Joint Radio Company Ltd

Calculation of Wind Turbine clearance zones for JRC UHF (460MHz) Telemetry Systems when turbine sizes and locations are accurately known.

Version 3.1
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Version	Issue Date	Changes	Author	Editor	Authorised
3.0.0	JUN 2006	Initial Issue	PAS		
3.0.1	30 OCT 2006	Clarification of low-frequency microwave link W/U and maximum link losses for UHF Telemetry.			
		Bibliography updated.	PAS	SJP	AAG
3.0.2	9 JAN 2007	Modification (relaxation) of the criteria for small turbines (of less than 100m2 swept area).			
		Minor amendments to clarify text and inclusion of Version Information Table.	PAS	SJP	AAG
3.1	July 2009	Major Revision	PAS	SJP	AAG

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1 Background

(1) The current Government drive to find renewable sources of energy has resulted in the rapid development of wind farms. Wind energy is likely to be the single greatest contributor to the Government's "10% by 2010" renewable energy target and "30% by 2020" renewable aspiration. But there is a downside. Wind turbines reflect radio energy and because of their large moving surfaces the effect is difficult to predict and constantly changing. The effect has been described as similar to a dance hall mirror-ball, although the number of reflecting surfaces on a wind turbine is smaller.

(2) Although this ability to reflect radio waves means that wind turbines have some sort of effect on all radio communications, the systems most affected are those that rely on a stable propagation environment such as aircraft radars, television and fixed data systems.

(3) Although the turbine blades are not of metallic construction they can nevertheless reflect and diffract radio waves. The lightning protection schemes built into turbine blades can further enhance their reflective radio properties.

(4) The interference effect of wind turbines on radar systems and analogue terrestrial TV systems have been investigated extensively. Ofcom, and its predecessor, the Radiocommunications Agency undertook some theoretical work on the potential for wind turbines to interfere with microwave fixed links but, because of the relatively small size of the market for utility telemetry radio systems, less research has been directed at this service.

(5) In 2002, the Radiocommunications Agency (now the Office of Communications) issued a paper that attempted to model the environment with respect to line-of-sight (LOS) microwave links and wind farms. The method described here is a modification of this LOS Microwave method that addresses the added complication offered by the fact that UHF links are often laid over obstructed paths.

(6) JRC has been assessing the potential for wind farms to cause interference to gas and electricity industry Ultra High Frequency (UHF) telemetry links for over five years. JRC has co-ordinated over 2500 wind farm applications in the last 18 months. These telemetry links in most cases are an integral part of the Supervisory Control and Data Acquisition (SCADA) systems used by utilities for monitoring and controlling their networks - including the infrastructure connecting the wind farms to the grid. Interruption to the reliable operation of these links compromises the integrity of the UK energy generation, transmission and distribution systems.

(7) UHF telemetry links are normally planned on the basis of approximately 99.9% availability. The assignment criteria is such that only the amount of power required to achieve this is licensed for use as per Ofcom OFW 49 assignment criteria.

(8) UHF frequencies are particularly suited to this application as a single hop can provide a reliable link over a 25 km path (up to 50 km under ideal circumstances) and it is not necessary to have a line-of-sight path from transmitter to receiver. This ability of UHF telemetry systems to operate over obstructed paths is the feature that creates the greatest potential for incompatibility with wind turbines.

(9) Because the wind turbines frequently occupy the higher ground and protrude above the landscape they act as massive radio reflectors such that the reflected path via the wind turbine can be superior to the intended path. The reflected signal can thus be strong enough to cause harmful interference.

(10) In order that JRC can assess the potential effect of a wind farm on existing telemetry links it was necessary to develop a methodology that, as accurately as possible, models the real-life situation. It is desirable that the model is as accurate as possible due to the substantial investments on both sides. Imprecise coordination could be extremely expensive to rectify post construction, and thus a rigorous, practical, science-based approach to the subject is essential.

(11) JRC may modify its criteria if more information becomes available due to practical experience and research into wind turbine interaction with radio links.

(12) In March 2009 OFCOM released a paper outlining practical tests carried out on wind turbines at various frequencies including 460 MHz, this confirms the interference potential (particularly reflections) of industrial size wind turbines and suggests that under certain conditions the problem may be greater than initially thought.

(13) The latest version of this document is always available at www.jrc.co.uk/windfarms

2 Determination of the Clearance Zone

(14) There are various issues to be examined when considering the potential for wind farms to cause interference to radio links:

Near field effects-
where a transmitting or receiving antenna has a near-field zone where local inductive fields are significant, and within which it is not simple to predict the effect of other objects.

Obstruction –
the physical obstruction to the radio path by a turbine structure that is attenuating the received and/or transmitted signal.

Diffraction –
although not directly obstructing the radio signal, because of the wave-like nature of a radio signal, large structures close to the radio path can cause interference patterns to be generated.

Reflection/Scattering –
where the radio waves are reflected or scattered off a large structure and interfere with the wanted signal, a more significant problem when the reflection surface is moving.

(15) At UHF frequencies and with the antennas types deployed for telemetry links, the near field clearance zones are always less than the other clearance zones and are therefore not usually used in the determination of the Clearance Zone.

