Environmental Impact Assessment Report

Volume 4

Appendix 18.3 Television and Radio Desk-Based Report

PAGERPOWER
Urban & Renewables

Television and Radio Desk-Based Report

Natural Power Consultants Limited

Codling Wind Park Project

July 2024

ADMINISTRATION PAGE

Job Reference:	11105C
Date:	July 2024
Author:	Abdul Wadud
Telephone:	+44 (0)1787 319001
Email:	abdul@pagerpower.com

Reviewers:	Waqar Qureshi (Issue 1); Kai Frolic (Issue 1)
Email:	waqar@pagerpower.com; kai@pagerpower.com

Issue	Date	Detail of Changes
1	December 2022	Initial issue
2	January 2024	Administrative revisions
3	July 2024	Client revisions

Pager Power Limited, Stour Valley Business Centre, Sudbury, CO107GB, United Kingdom

T: +44 (0)1787 319001 E: info@pagerpower.com W: www.pagerpower.com

EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained by Natural Power to assess the potential television and radio interference effects associated with the proposed offshore windfarm development, the Codling Windpark Project (CWP), located near Greystones, Republic of Ireland.

Relevant Transmitters

The main television transmitters serving the area are Kippure and Greystones, located approximately 32km and 17km west of CWP respectively. Both transmitters broadcast terrestrial Saorview digital terrestrial television services and radio transmissions.

Overall Results

Negligible impacts are anticipated for areas receiving signals from the Kippure and Greystones transmitter. A breakdown of the overall results is presented in the following sections.

Terrestrial Television Results

The CWP is predicted to produce an interference zone to the southeast of the turbine area, where no dwellings or receivers exist.

Isolated cases of interference cannot be entirely ruled out and any reported interference should be considered case-by-case with local mitigation solutions applied where appropriate. The overall impact is considered low.

Radio Results

Noticeable impacts on radio signals in the surrounding area are not predicted as a result of CWP. This is because no interference is predicted for transmitted signals within populated areas. Additionally, alternate transmitters can provide coverage as radio transmission are more robust and receivers are designed to accept transmissions in dynamic environments.

Mitigation

Mitigation is not expected to be a requirement, as no significant impacts are predicted.

Next Steps

The proposed development is not considered to require mitigation. Therefore, any reported interference following construction should be investigated if attributable to the wind development.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 59 countries within Europe, Africa, America, Asia and Australasia.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems. Over the years, the company has expanded into numerous fields including:

- Renewable energy projects;
- Building developments;
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power's assessments withstand legal scrutiny and the company can provide support for a project at any stage.

1 INTRODUCTION

1.1 Overview

Pager Power has been retained by Natural Power to assess the potential television and radio interference effects associated with the proposed offshore windfarm development, the Codling Wind Park Project (CWP), located near Greystones, Republic of Ireland.

1.2 Proposed Development Details

1.2.1 Turbine Details

The assessment has considered initial layouts with a greater number of: L200 and L196. As such, all predicted interactions in this assessment are now inherently reduced. Table 1 below summaries the details of the turbines for each layout option.

- For layout L200, the final 75 turbine locations are to be selected from 90 possible positions;
- For layout L196, the final 60 turbine locations are to be selected from 73 positions.

	Layout	
	L200	L196
Rotor Diameter (m)	250	276
Tip Height above LAT (m)	288	314
Nominal Hub Height above LAT (m)	163	176

Table 1 *Wind turbine details*

1.2.2 Proposed Development Location

The CWP is an offshore windfarm development. Figure 1 below shows the redline boundary of the CWP.

Figure 1 *CWP redline boundary*

1.2.3 Locations of Residential Areas

Figure 2 below highlights the location of significant residential areas (yellow circles) in the surrounding area relative to CWP.

Figure 2 *Residential areas in proximity to the proposed development*

2 TELEVISION TRANSMITTER DETAILS

2.1 Coverage Maps

Coverage maps for the area were assessed and the Saorview coverage checker was also used to determine which transmitter(s) provide services in the area.

Digital terrestrial television signals in the area are understood to be provided by the Kippure[1] main transmitter and Greystones transmitter, both providing channels on two digital multiplexes. The Three Rock main transmitter also exists on a similar bearing and distance from CWP as the Kippure main transmitter, however the coverage checker indicates that Kippure and Greystones serves the area closest to the CWP area and therefore have been considered.

2.2 Kippure and Greystones Transmitter

Kippure and Greystones are two of Ireland's main television transmitters located approximately 32km and 17km west of CWP respectively. Kippure transmits its main multiplexes on channels 34 and 35, and Greystones transmits its main multiplexes on channels 42 and 45.

Both transmitters broadcast terrestrial Saorview digital terrestrial television services. Television coverage for both transmitters in the area is generally good[2], but does have some 'dead spots', most likely due to terrain variations. Based on a review of the coverage maps and orientation of aerials using street level imagery, it is likely that a variety of sources provide television services to the wider area including:

- Either Kippure or Greystones transmitters depending on coverage;
- Satellites (e.g. Sky or SAORSAT);
- The internet (e.g. streaming services).

Impacts on services from the other sources (excluding the main transmitters) are unlikely to be significant. Satellite and internet-based services are unlikely to be affected due to the nature of transmission.

Figure 3 on the following page shows the relative location of the transmitters and CWP.

