Radio Advisory Board of Canada (RABC)

Canadian Wind Energy Association (CanWEA)

Technical Information and Guidelines on the Assessment of the Potential Impact of Wind Turbines on Radiocommunication, Radar and Seismoacoustic Systems

April 2007

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Foreword

The contributors to this document are fully supportive of the development of alternative energy sources and recognize that effective and appropriate development of alternative energy sources is good for the environment and the economy.

At the same time, the contributors also recognize that radio, telecommunications, radar and seismoacoustic systems are also important for Canadians.

The purpose of this document is therefore to facilitate effective cohabitation between such existing systems and wind energy systems through the effective and early sharing of information.

In certain circumstances, wind turbines, either as single units or grouped together in a wind farm, can negatively affect radio, telecommunications, radar or seismoacoustic systems within a certain distance of the turbine(s). Early consultation with stakeholders is recommended to ensure that a given installation does not bring about unacceptable interference, thereby leading to costly changes or delays at a later stage in the wind farm development process.

To avoid any potential difficulties, the following process is recommended:

Step 1. The wind project proponent develops a map showing the location of the proposed wind farm and all the wind turbines within it.
Step 2. The proponent then consults the Guidelines contained in this document to determine if there is any possibility that the proposed wind farm *may* impact radio, telecommunications, radar or seismoacoustic systems in the area.
Step 3. In the event that the guidelines indicate that a given installation may have an unacceptable impact, the wind project proponent contacts the applicable authority to determine if in fact further investigation is warranted.
Step 4. The wind proponent and applicable authority then undertake the necessary studies and non-regulatory mitigation measures to resolve the issue to the satisfaction of both.

The present Guidelines address Step 2 of the above process. As such, they serve as a risk management tool that helps wind project proponents and radar, radio and seismic system operators avoid any potential conflicts at an early stage in wind farm development. In essence, the Guidelines provide a series of analytical methodologies and thresholds that help to indicate where a potential interference *may* occur, thereby acting as a voluntary (but highly recommended) trigger for the proponent to notify the applicable authority (Step 3 of the above process). *The Guidelines are not intended as a regulatory document, nor should they be used as the basis for any regulatory decision.*

It is important to point out that the Guidelines themselves are not able to determine if unacceptable interference actually *will* occur. The determination of whether or not a proposed turbine or wind farm may create an unacceptable level of interference with existing radio, telecommunications, radar and seismoacoustic systems is very complex and it is not possible to categorically determine if unacceptable interference will occur unless a site-specific analysis is undertaken. The scope of that site-specific analysis and any potential mitigation measures undertaken (Step 4 of the above process), are not addressed in the present Guidelines.

This document has been written by a wide range of stakeholders, and it represents a general consensus in terms of analytical approach and acceptable thresholds for Canada. To the extent possible, it is consistent with documentation either existing or under development in other countries.

1. Impact of Wind Turbines on Radiocommunication, Radar and Seismoacoustic Systems

1.1 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 a wind turbine.

Experience and studies[2] in Europe and the United States have indicated that both the physical structures of the tower/turbine and the rotating blades can cause interference on conventional and Doppler radar signals. Wind turbines, which are within the "Line of Sight" of radars, can have a negative impact on radar data.

An extensive study[3] of microseismic and infrasonic effects of low frequency noise and vibrations from windfarms has shown that wind turbines can have a negative impact on seismoacoustic (seismological and infrasound) recording equipment that can reduce their sensitivity and hence effectiveness for monitoring earthquakes and nuclear explosions. Wind turbines generate detectable seismic vibrations in the earth, and low-frequency acoustic signals in the atmosphere, which increase with wind speed. The greater the number of wind turbines, the higher the level of seismic and acoustic noise.

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

- Cable distribution off-air receive systems (Head-ends);
- Satellite uplinks and receive systems;
- Direct-to-home (DTH) receive systems (Star Choice, Bell Expressvu);
- Radar (weather, defence and air traffic);
- Airport communications and guidance systems;
- Broadcasting – AM, FM and TV;
- Coast Guard communications and vessel traffic radar systems;
- Point-to-point radiocommunication links;
- Point-to-multipoint systems;
- Cellular type networks, and
- Seismological and infrasound monitoring systems.

