Appendix B).



5.2 Diffraction Clearance zone calculation.

The Diffraction Clearance assessment used by JRC is that the no part of the windfarm turbine should encroach on the appropriate Fresnel clearance zone given in Table 5.1 : Fresnel Clearance Zones.

Frequency	Clearance criteria
UHF	60% of the 1st Fresnel zone
1 to 3 GHz	1st Fresnel zone
Microwave Links > 3 GHz	2nd Fresnel zone

Table 5.1 : Fresnel Clearance Zones

Figure 11. Extract from JRC report stating that the 0.6 F1 Zone should be used for UHF Links

5.2.1 Baseline Telecommunications Impact Analysis:

A summary of the results of the Baseline Telecommunications Impact Analysis is provided in the table below.

Obstruction	2nd Fresnel Zone	0.6F1 Zone	Comments
Carrowleagh Turbine	Pass	Pass	The Carrowleagh turbine does not obstruct the 2nd Fresnel Zone (Clearance = 45.82 m). The Carrowleagh turbine does not obstruct the 0.6 F1 Fresnel Zone (Clearance = 52.04m)
Terrain	Fail	Fail	Existing terrain obstructs the 2nd Fresnel Zone (Interference = 55.38 m). Existing terrain obstructs the 0.6 F1 Fresnel Zone (Interference = 5.38 m).

Table 5. Baseline Telecommunications Impact Analysis - Calculation Results

5.2.2 Proposed Turbines Impact Analysis

A summary of the results of the Proposed Turbines Impact Analysis is provided in the table below.

Obstruction	2nd Fresnel Zone	0.6F1 Zone	Comments
T01	Pass	Pass	T01 passes the 2nd Fresnel Zone clearance criteria (Clearance = 144.4m). T01 passes the 0.6 F1 Fresnel Zone clearance criteria (Clearance > 150m). No issues expected.
T02	Fail	Pass	T02 obstructs the 2nd Fresnel Zone by a distance of 8.47m. T02 passes the 0.6 F1 Fresnel Zone clearance criteria (Clearance = 11.48m) As the 0.6F1 Fresnel Zone is not impacted, no issues are expected.
T03	Pass	Pass	No issues expected.
T04	Pass	Pass	No issues expected.
T05	Pass	Pass	No issues expected.
T06	Pass	Pass	No issues expected.
T07	Pass	Pass	No issues expected.
T08	Pass	Pass	No issues expected.
T09	Pass	Pass	No issues expected.
T10	Pass	Pass	No issues expected.
T11	Pass	Pass	T11 passes the 2nd Fresnel Zone clearance criteria (Clearance = 69.83) T11 passes the 0.6 F1 Fresnel Zone clearance criteria (Clearance = 83.53m) No issues expected.
T12	Pass	Pass	No issues expected.
T13	Pass	Pass	No issues expected.

Table 6. Proposed Turbine(s) Impact Analysis - Calculation Results

Section 6 - Mitigation Measures

6 Mitigation Measures

Section 6.1 that follows describes the mitigation measures available to the wind farm developer to offset any potential impact due to the proposed turbines on the ESB radio link between Fiddandarry and Ballina AO.

6.2 Mitigation Measure Solutions

To offset the potential impact of the turbines on the ESB radio link the following mitigation solutions are available:

i) Provision of Relay Mast South of Turbine T02.

This mitigation measure is described in more detail in Section 6.1.1 that follows.

6.1.1 Provision of Relay Mast South of Turbine T02.

An option of offset any potential impact of T02 on the ESB communications link would be to provision a relay mast-structure adjacent to turbine T02. This would require a telecoms mast or mono-pole structure to be erected ~130m from T02, which would provide an alternative telecommunication site to ESB so that the turbines would not obstruct radio the radio signal path. An outdoor cabinet would also be required to house the radio indoor equipment and electrical power supply, which could be taken from T02.

Figure 12 below illustrates how a relay mast could be used to mitigate against an obstructing turbine. Figure 13 show example structures that could be used at a relay mast-site.

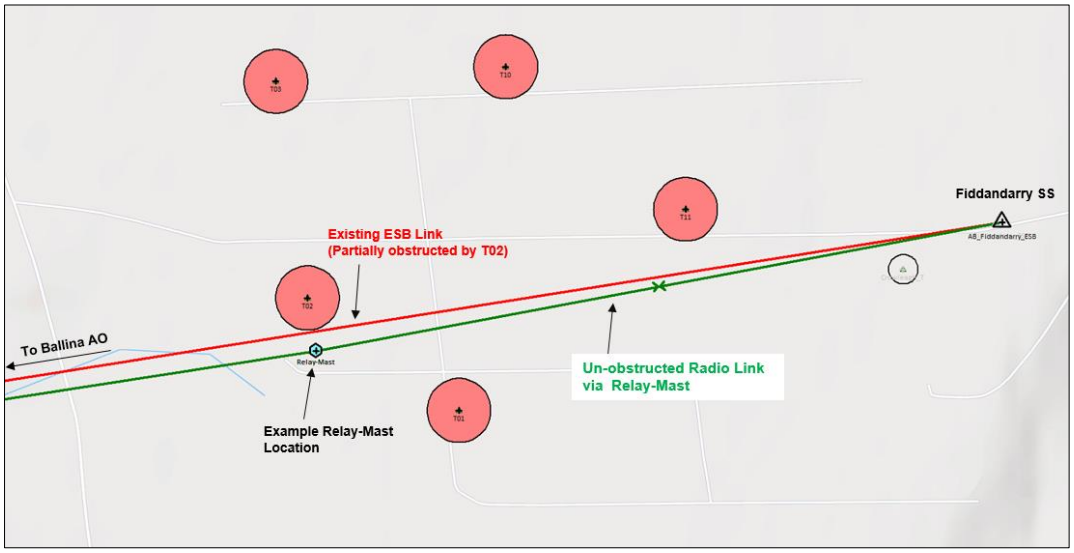


Figure 12. Example of a relay mast used to mitigate against an obstructing turbine.

Figure 13. Example structures that could be used at a relay mast-site.

3D Analysis has been carried out to assess if the relay link could meet the Critical 0.6F1 Zone Clearance Criteria. Figure 14 below shows a 3D model of a link from the relay-mast to Fiddandarry Substation. The Figure shows that the Critical 0.6F1 Zone would not be obstructed.

Figure 15 shows the Path Profile of the radio link between the Relay-Mast and Fiddandarry Substation. The Path Profile shows that there would be no infringement into the Critical 0.6F1 Zone.