[1] https://saorview.ie/en/check-coverage/

[2] Based on the coverage map: https://saorview.ie/en/check-coverage/

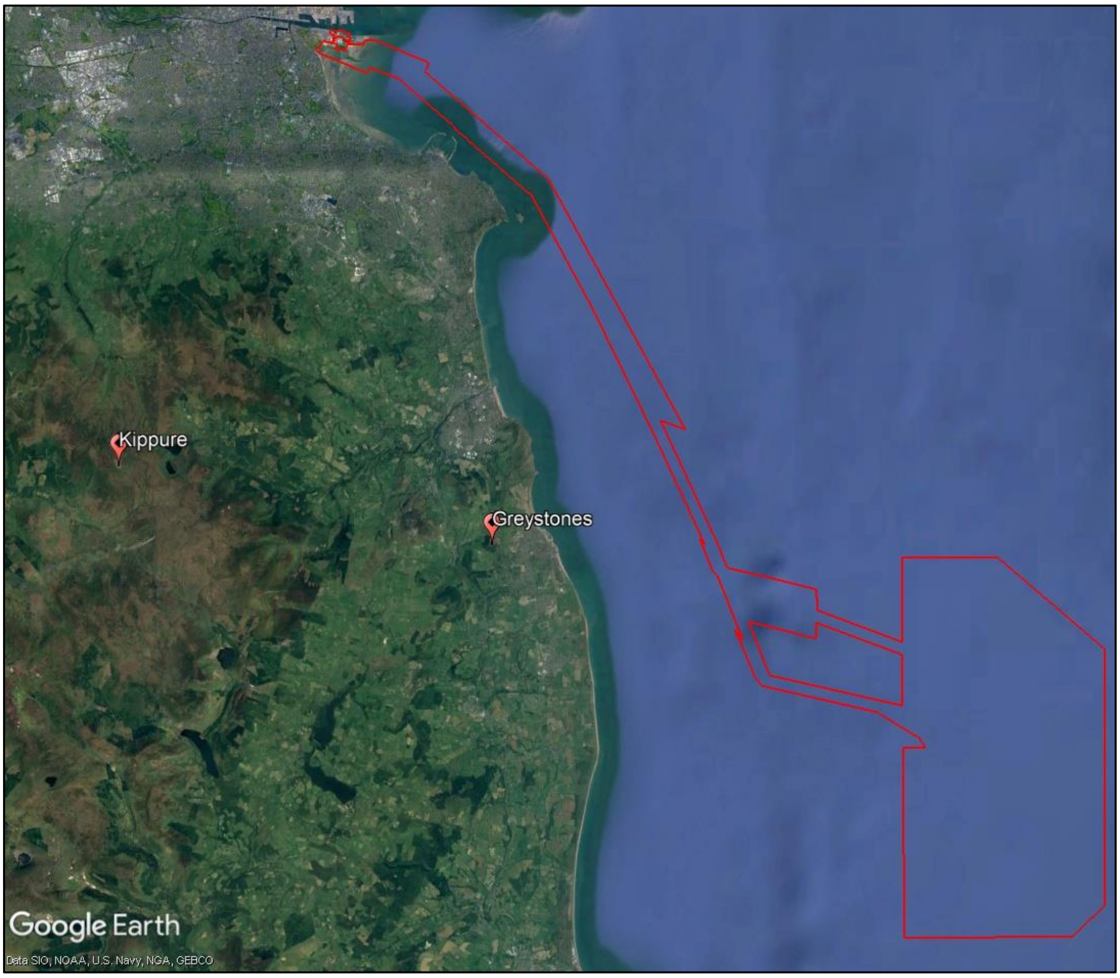

Figure 3 *Transmitters relative to CWP*

3 RADIO TRANSMISSIONS

3.1 Sources

Radio services are provided in many ways within Ireland, including[3]:

- Analogue transmissions from transmitters – including Kippure and Greystones;
- Analogue services via cable;
- Digital transmissions (understood to be available for 54% of the population, predominantly in Cork, Limerick and the greater Dublin area);
- Television;
- Web/podcast;
- Mobile devices.

Of the sources above, the most relevant with regard to interference from the proposed development is terrestrial analogue transmissions. These are available in the area from both assessed transmitters.

[3] Source: RTE

4 GUIDANCE

4.1 Overview

There is little in the way of official guidance with regard to managing television and radio interference issues associated with offshore wind developments. However, there are some publications pertaining to onshore wind developments that warrant consideration when evaluating potential impacts.

4.2 Guidance used for Modelling

Appendix A of this report lists an overview of published works that have informed the modelling approach used within this report.

4.3 Guidance for Evaluating Potential Interference

Further to the publications shown in Appendix A, the most relevant advice for considering potential interference for digital television signals can be found[4] in ITU-R BT.2142-1. Key points within this publication are:

- Small interference signals can be dealt with by a standard antenna whilst larger ones can typically be mitigated by a more directional antenna.
- In the backscatter region[5] there is little effect from scattering from wind turbines on the performance of digital television, but in the forward scattering region, if there is significant blockage of the direct signal, significant interference to the reception of the digital television signal is possible.

The above is not an extensive review of the ITU publication, however these two points are particularly relevant with regard to quantifying potential interference.

4.4 Susceptibility of Radio Transmissions to Wind Turbine Interference

In principle, radio transmissions are subject to the same interference mechanisms as television transmissions.

Radio services are, in general, more robust to interference than television signals are. This is partly due to radio services being audio only and partly due to radio systems being generally designed to operate in a dynamic environment.

Broadly speaking, the interference zones for television services from the Kippure transmitter will be applicable for radio services from the same transmitter, although the risk of radio interference is judged to be lower.

[4] Published in 2010 by the International Telecommunications Union.

[5] In between the transmitter and the wind turbine(s).

4.5 Practical Experience

The results of Pager Power's model also compare well with real-world cases. Cases of television interference that have been reported post-construction are almost always in areas where potential impacts have been predicted by the model. The author is not aware of any occasions when interference has occurred outside a modelled zone of interference.

Reported impacts on radio signals due to offshore wind developments are very rare in practice.

In Pager Power's experience effects from wind farms on television signals are unlikely beyond distances of 10-15 km. Effects on radio services are judged to be unlikely beyond distances of 5 km.

5 TELEVISION INTERFERENCE ANALYSIS

5.1 Technical Overview

Terrestrial television services are provided by means of UHF radio waves which propagate from transmitters to receiving aerials which then relay the signal to a television set.

The quality of the image and sound on a television set is dependent on both the strength of the signal received directly from the transmitter (carrier signal) and the strength of Interference signals from other sources. In this case the interference signals are modelled as reflections of the Carrier signal by wind turbine.

Pager Power's methodology for assessment of interference effects was developed based on evaluation of the predicted Carrier to Interference Ratio (CIR). Whilst this parameter is related to analogue services, the interference mechanisms for digital transmissions are similar to those for analogue transmissions. The main difference is the manner in which the interference is manifested on the television screen. Analogue signals may suffer degradation that reduces the signal quality by causing various effects such as ghosting or flickering. Digital transmissions tend to be robust to small amounts of interference but are drastically affected by more severe interference. The interference zones modelled here are equally applicable to digital transmissions as analogue transmissions. The CIR is interpreted as shown in Table 2 below.

Colour	CIR (dB)	Interference Level	Likelihood of Interference
Red	<5	High	Likely
Yellow	5 – 15	Medium	Possible
Blue	>15	Low	Unlikely

Table 2 *Interpreting the CIR*

The CIR is evaluated by taking the ratio of the predicted signal strength (provided directly from the transmitter) to the predicted interference signal strength (reflections from the turbine). More detail on the calculation method can be found in Appendix A.

The television interference model used for the analysis is considered to be conservative.

5.2 Modelling Approach

In order to quantify the potential effects in a meaningful way, the following steps to do so are outlined below:

Step 1: Model the effects of the proposed turbines on Kippure and Greystones transmissions for a $400km^2$-$25km^2$ area at 1km-250km resolution.

Step 2: Identify the populated areas within the potentially affected areas. This is where effects would be potentially significant because effects would be noticed.

Step 3: Evaluate the modelling results.

