

Desk Based Television Interference Assessment

Savills UK Ltd.

Mynydd Fforch Dwn

May 2023

PLANNING SOLUTIONS FOR:

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ADMINISTRATION PAGE

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Issue	Date	Detail of Changes
1	October 2022	Initial issue
2	May 2023	Removal of turbine T2 and two turbine dimensions reduced

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects on television reception related to a proposed development located approximately 1 km to the northeast of the village of Tonmawr, Neath Port Talbot, Wales.

Assessed Scenario

The following assessment was initially completed based on a maximum tip height of 220m above ground level for turbines T4 and T5. The maximum tip height for turbines T4 and T5 are now 200m above ground level. Furthermore, turbine T2 is no longer to be progressed. The changes are therefore of no consequence with respect to the conclusions of the following analysis.

Conclusions

Impacts on television reception are likely to be small and may not be noticeable at all in practice because terrestrial coverage in the area is provided by a large number¹ of relay transmitters due to the varying terrain which already affects coverage significantly. The localised areas of coverage mean that the wind development is not predicted to lie in between a transmitter and an area to which it provides coverage.

In addition, there is significant existing wind turbine development near the proposed development, such that the increase in potential interference sources is reduced when considering the cumulative environment.

Impacts on satellite television reception are not anticipated because dwellings are not located within the shadow zones associated with the proposed wind turbines.

Recommendations

No requirement for pre-emptive mitigation has been identified. Any reported effects following construction of the development should be investigated with reference to this report, specifically in the context of whether they occur in an area that is in the forward scatter region for the transmitter providing coverage (see Section 3.4 for a technical description).

Further data regarding the baseline coverage environment, which would also increase the accuracy of subsequent investigations of reported interference, could be collected via a physical reception survey prior to construction of the wind turbines. Mitigation options, should these be required, are presented in Section 6.

¹ Most surrounding areas are predicted to receive coverage from one or more of the following terrestrial transmitters: Kilvey Hill, Cilfrew, Rheola, Neath Abbey, Pontardawe, Briton Ferry, Mynydd Emroch, South Maesteg, Croesew, Efail Fach and Ystalyfera.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 58 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 BACKGROUND

1.1 Introduction

Pager Power has been retained to assess the possible effects on terrestrial and satellite television reception from a renewable energy development located approximately 1 km to the northeast of the village of Tonmawr, Neath Port Talbot, Wales. The development comprises solar photovoltaic solar panels and wind turbines. In the context of television interference, only the proposed wind turbines are relevant. Solar panels do not have a realistic likelihood of causing noticeable effects on television coverage in their vicinity².

1.2 Development Location and Details

The layout of the proposed development is shown in Figure 1 below. Turbine 2 is no longer to be progressed.



Figure 1 Proposed development layout

² Based on industry experience and first principles.

Table 1 below shows the turbine details. Coordinates are shown in British National Grid Eastings and Northings. Turbine 2 is no longer to be progressed.

Turbine	Easting	Northing	Tip Height above ground (m)	Hub height above ground (m)
1	281131	197711	180	150
2	280820	197190	165	150
3	280629	197599	180	150
4	283088	197744	200	150
5	282628	198074	200	150
6	282522	197493	200	150
7	282036	197830	200	150

Table 1 *Turbine details*

2 TELEVISION TRANSMITTER DETAILS

2.1 Terrestrial Coverage

Television coverage was investigated via publicly available coverage maps and coverage by postcode as advised by Freeview via their own coverage checker service. The area surrounding the proposed development is predicted to receive coverage from numerous transmitters, most of them relatively low-powered relay transmitters. This is common in rural environments with varying terrain, because providing reliable coverage from the UK's main transmitters is impractical within valleys due to shadowing from the ground higher up. Therefore, relay transmitters are often located such that they can receive a direct signal from the main transmitter and re-broadcast this locally to areas that do not receive a good direct signal.

Table 2 below shows the transmitter information by postcode as advised by Freeview. The alternative options are those transmitters listed as alternates that provide good coverage in the area.

Postcode	Transmitter providing coverage	Alternative transmitter option(s)
SA11 4HH	Cilfrew	Kilvey Hill, Rheola
SA11 3LJ	Kilvey Hill	Cilfrew, Neath Abbey VP ³
SA11 2QA	Kilvey Hill	Neath Abbey
SA11 1BZ	Kilvey Hill	Pontardawe, Neath Abbey VP
SA10 6EW	Kilvey Hill	Briton Ferry, Neath Abbey HP ⁴
SA10 7TG	Neath Abbey	Kilvey Hill, Pontardawe, Briton Ferry, Neath Abbey HP
SA12 8UB	Kilvey Hill	-
SA13 1BH	Kilvey Hill	Mynydd Emroch
CF34 9TS	South Maesteg	Maesteg
CF34 0PE	Mesteg	Croeserw
SA12 9UR	Efail Fach	-
SA10 8PD	Ystalyfera	-
SA11 5HF	Rheola	Cilfrew

Table 2 Coverage information

³ Vertically Polarised

⁴ Horizontally Polarised

2.2 Modelled Terrestrial Transmitter

Carrier to Interference Ratio (CIR⁵) modelling has been undertaken for the Kilvey Hill transmitter, because it appears most likely to be providing coverage to the most homes in the area. The results must be interpreted in the context of available coverage, see Section 4.