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

1.2 Impact on Radiocommunication Systems

Impact on radiocommunication systems can be divided in two parts: impact on broadcast-type systems (including cellular type networks) and impact on point-to-point systems (including local microwave, studio to transmitter links (STL).and transmitter to transmitter links (TTL); either one-way or two-way) and point-to-multipoint systems). Propagation effects are mainly associated with the type of modulation used (AM or FM/PM) and impacted areas and mitigation measures differ.

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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

[2] Various reports listed in the reference annex.

[3] Microseismic and Infrasound Monitoring of Low Frequency Noise and Vibrations From Wind Farms: Recommendations on the Siting of Wind Farms in the Vicinity of Eskdalemuir, Scotland, P. Styles, I. Stimpson, S. Toon, R. England, and M. Wright, 2005

Shadowing

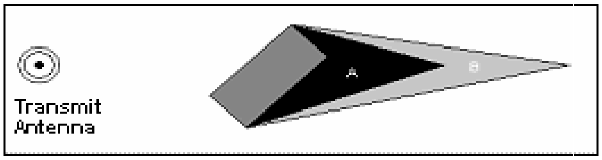

Figure 1.1 – Shadowed areas due to structures

Large obstacles, such as buildings, hills or wind farms 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.

Mirror-Type Reflections

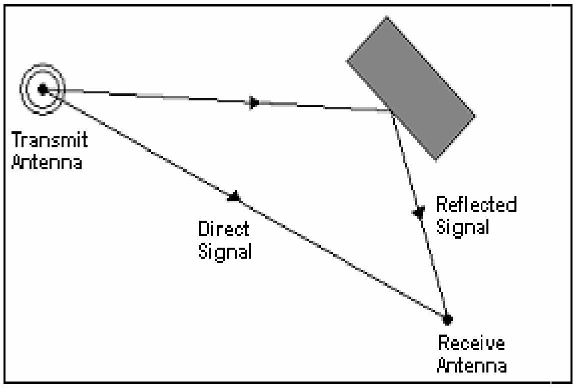

Figure 1.2 – Mirror-Type Reflections

Mirror-type (specular) 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 AM receiver, when the two signals are received simultaneously and one is delayed, the delayed signal can degrade the direct signal. In extreme cases, degradation can also occur in FM receivers. These reflections mainly occur in the back scatter zone.

Scattering

When a radiocommunication signal reaches a wind turbine, the rotating blades of the turbine can produce a pulsed scattering of this signal synchronized 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 mainly occurs in the front scatter zone, but can also occur in the back scatter zone.

In the front scatter zone which encompasses an area behind the wind turbine of approximately 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.

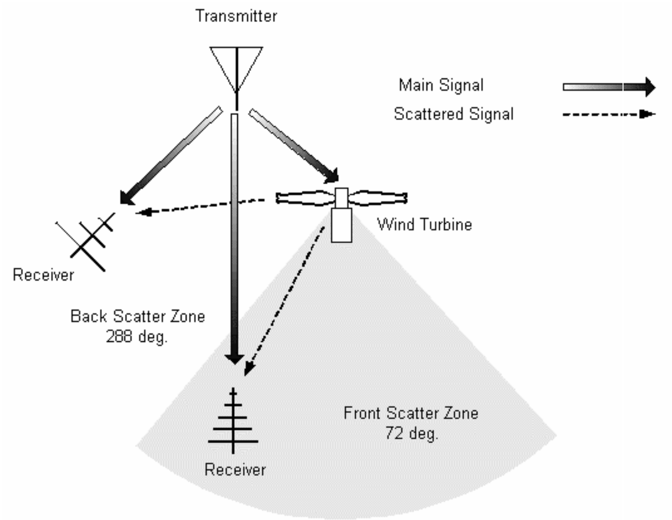

Figure 1.3 – Front and Back Scatter Zones

Terrain Obstructions

With the exception of radar systems, the possible impact to a radio communication 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 desired to undesired signal (D/U) ratio at the receiver is reduced, making any detrimental effects from the wind turbines more pronounced.