6 MODELLING RESULTS

6.1 Assessed Area – Interference Modelling

Analysis of an approximately 400km^2 area centred on the proposed development has been undertaken. Three different areas have been assessed each decreasing in size but with a higher resolution. This is because interference effects are more likely closer to the turbines. The areas sizes and resolutions are as follows:

- 20km-diameter at 1km resolution (green outline);
- 10km-diameter at 500m resolution (blue outline);
- 5km-diameter at 250m resolution (yellow outline).

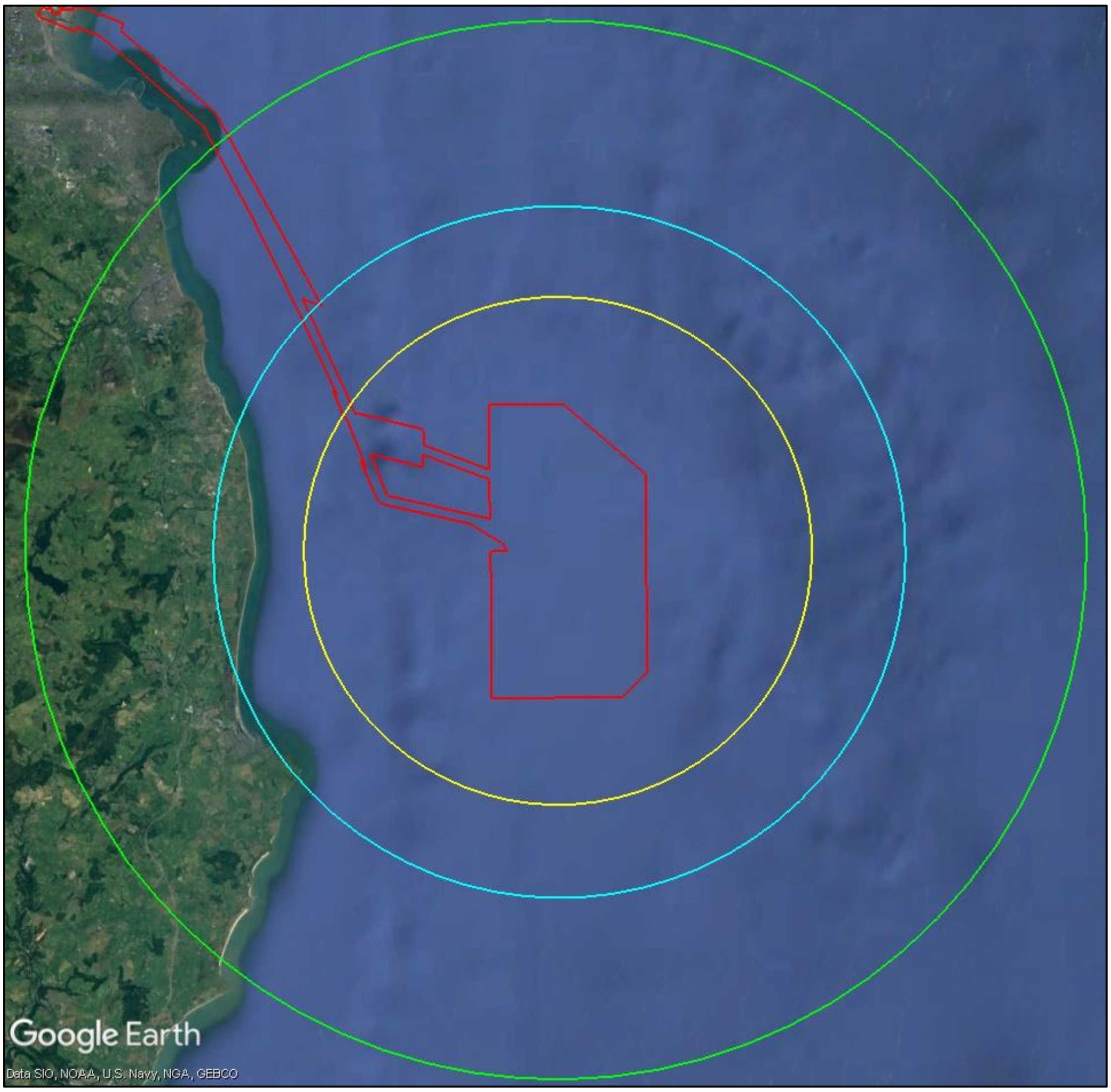

Figure 4 *Modelled areas*

Figure 5 below shows the modelled areas relative to the transmitters.