Figure 2 below shows the location of each of the identified transmitters as radial icons relative to the proposed turbine positions, which are shown as pink balloon icons⁶.

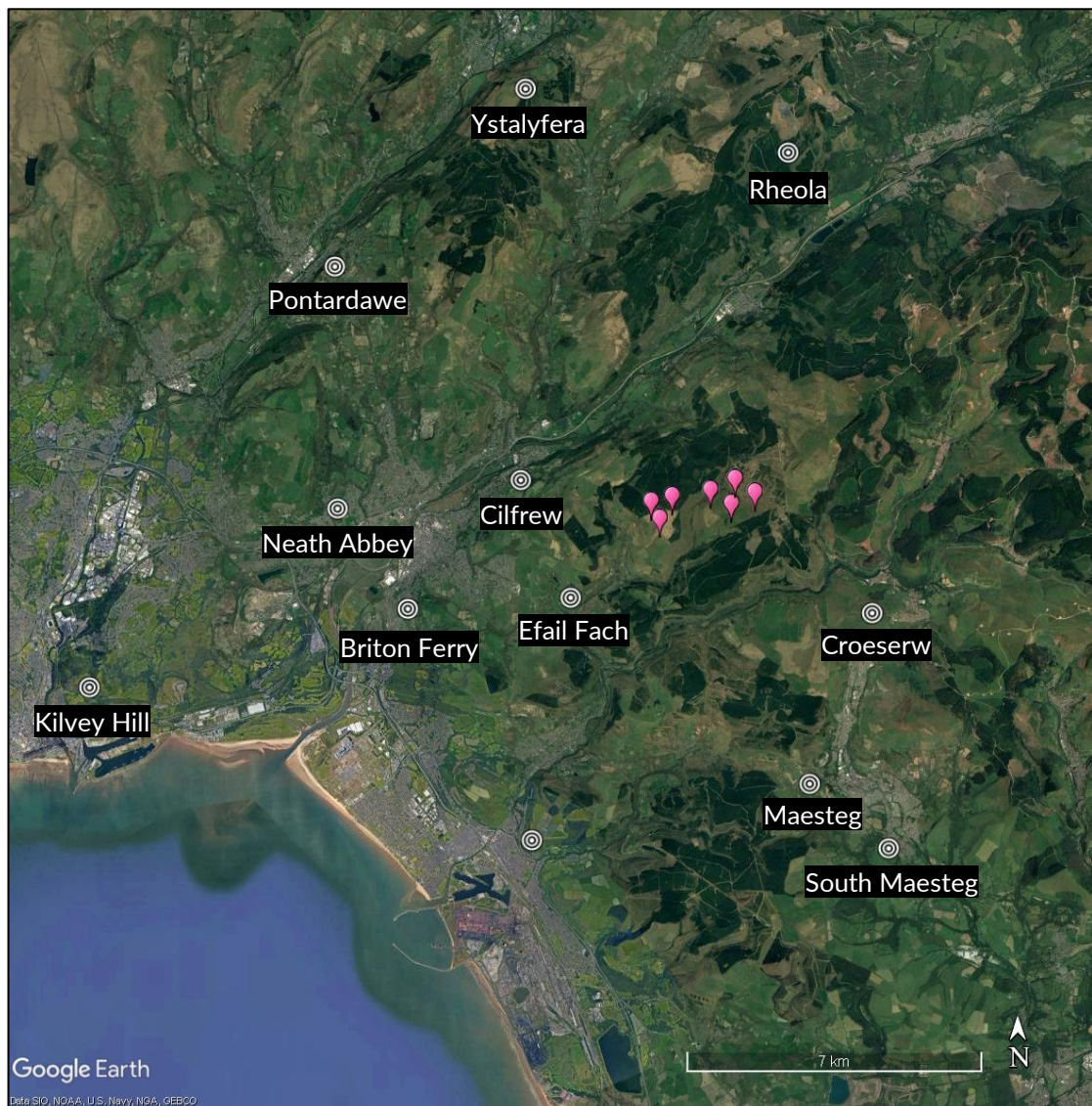


Figure 2 Transmitter locations

⁵ An industry-standard measure of the likelihood of interference for a broadcast radio signal such as terrestrial television.

⁶ T2 is shown in the figure but will not be progressed any longer.

Consequently, it is likely that a variety of sources provide television services to the wider area including:

- The Kilvey Hill terrestrial transmitter (modelled in detail).
- Low-powered local relay transmitters.
- Satellites (e.g. Sky).
- The internet (e.g. streaming services).

2.3 Satellite Television

Satellites that broadcast TV services are located in geostationary orbit over the equator – i.e. at a latitude of zero degrees. Different satellites can be located at different longitudes. In Europe, satellite TV services are received at over 150 million locations from the ASTRA satellites, which are broadly located at five locations over central Africa.

