BTAC – Subcommittee 18

Technical Information On The Assessment Of The Potential Impact Of Wind Turbines On Radiocommunication Systems

Montreal - September 13th, 2004

Revised July 22nd, 2005

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1. Description of the Impact of Wind Turbines on Radiocommunication Systems

Introduction

This document is intended to provide technical information on how to assess the potential impact of wind turbines on radiocommunication systems. Hence it contains technical information that can be used by interested parties to help determine whether a wind farm would impact surrounding radiocommunication systems.

General

Studies[1] have shown that the rotating blades and support structure of a wind turbine can impact AM (amplitude modulated) RF (Radio Frequency) signals. FM (frequency modulated) signals are much more immune to this phenomena and may only become impaired in very close proximity to the wind turbines.

Based on this, the following RF systems could be negatively impacted by the proximity of wind turbines:

- Cable distribution receive sites (Head-ends);
- Satellite uplinks & receive systems;
- DTH signals (Star Choice, Bell Express vu);
- Radar;
- Airport communications and guidance systems;
- TV Broadcasters;
- Coast Guard communications systems;
- Point-to-Point Radiocommunication links;
- MMDS systems;
- Digital TV;
- MATV receive systems.

Wind turbines can affect radiocommunication signals in a number of ways including, through shadowing, mirror-type reflections or signal scattering.

Shadowing

Large obstacles, such as buildings, hills or wind turbine parks can create shadowed areas blocking the line of sight from the receiver to the transmitter. These areas can be broken down into two regions: Region “A” where signal loss, due to the blockage, is high and receiving a usable signal is difficult if not impossible; and Region “B” where the signal is attenuated but to a lesser degree than in “A” allowing the receiver to continue to pick up a usable signal. The size of each of the areas depends upon the shape and composition of the obstacle. Typically, Region “B” can extend up to 10 km from the obstacle.

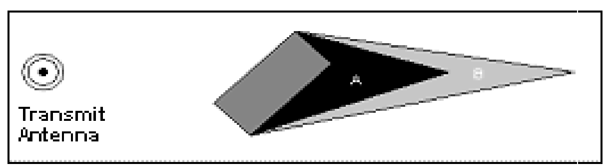

Figure 1.1 – Shadowed areas due to structures

Mirror-Type Reflections

Reflections are caused when the signal from the transmitter bounces off an obstacle before being received at the antenna. This bounced signal has a longer path than the direct signal, causing it to be delayed in time at the receiver. In a conventional receiver, when the 2 signals are received simultaneously and one is delayed, the delayed signal can degrade the direct signal.

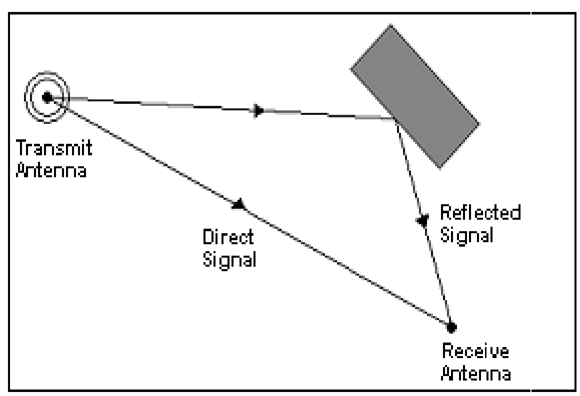

Figure 1.2 – Mirror-Typel Reflections

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[1] Effects of Wind Turbines on UHF Television Reception, Field tests in Denmark, D. T. Wright, 1991 & TV Measurements near Lendrum’s Bridge Wind Turbines, J. E. Goodson, 2003

Scattering

When a Radiocommunication signal reaches a wind turbine, the rotating blades of the turbine can produce a pulsed scattering of this signal syncronized with the rotational speed of the blades. These pulses can add a doppler effect to the signal, which produces variations in the scattered signal's phase and amplitude. This scattering can occur in both the front scatter zone and the back scatter zone.

In the front scatter zone, encompassing an area behind the wind turbine 72 degrees in width, the effect is analogous to shadowing, with the signal varying in amplitude and phase synchronously with the speed of the blades' rotation.