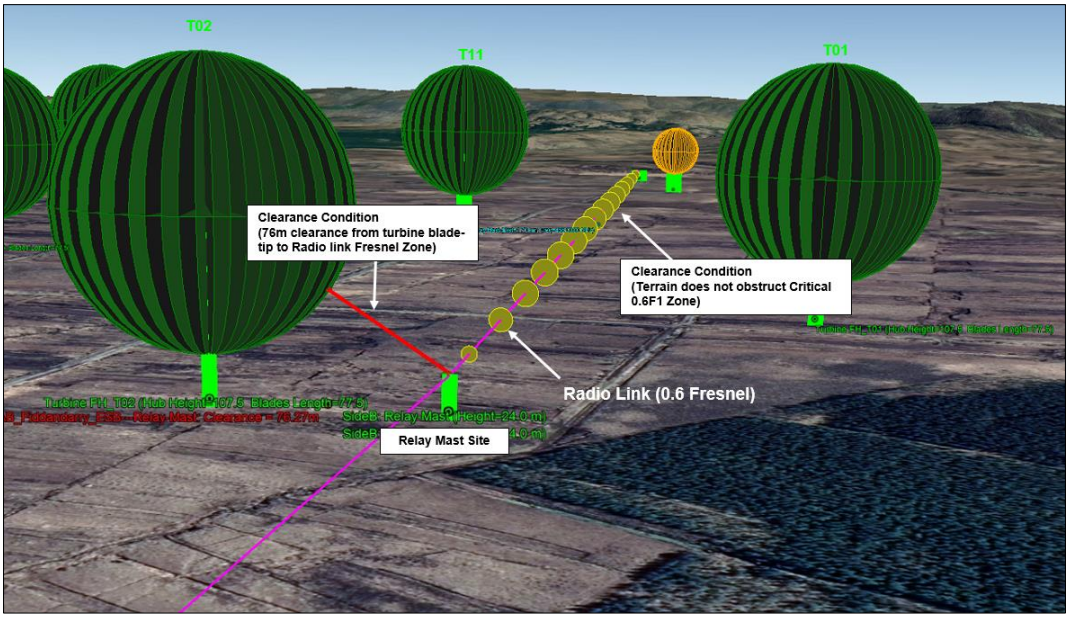


Figure 14. 3D Model showing 0.6 F1 of the relay radio link would not be obstructed.

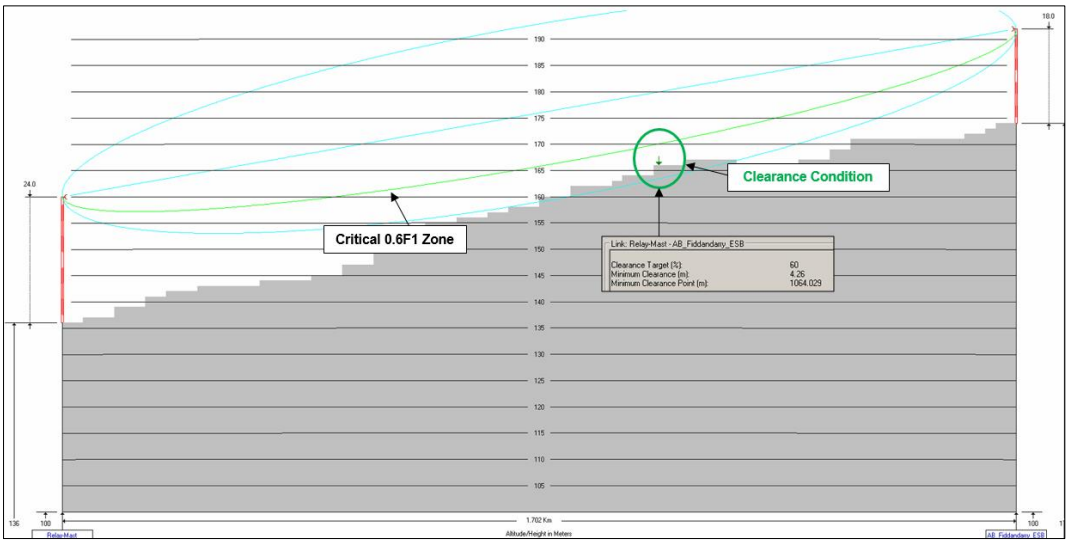


Figure 15. Path Profile showing a Clearance Condition

Section 7 - Conclusions

7 Conclusions

From the findings made in this report the following conclusions have been made:

- When the Worst-Case Scenario 2nd Fresnel Zone is used for Radio Link Clearance Calculations, turbine T02 would fail the clearance criteria by 8.47m.

- When using the radio diffraction theory the accepted 0.6F1 Fresnel Zone Radio Link Clearance Calculations, turbine T02 would pass the clearance criteria by 11.48m. Based on this approach Turbine T02 would not cause any impact to the ESB PMP link.

- Baseline Radio Link analysis shows that the existing radio link does not pass the 0.6F1 Fresnel Zone criteria. Results show that at distance of 0.6km from Fiddandarry Substation there is an obstruction due to terrain that encroaches into the 0.6F1 Zone by 5.38 m.

- In the unlikely event that there will be any impact to the ESB PMP radio link due to Turbine T02, a number of mitigation measures have been proposed to ESB.

- ESB have accepted the mitigation measure solution of a relay mast site erected to the south of T02. It has been agreed that UHF radio link would be relayed around T02 from Ballina to Fiddandarry Sub-station.

- It was agreed with ESB that the wind farm developer would cover the costs of the mast relay site mitigation measure as follows.

  Mast Relay Site Mitigation Measure Proposal:
  - Installation of UHF PMP telemetry link equipment to be installed and maintained on behalf of 2RN by a third party for duration of operation of the wind farm
  - Civil Construction by the wind farm developer of a concrete plinth, outdoor street side telecommunication cabinet, palisade fencing and a 6m monopole.

  Mast Relay Site Mitigation Measure Costs :
  - Once-off Civil Construction costs including concrete plinth palisade construction and monopole construction to be covered by the wind farm developer
  - Once-off Hardware & Installation Costs :
    - Street side Telecommunications Cabinet : € 2,641
    - Electrical & Battery Pack Supply : € 1,675
    - 2 no UHF Links including radio and antenna equipment : € 5,500
    - Design & Installation Costs : €4,500

8 References

(i) International Telecommunications Union Recommendation: ITU-R P.525 "International Telecommunications Union radio communications standard for the calculation of free-space attenuation."

(ii) International Telecommunications Union Recommendation: ITU-R P.526 "*International Telecommunications Union radio communications standard for the Propagation by diffraction*."

(iii) OFCOM Report: "*OfW 49 Fixed Point-to-Point and Point-to-Multipoint Scanning Telemetry Radio Services Operating in the Frequency Ranges 457.5 to 458.5 MHz paired with 463.0 to 464.0 MHz"* Published May 2017 Version 3.0

(iv) AEGIS Report: "*RF Measurement Assessment of Potential Wind Farm Interference to Fixed Links and Scanning Telemetry Devices*" Published March 2009 Issue 3

APPENDIX A – Firlough Wind Farm Turbine Co-ordinates

Appendix A – Firlough Wind Farm Turbine Co-ordinates

The co-ordinates of the turbines studies in this report are shown below in Table A1.