Services are received by dishes which are aligned towards the relevant satellite. In the south of the UK, the elevation angle required is approximately 25 degrees above the horizontal. The azimuth angle for the ASTRA satellites ranges between 5 and 31.5 degrees.

3 GUIDANCE

3.1 Guidance used for Modelling

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

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

3.2 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 found⁷ 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 region⁸ 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.

3.3 Practical Experience

The results of Pager Power's model also compare well with real-world cases. Cases of interference that have been reported post-construction are almost always in areas where potential impacts have been predicted by the model.

In Pager Power's experience effects from wind farms on television signals are unlikely beyond distances of 20km.

⁷ Published in 2010 by the International Telecommunications Union.

⁸ In between the transmitter and the wind turbine(s).

3.4 Forward Scatter Region

The relevant literature and practical experience both suggest that interference is most likely within the forward scatter region. Figure 3 below, taken from ITU-BT.805, illustrates the forward scatter region.

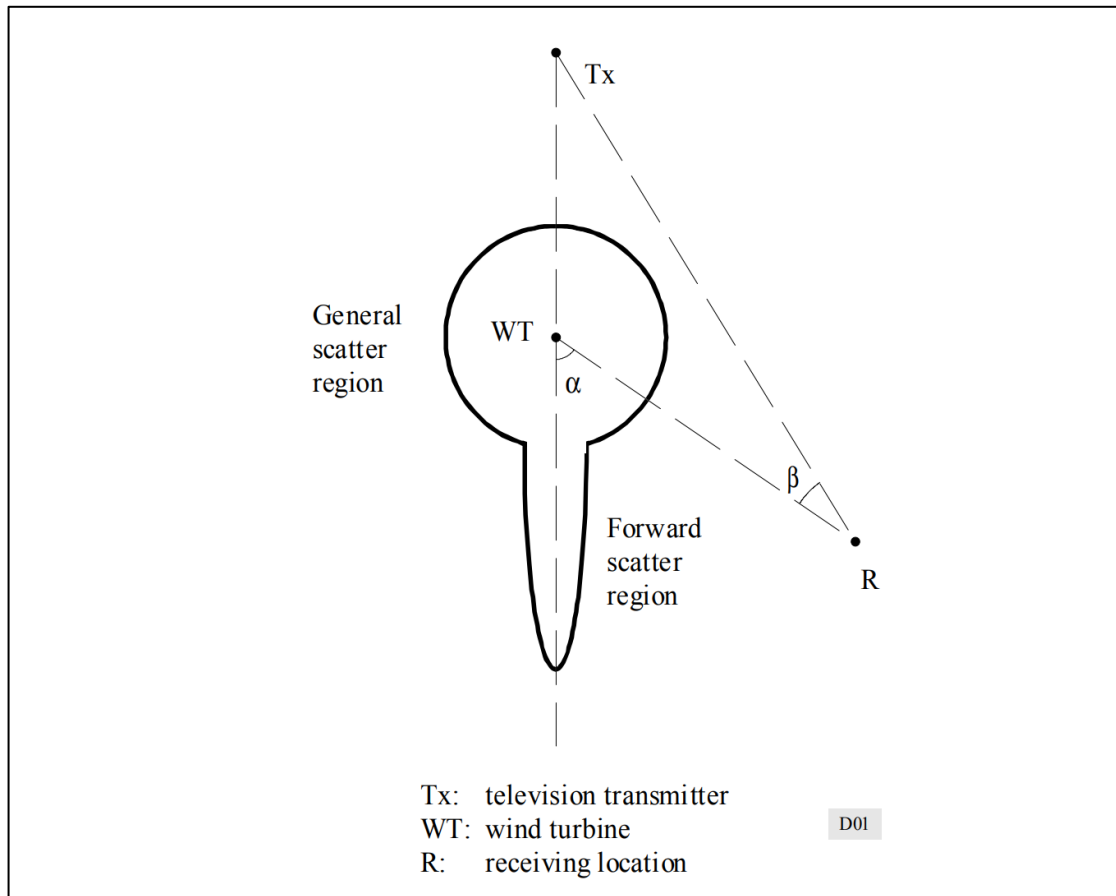


Figure 3 Plan view of forward scatter region

4 TELEVISION INTERFERENCE ANALYSIS

4.1 Technical Overview (Terrestrial TV)

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 3 below.

Colour	CIR (dB)	Interference Level	Likelihood of Interference
Red	<5	High	Likely
Yellow	5 – 15	Medium	Possible
None	>15	Low	Unlikely

Table 3 *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.

4.2 Technical Overview (Satellite TV)

Satellite television is received via fixed satellite dishes, typically mounted to the outside of houses. The signal received is very directional and the most significant source of interference is the potential blocking of the signal path between the satellite and the receiver. This can be due to weather, or due to obstructions near the dish itself. This is illustrated in Figure 4 on the following page.