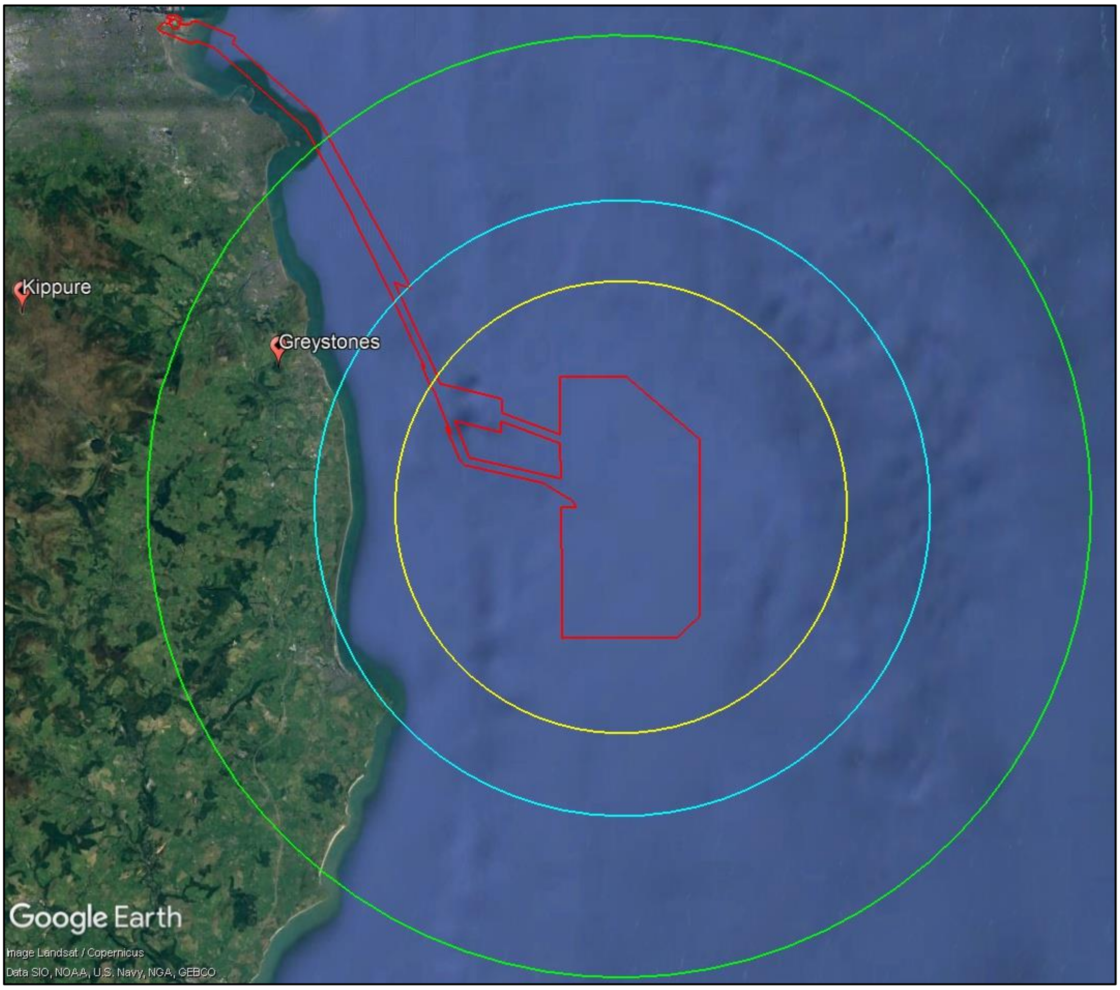

Figure 5 *Modelled areas relative to transmitters*

6.2 Interference Mechanisms

Worst case interference will occur where the turbines interfere with the signal which then goes on to be received by the aerial. The distance to which this area extends beyond a turbine depends on the size of the turbine (and number) as well as the height of a wind turbine and broadcasting transmitter. It is this area where it is most likely that interference will materialise.

High (red – CIR less than 5) and medium (yellow – CIR 5-15) interference produced by the presence of a wind development can cause significant problems if it occurs in populated areas. It is therefore important to determine what is located within these areas of interference, which transmitter signal is being received and what signal the aerials in the area are directed to receive.

6.3 Main Transmitter Results

6.3.1 Step 1: Interference Modelling

The predicted interference levels are influenced by the strength of the direct signal and are interpreted in accordance with the ITU findings set out in Section 4. The areas where noticeable effects are generally possible are those within the forward scatter region, or close to it i.e. north west of the proposed development relative to the transmitter.

The cumulative interference zones, with respect to CWP, for the Kippure and Greystones transmitters are illustrated in Figure 6 below. Areas of red and yellow indicate zones of high and medium interference respectively.

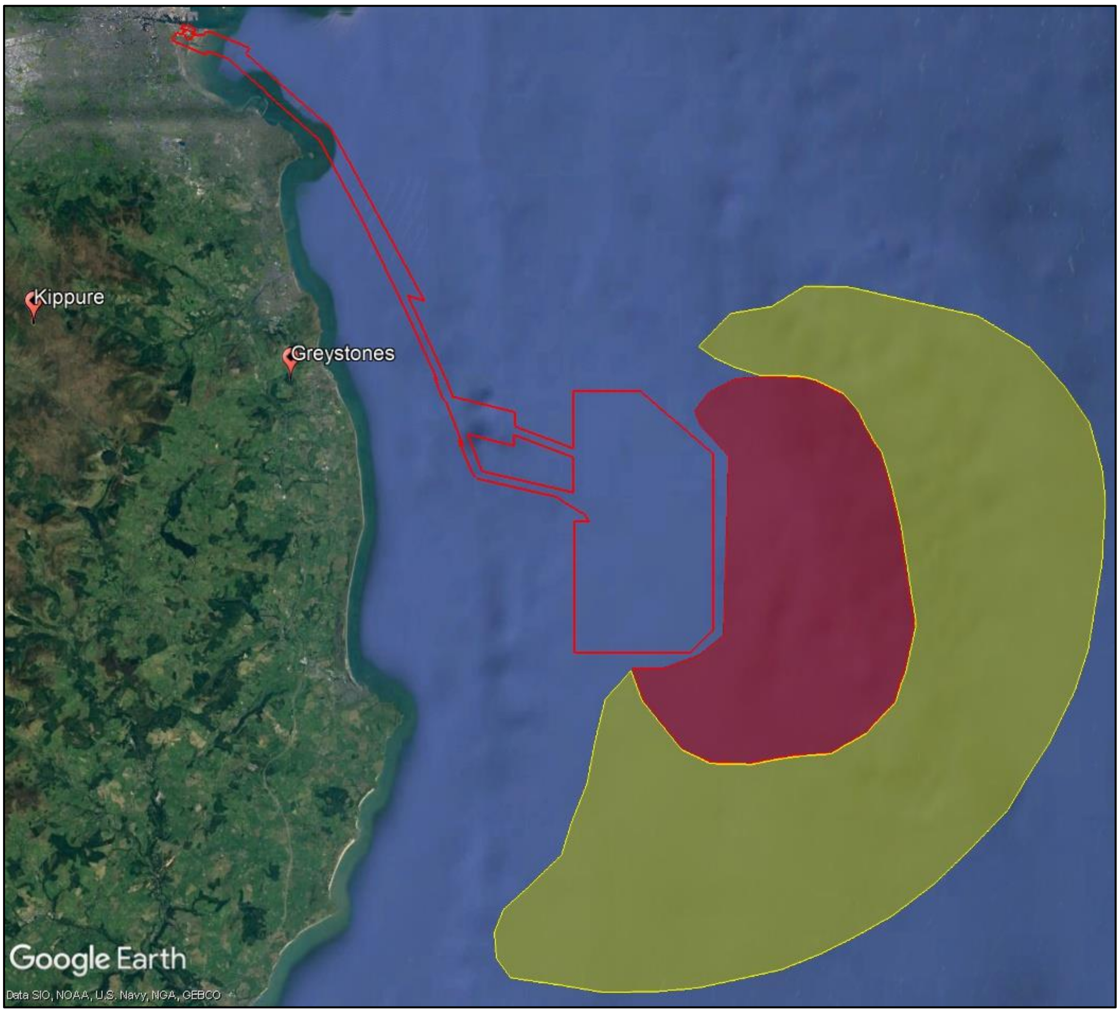

Figure 6 *Cumulative interference zones for Kippure and Greystones transmitters, with respect to CWP*

6.3.2 Step 2: Identifying Populated Areas in Interference Zones

The figure on the previous pages show that the interference zones for Kippure and Greystones transmissions are not predicted to affect receivers on the mainland, including possible interference from the onshore cable routing. No populated areas in the interference zones have been identified.

6.3.3 Step 3: Evaluation of Impacts

No interference is predicted for transmissions between the Kipurre and Greystone transmissions and receiver, .as no receivers are located within the interference zones of the CWP. Negligible effects are predicted within the backscatter region, as signals from the transmitter reach receivers before encountering the turbines. Therefore, no impacts are predicted.