(16) When protecting link availability approaching 99.9%, the wind turbine must be profiled in the worst case scenario, i.e. maximum horizontal profile, maximum radar cross section, maximum Doppler shift, etc. It is accepted that all of these conditions will not be fulfilled at all times, and in practice may only be for a small percentage of time. However, it must be remembered that the total tolerance for loss of service to such a link is no more than 0.1% of the time.

(17) The Clearance Zone is not an amalgam of the Diffraction and Reflection/Scattering Zones but simply the largest of the zones.

2.1 Determining the Diffraction Clearance Zone

(18) The Diffraction Clearance Zone used by JRC for evaluating wind farms on links below 1000MHz has been modified to the following:

- For structures with non-moving elements or small turbines having moving elements with less than 100m^2 swept area, the hub and tower must not infringe the 0.6 Fresnel zone.
- For structures with moving elements above 100m2, neither the tower, hub nor any part of the blades may intrude into the 0.6 Fresnel zone.
- For links above 1000MHz 2.0 Fresnel zones are still used.

(19) To this is added a buffer zone to allow for location accuracy of the link ends, turbine construction and ellipsoid conversion anomalies.

- Initially or where 8 digit NGRs, or 6 digit Landranger NGRs are used, 150 metres is added;

- where 12 digit NGRs have been supplied **and verified by JRC**, 25 metres is added; and
- an additional allowance is also added for turbine micro-siting; if this is unknown, 100m is assumed.

(20) No part of the turbine shall enter the Diffraction Clearance Zone.

(21) For example, the worst case 0.6 Fresnel zone clearance on a 25 km path would be ~50 m plus uncertainty; on a 4 km path this would drop to 20 m plus uncertainty.

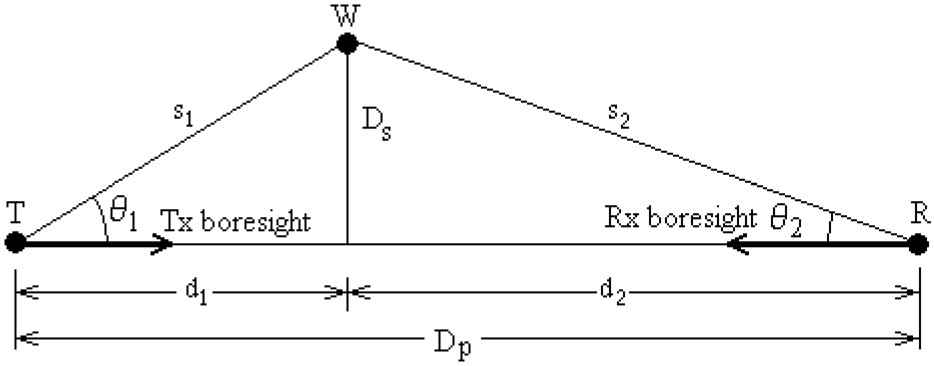
(22) When a link is 'line of sight' (LOS), turbine height and ground height in relation to the ray path and Fresnel zone are taken into consideration when calculating the clearance required for a detailed co ordination.

2.2 Calculation of the Reflection/Scattering zone.

(23) The David Bacon Method of determining the effects of reflection scattering on LOS microwave links as defined in the Ofcom document *"Fixed-link wind-turbine exclusion zone method" [1],* whilst not appropriate for determining clearance zones for non-line-of-sight UHF paths, can be used as a basis to determine the clearance required (with some modifications, see below).

Extract from the document.

A1.3 Reflection/scattering clearance zone



This zone sets a lateral distance from the radio path D_s to ensure that any multipath effects due to reflection or scattering from the wind turbine 'W' are negligible, as shown in figure A1.2. All distances are in km.

Figure A1.2: Reflection/scattering clearance zone

The ratio, expressed in dB, of the wanted signal level received from the direct T-R path divided by the worst-case signal level received from the indirect T-W-R path, is given by:

$$R_{ci} = 71 - S + 20 \log (s_1 s_2) - \sqrt{d_{1,2}^2 + D_s^2}\ 20 \log (D_p) + G_1(0) + G_2(0) - G_1(\theta_1) - G_2(\theta_2) \quad \text{(dB)} \qquad \text{(A1.3)}$$

where:

$s_{1,2}$	=		(km)	(A
S	=	$10 \log(\sigma)$	(dB)	(A
σ	=	Worst-case radar cross section of turbine	(m^2)	
$G_{1,2}(0)$	=	Antenna boresight gains	(dBi)	(A
$G_{1,2}(\theta_{1,2})$	=	Antenna gain at off-boresight angles θ	(dBi)	(A
$\theta_{1,2}$	=	angle (D_s , $d_{1,2}$)		(A

where the function 'angle' represents a generalised form of arctan (D_s / d) with protection against zero-divide for d=0, and returning a result in the range zero to 180 degrees.

End of extract from document.

(24) UHF telemetry links, unlike links that operate at higher frequencies (above 3 GHz), do not always operate over a clear line-of-sight path with no intrusion into the Fresnel Zone. This feature adds further complication to the David Bacon calculation and these additional considerations are discussed below.