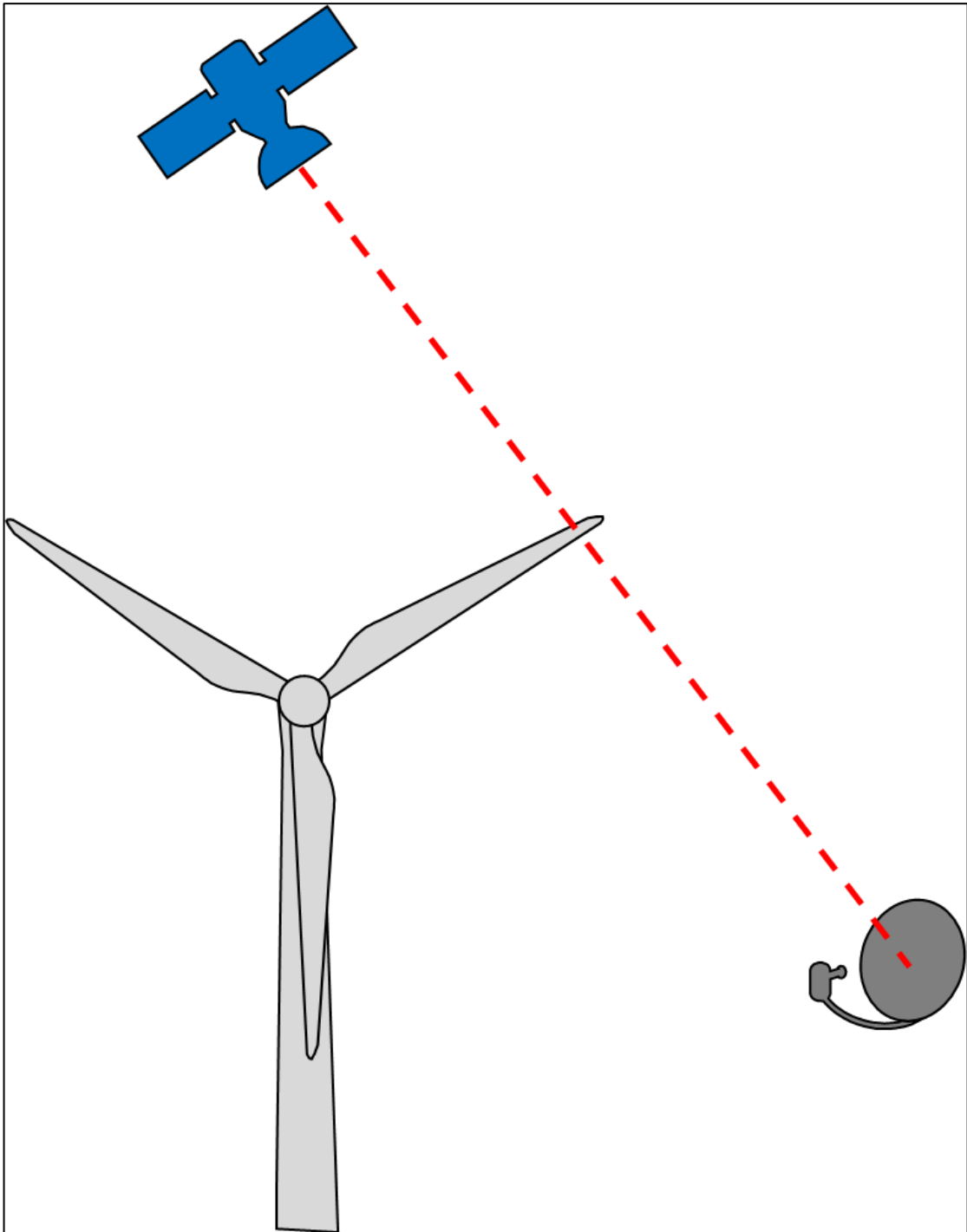


Figure 4 Potential obstruction of satellite signal

4.3 Terrestrial Television Interference Modelling

Analysis of an approximately 400km² area centred on the proposed development has been undertaken. This area is defined by the coordinates shown in Table 4 below.

Boundary Point	Coordinates	
	Easting	Northing
Top Right	291800	207600
Bottom Left	271800	187600

Table 4 Boundary coordinates

Figure 5 below shows the modelled area (black outline). The turbine locations are shown as pink icons for reference purposes⁹.