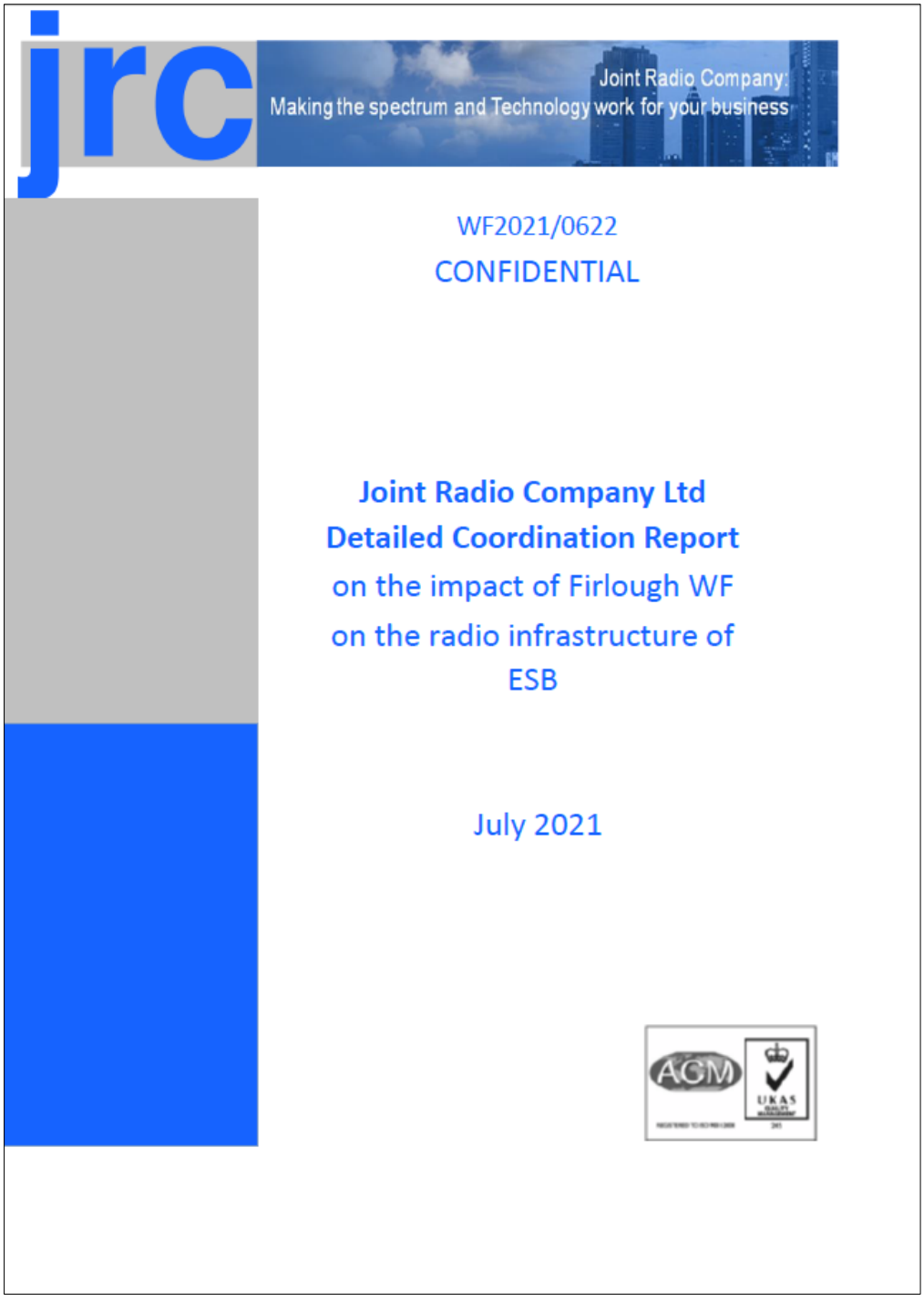
Firlough Wind Farm Co. Mayo				
Turbine No.	ITM Easting (m)	ITM Northing (m)	ING Easting (m)	ING Northing (m)
T01	536377	820426	136412	320417
T02	536011	820705	136045	320697
T03	535941	821233	135976	321224
T04	535914	821771	135949	321762
T05	535621	822154	135655	322146
T06	535370	822589	135405	322581
T07	536207	822527	136242	322519
T08	536697	822453	136732	322445
T09	536577	821915	136612	321907
T10	536503	821261	136538	321253
T11	536937	820908	136972	320899
T12	537033	821489	137068	321480
T13	537134	822272	137169	322263

Table A1 - Firlough Wind Farm Turbine Co-ordinates

APPENDIX B – JRC EMI Report for ESB

Appendix B – JRC EMI Report for ESB

The EMI report prepared by JCR for ESB is provided below.



Executive Summary

This report presents the results of an investigation into the effects of potential interference caused to ESB licensed radio systems by the construction of the Firlough Windfarm. The windfarm details are as per the email information by ESB.

A summary of the detailed assessment is given in the table below.

On Initial analysis T2, T11, T1, T10, T3 and T12 were identified as having potential impact on one or more operational links, detailed analysis quickly cleared T10, T3 & T12 as not being a risk (based on their current notified position / size (with assumed 50m micro-siting).

T11, T2 and T1 of the proposed windfarm fail one or more criteria with respect to one or more operational links as detailed in the table below.

The most significant impact from these three turbines comes from T11 & T2 with a minor contribution from T1, there is no easy mitigation solution other than moving each of those Turbines from the link path, I have detailed the necessary buffer zone required around the impacted link in section 7 – Mitigation.

Although the final decision on any objection rests with the link operator, our recommendation will be to Object to this proposal if submitted for planning unless the proposed mitigation solution is acceptable.

UHF Link Affected	Turbine No	Obstruction	Diffraction	Reflection/ Scattering	Comment
Fiddandarry 38KV to Balina AO	2	Fail	Fail	Fail	This turbine fails on all three tests with a W/U of 32.7 (5.3dB below the required 38dB)
	11	Pass	Fail	Fail	Although this turbine passes the basic clearance test it has the worst W/U of 26.9 (11.1dB below the required 38dB)
	1	Pass	Pass	Fail	This turbine on its own almost passes being just 1 dB below the required W/U of 38dB but as part of the group contributes to the overall failure
	10	Pass	Pass	Pass	No concern after detailed analysis
	3	Pass	Pass	Pass	No concern after detailed analysis
	12	Pass	Pass	Pass	No concern after detailed analysis

Table 1.1: Summary of turbine assessment on potentially affected UHF links

Any changes to the proposed wind farm (other than those detailed in the mitigation section) will require a new analysis since these results will no longer apply. This analysis is correct as of the advised configuration on 23rd April 2021.

Document Control

Issue	Date	Change History	Authority
0.1	10/06/21	Initial Draft	JSB
0.2	21/06/2021	Initial Review	LK
0.3		Technical review & updates	
1.0		Final Review	

Distribution	
Windfarm Developer	N/A
Link Operator	ESB – Myles Redmond
JRC	

Published by The Joint Radio Company Ltd.

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<www.jrc.co.uk/about-jrc >

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NOTICE: This report is a study of the predicted effect of the stated development on those radio systems defined in this document and shall not be used for any other purpose.