(25) Low frequency microwave links (1300 to 1550 MHz) also do not always operate over paths with the first Fresnel zone clear. Consequently, the path loss of these links can also be greater than free space loss.

2.2.1 Additional considerations required when link path loss is greater than free space loss.

(26) Result of A1.3 – (PL [Dp]-FS [Dp]) + (PL [s1]-FS [s1]) + (PL [s2]-FS [s2])

FS = Free Space Path Loss: where FSL = 32.4+20logF[MHz]+20logD[km]

PL = Path Loss: derived from radio planning tool using ITU-R. 525/526 propagation model and a k factor of 4/3.

(27) This loss is computed for path loss using antenna heights, and turbine hub height. As it is impractical to measure the signal at hub height of the proposed turbines, JRC has to rely on predictions for this path. Consequently the predicted signal level is used for the wanted signal as well, the theory being that **IF** the paths are similar in horizontal angle then any inaccuracies will appear on both paths and cancel. If the angles are vastly different then a more in depth investigation into local clutter is required.

(28) The wanted/unwanted (W/U) ratio used by JRC for UHF telemetry links is 38 dB.

(29) JRC acknowledge that these figures taken in isolation appear conservative, but:

- The unwanted signal is a delayed image of the wanted signal and has continuously variable Doppler shift; this is a different scenario than normal co-channel interference or noise.
- The path losses used are computer predictions.
- The interaction of multiple turbines is difficult to predict accurately.
- Accurate RCS figures for different types/sizes of turbines at frequencies used by JRC links are not available. The algorithm JRC has traditionally used for calculating monostatic RCS at 460 MHz could be underestimating the RCS in light of tests carried out in the latest OFCOM sponsored report and also ifone were to back calculate the RCS from ITU-r BT805.

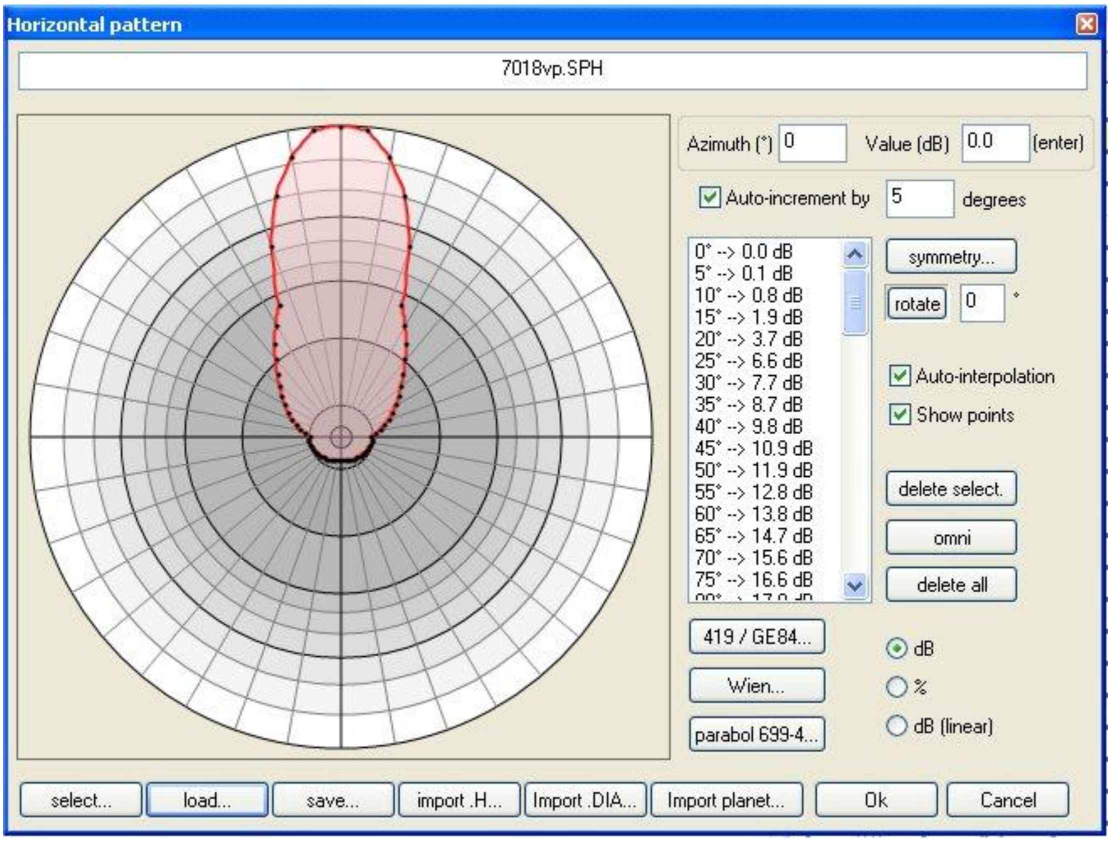
(30) Until more meaningful tests are carried out on different turbine types to determine an accurate maximum static and moving bi-static Radar Cross Section (RCS) across all pitch and yaw situations at JRC link frequencies (specifically 460 MHz and 1450 MHz) and long term tests are made on individual equipment types under these conditions, then 38 dB is considered a reasonable figure to use in these calculations.