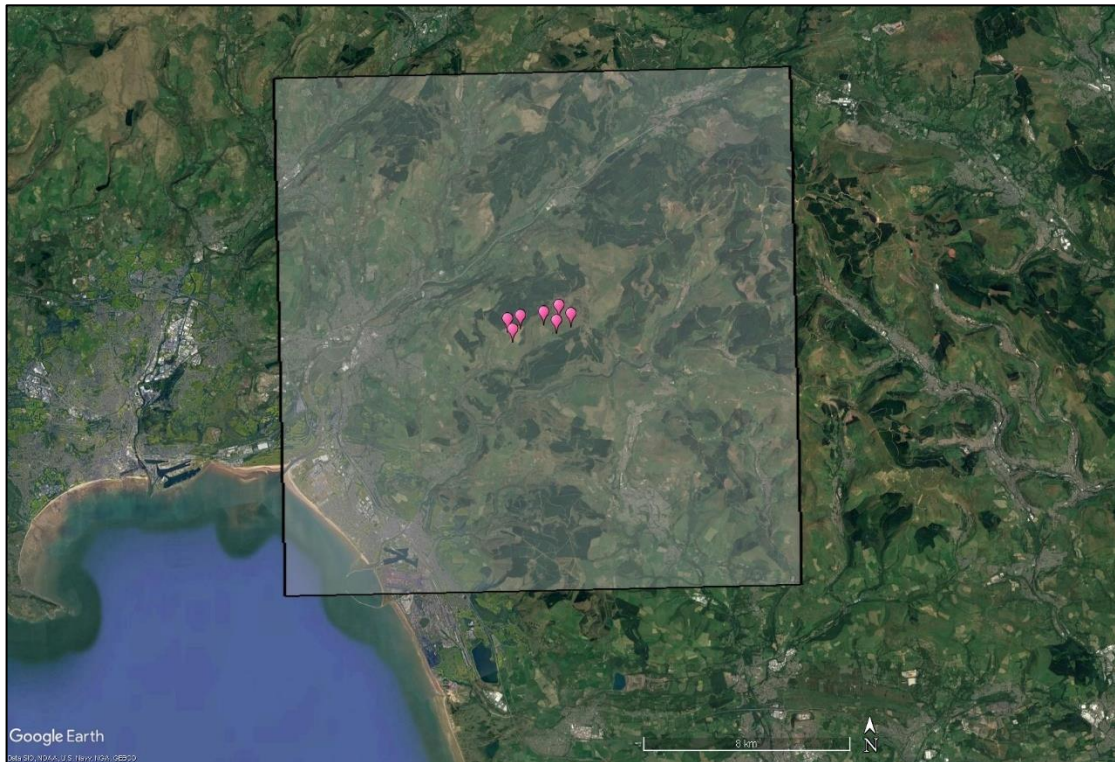


Figure 5 Modelled area

Figure 6 on the following page shows the modelling output for the Kilvey Hill transmitter¹⁰.

⁹ T2 is shown in the figure but will not be progressed any longer.

¹⁰ T2 is shown in the figure but will not be progressed any longer. Small variances in the interference modeling output as a result in changes to turbine dimensions are possible but these do not affect the overall pattern or resulting conclusions.