In the back scatter zone, which encompasses the remaining 288 degrees of arc, the effect is similar to a mirror reflection. However, here again, the scattered signal contains both phase and amplitude variations.

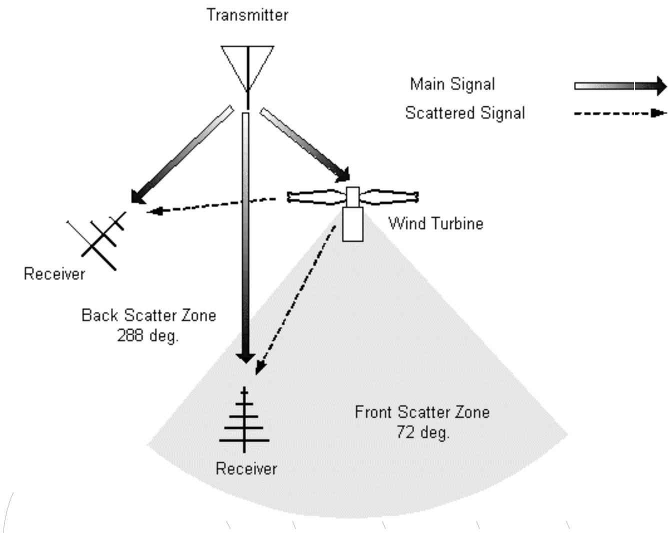

Figure 1.3 – Front and Back Scatter Zones

Terrain Obstructions

The possible impact to a radiocommunication signal caused by the proximity of wind turbines is magnified when the main signal path between the transmitter and the receiver is partially obstructed, while the signal paths between the transmitter and the wind turbines and between the wind turbines and the receivers have no obstructions. In these situations, the D/U ratio at the receiver is reduced, making any detrimental effects from the wind turbines more pronounced.

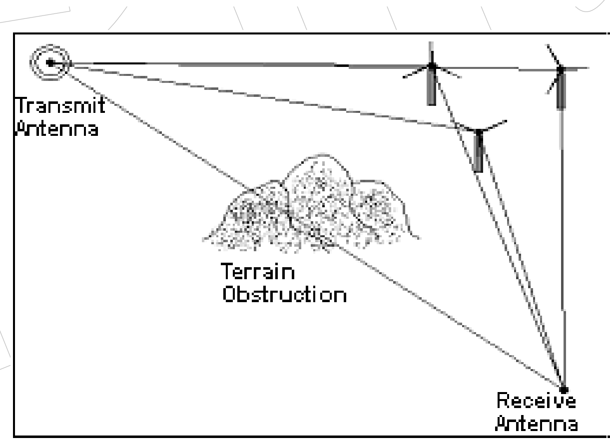

Fig 1.4 – Terrain obstructions in the main signal path

Impacted Areas

The effect wind turbines may have on radiocommunication systems is easier analyzed if we define areas around radiocommunication systems outside of which the effects of wind turbines is negligible. Inside these areas, if there are wind turbines, or radiocmmunication receivers further analysis would be required.

Mitigation Measures

In areas where wind turbines could have a perceptible impact on the received signal a number of mitigation measures may be available to reduce or eliminate the effect of wind turbines on radiocommunication systems

During the planning stage, the placement of individual wind turbines should take into consideration local microwave, STL and TTL links as well as the path between broadcast transmitters and the local cable TV off-air receiving locations. Moving a wind turbine a short distance may be enough to clear the Radiocommunication path and eliminate the potential for interference.

In the operational phase of the project, there are a number of mitigation methods available. These include replacing the receive antenna with one that has a better discrimination to the unwanted signals, relocating either the transmitter or receiver, or switching to an alternate means of receiving the off-air signal.

Although these solutions may not all be technically or economically viable in each situation, they can be used individually or in combinations to help reduce or eliminate any detrimental effects from the wind turbines.

The table on the following page provides examples of how these impacted areas may be determined. Any mitigating techniques contemplated sould be discussed among the interested parties.