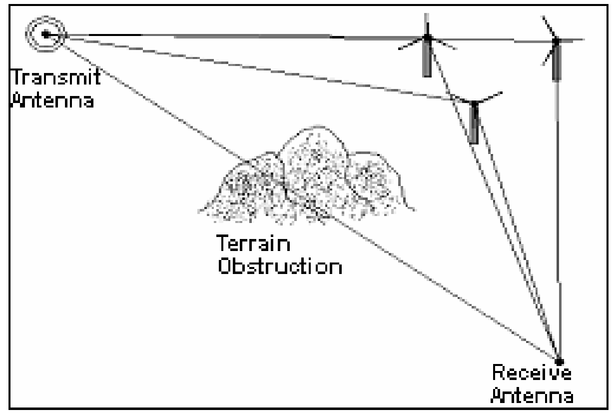

Fig 1.4 – Terrain obstructions in the main signal path

Impacted Areas

The effect wind turbines may have on radio communication systems is more easily analyzed if we define areas around radio communication systems outside of which the effects of wind turbines are negligible. Inside these areas, if there were wind turbines and radio communication receivers, further analysis would be required.

Mitigation Measures – Point-to-Point Systems

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

During the planning stage, the placement of individual wind turbines should take into consideration local microwave, STL and TTL links. Moving a wind turbine a short distance may be enough to clear the radiocommunication path and eliminate the potential for interference.

If proper care is taken at the wind farm planning stage, radicommunication systems will most likely not be impacted. If degradation is noticed 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 information (fiber optic or other means).

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

Mitigation Measures – Broadcast-Type Networks

In areas where wind turbines could have a perceptible effect on broadcast-type networks, a number of mitigation measures may be available to reduce or eliminate the effect of wind turbines.

During the planning stage, the placement of individual wind turbines should take into consideration site location and the area/population it serves. Moving a wind turbine outside the path between the site and the served populated area and away from the agglomeration may be enough to eliminate or at least reduce the potential for interference, especially for AM modulated broadcast signals.

In the operational phase of the project, there are a number of mitigation methods available including changing the network's system parameters and modifying the antenna system 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 combination to help reduce or eliminate any detrimental effects from wind turbines.

1.3 Impact on Radar Systems

The effect of wind turbines on radar systems is not easy to determine. If a wind farm is in direct line of sight to radar it may have a detrimental effect upon radar performance, as the rotating blades can be a source of interference. Where wind turbines are in `line of sight' to the radar, the turbines can appear as genuine aircraft targets. The turbines could mask real aircraft responses or desensitise the radar within the radar sector containing the wind farm thereby potentially creating interference and flight safety issues.

Each proposed site would have to be reviewed on a case-by-case basis. Each radar has a different coverage footprint, depending on its location and the topographical layout of the surrounding area. A proposed wind turbine site 50 km from a radar may have a large negative effect while a proposed site at 25 km may have no impact at all.

Blockage

A single turbine in close proximity to a radar site or a group of turbines at a distance can block a certain angular sector of the radar beam. The blockage should not be more than 10% occultation of the beam width to cause insignificant impact on a radar, according to the European OPERA (Operational Programme for the Exchange of Weather Radar Information) standard. Potential severe blockage could lead to a loss of meteorological data, which could affect the radar's operational performance (e.g. storm detection, rainfall/snowfall rate and lower level wind shear) hence potentially causing extreme weather conditions to go undetected. Given the potential serious impacts of blockage on Air Defence or Air Traffic Control Radars, the threshold for an unacceptable level of blockage would even be less than the 10% occultation quoted

Clutter

Clutter is defined as unwanted echoes on radar display. In this case "clutter" is unwanted echoes from wind turbines. The impact of clutter depends on the radar cross section (RCS) of the supporting structure, the nacelles and the cross section area of the rotating blades, which in turn, depends on the orientation of the turbine. Since the turbine can rotate 360 degrees azimuthally in order align itself with the prevailing wind direction, the RCS changes with the wind direction, with a maximum possible RCS approximately equal to that of a 747 aircraft. This can have negative impact on radar data.