The information supplied in this document is strictly confidential and is intended for the use of the customer only. It shall not be disclosed to or used by any third party without the written permission of an authorised representative of JRC Ltd.

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This document was Printed:June 2021

Disclaimer

The assessment of the effect of windfarms on radio links is based on a combination of statistical modelling and radio propagation predictions. JRC has developed its methodology based on published documents and best practice within the industry, but the nature of radio propagation and the statistical approximations inherent in the planning tools mean that JRC cannot offer any guarantee that the effects will be exactly as predicted. However, the influence of wind turbines on UHF telemetry and microwave links is sufficiently well understood to have reasonable confidence in the predicted effects. JRC cannot be held responsible for any inaccuracies in data provided by third parties.

The use of the radio spectrum is dynamic and new radio links are being planned and installed all the time. As a result, you are advised to seek re-coordination prior to submitting a formal planning application. This will avoid the possibility of an objection being raised at that time due to any new links being assigned between the publication of this report and the finalisation of your project. Only when a windfarm proposal has been submitted for planning permission will JRC or its member companies take into account the proposal when planning new radio-based services.

If mitigation is required that involves the re-routing of link paths, then these paths will not be protected against new proposed turbine developments in the planning system until an agreement has been reached between the developer and the link operator and the links have been licensed and installed.

This report appertains only to the date of its issue and the configuration of the windfarm and radio links detailed in Sections 3 and 4 of this document. Any changes to the windfarm development after this report is issued, especially changes in the location or profile of any of the turbines, may negate the analyses that have been conducted.

Contents

1 Background

The adverse effect of Wind farms on radio propagation is relatively well understood, and several sophisticated modelling tools exist to predict the effects. The large rotating elements are a particular challenge in the radio environment.

JRC is the radio spectrum manager for the UK gas and electricity industry and is experienced in radio engineering associated with operational radio systems used by the utilities. It is therefore uniquely placed to investigate the potential impact of proposed wind farm developments. JRC is also a part of the energy sector and therefore committed to finding solutions to the problems posed by windfarms.

1.1 Radio systems affected

There are three main classes of utility operational services that might be affected by a wind farm.

Microwave fixed links: used for point-to-point communications, typically operating in frequency bands of 1.4/1.5 GHz, 6 GHz, 7.5 GHz, 10/11GHz, 13/14 GHz, 23 GHz, 26 GHz, 38 GHz and 58 GHz and employing a variety of digital modulation techniques.

Scanning Telemetry and Telecontrol links: used for point to multi-point communications in accordance with OfW49 in the UHF 450-470 MHz band and 140 MHz band.

Private Mobile Radio (PMR): for communications with mobile and hand-held radios. For the electricity industry, these systems usually operate around 140 MHz and employ MPT1327 or DMR trunking protocols. JRC do not coordinate wind turbines with PMR systems except when the turbine is very close (<500m) to the Transmitter site.

JRC uses a simple buffer coordination zone to initially determine which radio links may be impacted by the wind farm.

Radio Link Frequency	Buffer distance for coordination
Below 1 GHz	1000m
Above 1 GHz	500m

Table 1.1 : Initial coordination buffer distances

To the rear of the link, where a directional antenna is in use, the buffer distance is halved.

1.2 Mechanisms by which wind farms may affect radio transmissions

The effects of wind turbines on radio transmissions can be described under three main headings:

Obstruction: Where the wind farm is physically obstructing the direct radio path, attenuating the received signal.

Diffraction: Where a wind farm, although not directly obstructing the radio signal causes interference patterns to be generated (Fresnel Zone Interference).

Reflection/Scattering: Where the radio waves are reflected or scattered by the wind farm and interfere with the wanted signal.

Wind turbines pose problems for radio transmissions as the turbines tend to occupy the high ground also used by the radio infrastructure, and their size implies that they offer radio interference paths that may be superior to the designed radio path profile.

The sensitivity of a particular radio service to interference will depend on the radio parameters, including the frequency, modulation and the polarisation of the radio signal.

The severity of the effect on radio signals will depend on the construction of the turbine including the height, blade size, construction material, blade rotation, the pitch of the turbine blades, the yaw of the turbine nacelle and moisture retention or icing of the turbine blades.

2 Scope

It was agreed that JRC will undertake the following activities to assess the impact of the proposed Firlough wind farm.

- To undertake a detailed study and survey into the existing radio communication infrastructure within the area of the wind farm to confirm the parameters for the services operated by ESB.
- To review the theoretical analysis of the impact of the proposed wind turbine position on the licensed radio systems.
- This report was undertaken using information supplied by ESB.

3 Proposed windfarm development

Turbine No.	Eastings (IGR)	Northings (IGR)	Hub Height (m)	Rotor Diameter (m)	Tip Height (m)
1	136412	320417	90	50	140
2	136045	320697	90	50	140
3	135976	321224	90	50	140
4	135949	321762	90	50	140
5	135655	322146	90	50	140
6	135405	322581	90	50	140
7	136242	322519	90	50	140
8	136732	322445	90	50	140
9	136612	321907	90	50	140
10	136538	321253	90	50	140
11	136972	320899	90	50	140
12	137068	321480	90	50	140
13	137169	322263	90	50	140

Table 3.1 : Wind farm parameters

Development parameters used for the analysis is as per the information by ESB. Any modifications from these details will require a new analysis.

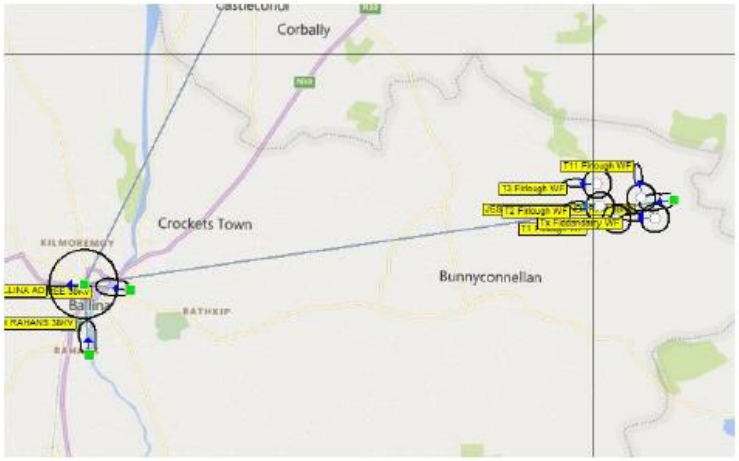
4 Affected radio links.

ESB operates one or more UHF telemetry links within the coordination zone. The end point of these links has been verified by JRC.