Table 1 - Guidelines for Determining the Impacted Areas

Systems	General guidelines
<u>Point-to-Point Systems</u>: Microwave Hops STLs TTLs NTLs An example of a typical point-to-point impacted areas is shown in Section 2	1) For proximity reasons, wind turbines should be at least 1.0 km from both the transmit and receive locations, plus 2) Outside this 1.0 km, a cylinder of diameter "L_c "[2], between the transmit and receive locations, should be cleared where: $$L_{c(m)} = 52\left(\frac{D_{(km)}}{F_{(GHz)}}\right)^{1/2} + 2B$$ L_c = Diameter of the cylinder in meters D = Transmit to receive path length in kilometers F = Frequency in GHz B = Length of one wind turbine blade
<u>Over-the-Air Reception</u> (off-air pickup and broadcast receivers) MATV Receive Systems CATV Head Ends MMDS Systems VHF TV UHF TV DTV Examples of impacted areas are given in Section 3	**FM**: For proximity reasons, wind turbines should be at least 1.0 km from the FM transmitter **TV:** Two conditions should be examined: 1) For proximity reasons, wind turbines should be at least 1.0 km from any TV transmitter 2) No receivers should be within the impacted area "R"[3] defined by: $$R = 0.051 * B * \sqrt{T}$$ R = the radius of the investigation zone in kilometers from the geographical center of the wind farm B = length of one of the wind turbine's blades in meters T = Number of turbines in the park
<u>Satellite Systems</u> DTH Satellite Ground Stations An example of a typical satellite ground station impacted area is shown in Section 4	1) For proximity reasons, wind turbines should be at least 1.0 km from the satellite transmit/receive location, , plus 2) Beyond this 1.0 km, a cone of width "L_c "[4] should be clear of any wind turbines where "L_c " is defined as: $$L_{c(m)} = 104\left(\frac{D_{(km)}}{F_{(GHz)}}\right)^{1/2} + 2B$$ L_c = Width of the cone in meters D = Distance from the ground satellite antenna in kilometers (max distance = 10 km) F = Frequency in GHz B = Length of one wind turbine blade
<u>Terrestrial Cellular Networks & Land Mobile Networks</u>	TBD
<u>Radar</u>	TBD

[2] Fixed-Link Wind-Turbine Exclusion Zone Method, D. F. Bacon & based on 3 x the maximum first Fresnel Zone clearance

[3] Electromagnetic Interference from Wind Turbines, Sengupta & Senior, 1994, Equation 9.31 using typical values m_r=0.15, η_s=0.5, Fe=2.2, Fa=1, N=5, Φ=0 deg., $E_{ps,d}=E_{r,d}$ and assuming a 10 db main path obstruction

[4] Electromagnetic Interference from Wind Turbines, Sengupta & Senior, Pg 482

2. Impacted Area Calculations for Point-to-Point Links

Point-to-Point Radiocommunication Links

These are defined as any point-to-point radiocommunication transmissions where it is primarily intended that the signal at the receive end will be re-transmitted in some forms or types of modulation. It includes such links as STLs (Studio to Transmitter Links), TTLs (Transmitter to Transmitter Links and NTLs (Network to Transmitter Links).

The impacted areas related to these systems are based on the path's Fresnel zone clearance and can be determined from the following two conditions stipulated in Table 1:

a) A 1.0 km radius around the transmit and receive antennas, plus

b) A cylinder between the transmitter and receiver outside of the one kilometer radius from either end defined by:

$$L_{c(m)} = 52\left(\frac{D_{0(km)}}{F_{0(GHz)}}\right)^{1/2} + 2B$$

Example:

For a 25 km, 7.0 GHz microwave point-to-point hop, the Impacted areas, assuming the wind turbines in the area have 40m blades, are:

a) 1.0 km around the transmitter and receiver ... plus

b) $L_{c(m)} = 52\left(\frac{25}{7}\right)^{1/2} + 2(40)$

$\boldsymbol{L_c = 178m}$

If there are any wind turbines within these boundries, then it is recommended that a detailed impact analysis be undertaken by a qualified Radiocommunication Engineer.