Doppler Signal

Weather radars can use the Doppler effect to detect the motion of targets, and this motion is used in various meteorological techniques. Radar picks up non-meteorological Doppler signals from the tips of rotating blades, as well as the wake turbulence produced by the blades. The degradation of Doppler signal can reduce the ability to detect a rotating storm (usually associated with severe weather) and low-level wind shear (which is especially important for aviation purposes). The weather radars have some Doppler-based filters to remove stationary clutter due to ground targets, but turbines defeat those filters because the rotors and blades move. Any organization considering constructing a wind turbine within 80km of a Meteorological Radar should contact Environment Canada regarding possible impacts and mitigation measures.

Air Defence Radar Concerns

The role of the Canadian Air Defence System (ADS) is to provide aerospace surveillance contributing to the defence of North America. The Canadian ADS constitutes Canada's commitment to the North American Aerospace Defence (NORAD) Atmospheric Early Warning System (AEWS). The ADS in Canada is comprised of 52 radars. These radars are located throughout Canada's arctic, coastal, and inland regions.

Air Defence (AD) radars must be capable of tracking friendly and hostile targets within Canada's aerospace. Detailed studies have shown that Wind Turbine Generators (WTGs) cause a number of serious problems with respect to AD radars. These problems include blanking, reducing the radar's ability to detect real targets, clutter, false targets, and reporting inaccurate positional information on real targets.

Any organization considering establishing a WTG site, within a 100 km radius of an AD radar, should contact the Department of National Defence (DND). DND can determine if the proposed WTG is within line of sight of the radar beam and/or if interference problems are likely. In order to avoid potential interference with Air Defence radars used in support of national sovereignty, it is important to consult with the appropriate authority prior to establishing a WTG site.

Air Traffic Control Radar Concerns

Wind turbines in line of sight of an air traffic control (ATC) radar have a significant impact on the ability to support air traffic services (ATS). This effect is in the form of obscuration and displayed clutter which are a result of strong radar reflections from high radar cross section moving targets such as wind turbines. ATC controllers must always honour the presence of a displayed radar return on their screen and treat it at as a real aircraft. Displayed clutter is a significant problem. Aircraft close to airfields will often operate in Instrumented Flight Rules (IFR) and rely on ATC for safe separation from other aircraft. It is highly undesirable for aircraft on approach to have to manoeuvre laterally to avoid other unknown radar contacts, particularly those generated by wind turbines. Flying over or close to a wind turbine can significantly hamper the ability of an ATC operator to maintain the identity of his own aircraft and safely provide ATS.

A wind farm close to an airfield is not compatible with ATC operations. Lateral separation of at least 10 km should be maintained between wind turbines and areas where critical ATC operations take place. A wind developer considering building a wind turbine or farm within 60 kms of an Air Traffic Control Primary Search Radar should determine if the turbine(s) will be within the line of sight of the radar and should assess what effect they may have on the provision of Air Traffic Services.

Mitigation Measures

In areas where wind turbines could have a perceptible impact on radar systems, a limited number of mitigation measures may be available to reduce the effect of wind turbines on radar systems

Wind turbines can affect weather radar signals by partial or total blockage and create intensity (ground) and Doppler (broad spectral width) clutter. Implementation of software filters and masks may reduce or eliminate the impacts on clutter. However, this can sometimes create "blind spots" or missing data on the radar display over certain areas. Reducing the radar cross section (RCS) by rearranging/relocating the turbines a short distance may also mitigate the impact caused by the wind farm. Radar absorbing or non-reflective material may also be used as an alternative for building tower/turbine, and may have little or no significant additional costs.