Site A Name	Link Type	Site A Easting	Site A Northing	Site B Name	Site B Easting	Site B Northing
Balina AO HS1	UHF P2MP	124227	318922	Fidandarry 38KV SS	137712	320866

Table 4.1 : Radio Link Parameters

The proposed wind turbine layout and the relationship to the affected radio links can be seen in the following diagram



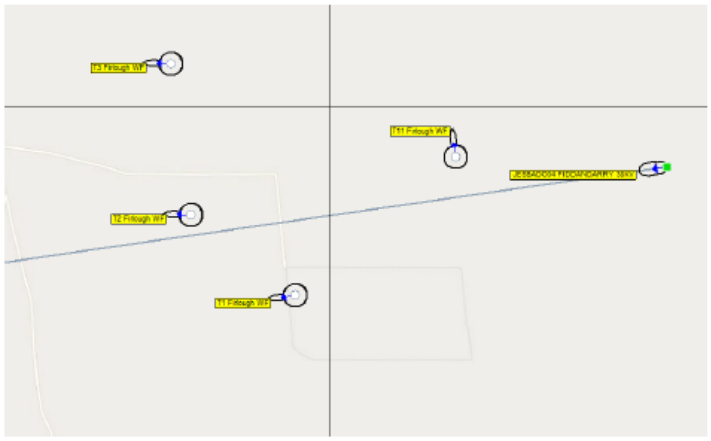


Figure 4-1 : Radio Link and Turbine Location

A larger version of this appears in Appendix A: Disposition of the turbine in relation to ESB link infrastructure

5 Impact Assessment Methodology

5.1 Calculation Method

The analysis of the potential impact of the proposed wind farm follows the methods set out in the JRC paper "Calculation of The Clearance Zone" [1]. A full explanation of this method can be found in on the JRC web site https://www.jrc.co.uk/what-we-do/wind-farms .
When protecting link availability approaching 99.9%, the wind turbine must be profiled in the worst case, i.e. with maximum horizontal profile, maximum radar cross section, maximum Doppler shift, etc. It is accepted that all of these conditions will not be fulfilled at all times, and in practice may only be for a small percentage of time, but the total tolerance for loss of service to such a link is no more than 0.1% of the time.

JRC employs a number of tools to complete the wind farm assessment:

- An in-house tool developed within MapInfo is used for identifying the potentially affected links and their location relative to the proposed turbines
- ATDI's HTZ radio planning tool to calculate the predicted path loss for the link path and for the path between the link ends and the turbine. HTZ is integrated with the 20m terrain dataset and 20m (for the Island of Ireland) clutter datasets and building data where available and uses ITU-R P.525 and P.526 with Delta Bullington diffraction propagation algorithms.
The JRC method calculates both the diffraction clearance and reflection / scattering clearance required to protect the link from interference.

5.2 Diffraction Clearance zone calculation.

The Diffraction Clearance assessment used by JRC is that the no part of the windfarm turbine should encroach on the appropriate Fresnel clearance zone given in Table 5.1 : Fresnel Clearance Zones.

Frequency	Clearance criteria
UHF	60% of the 1st Fresnel zone
1 to 3 GHz	1st Fresnel zone
Microwave Links > 3 GHz	2nd Fresnel zone

Table 5.1 : Fresnel Clearance Zones

A buffer zone is added to the diffraction clearance to allow for location uncertainty of the link ends and turbine construction. This buffer zone varies from 25m to 150m depending on the accuracy of the link locations. An additional allowance is also added for turbine micro-siting which can vary from 100m to 25m depending on the information provided. These buffer figures may be reduced if a JRC site survey is undertaken.
To complement the basic clearance, the 3D diffraction clearance can be visualised using the MapInfo tool.

5.3 UHF Telemetry links Reflection / Scattering interference method.

HTZ is used to predict the path loss from the link transmitter to the turbine and then from the turbine to the receive end of the link. The field strength from this reflected path is compared to the measured and predicted field strength on the direct link. Where predicted, the links are calculated in accordance with OFW49 in the UK or the appropriate system for other countries unless the link is already known to be degraded, in which case the measured signal strength is used where available.

The wanted to unwanted ratio is calculated according to the JRC method detailed in the paper "Calculation of The Clearance Zone" [1].

If the reflection angle is less than 90 degrees, it is calculated assuming worst case micro siting and uncertainty buffer (towards the link) for forward scatter.

For yagi antennas at the outstation, a standard mask is used to determine antenna response. For nonstandard antennas, then the impact is assessed using both the standard mask and using the bespoke antenna pattern to determine the impact.

6 Results

A summary results of the detailed analysis can be seen in the table below:

UHF Link Affected	Turbine No	Obstruction	Diffraction	Reflection/ Scattering	Comment
Fiddandarry 38KV to Balina AO	2	Fail	Fail	Fail	This turbine fails on all three tests with a W/U of 32.7 (5.3dB below the required 38dB)
	11	Pass	Fail	Fail	Although this turbine passes the basic clearance test it has the worst W/U of 26.9 (11.1dB below the required 38dB)
	1	Pass	Pass	Fail	This turbine on its own almost passes being just 1 dB below the required W/U of 38dB but as part of the group contributes to the overall failure
	10	Pass	Pass	Pass	No concern after detailed analysis
	3	Pass	Pass	Pass	No concern after detailed analysis
	12	Pass	Pass	Pass	No concern after detailed analysis

Table 6.1 : JRC Calculation Results

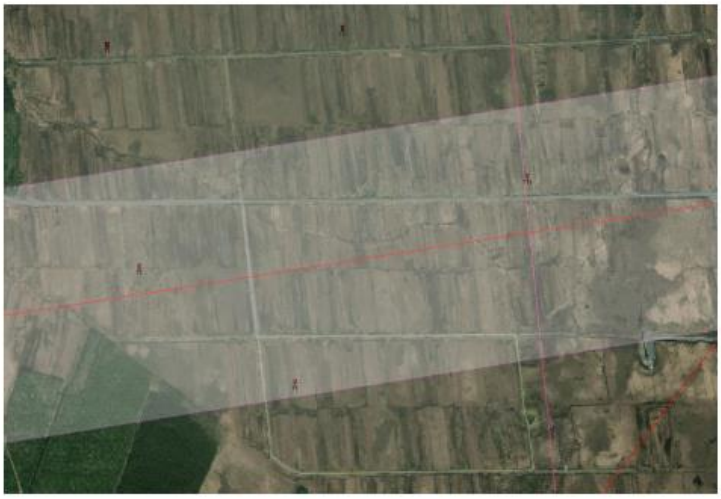
7 Potential Mitigation

As there is no viable solution other than removal of the three turbines T11, T2 and T1 from the path of the link we would recommend that each of the turbines T1, T2 and T11 be moved outside the buffer zone around the link as shown below and further would suggest that the appropriate distances to minimise impact on the Links would be as follows

T1 should move South of the existing location by a minimum of 100m with micrositing value of 25m

T2 should move North of the existing location by a minimum of 350m with micrositing value of 25m

T11 should move North of the existing location by a minimum of 250m with micrositing value of 25m



8 References

[1] "Calculation of the Clearance Zone". Peter Swan, et al. Version 3.1, September 2009, Joint Radio Company Ltd.

[2] "Fixed-link wind-turbine exclusion zone method". Dr. David Bacon. Version 1.1, 28 October 2002, UK Radiocommunications Agency (now part of Ofcom).