(31) Utility telemetry systems generally use an omni-directional antenna with isotropic gain (dBi) between 2 and 8 dB at the scanning site. Yagi antennas with a gain between 11 and 17 dBi are generally used at the outstation.

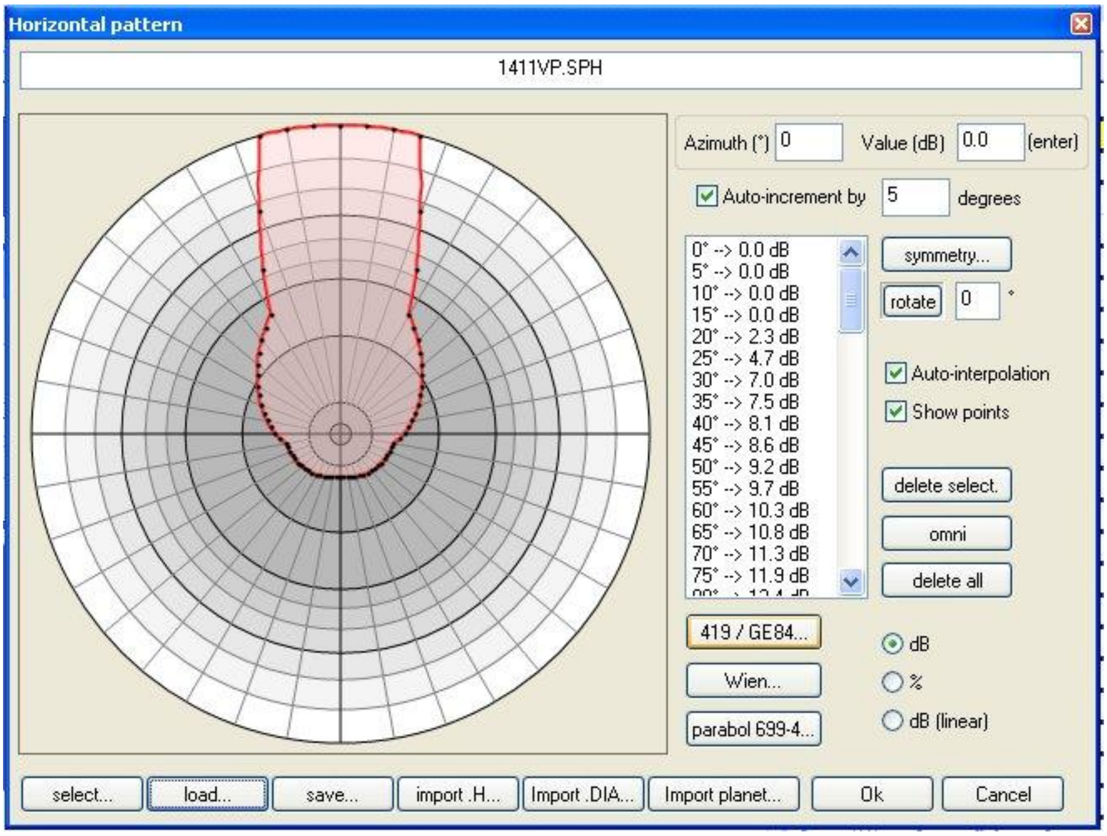
(32) Owing to the relatively flat response around the bore-sight of a Yagi antenna; the deep nulls in the polar pattern (up to 8 dB per 5°); and distortion of these nulls due to the effect of the mounting structure on their electrical characteristics, the accuracy of the nulls of Yagi-type antennas cannot be guaranteed. Thus a mask is used in preference to the actual polar pattern for response off bore-sight.

(33) The H-plane mask of one of the more popular outstation antenna in use compared with the RPE for a standard antenna as defined in VNS2111(formerly MPT 1411) is indicated in the figures below:

Horizontal polar pattern used in calculations, of a Jaybeam 7018 12 element vertically polarised yagi antenna. Gain is 14.2 dBi



Horizontal polar pattern for a standard antenna as defined in VNS2111. Gain is 11 dBi



(34) JRC will now use the RPE of the installed aerial or of the VNS2111 defined standard aerial in calculations, whichever has the better response.

(35) Generally, the scanner is on a high site installed on a mast in the region of 25 to 60 m above average ground level (AGL). Outstations normally have the antennas mounted at 4-10 m AGL, usually on the side of a low building or a free-standing pole.

(36) This means that when the turbines are close to the scanner end, the path advantage via the turbine is *generally* less than when the turbines are close to the outstation end.

(37) As the paths are not always line-of-sight with no Fresnel Zone incursions, there are instances where the full turbine profile can be seen from both ends of the link and the link has an obstructed path.

(38) When a turbine is close to an outstation it is not unusual for the additional loss compared to free space loss to be 10 to 15 dB worse on the direct path than via the turbine; in extreme cases this can be in excess of 30 dB.