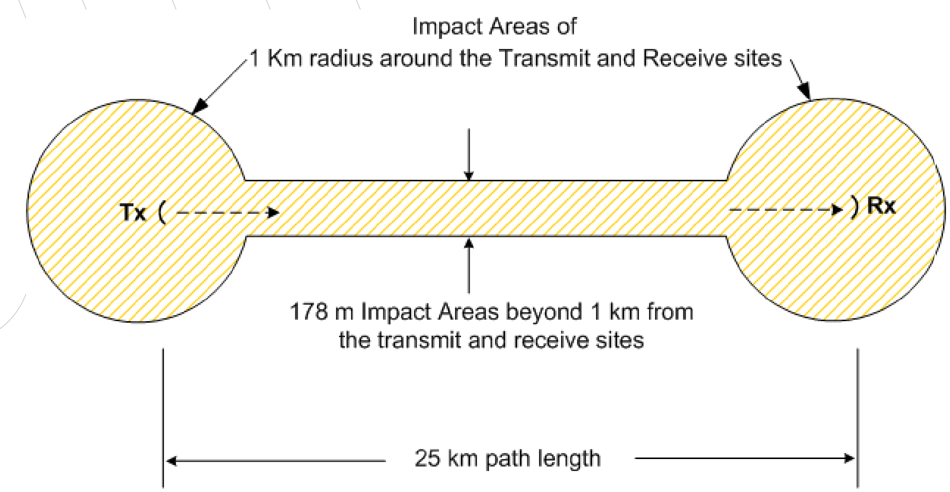

Fig 2.1 – Impacted areas for a Point-to-Point link

3. Impacted Area Calculations for Broadcast Receivers near Wind Turbines

Analogue and Digital TV Receivers Including Consumer Broadcast Receivers

Definition of a Wind Turbine Park

For all purposes of this note, a wind turbine Park is defined as a group of wind turbines where any two adjacent wind turbines are less than 3 kilometers apart. If groups of wind turbines are more than 3 kilometers apart then, from an impact perspective, they are considered as separate parks.

Determining the Worst Case Impacted Areas

The Radius of the impacted area can be determined through the following equation: if there are no analogue or digital TV receivers, including consumer receivers, located within the official coverage areas of the broadcast stations involved, that are within this impacted area then further analysis into the possible affects from the wind turbines is not required.

$$R = 0.051 * B * \sqrt{T}$$

Where:

R = the radius, in kilometers, of the impacted area from the geographic center of the wind farm

B = The length in meters of **a single** wind turbine blade

T = The number of wind turbines in the park

Examples:

Example 1

If you have 50 wind turbines in a single park (no wind turbine is more than 3 km away from an adjacent wind turbine) and each wind turbine has 30m blades, you would create an impacted area of:

$$R = 0.051 * 30 * \sqrt{50}$$

R = 11.0 km measured from the geographic center of the park

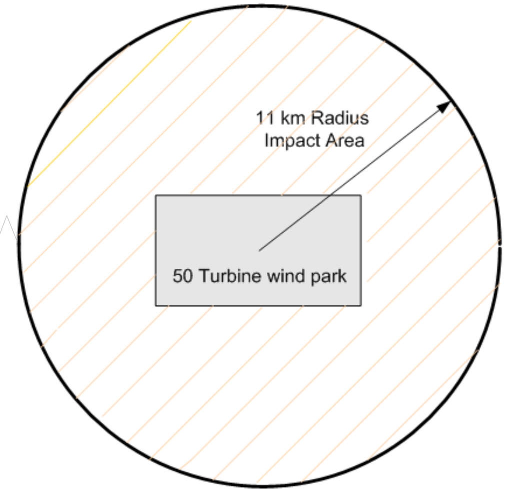

Figure 3.Impacted Area for a 50 Turbine Park

Example 2

If you had 50 wind turbines in a park and each wind turbine had 30m blades, but 25 of the wind turbines are clustered together on one hill and the other 25 are grouped on another hill 3 km away, then we would consider these as two separate parks and the impacted areawould be:

$$R = 0.051 * 30 * \sqrt{25} \quad \text{(for Park1) and}$$
$$R = 0.051 * 30 * \sqrt{25} \quad \text{(for Park2)}$$

R = 7.8 km measured from the geographic center of each of the 2 parks.