[3] Ofcom Independent Report on RF Measurement Assessment of Potential Wind Farm Interference to Fixed Links and Scanning Telemetry Devices, published in March 2009.

NOTE: More information on how JRC assesses Wind Energy Developments and links to other reference documents can be found on the JRC Web Site: http://www.jrc.co.uk/wind-farms

9 Appendix A: Disposition of the turbine in relation to ESB link infrastructure

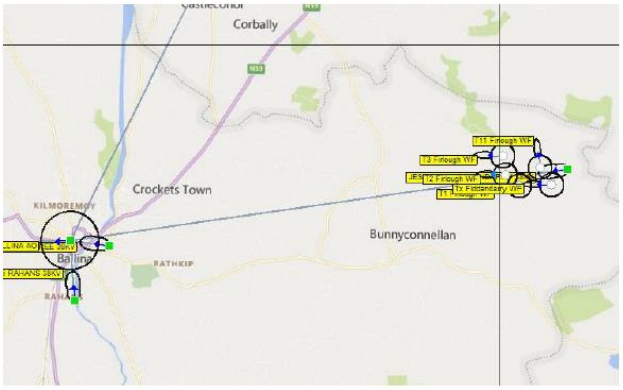


Figure 9-1 : Turbine locations with respect to ESB Links

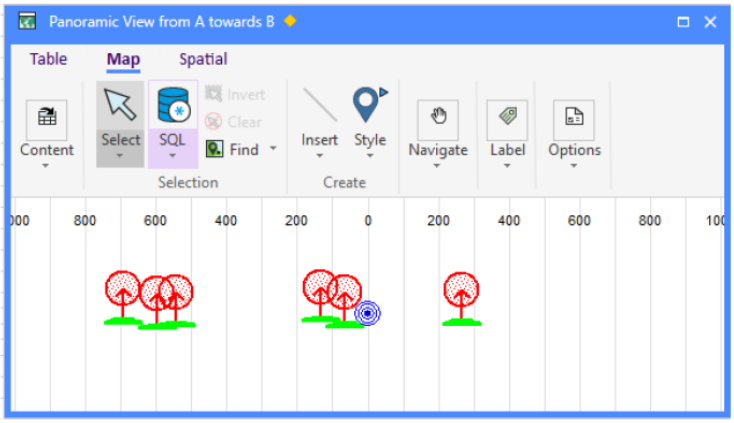


Figure 9-2 : Turbine locations with respect to ESB Links seen from A End

10 Appendix B: Path Profiles and Analysis

10.1 UHF Point to Multi Point telemetry links

10.1.1.1 Diffraction clearance (Fresnel interference)

For links below 1 GHz; the criterion used is that no part of a turbine should enter area defined by 60% of first Fresnel zone of the link.

To this is added a buffer zone to allow for location inaccuracy of the link ends and turbine construction and ellipsoid conversion anomalies; in this instance JRC has used 15m.

An allowance for micro-siting must be included. As we have no specified value from the developer, we have assumed the typical value of 50m.

10.1.2 Link Ballina AO HS1 to Fiddandarry 38KV SS

There is a single scanner connected to a single omnidirectional antenna at Ballina AO HS1.

There is a single vertically polarised 12 element Yagi antenna in use at the existing Fiddandarry 38KV SS.

The worst-case radio path analysis for the link can be seen in the following diagram Figure 10-2.

10.1.2.1 Overview of impact from proposed Turbines / WF installation

The most significant impact from these three turbines comes from T11 & T2 with a minor contribution from T1, there is no easy mitigation solution other than moving each of those Turbines at least 100m from the link path, however ESB have suggested a solution in creating a new scanner installation at the existing Glenree 110KV Substation, this would require a 36m tower at this station and all the Station currently on Ballina AO HS1 would have to reparented to this new Scanner, having completed an examination of the paths to the proposed station at Glenrees JRC would have no concerns in relation to Firlough WF

10.1.2.2 Diffraction clearance (Fresnel interference) - Results

The three-dimensional clearance is assessed for all the turbines against each link and can be seen in the figures below:

Figure 10-1: 'Basic' three-dimensional clearance for Turbine 2

(Not including buffer or micro-site).

The required clearance between turbine tip and Fresnel zone is 100m therefore as can be seen in the figure above and in the results table, Turbine 1 Fails the diffraction clearance assessment.

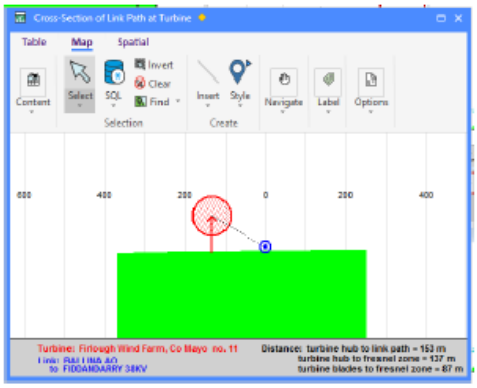


Figure 10-2: 'Basic' three-dimensional clearance for Turbine 11

(Not including buffer or micro-site).

The required clearance between turbine tip and Fresnel zone is 100m therefore as can be seen in the figure above and in the results table, Turbine 2 Fails the diffraction clearance assessment.

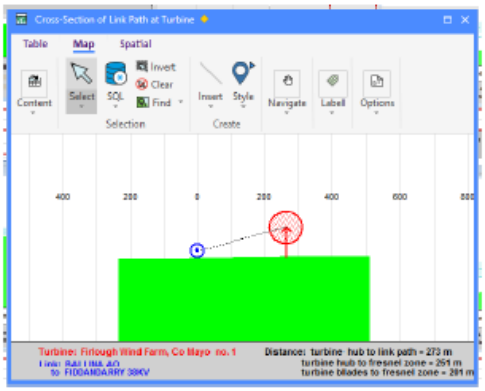


Figure 10-3: 'Basic' three-dimensional clearance for Turbine 1
(Not including buffer or micro-site).

The required clearance between turbine tip and Fresnel zone is 100m therefore as can be seen in the figure above and in the results table, Turbine 1 Passes the diffraction clearance assessment.

10.1.2.3 UHF Telemetry links Reflection/Scattering interference.

The existing links operate in the 460 MHz band. The turbines when added should therefore not reduce the W/U ratio of the link below the JRC threshold of 38dB.

Figure 10-4 : Radio path analysis B-A

As can be seen from the profile above, the link path is partially obstructed.

The predicted path loss is 115.4dB, Since the link path is partially obstructed, predicted loss rather than free space loss has been used for the main path.