(39) As the maximum allowed path loss in OFW 49 is 143 dB, a 10 km link ***could*** have as much as 37 dB loss above free space and still be acceptable.

(40) If the path loss of a link exceeds 143 dB and/or the received signal strength is below that specified in OFW 49 the link W/U will only be protected as if these parameters are met.

Extreme example path profile of a non LOS link with a wind turbine close to the outstation where the path via the turbine is significantly better than the direct path.

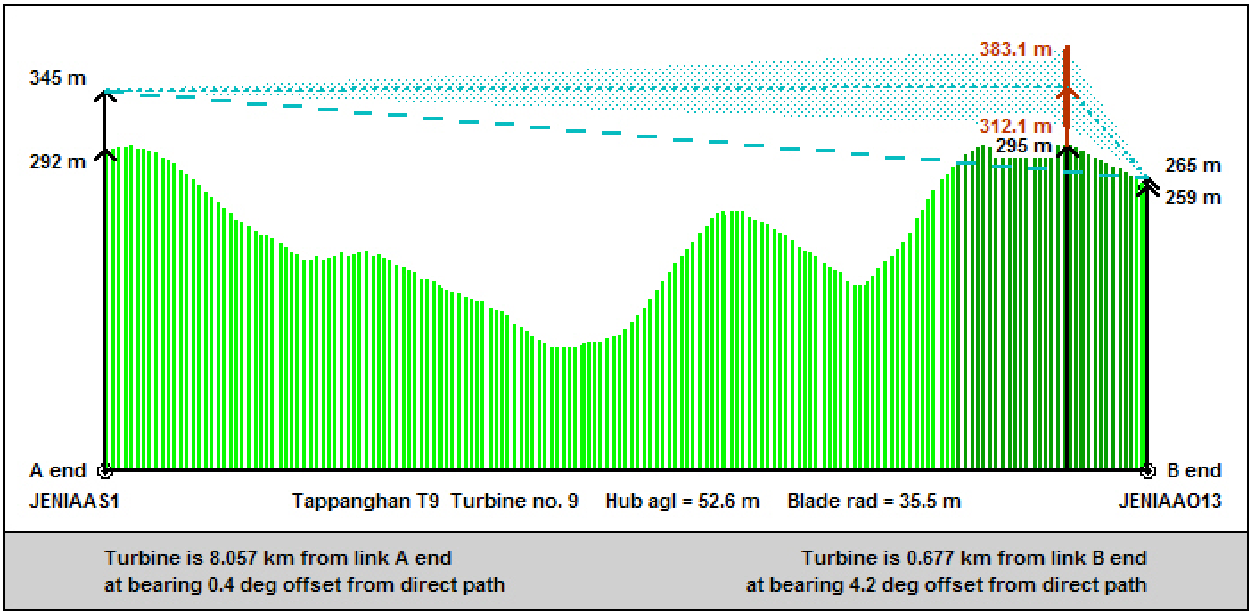


Table 2 – Simple example of <u>reflection</u> Clearance Zones for links, close to an outstation

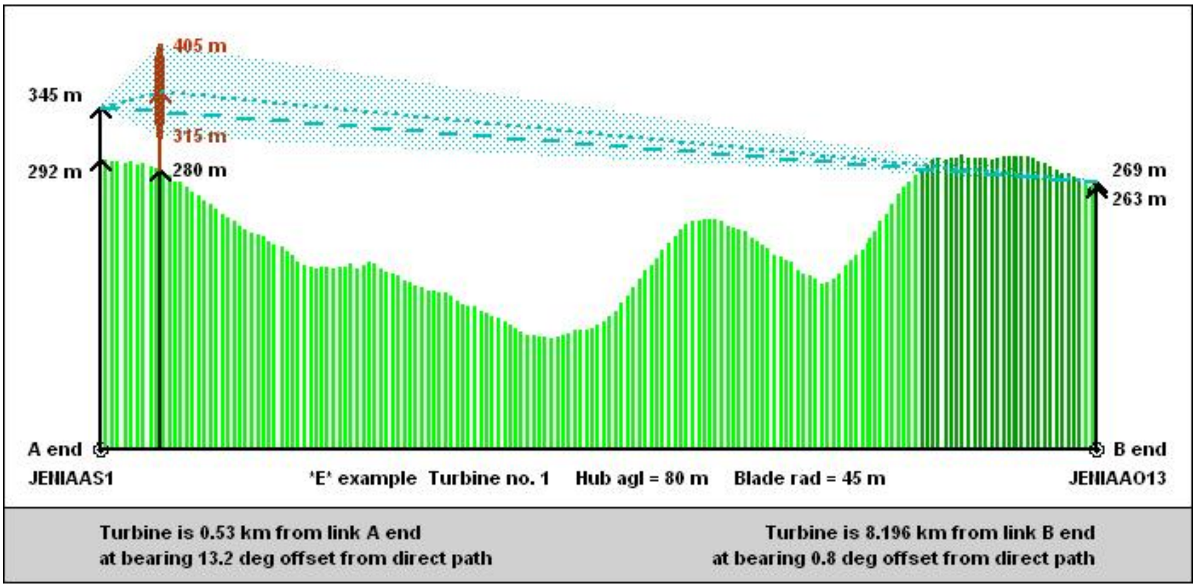
- against a turbine with an 90 m rotor (Peak RCS of +27.7 dBsm);
- for 38 dB W/U ratio at the outstation end;
- with paths of 20 km and 5 km where all the paths are free space;
- with the main path having 10 and 15 dB more loss with respect to free space loss than the reflected path;
- using a standard aerial as defined in VNS 2111
- assuming the antennas are in perfect alignment.