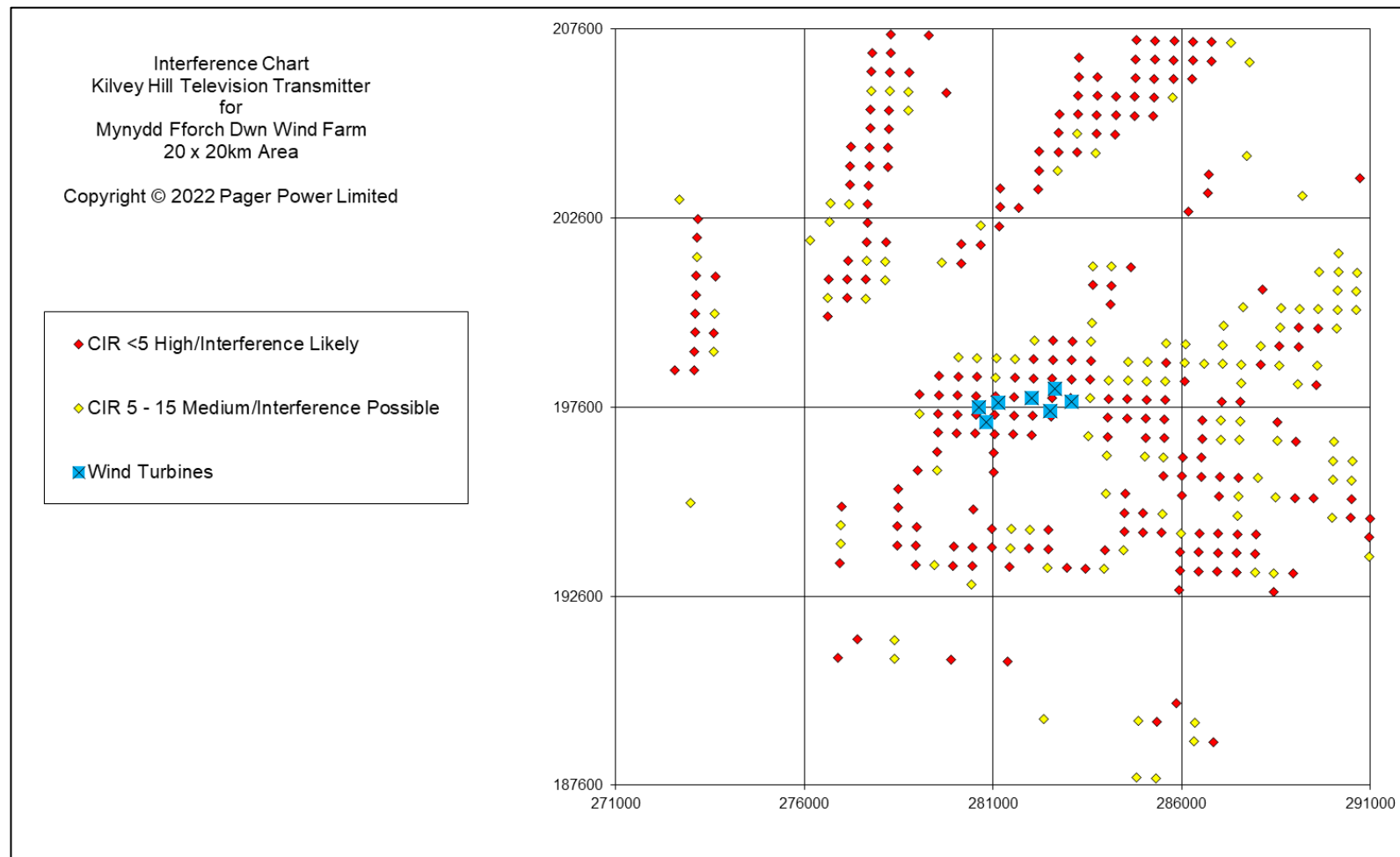


Figure 6 Interference modelling (Kilvey Hill)

Figure 7 below shows this interference pattern overlaid on imagery of the area. The transmitter location is shown for reference.

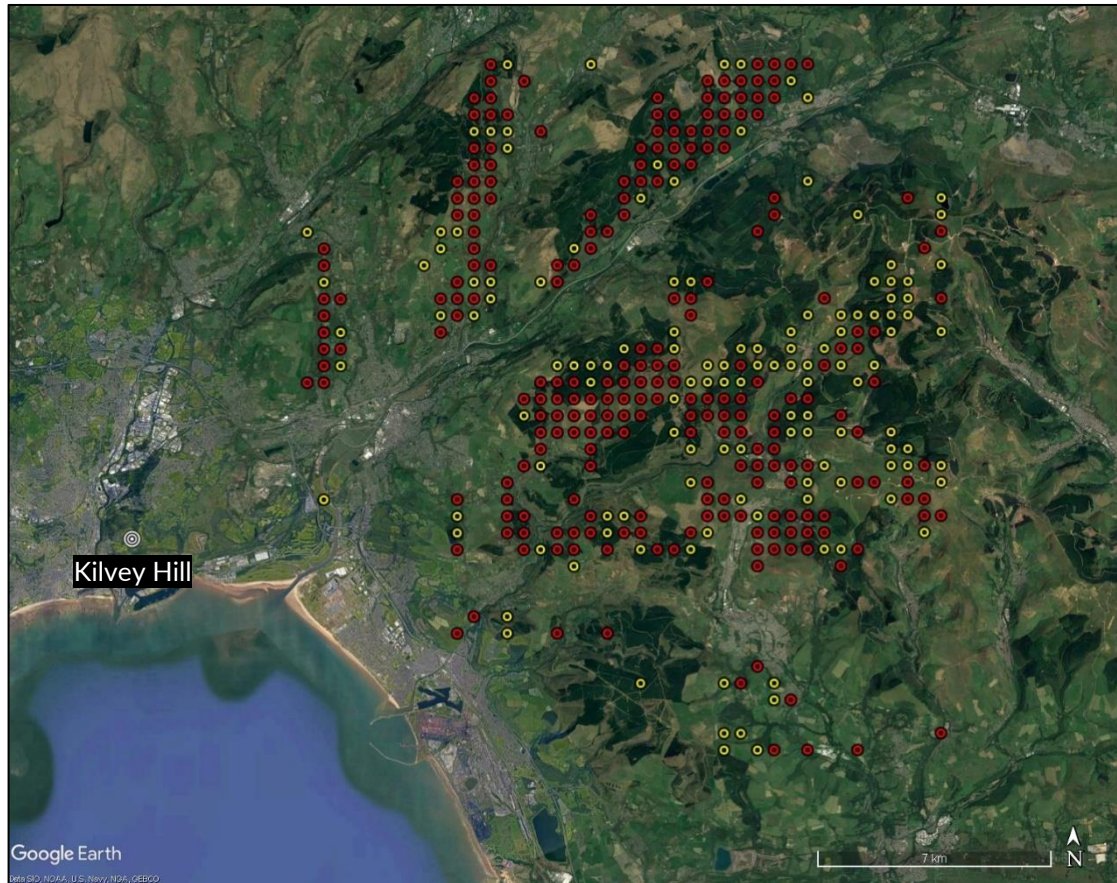


Figure 7 Interference in context (terrestrial)

Whilst there is a lot of interference potential shown by the model, the majority of this is not located over populated areas, such that actual interference would not be consequential.

Cases where potential interference is shown at or near residential areas, it is always either:

- Not an area where Kilvey Hill is the most likely transmitter to provide coverage¹¹; and/or:
- Not in the forward scatter region.

None of the other identified relay transmitters are likely to provide reliable coverage within the forward scatter region associated with the development.

In practice, widespread interference effects for terrestrial transmissions due to the development is not predicted. Isolated cases cannot be entirely ruled out. Any instances of interference are likely to be relatively restricted and may not become apparent at all.