The overall impact significance is deemed to be negligible, as dwellings and receivers are outside of the interference zone are not expected to be affected. Any mitigation requirement should be evaluated and implemented on a case-by-case basis where appropriate[6]..

6.4 Radio Conclusions

Noticeable impacts upon radio signals in the surrounding area are not predicted as a result of CWP. This is because no interference is predicted for transmission signals. Additionally, alternate transmitters can provide coverage as radio transmission are more robust and receivers are designed to accept transmissions in dynamic environments.

6.5 Baseline Reception Survey

A baseline reception survey could be completed in order to document the current signal quality in the surrounding residential areas. This would also allow a better estimate of the number of homes in the area that appear to rely on the Kippure or Greystones transmitter for television services. Baseline data would also facilitate a ‘before and after’ comparison in the event a complaint is received after construction.

In this case, due to the low risk, a baseline survey is not a requirement, however it would provide the most comprehensive technical basis of any reported effects.

7 TELEVISION COVERAGE MAPS

The requirement for mitigation will be influenced by a number of local factors including the origin of television/radio services and the equipment present at individual dwellings. Significant impacts on terrestrial television services and radio services is not anticipated.

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[6] Likely solutions would involve improvement or replacement of receiving equipment at individual dwellings, as opposed to a potential requirement for a new relay transmitter serving a densely populated area at a high risk of potential interference.

7.1 Coverage Maps

Figure 7 below and Figure 8 on the following page show the predicted coverage for Kippure and Greystones transmitters respectively, as per the UK Free TV website. The location of the CWP is indicated with a star.

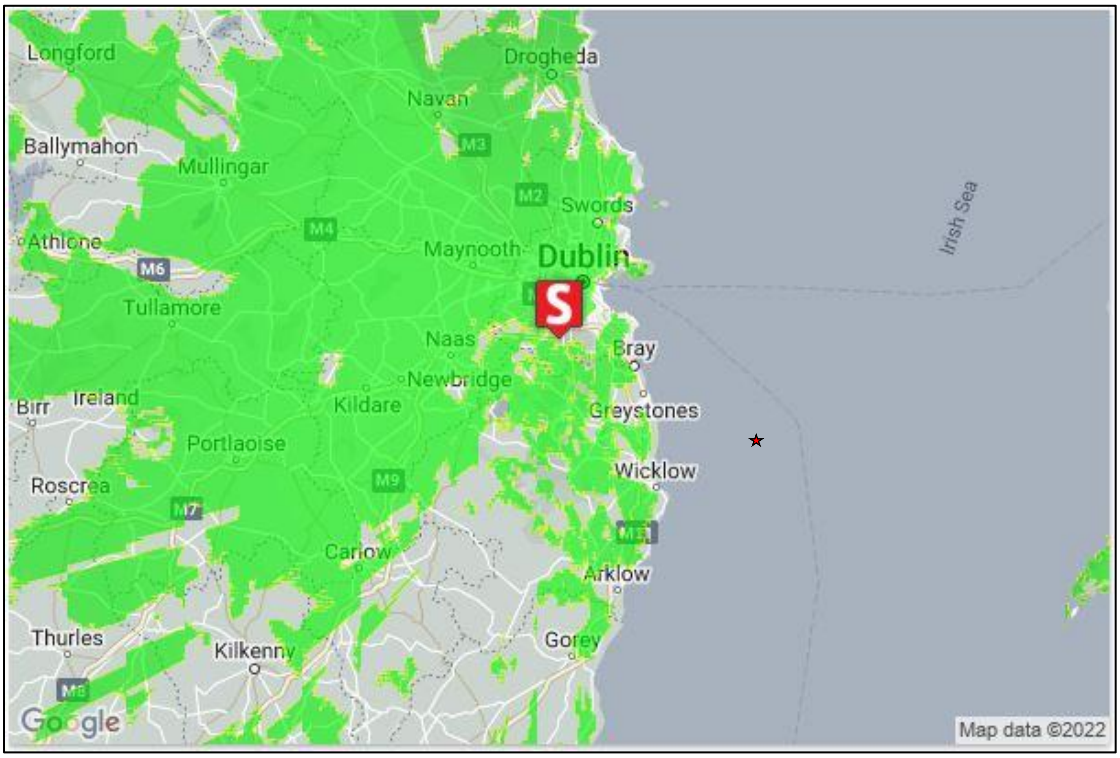

Figure 7 *Kippure Transmitter Coverage Chart*

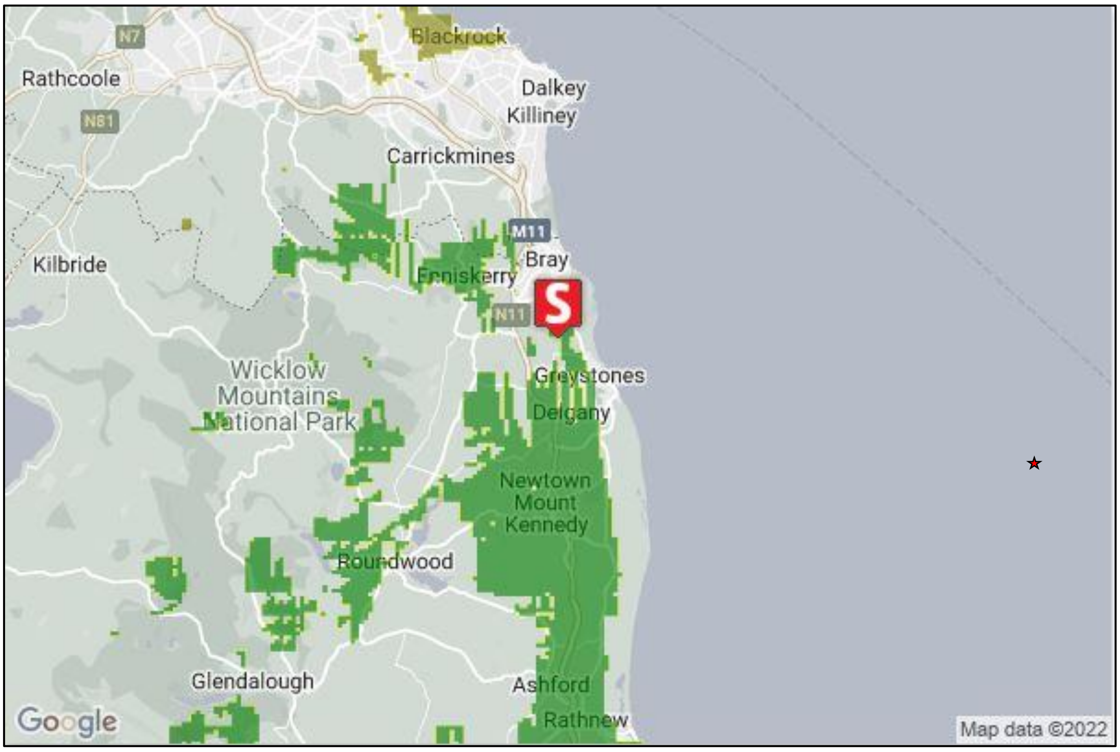

Figure 8 *Greystones Transmitter Coverage Chart*

7.2 Coverage Analysis

The charts show that both transmitters provide coverage not in the vicinity of the wind farm. Furthermore, the charts show overlapping coverage in some areas– suggesting that a viable mitigation solution could be to retune to an alternate transmitter in the event of interference.