Wind turbines can also affect Air Defence and Air Traffic Control Radars by blockage and clutter. Software filters have had limited success eliminating this clutter, although testing is continuing with newer versions of the software. Reducing the RCS of the turbine, as mentioned above is also a possibility. If a potential wind turbine developer would like to know if a proposed site that is within 100 km of a radar head would be acceptable with regards to radar interference, they can contact the appropriate department. Simulations will be run and a reply will be provided to the developer detailing the findings of the analysis.

1.4 Impact on Seismoacoustic Systems

Although seismoacoustic concerns are outside the normal scope of the Radio Advisory Board of Canada, they have been included in this document to ensure potential developers are aware of all areas of interest regarding the potential effects of wind turbines.

Detrimental Effects of Noise and Vibration

Low frequency noise/vibration from wind turbines can seriously hamper the ability of a seismological monitoring station to detect and record low-ampitude ground motion signals related to distant earthquakes or underground nuclear explosions. Similarly, the introduction of low-frequency noise into the atmosphere can reduce the ability of infrasound monitoring equipment to detect and record atmospheric explosions.

No turbines should be built within 10 km of a seismoacoustic-monitoring array. Before any wind turbines can be built within 50 kms of a monitoring array, it must first be determined whether the resulting loss in detectability falls within acceptable bounds. Besides arrays, turbines located within a few kilometres of single monitoring stations could also cause negative impact and proposed turbine locations in the vicinity of monitoring stations will also need to be considered.

Mitigation Measures

The only way to mitigate the effects of wind turbines of current design on seismoacoustic monitoring equipment is to restrict the number constructed close to monitoring facilities. A total acceptable level of seismic and acoustic noise generated by turbines within 50km would have to be determined. A computer model will be used to calculate the noise field for a proposed wind turbine or farm to ensure it will not exceed this threshold. No turbines should be constructed closer than 10 km to a seismoacoustic array; however, a lesser distance may be acceptable for single seismic monitoring stations. This process will need to be reassessed and restrictions possibly relaxed if new turbine designs are developed which transmit less noise into the air and ground.

2. Coordination Information

The following table lists contacts within different organisations that coordinate the assessment of possible wind turbine effects on radiocommunication, radar and seismoacoustic systems.

Table 1 - Coordination Contact List

Systems	Contact
Radio Advisory Board of Canada	RABC Website: http://www.rabc.ottawa.on.ca/e/index.cfm E-mail: r.a.b.c@on.aibn.com Phone: 1-888-902-5768 or 613-230-3261 Fax : 613 230-3262
Canadian Wind Energy Association	CanWEA Website: http://www.canwea.ca/en/ E-mail: info@canwea.ca Phone: 1-800-922-6932 or 613-234-8716 Fax : 613-234-5642
Radio Communication Users	Industry Canada Website: http://spectrum.ic.gc.ca/tafl/tafindxe.html E-mail: Phone: Fax : NOTE : The Industry Canada Website listed above does not list DND's or RCMP's radiocommunication users. Please contact: Department of National Defence Website: http://www.airforce.forces.gc.ca/8wing/squadron/atess_turbines_e.asp E-mail: lavoie.mj6@forces.gc.ca Phone : 613-992-3479 Fax : 613-991-3961 and Royal Canadian Mounted Police Mrs. Francine Boucher Manager, Radio Spectrum Management Section E-mail: Francine.boucher@rcmp-grc.gc.ca Phone: 613-998-7338 Fax: 613-998-7528
Weather Radars	Environment Canada Website: http://weatheroffice.ec.gc.ca/radar/index_e.html E-mail: weatherradars@ec.gc.ca Phone: Fax:
Civilian ATC Radars	Nav Canada Website: http://navcanada.ca/NavCanada.asp E-mail: FerrisD@navcanada.ca Phone : 613-248-7554 Fax : 613-248-XXXX
Military Air Defence and ATC Radars	Department of National Defence Website: http://www.airforce.forces.gc.ca/8wing/squadron/atess_e.asp E-mail: windturbines@forces.gc.ca Phone : 613-392-2811 Ext 7042