¹¹ Based on information from Freeview.

4.4 Satellite TV Shadow Zone Modelling

Indicative shadow zones for the most common sources of satellite television are shown for each turbine in Figure 8 below. The shadows are shown as blue polygons, the turbines as pink icons¹².



Figure 8 Satellite TV shadow zones

There will be some variance in the shadow dimension based on the height at which a satellite dish is mounted and its exact elevation. However, in general terms the shadow zone for satellite television is restricted to a few hundred metres north and north-northwest of each turbine. Dwellings are not present in these areas and noticeable effects are not predicted.

¹² T2 is shown in the figure but will not be progressed any longer. Furthermore, small variations in the dimensions of the shadow zones will result due to changes in the proposed turbine dimensions, however these do not affect the overall conclusions.

5 CUMULATIVE ENVIRONMENT (HIGH-LEVEL)

5.1 Key Considerations

Detailed modelling of cumulative effects is outside of the scope of this report. However, the presence of significant existing wind development is relevant. Figure 9 below shows the nearest existing turbines identified based on aerial imagery as blue icons, compared to the proposed turbines as pink icons¹³.

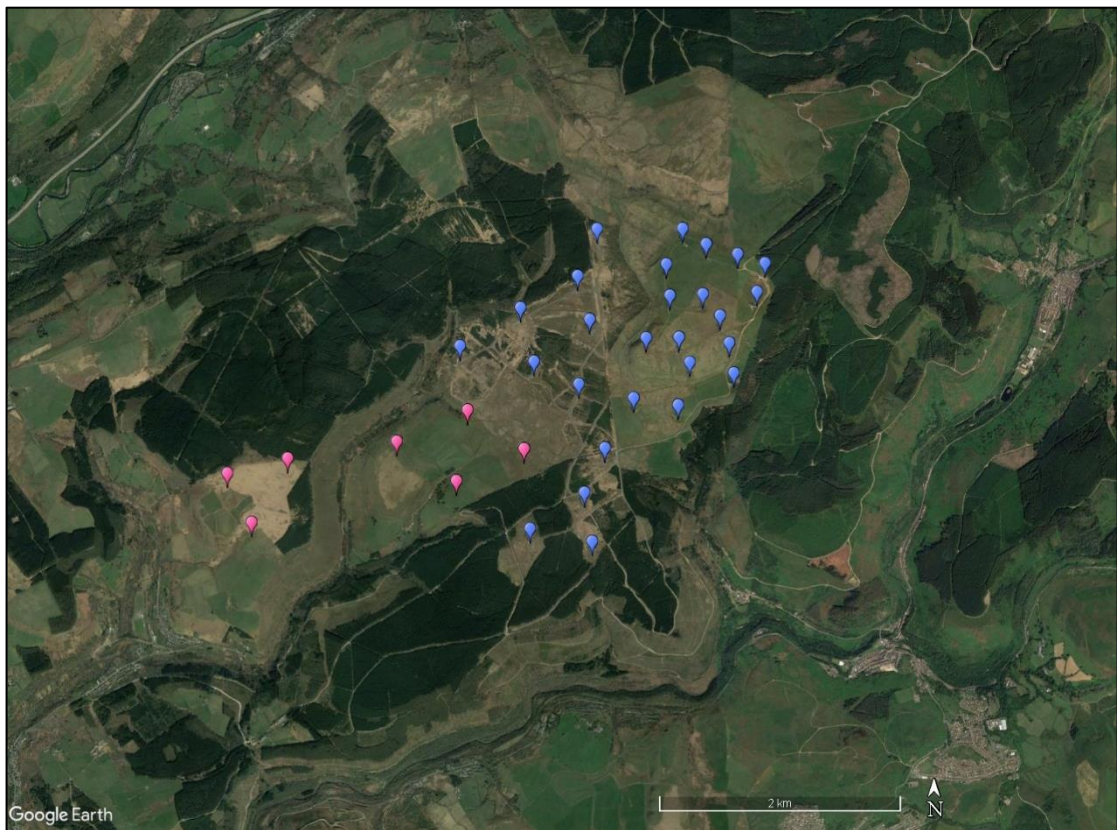


Figure 9 Surrounding wind development

The existing turbines extend significantly further northeast, those highlighted above are the closest to the proposed ones.

There is a sense in which the proposed development is an extension to the existing development, particularly for the eastern turbines.

This reduces the net impact of the development because the interference effects associated with the existing turbines would be similar to that of the proposed ones.

¹³ T2 is shown in the figure but will not be progressed any longer.

This does also mean that, in the event interference effects were reported, it could be problematic to elucidate which effects are attributable to the proposed development compared to those caused by the existing development.