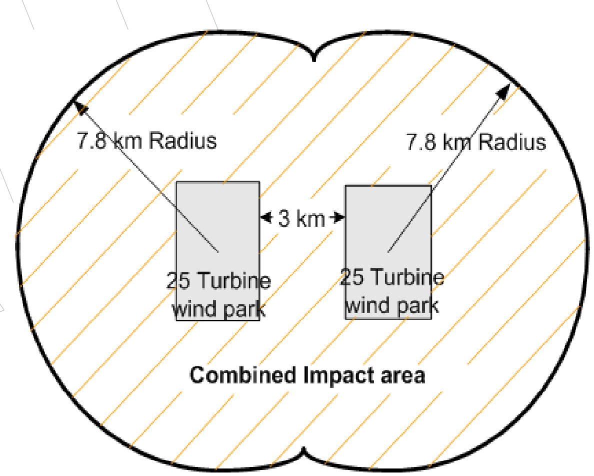

Figure 3.2 Impacted Area for 2 adjacent 25 Turbine wind Parks

If there are analogue or digital TV receivers, including consumer receivers, located within the official coverage areas of the broadcast stations involved, that are also within the impacted area then it is recommended that a detailed impact analysis be undertaken by a qualified Radiocommunication Engineer.

4. Impact Area Calculations for Satellite Ground Stations

Satellite Ground Stations Including Direct-to-Home Receivers

Satellite ground stations are locations where broadcasters either receive RF signals from, or transmit signals to, geo-stationary orbiting satellites. The impacted areas related to these systems are defined in Table 1 as:

a) A 1.0 km radius around the transmit and receive antennas plus

b) A cone of width $\boldsymbol{L_c}$ defined as:

$$L_{c(m)} = 104\left(\frac{D_{(km)}}{F_{(GHz)}}\right)^{1/2} + 2B$$

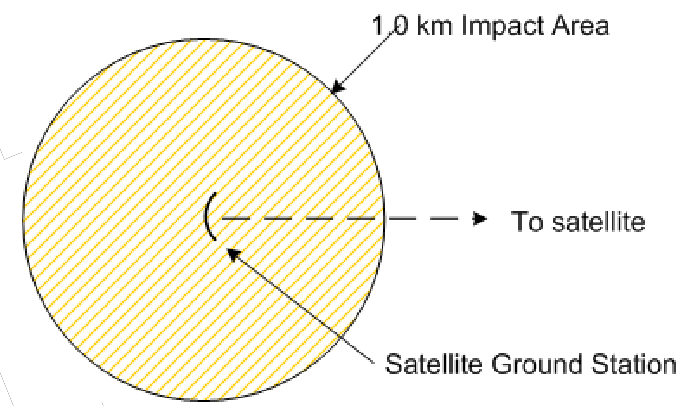

Fig 4.1 Impact Area within 1.0 km of the Satellite ground station

Example:

For a satellite ground station operating at 4.0 GHz, the impacted area, assuming the wind turbines have 40m blades, would be:

a) a 1.0 km radius around the satellite ground station plus

b) A conical shaped zone starting from 1.0 km from the satellite ground station and extending out 10 km defined by:

$$L_{c(m)} = 104\left(\frac{10}{4}\right)^{1/2} + 2(40)$$

At 10 kilometers from the satellite ground station, the impacted area would be:

$$\boldsymbol{L_c = 244m}$$

If there are any wind turbines inside these areas, then it is recommended that a detailed impact analysis be undertaken by a qualified Radiocommunication Engineer.