	Fax : 613-965-3132
Vessel Traffic System Radars	Canadian Coast Guard Website: TBD E-mail: mojicajf@dfo-mpo.gc.ca Phone : 613 998-1403 Fax : 613 993-3519
Seismological Monitoring Arrays	Natural Resources Canada Website: http://earthquakescanada.nrcan.gc.ca/index_e.php E-mail: cormack@seismo.nrcan.gc.ca jlyons@nrcan.gc.ca Phone: 613 992-8766 613 995-5526 Fax: 613 992-8836 613 992-6931

The tables on the following pages provide general area sizes around specific equipment that would require consultation between a potential developer and the appropriate agency. There are also examples of how these impacted areas may be determined. Any mitigating techniques contemplated should be discussed among the relevant parties.

Table 2 - Guidelines for Determining Consultation Zone

This table provides general area sizes (the "consultation zones") around specific equipment that would require consultation between a potential developer and the appropriate agency (see Table 1 above for agency contact information). Section 3 gives examples of how these consultation zones may be determined. Any mitigating techniques contemplated should be discussed among the relevant parties.

Systems	General guidelines
<u>Point-to-Point Systems</u>: Microwave Hops STLs TTLs NTLs An example of a typical point-to-point consultation zone is shown in Section 3.1.	1) For proximity reasons, the radius of the consultation zone around both the transmit and receive locations should be at least 1.0 km, 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 in meters
<u>Over-the-Air Reception</u> (off-air pickup and broadcast receivers) Master Antenna TV (MATV) Receive Systems Cable TV (CATV) Head Ends MMDS Systems VHF TV UHF TV DTV Examples of consultation zones are given in Section 3.2	**FM**: For proximity reasons, the radius of the consultation zone around an FM transmitter should be at least 1.0 km **TV:** Two conditions should be examined: 1) For proximity reasons, the radius of the consultation zone around any TV transmitter should be at least 1.0 km 2) No receivers should be within the consultation zone "***R***"[3] defined by: $R = 0.051 * B * \sqrt{T}$ ***R*** = the radius of the consultation zone in kilometers from the geographical centre of a proposed wind farm ***B*** = length of one of the wind turbine's blades in meters ***T*** = Number of turbines in the wind farm
<u>Cellular type network:</u>	1) For proximity reasons, the radius of the consultation zone around a cellular tower should be at least 1.0 km. 2) The cellular carriers are interested in carrying out additional studies and testing with wind turbines installed in the vicinity of cellular towers, since every site has different antenna arrangement and EIRP. The carriers have asked that industry coordinate with the local carrier if a turbine will be installed in the vicinity of a cellular tower so that further evaluation could be carried out.

[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

Satellite Systems DTH Satellite Ground Stations An example of a typical satellite ground station consultation zone is shown in Section 3.3	1) For proximity reasons, the radius of the consultation zone around a satellite transmit/receive location should be at least 1.0 km 2) Beyond this 1.0 km, the consultation zone should also include a cone of width "L_c "[4] 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 in meters
Land Mobile Networks	1) For proximity reasons, the radius of the consultation zone around a land mobile radio tower site should be at least 1.0 km The land mobile carriers including public safety cellular carriers are interested in carrying out additional studies and testing with wind turbines installed in the vicinity of LMR towers, since every site has different antenna arrangement and EIRP. The carriers have asked that industry coordinate with the local carrier if a turbine will be installed in the vicinity of a communications tower so that testing could be carried out.
Seismoacoustic Monitoring Equipment	1) The radius of the consultation zone around a Natural Resources Canada monitoring array should be at least 50 km, and at least 10 km around a single monitoring station 2) The radius of the consultation zone around a Seismoacoustic monitoring array should be at least 10 km For more information on the locations of Natural Resources Canada's Seismoacoustic Monitoring facilities, please refer to maps provided on their web site at http://earthquakescanada.nrcan.gc.ca/stnsdata/cnsn/stn_book/?tpl_sorting=map
Air Defence Radars, Vessel Traffic Radars and Air Traffic Control Radars	1) The radius of the consultation zone around any DND Air Defence Radar should be at least 100 km 2) The radius of the consultation zone around any DND or Nav Canada Air Traffic Control Search Radar should be at least 60 km 3) The radius of the consultation zone around any Canadian Coast Guard Vessel Traffic Radar System should be at least 60 km 4) The radius of the consultation zone aournd a major military or civilian airfield should be at least 10 km For more information on the locations of Department of National Defence, Nav Canada and Coast Guard's Radars, please refer to the maps provided by these organizations at: www.airforce.forces.gc.ca/8wing/squadron/atess_e.asp www.navcanada.ca - Flight Operations, ANS Programs, Land Use Proposal – procedures, Regional contacts
Weather Radars	1) The radius of the consultation zone around an Environment Canada Weather Radar should be at least 80 km For more information on the Environment Canada's Radar Network and the location of an individual radar, Please refer to the Environment Canada Weather Radar Site at http://weatheroffice.ec.gc.ca/radar/index_e.html If you require more information or you have any concerns on Environment Canada's Weather Radar Network, please contact weatherradars@ec.gc.ca