APPENDIX A – TELEVISION INTERFERENCE

Television Interference

Introduction

Terrestrial television signals propagate from transmitters to receiving aerials which in turn are connected to television receiving equipment. Transmissions are in the UHF frequency range and may be either analogue or digital. Television channels have a bandwidth of 8 MHz

When considering interference from buildings or wind farms it is usual to consider direct signals – those that pass from transmitter to receiver in a straight line and reflected, or indirect, signals. The reflected signal goes from transmitter to turbine (or building) to receiver.

Standard receiving aerials are directional meaning that signals from the transmitter direction are amplified and signals from the sides and rear of the aerial are attenuated.

Carrier to Interference Ratio

The likelihood of television interference is determined by considering the strength of the direct, or carrier, signal in comparison to the reflected, or interfering, signal. The Carrier to Interference Ratio (CI Ratio) quantifies the relative strength of the direct and reflected signals.

A high Carrier to Interference ratio means interference is less likely. A low Carrier to Interference ratio means that interference is more likely. The CI Ratio is normally expressed in decibels (dB).

Free Space Path Loss

Television signals weaken over distance. The closer a receiver is to a transmitter the stronger its received signal will be. This reduction in signal strength due to separation distance is referred to a Free Space Path Loss (FSPL).

Electromagnetic Propagation by Diffraction

An electromagnetic signal may travel between two points, even when no direct line of sight exists between those two points. This is because transmission travels as a series of waves rather than as a direct ray. When no direct line of sight exists between the two points the signal is considerably weakened. This weakening is known as a diffraction loss.

International Telecommunications Union (ITU) Recommendation ITU-R P526-7 describes a method for calculating diffraction losses over regular terrain.

Total path loss for a specific path is determined by adding Free Space Path Loss to Diffraction Loss.

Radar Cross Section

The size of the interfering signal is dependent on the amount of energy that is reflected from the wind turbine. This reflective quality is known as the Radar Cross Section (RCS) and can be expressed in metres squared or in dBm^2.

A lot of work has been carried out to help determine wind turbine RCS by various parties although little work has been carried out at UHF frequencies. Values cited typically vary between 25 and 300 m^2 with instantaneous peaks reaching 3000 m^2 for a single wind turbine.

The moving and static parts of the turbine are often considered separately.

Nature of Television Interference from Wind Turbines

Determining whether a television picture is impaired by wind turbines or whether the impairment is significant enough to cause picture quality to become unacceptable is considered a subjective matter. The level of effect is determined by looking at the picture when the turbine is operating. There is a subjective system for grading television picture impairment with grades from 5 down to 1 described in ITU-R 500. The impairments are shown in the table below.

Impairment Grade	Likelihood of Interference
5	Imperceptible
4	Perceptible, but not annoying
3	Slightly annoying
2	Annoying
1	Very Annoying

Grading Table

Where interference is marked it is generally clear that it is being caused by wind turbines. The picture regularly distorts with a time base matching the passing of turbine blades. This means that it is fairly easy to determine whether a viewer's interference problem is related to a wind turbine.

Conditions for Wind Turbine Interference

Simplistically the television picture is likely to be unacceptably affected by wind turbine interference when the CI Ratio is low. In practice interference is most noticeable when some or all of the following conditions are satisfied:

1. The received signal strength is weak.
2. The direct signal path between transmitter and receiver is physically obscured.
3. There is a clear signal path between transmitter and wind turbine.
4. There is a clear signal path between wind turbine and receiver.
5. The wind turbine lies directly between the transmitter and receiver.

Pager Power Approach

Having reviewed many relevant published works, a synopsis of which is included at the end of this text, Pager Power has arrived at a compound methodology including some additional factors such as:

- Triplicate calculations accounting for tip, hub and rotor bottom.
- Accounting for actual field strength
- Calculating interference in accordance with the Dabis Method
- Calculating interference in accordance with the ITU method

Following assessment by these various methods the following conclusions have been drawn:

- Although it is true that wind farm interference appears more likely when the received signal is weak there is no direct relationship between direct signal strength and observed picture interference.
- Observed picture interference is directly related to the CI Ratio.
- The ITU-R BT805 method appears to be significantly more accurate than the Dabis method for assessing observed interference.
- Summing of unwanted signals from each turbine to determine a total unwanted signal level appears to be reasonably accurate.
- The CIR threshold of 10dB cited by RES appears to be reasonable – it is certainly true that the threshold of 28-34 cited by BT805 is too high when using this method. Observations on a 32 wind turbine development suggest that a threshold of 15dB may be more reasonable in this case.
- Carrying out an assessment based on the hub height appears to be fairly representative – however there can be significant variation in CI Ratio over the blade span. In an example with no direct line of sight between transmitter and receiver the CI Ratio varies by 31dB between the top and bottom of the rotor. This is a large variation and should be considered or accounted for.

It was concluded therefore that triplicate calculations at tip, hub and rotor base should be considered. The principals of this calculation are as follows:

- The interference signal calculation should be carried out three times for each turbine – at tip, hub and rotor base.
- A weighted average of the three unwanted interference signal levels should be made (of absolute levels not decibel levels).
- A signal passing through the turbine at hub height is clearly going to be affected much more than one passing through the tip or rotor base so an increased weighting should be applied to the hub signal.
- The weighting applied to rotor tip and rotor base should be identical as the proportion of the signal passing through the rotor is identical at both heights.
- A geometric calculation suggested that following weightings be used for averaging:

Turbine Part	Weighting (%)
Tip	19.55
Hub	60.9
Rotor Bottom	19.55

Weighting

- The following rounded values have therefore been used for calculation purposes.