Three optional strategies of countering this limitation are:

1. Undertake detailed modelling of the existing development to quantify areas where cumulative effects are most likely. This is unlikely to yield significant additional predictors. This step could be undertaken pre-construction or post-construction in the event of reported effects. This is an unusual step to take for most wind developers.
2. Undertake a baseline reception survey ahead of construction to record the reception quality in the surrounding areas, which will inherently capture the effect of the existing turbines. This would need to be done pre-construction. This is a common step taken by wind developers.
3. In the event effects are reported, reception measurements could be taken with the turbines rotating and stopped for comparison purposes. This could only be done post-construction. It would need to be undertaken during favourable weather conditions i.e. ensuring that the proposed and existing turbines are operating. It would also result in downtime for the operational development. This has been done by UK wind developers in the past, however it is rare due to its complexity and drawbacks.

If further steps are to be taken to further understand the potential risks and prepare for potential reported effects, the recommended option is the baseline reception survey (Option 2 above).

6 MITIGATION OPTIONS

6.1 Requirement

No requirement for pre-emptive mitigation has been identified. Widespread effects are not predicted and there may be no mitigation requirement at all.

6.2 Mitigation Options

Common mitigation options for television interference include:

1. Replacement of receiving aerial with a more directional, or higher gain, aerial;
2. Repositioning the receiving aerial so that the received signal is strongest;
3. Directing the receiving aerial to an alternative transmitter that covers the area and re-tuning the television accordingly;
4. Upgrading antenna cabling and connections;
5. Installation of signal amplifiers;
6. Replacing terrestrial reception equipment with satellite or cable reception equipment;
7. Provision of television services via the internet;
8. Development of a bespoke local solution using a receiving aerial some distance from the dwelling.

6.3 Process

Mitigation would only be applied following reported interference that was subsequently determined to be due to the development. Specifics regarding the process to be followed and the associated timescale may be further defined as conditions of the planning permission.

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 as 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 dBm².

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 m² with instantaneous peaks reaching 3000 m² 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:

- Acquire terrain data in digital format.
- Determine the following for modelling:
 - Transmitter location and height.
 - Turbine locations and hub heights.
 - Single Blade Area.
 - Blade Width for modelling purposes.
 - Television signal wavelength for modelling purposes.
- Area of interest for interference modelling – this will be a rectangular area defined by top-right and bottom-left coordinate pair.
- Determine the sample point spacing for modelling purposes – this is currently a fixed value for the entire area.
- Determine the receiver aerial height for modelling purposes.
- Calculate coordinates of each Receiver Sample Point in the area of interest.
- Calculate Free Space Path Losses for the following paths:
 - Transmitter to each Wind Turbine FSPL_TW.
 - Transmitter to each Receiver Sample Point FSPL_TR.
 - 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
labs	-	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
TR	suffix	Denotes path from transmitter to receiver

Term	Unit	Description
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:

$I_h = FSWT + RF + \max(-10, RA) - 20\log(dkm)$ [a]

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

$FSWT = TXFIELD - FSPL_{TW} - DL_{TW}$ [b]

From first principles

$$I_h = \text{TXFIELD} - \text{FSPL_TW} - \text{DL_TW} + \text{RF} + \max(-10, \text{RA}) - 20\log(\text{dkm}) \text{ [c]}$$

Combining [b] and [a]

$$I_h = \text{TXFIELD} - \text{FSPL_TW} - \text{DL_TW} + \text{RF} + \max(-10, \text{RA}) - 20\log(\text{dkm}) - \text{DL_WR} \text{ [d]}$$

Accounts for additional diffraction losses between Wind Turbine and receiver

$$20\log(\text{dkm}) = 20\log(d/1000) = 20\log(d) - 60 \text{ [e]}$$

From first principles

$$\text{FSPL} = 20\log(4\pi/\lambda) + 20\log(d)$$

$$20\log(d) = \text{FSPL} - 20\log(4\pi/\lambda) \text{ [f]}$$

From [e] and first principles

$$20\log(\text{dkm}) = \text{FSPL} - 20\log(4\pi/\lambda) - 60 \text{ [g]}$$

Combining [f] and [e]

$$I_h = \text{TXFIELD} - \text{FSPL_TW} - \text{DL_TW} + \text{RF} + \max(-10, \text{RA}) - \text{FSPL_WR} + 60 + 20\log(4\pi/\lambda) - \text{DL_WR} \text{ [h]}$$

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.

I_t , I_h and I_r are all calculated as detailed in 6 above. These values will differ due to diffraction loss differences.

$$I_w = 20\log((0.2 \cdot 10^{(I_t/20)} + (0.6 \cdot 10^{(I_h/20)}) + (0.2 \cdot 10^{(I_r/20)}))$$

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:

$$I_w = 20\log(I_{abs})$$

$$I_{abs} = 10^{(I_w/20)}$$

$$\text{By definition } I_{wf} = 20\log(\sum(10^{(I_w/20)}))$$

Direct summing of absolute values – Pager Power and RES methodologies

9 Diffraction – Single Knife Edge

$$\text{DL} = 6.9 + 20\log(\sqrt{((v-0.1)^2 + 1)} + v - 0.1) \quad \text{when } v > -0.7$$

$$\text{DL} = 0 \quad \text{when } v \leq -0.7$$

Equation 17 of ITU-R P526 ($DL \approx 0$ when $v \leq -0.7$ 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.



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