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

3. Consultation Zone Calculations

3.1 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 consultation zones 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 2:

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 consultation zone, assuming the wind turbines in the area have 40m blades, is:

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.

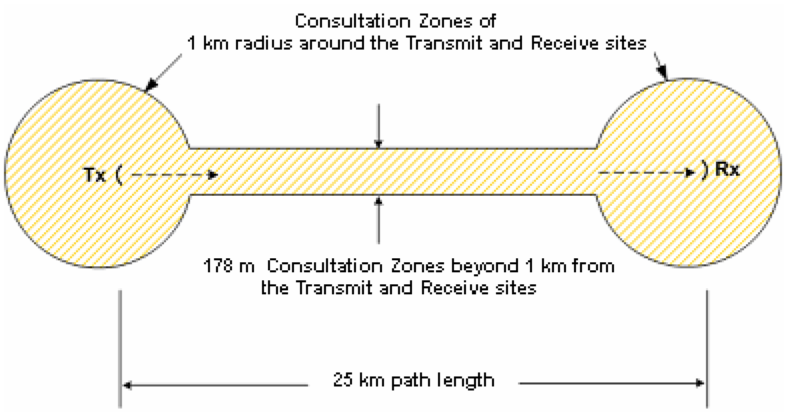

Fig 2.1 – Consultation zone for a point-to-point link

3.2 Broadcast Receivers Near Wind Turbines

Analogue and Digital TV Receivers Including Consumer Broadcast Receivers

Definition of a Wind Farm

For all purposes of this note, a wind farm 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 farms.

Determining the Worst Case Consultation Zone

The radius of the consultation zone can be determined through the equation below. If there are no analogue or digital TV receivers located within this consultation zone (including consumer receivers located within the official coverage areas of the broadcast stations involved), further analysis into the possible effects from the wind turbines is not required.

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

Where:

R = the radius, in kilometers, of the consultation zone from the geographic centre of the wind farm

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

T = The number of wind turbines in the farm

Examples:

Example 1

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

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

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

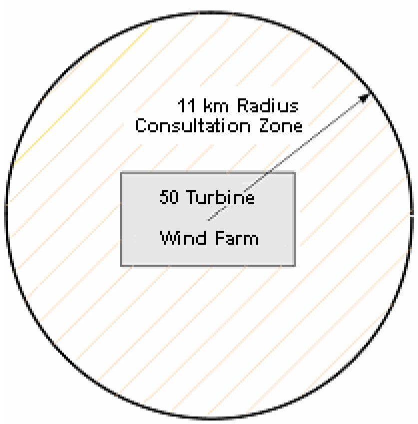

Figure 3.1. Consultation zone for a 50 turbine farm

Example 2

If you have 50 wind turbines in a farm 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 these would be considered as as two separate farms and the consultation zone would be defined by:

$$R = 0.051 * 30 * \sqrt{25} \quad \text{(for Park 1) and}$$
$$R = 0.051 * 30 * \sqrt{25} \quad \text{(for Park 2)}$$

R = 7.8 km measured from the geographic centre of each of the 2 farms.