Path A-B m	RCS dBsm	Path Difference dB [NOTE 2]	Distance from O S along link m	Distance from Link m	T-B m	A-T m	Discrimination Angle OS degrees [NOTE 1]	Aerial Discrimination dB	W/U dB [NOTE 3]
20000	27.7	0.0	560	0	**560**	19440	0.0	0.0	**38.0**
20000	27.7	0.0	212	122	**245**	19788	30	7.0	**38.0**
20000	27.7	0.0	144	144	**204**	19857	45	8.6	**38.0**
20000	27.7	0.0	83	144	**166**	19918	60	10.3	**38.0**
20000	27.7	10.0	1900	0	**1900**	18100	0.0	0.0	**38.0**
20000	27.7	10.0	690	398	**797**	19314	30	7.0	**38.0**
20000	27.7	10.0	460	460	**651**	19545	45	8.6	**38.0**
20000	27.7	10.0	265	459	**530**	19740	60	10.3	**38.0**
20000	27.7	15.0	3750	0	**3750**	16250	0.0	0.0	**38.0**
20000	27.7	15.0	1260	727	**1455**	18754	30	7.0	**38.0**
20000	27.7	15.0	840	840	**1188**	19178	45	8.6	**38.0**
20000	27.7	15.0	480	831	**960**	19538	60	10.3	**38.0**
5000	27.7	0.0	620	0	**620**	4380	0.0	0.0	**38.0**
5000	27.7	0.0	220	127	**254**	4782	30	7.0	**38.0**
5000	27.7	0.0	147	147	**208**	4855	45	8.6	**38.0**
5000	27.7	0.0	84	145	**168**	4918	60	10.3	**38.0**
5000	27.7	10.0	2500	0	**2500**	2500	0.0	0.0	**35.2**
5000	27.7	10.0	780	450	**901**	4244	30	7.0	**38.0**
5000	27.7	10.0	500	500	**707**	4528	45	8.6	**38.0**
5000	27.7	10.0	275	476	**550**	4749	60	10.3	**38.0**
5000	27.7	15.0	2500	0	**2500**	2500	0.0	0.0	**30.2**
5000	27.7	15.0	1720	993	**1986**	3427	30	7.0	**38.0**
5000	27.7	15.0	970	970	**1372**	4145	45	8.6	**38.0**
5000	27.7	15.0	510	883	**1020**	4576	60	10.3	**38.0**

NOTE 1: "Discrimination angle" of interfering signal with respect to wanted signal
NOTE 2: "Path difference" is the Main/Reflected path difference with respect to the free space loss paths.
NOTE 3: Where the "path difference" exceeds 7.2 dB on a 5 km link, 38 dB W/U cannot be achieved anywhere along the link without aerial discrimination.

(41) When a turbine is close to the scanner, the difference in additional loss compared to free space loss on the two paths is less (generally in the region of 0 to 10 dB). However this is dependant on mast height, hub height and local topography, although it is offset by the omni-directional antennas generally used at the scanner end which have no attenuation of the unwanted signal.

The same extreme example path profile of a non LOS link with a wind turbine close to the scanner where the path via the turbine is only marginally better than the direct path.



(42) Table 3 – Simple example of <u>reflection</u> Clearance Zones for links, close to a scanner:

- against a turbine with an 90 m rotor (Peak RCS of +27.7 dBsm);
- for 38 dB W/U ratio at the outstation end;
- with paths of 20 km and 5 km where all the paths are free space;
- with the main path having 3 and 6 dB more loss with respect to free space loss than the reflected path; and
- using an omni-directional antenna. *(all distances in metres)*

Path A-B m	RCS dBsm	Path Difference dB	Distance from O S along link m	Distance from Link m	T-B m	A-T m	Discrimination Angle OS	Aerial Discrimination dB	W/U dB
20000	27.7	0.0	560	0	**560**	19440	0.0	0.0	**38.0**
20000	27.7	3.0	800	0	**800**	19200	0.0	0.0	**38.0**
20000	27.7	6.0	1150	0	**1150**	18850	0.0	0.0	**38.0**
5000	27.7	0.0	620	0	**620**	4380	0.0	0.0	**38.0**
5000	27.7	3.0	950	0	**950**	4050	0.0	0.0	**38.0**
5000	27.7	6.0	1580	0	**1580**	3420	0.0	0.0	**38.0**

NOTE 1: Discrimination angle of interfering signal with respect to wanted signal
NOTE 2: “Path Difference” is the Main/Reflected path difference with respect to free space loss.