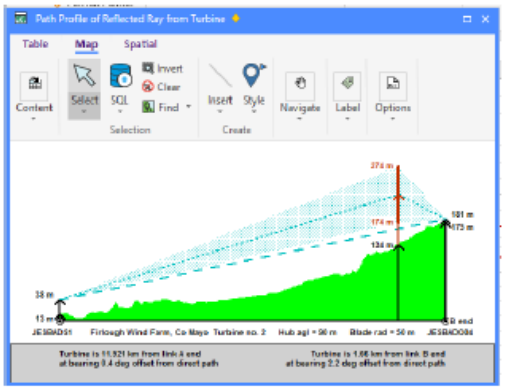


Figure 10-5 : Basic radio reflection diagram for Turbine 2

Turbine 2 has an unobstructed path to the link path, predicted loss is used in the initial Wanted to Unwanted calculation

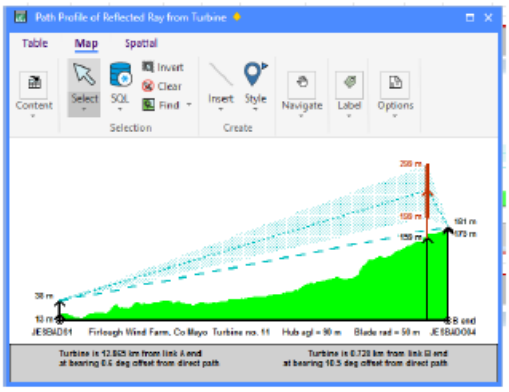


Figure.10-6 : Basic radio reflection diagram for Turbine 11.

Turbine 11 has an unobstructed path to the link path, predicted loss is used in the initial Wanted to Unwanted calculation

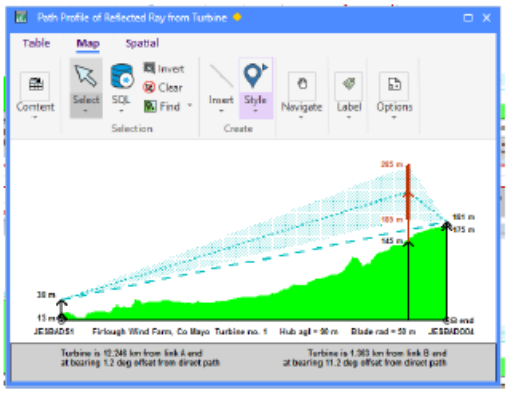


Figure.10-7 : Basic radio reflection diagram for Turbine 1.

Turbine 1 has an unobstructed path to the link path, predicted loss is used in the initial Wanted to Unwanted calculation

10.1.2.4 W/U Result

JRC W/U Power Sum including antenna discrimination & scatter			
All Turbines	25.3	Selected turbines	25.6
Above Threshold	-12.7	Above Threshold	-12.4

11 Appendix C: Calculation Results for turbines against Links

UHF Link Ballina AO HS1 to Fiddandarry 38KV SS Detailed Calculations

A-End antenna: Omnidirectional B-End Antenna: 12 element VP Yagi

Link ID	WF Name	Turbine No	Micro siting (MS)	Link Buffer (LB)	Basic Clearances		Loss above Free Space Path			Antenna Discrimination Modifiers		Basic W/U Ratio (no scatter)		Include Turbine in Calc?	Scatter Modifiers		HTZ Predicted Path Loss		Modified JRC W/U Ratio (with scatter)
					Basic	Plus MS & LB	Link A to B	Link End A to Turbine	Turbine to Link End B	A End	B End	Beam (inc. ant. discr)	JRC (inc. ant discr)		Forward	Back	Link End A to Turbine	Turbine to Link End B	JRC
FIDDANDARRY 38KV	Firlough	2	50	50	-4.2	-104.2	9.22	-0.04	-0.02	0.00	0.00	45.7	42.70	y	10.00	0.00	107.2	90.1	32.7
	Firlough	11	50		69.4	-30.6		0.00	0.04	0.00	-0.01	39.2	36.31	y	9.40	0.00	107.9	83.0	26.9
	Firlough	1	50		197.4	97.4		0.00	0.00	0.00	-0.08	44.3	41.36	y	4.40	0.00	0.0	0.0	37.0
	Firlough	10			479.2	379.2		0.00	0.00	0.00	-0.81	44.2	41.31	n	0.00	0.00	0.0	0.0	41.3
	Firlough	3			526.7	426.7		0.00	0.00	0.00	-0.45	46.6	43.71	n	0.00	0.00	0.0	0.0	43.7
	Firlough	12			632.1	532.1		0.00	0.00	0.00	-4.44	45.4	42.45	n	0.00	0.00	0.0	0.0	42.5

Link Ballina AO HS1 to Fiddandarry 38KV Stn Results –

Basic JRC W/U Power Sum including antenna discrimination Threshold = 38			
All Turbines	32.7	Selected Turbines	34.4
Above Threshold	-5.3	Above Threshold	-3.6

JRC W/U Power Sum including antenna discrimination & scatter Threshold = 38			
All Turbines	25.3	Selected turbines	25.6
Above Threshold	-12.7	Above Threshold	-12.4

APPENDIX C – Ballina AO to Fiddandarry Radio Link Path Profile Report

Appendix C – Ballina AO to Fiddandarry Radio Link Path Profile Report

The Ballina AO to Fiddandarry Radio Link Path Profile Report is provided below.

Site:	AB_BallinaAO_ESB		AB_Fiddandarry_ESB	
Name:				
Type:	Cell		Cell	
Latitude:	54°06'49.8"N		54°07'58.9"N	
Longitude:	9°09'33.9"W		8°57'11.2"W	
Altitude (m):	12		174	
UserData1:	User Data			
Datum:	World Geodetic System 1984 (WGS 84)			
	Forward Link		Reverse Link	
Transmission Site:	AB_BallinaAO_ESB		AB_Fiddandarry_ESB	
Reception Site:	AB_Fiddandarry_ESB		AB_BallinaAO_ESB	
Radio Type:	NetRadio0001		NetRadio0001	
Modulation Scheme:	4-QAM		4-QAM	
Bandwidth (MHz):	2		2	
Roll-Off Factor:	0.2		0.2	
Coding Gain (dB):	0		0	
System Gains (dB):	0		0	
Channel Overhead (%):	20		20	
FEC Overhead (%):	0		0	
Reference Temperature (°K):	290		290	
Receiver Noise Figure (dB):	5		5	
Maximum Data Rate (Mbps):	2.667		2.667	
Maximum Bit Rate (Mbps):	3.333		3.333	
Required Bit Error Rate:	BER 10-3	BER 10-6	BER 10-3	BER 10-6
Service Threshold (dBm):	-91	-90	-91	-90
Carrier to Noise Ratio (dB):	14.965	15.965	14.965	15.965
Cross Polarization Improvement Factor (dB):	20	20	20	20
Rx Equalization Sig Norm Parameter (Kn,M):	0.1	0.1	0.1	0.1
Rx Equalization Sig Norm Parameter (Kn,NM):	0.1	0.1	0.1	0.1
UserData1:	User Data		User Data	
Center Frequency (MHz):	458		458	
Channel Bandwidth (MHz):	28		28	
Transmission Power (dBm):	30		30	
Transmission Gains (dB):	0		0	