Turbine Part	Weighting (%)
Tip	20
Hub	60
Rotor Bottom	20

Weighting for calculation

Pager Power Assessment Methodology

Having considered the various published works, exploring knowledge of real interference caused by wind farms, and modelling interference in various ways Pager Power has developed an effective modelling method for mapping likely television interference from wind farms. The process involves the following stages:

1. Acquire terrain data in digital format.
2. Determine the following for modelling:
    a. Transmitter location and height.
    b. Turbine locations and hub heights.
    c. Single Blade Area.
    d. Blade Width for modelling purposes.
    e. Television signal wavelength for modelling purposes.
3. Area of interest for interference modelling – this will be a rectangular area defined by top-right and bottom-left coordinate pair.
4. Determine the sample point spacing for modelling purposes – this is currently a fixed value for the entire area.
5. Determine the receiver aerial height for modelling purposes.
6. Calculate coordinates of each Receiver Sample Point in the area of interest.
7. Calculate Free Space Path Losses for the following paths:
    a. Transmitter to each Wind Turbine FSPL_TW.
    b. Transmitter to each Receiver Sample Point FSPL_TR.
    c. Each Wind Turbine to each Receiver Sample Point FSPL_WR.

8. Build electronic terrain profile for each of the above paths. The number of points in the profile is determined dynamically based on the source terrain data resolution and the particular path length.
9. Determine additional diffraction losses for each of the above paths using ITU-R 526 method. These losses are DL_TW, DL_TR and DL_WR respectively. These calculations are carried out for the turbine tip, turbine hub and turbine rotor.
10. Calculate a Wind Turbine Reflection Factor (RF) in accordance with ITU-R BT805.
11. Calculate an adjustment factor (ADJ) to compensate for the 1km free space path loss built into the Relative Amplitude (RA) calculation defined in ITU-R BT805. This is 88.662dB.
12. Determine the following for each wind turbine – sample point pair:
    a. Horizontal Angle (alpha) at the turbine between extended path from transmitter and path to sample point.
    b. Horizontal Angle (beta) at sample point between turbine and transmitter.
    c. Calculate Relative Amplitude (RA) based in accordance with ITU-R BT805. If RA is calculated to be smaller than -10 it is changed to -10 (as described in BT805).
    d. Calculate Loss due to Antenna Directivity (AL) based on angle beta and the curves in ITU-R BT419.
13. Calculate Interference Signal Magnitude for each Turbine Receiver Sample Point Pair at turbine tip, hub and rotor base by summing the following:
    a. - FSPL_TW
    b. - DL_TW
    c. - FSPL_WR
    d. - DL_WR
    e. RF
    f. RA
    g. ADJ
    h. –AL
14. The above absolute values are summed for each turbine sample point and converted back into decibel values and saved as Summed Interference Values (I). Summing occurs with a 20/60/20 respective weighting split for tip, hub and rotor base.
15. Carrier Signal Magnitude (C) is then determined for each Receiver Sample Point by summing:
    a. – FSPL_TR
    b. – DL_TR
16. CI Ratio is then calculated for each point by subtracting I from C.
17. CI Ratio for each sample point is then recorded on an interference map.

Formulae

Term	Unit	Description
A	m^2	Blade Area
AL	dB	Antenna Loss due to angle between signal source and antenna direction
Ave aC	dB	Carrier signal strength (based on inverse of losses)
CIR	dB	Carrier to Interference Ratio
d	m	Length of signal path
dkm	km	Length of signal path
DL	dB	Diffraction Loss
FSPL	dB	Free Space Path Loss
FSWT	dBV/m	Field Strength at Wind Turbine
I	dB	Interference signal strength
Iabs	-	Interference signal strength (absolute)
Ih	dB	Interference signal strength due to a single turbine calculated at hub height
Ir	dB	Interference signal strength due to a single turbine calculated at bottom of rotor
It	dB	Interference signal strength due to a single turbine calculated at tip height
Iw	dB	Interference due to a single wind turbine
Iwf	dB	Interference due to a wind farm
RA	dB	Relative Amplitude in forward scatter region
RF	dB	Reflection factor for a wind turbine including free space path loss for 1km
TW	suffix	Denotes path from transmitter to Wind Turbine

Term	Unit	Description
TR	suffix	Denotes path from transmitter to receiver
TXFIELD	dBV/m	Transmitter field strength at 1 metre
v	-	Diffraction Parameter
W	m	Width of blade
WR	suffix	Denotes path from wind turbine to receiver
α	Radians	Horizontal angle at turbine between extended path from transmitter and path to receiver
β	Degrees	Horizontal angle between path to signal source and direction receiving antenna is pointing
λ	m	Wavelength

Glossary of terms

1 Antenna Loss

AL = 0 when $\beta<20$

AL = $(\beta-20) \times 0.4$ when β between 20 and 60

AL = 16 when $\beta>60$

From Figure 1 of ITU-R BT419 Bands IV and V (UHF)

2 Reflection Factor

RF = $20\log(A/\lambda)-60$ (From Annex 1 of ITU-R BT805).

3 Relative Amplitude

RA=$20\log \sin(\pi\times W/\lambda\times\sin\alpha)/(\pi\times W/\lambda\times\sin\alpha)$ (From Annex 1 of ITU-R BT805).

4 Carrier to Interference Ratio

CIR = C – I (From first principles by definition when values expressed in dB)

5 Free Space Path Loss

FSPL = $20\log(4\pi d/\lambda)$ (From Dabis paper and by definition)

6 Interference – Single Turbine – Hub Height

Formulae for a single path at hub height:

Ih = FSWT + RF + max(-10,RA) - 20log(dkm) [**a**]

From ITU-R BT805 for an unobscured path from Wind Turbine to transmitter

FSWT = TXFIELD - FSPL_TW - DL_TW [**b**]

From first principles

Ih = TXFIELD - FSPL_TW - DL_TW + RF + max(-10,RA) - 20log(dkm) [**c**]

Combining [**b**] and [**a**]

Ih = TXFIELD-FSPL_TW-DL_TW+RF+max(-10,RA)-20log(dkm)-DL_WR [**d**]

Accounts for additional diffraction losses between Wind Turbine and receiver

20log(dkm) = 20log(d/1000) = 20log(d) - 60 [**e**]

From first principles

FSPL = 20log(4π/λ) + 20log(d)

20log(d) = FSPL - 20log(4π/λ) [**f**]

From [**e**] and first principles

20log(dkm) = FSPL - 20log(4π/λ) - 60 [**g**]

Combining [**f**] and [**e**]

Ih = TXFIELD - FSPL_TW - DL_TW + RF + max(-10,RA) - FSPL_WR + 60 + 20log(4π/λ) - DL_WR [**h**]

Combining [**d**] and [**g**]

7 Interference Single Turbine

Interference for a single turbine is calculated by taking a weighted average of interferences at tip, hub and rotor base.

It, Ih and Ir are all calculated as detailed in 6 above. These values will differ due to diffraction loss differences.