(43) It should be noted that inversely in some instances the path via the turbine will be inferior to the wanted path in which case the clearance zone will be less.

2.3 RCS Modifier with respect to the reflection angle.

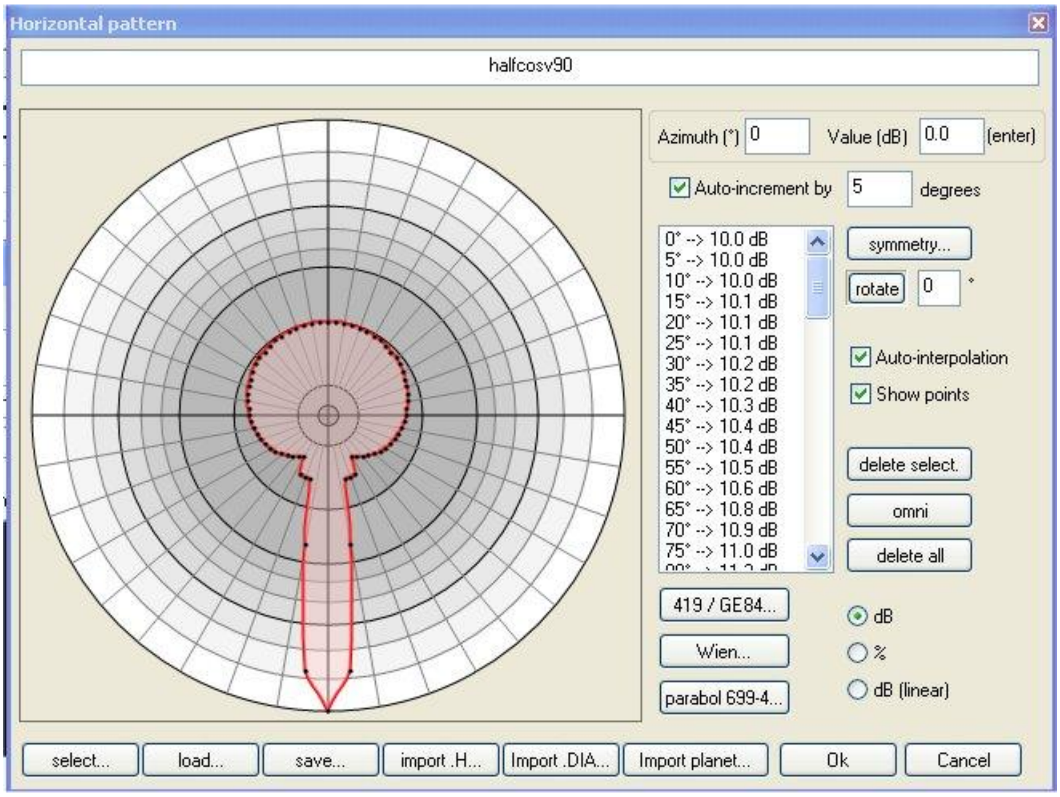
(44) The RCS figures used so far in this report are peak mono-static figures, that is, the transmitter and receiver are co-located and the return comes directly back off of the turbine. When considering turbines JRC is generally more interested in the bi-static RCS where the transmitter and receiver are not co-located. This varies with reflection angle. There are three additional zones:

* **Forward scatter** where the wanted and unwanted signal are from the same direction with the turbine directly between the A and B end, enhancing the mono-static RCS. For this JRC use the RA figure as defined in ITU-R BT805, the peak enhancement being 10 dB at 0 degree reflection angle. The thicker the blade the narrower the enhancement sector: the higher the frequency the smaller the enhancement zone. As an example on a 90m turbine at 461 MHz some enhancement occurs over a +/- 11 degree reflection angle.

* **Side Scatter** this occurs between the forward scatter zone and a reflection angle of 180 degrees. This will reduce the mono static figure depending on reflection angle. A turbine is a difficult structure to assess as it's a mixture of flat, round spherical and tapered surfaces that all have different responses with respect to reflection angles. JRC has produced a compromise for the reduction used.

* **Angles close to the forward scatter zone:** there is an area where there is some forward scatter that is below the mono static RCS value but above the reduction due to reflection angle.

An example; the polar response of a 90m rotor diameter turbine, used by JRC when analysing reflections. Peak RCS is 37.7 dBsm. Mono Static RCS is +27.7 dBsm.



(45) JRC now also cross references ITU-R BT805 - the recommendation used for impairment caused to television reception by a wind turbine (That uses similar frequencies and aerials as scanning telemetry), but with the addition of JRC side scatter reduction using 22 dB as the Wanted/Unwanted ratio when the reflected delay is not greater than 0.25 of symbol time. Reference is also made to the normal radar formulae as a cross check with the basic JRC method.

Comparative figures used for a 90m turbine in analysis.