Transmission System Loss (dB):	0		0	
Transmission Line Loss (dB/100m):	4		4	
Transmission Line Length (m):	10		10	
Transmission Connection Loss (dB):	0.3		0.3	
Transmission Number of Connections:	2		2	
Transmission Additional Loss (dB):	0		0	
Transmission Losses (dB):	1		1	
Transmission Antenna:	Bcd-4506		Bcd-4506	
Transmission Antenna Size (m):	3.675		3.675	
Transmission Antenna Height (m):	18		6	
Transmission Antenna Gain (dBd):	6		6	
Transmission Antenna Gain (dBi):	8.14		8.14	
Transmission Power EIRP (dBm):	37.14		37.14	
Reception Gains (dB):	0		0	
Reception System Loss (dB):	0		0	
Reception Line Loss (dB/100m):	4		4	
Reception Line Length (m):	10		10	
Reception Connection Loss (dB):	0.3		0.3	
Reception Number of Connections:	2		2	
Reception Additional Loss (dB):	0		0	
Reception Losses (dB):	1		1	
Reception Antenna:	Bcd-4506		Bcd-4506	
Reception Antenna Size (m):	3.675		3.675	
Reception Antenna Height (m):	6		18	
Reception Antenna Gain (dBd):	6		6	
Reception Antenna Gain (dBi):	8.14		8.14	
Link Polarization:	Vertical		Vertical	
Cross Polarization Factor (dB):	30		30	
Link Distance (m):	13641.552		13641.552	
Azimuth - True (°):	80.895		261.063	
Azimuth - Magnetic (°):	84.601		264.687	
Transmission Inclination (°):	-0.63		0.63	
Reception Inclination (°):	-0.63		0.63	
ITU Recommendation:	ITU-R P.525-2			
Free Space Distance (m):	13642.376		13642.376	

Center Frequency (MHz):	458		458	
Free Space Loss (dB):	108.355		108.355	
Max Fresnel Radius (m):	47.264		47.264	
Max 2nd Fresnel Radius (m):	66.841		66.841	
Earth Radius Factor (K):	4/3			
Effective Radius (m):	8502056			
ITU Recommendation:	ITU-R P.526-11			
Diffraction Model:	Cascade Knife Edge			
Diffraction:	No LOS Diffraction		No LOS Diffraction	
Diffraction Loss (dB):	5.573		5.573	
Clearance Target (%):	60			
Minimum Clearance (m):	-5.384		-5.384	
Minimum Clearance Point (m):	13008.129		13008.129	
Terrain Reflection Dispersion (°):	0.5			
Reflection Area 1 (m):	798.664		798.664	
Reflection Area 2 (m):	853.745		853.745	
Reflection Area 3 (m):	1018.985		1018.985	
Reflection Area 4 (m):	1055.706		1055.706	
Reflection Area 5 (m):	1092.4 - 1147.5		1092.4 - 1147.5	
Reflection Area 6 (m):	1202.6 - 1257.7		1202.6 - 1257.7	
Reflection Area 7 (m):	1624.9 - 1643.2		1624.9 - 1643.2	
Reflection Area 8 (m):	13228.449		13228.449	
ITU Recommendation:	ITU-R P.676-8			
Atmospheric Pressure (hPa):	1013		1013	
Standard Temperature (°C):	15		15	
Water Vapor Density (g/m³):	7.5		7.5	
Atmospheric Gases Loss (dB):	0.038		0.038	
Total Path Loss (dB):	113.965		113.965	
Reception Signal Level (dBm):	-69.685		-69.685	
	BER 10-3	BER 10-6	BER 10-3	BER 10-6
Service Threshold (dBm):	-91	-90	-91	-90
Link Gross Margin (dB):	21.315	20.315	21.315	20.315
ITU Recommendation:	ITU-R F.1703-0 / ITU-T G.827			
Objective ITU Quality Grade:	Short Haul SDH Networks			
Unavailability Objective (%):	2.00E-02			
Availability Objective (%):	99.98			

ITU Recommendation:	ITU-R F.1668-1 / ITU-T G.826			
Error Performance Objective BBER (%):	1.60E-05		1.60E-05	
Error Performance Objective BBER (s/Month):	0.42		0.42	
	SESR	ESR	SESR	ESR
Error Performance Objective (%):	1.60E-04	3.20E-03	1.60E-04	3.20E-03
Error Performance Objective (s/Month):	4.205	84.096	4.205	84.096
ITU Recommendation:	ITU-R F.1668-1 / ITU-T G.828			
Error Performance Objective BBER (%):	4.00E-06		4.00E-06	
Error Performance Objective BBER (s/Month):	0.105		0.105	
	SESR	ESR	SESR	ESR
Error Performance Objective (%):	1.60E-04	8.00E-04	1.60E-04	8.00E-04
Error Performance Objective (s/Month):	4.205	21.024	4.205	21.024
Multipath Model:	ITU-R P.530-15			
Multipath Planning Type:	Quick Planning			
Multipath Time Frame:	Average annual distribution			
ITU Recommendation:	ITU-R P.453-9			
Point Refractivity Gradient (dN1):	-76.7			
Geoclimatic Factor:	4.05E-05		4.05E-05	
Multipath Occurrence Factor (%):	2.72E-03		2.72E-03	
Precipitation Model:	ITU-R P.530-15			
ITU Recommendation:	ITU-R P.837-5 / ITU-R P.841-4			
Precipitation Time Frame:	Average annual distribution			
Precipitation Rate @ 0.01% (mm/h):	22			
ITU Recommendation:	ITU-R P.838-3			
Specific Attenuation (dB/km):	0.002874		0.002874	
Rainfall Attenuation (dB):	-0.19		-0.19	
	BER 10-3	BER 10-6	BER 10-3	BER 10-6
Fading Outage (%):	1.93E-06	2.58E-06	1.93E-06	2.58E-06
Selective Fading Outage (%):	1.51E-10	1.51E-10	1.51E-10	1.51E-10
Composite Fading Outage (%):	1.93E-06	2.58E-06	1.93E-06	2.58E-06
Fading Outage (s/Month):	0.051	0.068	0.051	0.068
Selective Fading Outage (s/Month):	0	0	0	0
Composite Fading Outage (s/Month):	0.051	0.068	0.051	0.068

	BER 10-3	BER 10-6	BER 10-3	BER 10-6
Unavailability due to Rain (%):	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Unavailability due to Rain (s/Year):	0	0	0	0
	BER 10-3	BER 10-6	BER 10-3	BER 10-6
Unavailability due to Fading (%):	1.93E-06	2.58E-06	1.93E-06	2.58E-06
Unavailability due to Rain (%):	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total Unavailability (%):	1.93E-06	2.58E-06	1.93E-06	2.58E-06
Unavailability Objective (%):	2.00E-02	2.00E-02	2.00E-02	2.00E-02
Unavailability due to Fading (s/Year):	0.609	0.814	0.609	0.814
Unavailability due to Rain (s/Year):	0	0	0	0
Total Unavailability (s/Year):	0.609	0.814	0.609	0.814
Unavailability Objective (s/Year):	6307.2	6307.2	6307.2	6307.2
Total Availability (%):	100	100	100	100
Availability Objective (%):	99.98	99.98	99.98	99.98
	* PASS *	* PASS *	* PASS *	* PASS *