Iw = 20log((0.2*10^(It/20))+(0.6*10^(Ih/20))+(0.2*10^(Ir/20)))

Absolute averaging of signals with a 20/60/20 weighting – Pager Power Methodology

8 Interference Multiple Turbines

Multiple Turbines based on calculations at hub height.

Interference signals from multiple sources are calculated by summing absolute values. The following formulae apply:

Iw = 20log(Iabs)

Iabs =10^(Iw/20)

By definition Iwf=20log(Σ(10^(Iw/20)))

Direct summing of absolute values – Pager Power and RES methodologies

9 Diffraction – Single Knife Edge

DL = 6.9 + 20log(sqrt(((v-0.1)^2)+1)+v-0.1) when v > -0.7

DL = 0 when v <= -0.7

Equation 17 of ITU-R P526 (DL ≈ 0 when v<= -0.7 from the graph at Figure 7)

10 Diffraction – Path over Irregular Terrain

The general method is described in Section 4.5 of ITU-R P526.

Up to three peaks are considered as specified by the method.

An effective Earth Radius (to account for atmospheric refraction) of 8,494,678 metres is used for calculation purposes.

Review of Published Works

A number of documents relate to the interference effects of wind turbines on television and radio systems. These include:

1. BBC, The impact of large buildings and structures (including wind farms) on terrestrial televisions reception
2. International Telecommunications Union, Assessment of impairment caused to television reception by a wind turbine, Recommendation ITU-R BT805*, 1992
3. Bacon, DF, A proposed method for establishing an exclusion zone around a terrestrial fixed radio link outside of which a wind turbine will cause negligible degradation of the radio link performance, Radio Communications Agency, 2002
4. Hall, SH, The assessment and avoidance of electromagnetic interference due to wind farms, Wind Engineering Vol 16 No 6, 1992
5. Dabis, HS, The provision of guidelines for the installation of wind turbines near aeronautical radio stations, Civil Aviation Authority, CAA Paper 99002, 1999
6. ETSU, Feasibility of mitigating the effects of wind farms on primary radar, ETSU W/14/00623/REP, 2003
7. Dabis, HS, The establishment of guidelines for the installation of wind turbines near radio systems, Proceedings of the eighteenth BWEA Wind Energy Conference, 1996
8. FES, Wind farms impact on aviation interests – final report, FES W/16/00614/00/REP, 2003
9. S Vila-Moreno, A Methodology to Assess Interference to TV Reception due to Wind Farms, RES, 2005

The two Dabis papers describe a method for determining the likely interference from a wind turbine based on it behaving like a reflector. This methodology is generally used for interference predictions. The methodology in these papers does not address the significant increase in the level of interference observed when the wind turbine is on the direct path between transmitter and receiver and in addition a method for accounting for multiple wind turbines is not provided.

The ITU-R BT805 paper is quite useful and applies to a single wind turbine. It suggests:

- A CIR in excess of 28-34 dB is required to attain a good analogue picture quality having impairment grade 4 or above.
- Interference levels directly behind the turbine are 10dB higher than interference levels to the side of the turbine.
- Interference levels in flat terrain are unlikely at distances of more than 500m from the wind turbine site.
- Investigation of interference levels is not required at distances of more than 5km from the site.
- The paper refers to the ratio of the wanted signal to the unwanted signal which the Dabis papers refer to as CI Ratio. This document uses the term CI Ratio or CIR.

Radar studies have shown that reflected or scattered signals are much stronger immediately beyond the turbine. This is normally accounted for in interference calculations by using a higher RCS for scenarios where the turbine lies between transmitter and receiver.

The RES document describes a similar approach but includes a method for accounting for the effects of multiple wind turbines by summing the unwanted reflected signals (absolute not decibel). The RES document also suggests:

- a study area of 20km x 20km centred on the wind farm
- allowing for a standard receiving antenna characteristic
- summing unwanted signals directly
- a CIR threshold of 10db – Interference being likely when CIR is less than 10dB.

APPENDIX B – TECHNCIAL INFORMATION

Redline Boundary Details

The coordinates define the cabling route and area of turbines.

Coordinate	Longitude (°)	Latitude (°)	Coordinate	Longitude (°)	Latitude (°)
1	-6.18084	53.32667	37	-5.98002	53.19245
2	-6.17923	53.32870	38	-6.06497	53.28617
3	-6.16034	53.32449	39	-6.14366	53.32733
4	-6.12634	53.30701	40	-6.14125	53.33048
5	-6.12441	53.30526	41	-6.17624	53.33925
6	-6.11631	53.30114	42	-6.18178	53.33902
7	-6.07778	53.28091	43	-6.18245	53.33766
8	-6.07708	53.28110	44	-6.19201	53.33744
9	-6.05917	53.26128	45	-6.19314	53.33713
10	-6.02912	53.22707	46	-6.19449	53.33517
11	-5.99873	53.18919	47	-6.20041	53.33569
12	-5.96712	53.14846	48	-6.19982	53.33772
13	-5.97011	53.15022	49	-6.20183	53.33774
14	-5.96309	53.13912	50	-6.20024	53.34012
15	-5.95934	53.13638	51	-6.19961	53.34009
16	-5.94401	53.11273	52	-6.19868	53.34036
17	-5.94815	53.11631	53	-6.19552	53.33986
18	-5.93729	53.09935	54	-6.19507	53.33926

19	-5.93179	53.09545	55	-6.19286	53.33901
20	-5.85865	53.08512	56	-6.19284	53.33773
21	-5.85738	53.08428	57	-6.19126	53.33771
22	-5.83595	53.07635	58	-6.19147	53.33876
23	-5.83343	53.07608	59	-6.19211	53.33917
24	-5.82930	53.07157	60	-6.19126	53.34049
25	-5.84324	53.07145	61	-6.19178	53.34158
26	-5.84326	52.99983	62	-6.19442	53.34156
27	-5.73853	52.99925	63	-6.19456	53.34238
28	-5.71642	53.01220	64	-6.20353	53.34269
29	-5.71722	53.10859	65	-6.20369	53.34140
30	-5.78221	53.14338	66	-6.20117	53.34067
31	-5.84374	53.14265	67	-6.20236	53.33777
32	-5.84295	53.11199	68	-6.20811	53.33858
33	-5.89679	53.12373	69	-6.20952	53.33729
34	-5.89688	53.13101	70	-6.21287	53.33502
35	-5.95329	53.13933	71	-6.20862	53.33355
36	-5.99393	53.19472			

Redline Boundary Details

PAGERPOWER
Urban & Renewables

Pager Power Limited
Stour Valley Business Centre
Sudbury
Suffolk
CO10 7GB

Tel: +44 1787 319001 **Email:** info@pagerpower.com **Web:** www.pagerpower.com