Frequency	461.00 MHz
Turbine Blade Diameter m	**90.00**
Turbine Blade width m	2.54
Turbine Blade Area m^2	85.56
RCS Monostatic dBsm JRC	27.67
RCS Factor Monostatic dB JRC	42.41
RF-BT 805 dB	17.62
Equivalent JRC RCS using BT805	43.38
Equivalent JRC RCS using BT805 Worst FS	53.38
Diff Mono RCS JRC - BT805	15.70

2.4 The Effect of Multiple Turbines.

(46) **If** the unwanted signal was considered as interference then:

- two turbines with the same calculated W/U will degrade the resultant W/U by 3 dB IF the interfering signals arrive in phase;
- four turbines will degrade the W/U by 6 dB; and
- eight turbines by 9 dB (10 log no of turbines).

(47) There are however normally predominant turbines when analysing turbine interference. If there were:

- two turbines and the second turbine's predicted W/U was 10 dB better than the first, the resultant W/U degrade would be ~0.5 dB;
- four turbines and the other three turbines predicted W/U were 10 dB better than the first, the resultant W/U degrade would be ~1.2 dB;
- eight turbines and the other seven turbines predicted W/U was 10 dB better than the first, the resultant W/U degrade would be ~2.3 dB.

(48) In analysing scenarios, JRC now initially considers the addition of **all** turbines within 1000m of a link below 1000 MHz (500m above 1000MHz). The resultant W/U is calculated as if the interfering signals were in phase.

2.5 Low Frequency Microwave Links

(49) This document is primarily intended for the evaluation of 460 MHz UHF links. The formulae used are relevant for 1400 MHz links although the W/U required is 49 dB for a class 4 link and 42 dB for a class 2. The class 4 link requirement figure is close to that suggested for digital links in the "Fixed-link wind-turbine exclusion zone method" [1].

3 References

[1] **Radiocommunications Agency -**
Title: "Fixed-link wind-turbine exclusion zone method"
Author: D F Bacon
Status: released 28 Oct 2002
Version: 1.1 (Current Version)
URL: http://www.ofcom.org.uk/radiocomms/ifi/licensing/classes/fixed/Windfarms/windfarmdavidbacon.pdf

[2] **QinetiQ (for DTI)-**
Title: "Wind farms impact on radar aviation interests"
Author: Gavin J Poupart (Prepared by)
Status: Final report, September 2003
Version: DTI PUB URN 03/1294
URL: <http://www.dti.gov.uk/energy/page18050.html>

[3] **OFW 49**
Title: "Frequency Assignment Criteria, Scanning telemetry radio services operating in the band 457.5 to 458.5 MHz and 463 to 464 MHz in which spectrum is managed by the Radiocommunications Agency." The previous RA version of the document is designated RA 375 and before that MPT 1411.

[4] **VNS2111**
Title "Performance Parameters for Scanning Telemetry and Telecontrol Systems Operating in the Frequency Band 457.5 MHz to 464.0 MHz"

[5] **ITU-r BT805**
Title: "Assessment of impairment caused to television reception by a wind turbine"

[6] **Ofcom Independent Report**
Title: "RF Measurement Assessment of Potential Wind Farm Interference to Fixed Links and Scanning Telemetry Devices", published in March 2009
URL:. http://www.ofcom.org.uk/radiocomms/ifi/licensing/classes/fixed/Windfarms/rf_measurement/

4 Acronyms & Abbreviations

dBsm = decibel square metres, an alternative way of expressing RCS, equivalent to 10LOG(RCS) in m^2 .

Fresnel Zone

(pronounced FRA-nel Zone), named for physicist Augustin-Jean Fresnel, is one of a (theoretically infinite) number of a concentric ellipsoids of revolution which define volumes in the radiation pattern of a (usually) circular aperture. Fresnel zones result from diffraction by the circular aperture.
More: <http://en.wikipedia.org/wiki/Fresnel_zone>

Harmful Interference:

Interference which endangers the functioning of a Radionavigation Service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with the ITU-R Radio Regulations.
(International Telecommunication Union Radio Regulations)

Interference:

The effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, or loss of information which could be extracted in the absence of such unwanted energy.
(International Telecommunication Union Radio Regulations)

Microwaves:

Microwaves are electromagnetic waves with wavelengths longer than those of Terahertz (THz) wavelengths, but relatively short for radio waves. Microwaves have wavelengths approximately in the range of 30 cm (1 GHz) to 1 mm (300 GHz). However, the boundaries between far infrared light, Terahertz radiation, microwaves, and UHF radio waves are fairly arbitrary and are used variously between different fields of study. For instance, in the David Bacon Report the term effectively referred to frequencies above 3 GHz where radio links are increasingly line-of-sight with respect to increasing frequency.
More: <http://en.wikipedia.org/wiki/Microwave>

RCS

A term that represents the radar "size" of an object, the Radar Cross Section in square metres. Note that it gives an equivalent area that represents how much power is reflected and does not correspond to physical size. Sometimes expressed as dBsm, decibel square metres (10LOG RCS in square metres).
More: <http://en.wikipedia.org/wiki/Radar_cross_section>

UHF

Ultra High Frequency – officially defined as the range 300 MHz to 3000 MHz and includes part of the region often referred to as “Microwaves”.
More: <http://en.wikipedia.org/wiki/UHF>

W/U

Wanted to Unwanted (ratio). The ratio of the wanted signal with respect to the unwanted. Usually expressed in decibels.