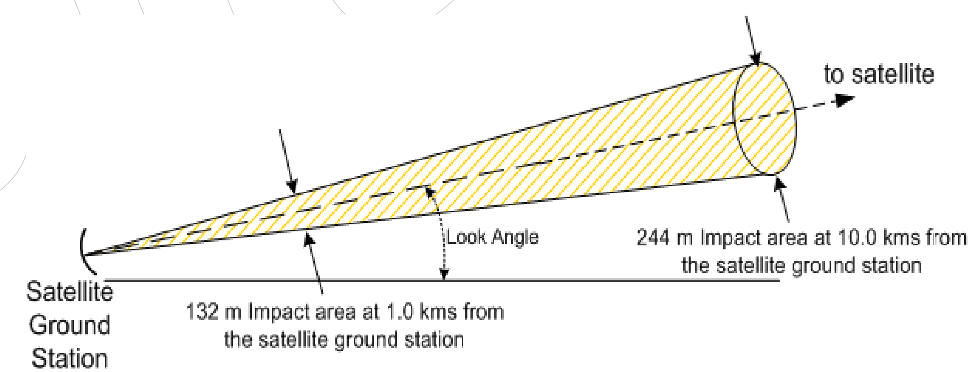

Fig 4.2 Impact area for a Satellite Ground Station from 1.0 km to 10 km

Glossary of Terms and Acronyms

Terms

D = *Diameter of the circle circumscribed by the wind turbine blades (twice the length of one blade).*

D/U = *the ratio of the **D**esired (wanted) signal to the **U**ndesired (interfering) signal.*

$\mathbf{E_{PS,D}}$ = *Average Amplitude of the direct signal incident on each of the wind turbines in the park.*

$\mathbf{E_{R,D}}$ = *Amplitude of the direct field at the receiver. Where the receivers are far from the transmitter* $E_{PS,D} = E_{R,D}$.

$\mathbf{F_{A,W}}$ = *Antenna Factor in the direction of the wind turbine. Defines the antenna gain in the direction of the wind turbine.*

$\mathbf{F_E}$ = *Empirical Exceedance Factor. Based on a 1% probability that the observed scatter ratio will be greater than the idealized scatter ratio.*

M = *Number of clusters of wind turbines.*

$\mathbf{m_R}$ = *Modulation Perception Index – Dr. Sengupta's threshold at which the scattered signal becomes visible in the picture.*

N = *Number of wind turbines in a cluster operating synchronously at any time.*

$\boldsymbol{\eta_S}$ = *Signal scattering efficiency of the wind turbines. The ratio of the amount of signal reflected relative to the incident signal.*

Radiocommunication – *the transmission, emission or reception of signs, signals, writing, images, sounds or intelligence of any nature by means of electromagnetic waves of frequencies lower than 3 000 GHz propagated in space without artificial guide*

Satellite ground stations = *a fixed ground based parabolic antenna that either receives signals from, or transmits signals to, a geo-stationary communications satellite.*

Φ = *Angle between the direct and scattered signal.*

ζ = *Distance from the geographic center of the wind farm to the limit of the possible signal degradation zone in meters*

Acronyms

CATV = *Community Antenna TeleVision (Cable TV).*

DTH = *Direct to Home TV, (Subscription television service delivered by satellite).*

DTV = *Digital Television (using the Canadian ATSC standard).*

MATV = *Master Antenna Television, (off-air pickup location for TV and Radio channels fed to an apartment building or block of apartment buildings).*

MMDS – *Multi-channel Multipoint Distribution Service, (a wireless cable TV system that uses microwave frequencies to transmit TV signals to subscribers).*

NTL = *Network to Transmitter Link.*

STL = *Studio to Transmitter Link.*

TBD = *To Be Determined.*

TTL = Transmitter to Transmitter *Link (the wireless path between two transmitters where one of the transmitters receives its input signal off air from the other)*.

UHF-TV = *Ultra High Frequency Television – a group of TV channels, numbered 14-69, that fall between 470 MHz and 806 MHz.*

VHF-TV = *Very High Frequency – Television, Group of TV channels, numbered 2-13, that fall between 50 MHz and 220 MHz.*

References

1) BPR Part 4, *Application Procedures and Rules for a Television Broadcasting Undertaking*. – Industry Canada, 1997

2) *Electromagnetic Interference from Wind Turbines* – Sengupta & Senior, 1994

3) *Fixed-Link Wind-Turbine Exclusion Zone Method* - D. F. Bacon, October 2002

4) TB–5, *Report on Predicting Television Ghosting Interference and Picture Quality* – Industry Canada, July 1989 Issue 2

5) *The Impact of Large Buildings and Structures (including Wind Farms) on Terrestrial Television Reception* – BBC / RA / ITC