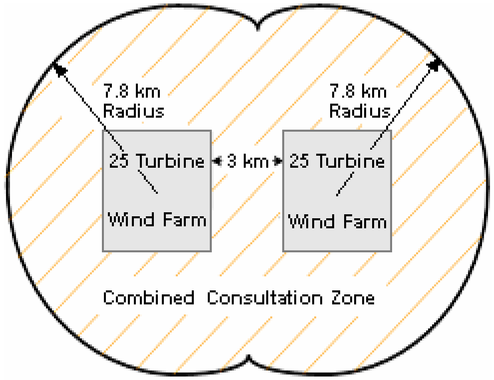

Figure 3.2. Consultation zone for 2 adjacent 25 turbine wind farms

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

3.3 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 consultation zones related to these systems are defined in Table 2 as:

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

b) A cone of width L_c defined as:

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

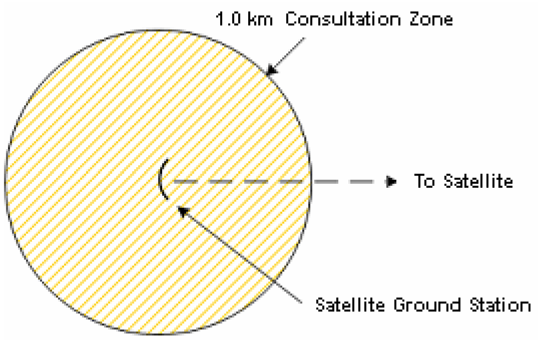

Fig 4.1 Consultation zone within 1.0 km of the satellite ground station

Example:

For a satellite ground station operating at 4.0 GHz, the consultation zone, 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 kilometres from the satellite ground station, the consultation zone would be:

$$L_c = 244m$$

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.

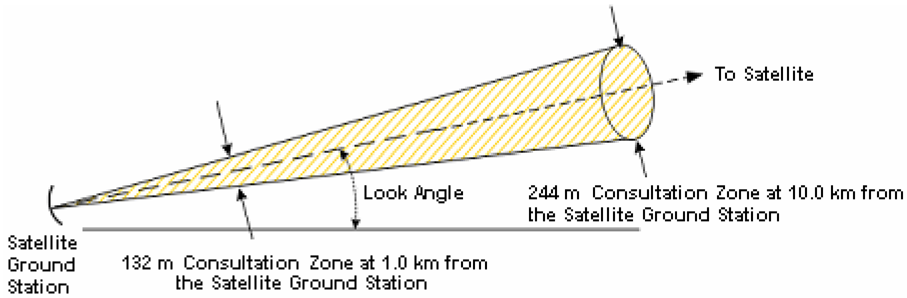

Fig 4.2 Consultation zone for a satellite ground station from 1.0 km to 10 km

Glossary of 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 wind farm.
$\mathbf{E_{R,D}}$ = 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.
Radio communication – 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.
$\boldsymbol{\Phi}$ = Angle between the direct and scattered signal.
$\boldsymbol{\zeta}$ = Distance from the geographic centre of the wind farm to the limit of the possible signal degradation zone in meters

Glossary of Acronyms

AD	Air Defence
ATC	Air Traffic Control
ATESS	Aerospace Telecommunications & Engineering Support Squadron
BWEA	British Wind Energy Association
CanWEA	Canadian Wind Energy Association
CATV	Community Antenna TeleVision (Cable TV).
DND	Department of National Defence
DTH	Direct to Home TV, (Subscription television service delivered by satellite).
DTV	Digital Television (using the Canadian ATSC standard).
EIRP	Effective Isotropic Radiated Power
EM	Electromagnetic
LOS	Line Of Sight
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.
POC	Point of Contact
RADAR	Radio Detection and Ranging
RCS	Radar Cross Section
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.

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