APPENDIX 17

Sapphire Wind Farm, NSW – Investigation of Possible Impacts on Radiocommunication Services

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EXECUTIVE SUMMARY

Wind Prospect are developing a proposal for the construction of the Sapphire Wind Farm near Glen Innes in NSW.

A large number of existing ACMA registered radiocommunication services are located in the general area and three point-to-point radio services cross the wind farm nominal site boundaries. To ensure that the locations of turbines will not potentially degrade the performance of radio systems minimum separation distances and exclusion zones are to be established for the turbine structures. The area surrounding the wind farm is also provided with TV, FM Sound and other services from high power transmitters located on Mt Dowe (Upper Namoi), and from low power stations near Glen Innes, Inverell and Emmaville. Identification of the TV/Sound providers providing service to the area is required to facilitate correspondence with the organisations involved to request an impact assessment on these services.

This Report provides an analysis of each of the radio facilities registered near the wind farm and establishes recommended clearances based on accepted industry criteria for radio links crossing the wind farm and any required buffer zones for other radiocommunications sites.

1 INTRODUCTION

Two proposed layouts of wind turbines are being considered for the site, one with 80 metre diameter rotors and the other with 112 metre diameter rotors. The coordinates of the wind turbines for both cases provided by Wind Prospect CWP are shown in Attachment 1.

1.1 Objective of this Study

The objective of this study and Report is to determine the clearance requirements for the radio services in the area to allow a turbine layout to be planned so that there will be no detrimental effects on the performance of the existing services. The object also is to derive a minimum required buffer zone for the omnidirectional services including mobile radio base stations and any nearby TV/ FM Broadcasting transmitting station while ensuring an acceptable grade of protection to the coverage required in the service areas of each service. A check that the proposed turbine layouts meet the required clearance criteria is also required.

1.2 Scope

The criteria for clearance of obstructions from point-to-point link ray lines has been well established in the literature including for the specific case of rotating turbines. For omnidirectional mobile and other services however any need for a buffer zone is usually dismissed on the basis of the accepted variability of coverage to/from the mobile or hand held terminals in the normal operational environment. The known exception to this is the SA DTEI guidelines prepared by Telstra where an exclusion zone for the SA – GRN 400 MHz mobile radio base stations has been derived. This Report considers the factors involved in the specific services in the area and proposes what are considered to be acceptable clearance zones.

The possible impact on Free-to Air TV and Radio Broadcasting services to residents near the wind farm is outside the scope of this Report however the appropriate Organisations operating these services which cover the general proximity of the wind farm have been identified for future contact with them.

1.3 Assumptions

The source of data for the existing services in the area is the ACMA data base for licensed radiocommunication services both from a recent issued CD and the ACMA public web site. The accuracy of the location of towers is that contained in the data base, shown in some cases to be within 10 metres and in the others within 100 metres. No check survey has been carried out.

It is also assumed that modern wind generators are well shielded to international standards and are not the source of any significant generated electromagnetic interference in the frequency bands used by radio services in the area. This report considers the reflection, scattering or obstruction of signals to the radio services, potentially caused by close spacing of the turbines

2 WIND TURBINE IMPACTS ON RADIO COMMUNICATIONS

A paper, Ref 1, by D. F. Bacon in 2002, issued by Ofcom, the regulator for the UK communications industries, appears to have become the most used reference by the industry for the calculation of clearance zones from turbines to the ray line and antennas for point to point links. The Paper identifies three principal mechanisms which are relevant to a wind turbine in proximity to a microwave link. These are:

2.1 Near-field Effects

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. Bacon's paper provides the well known formulae for calculation of the near-field distance depending on the gain or physical aperture of antenna. The near field distance is a function of frequency and the physical dimensions or gain of the antenna

2.2 Diffraction

An object detrimentally modifies an advancing wavefront when it obstructs the wave's path of travel Here the formula applied is for the classical Fresnel zone distance where diffraction will be insignificant if obstructions are kept outside a specified volume of revolution around a radio path.

2.3 Reflection

The physical structure of the turbine and in particular the rotating turbine blades reflect interfering signals into the receiving antenna of a fixed link. A formula is given in Bacon's Paper to derive a distance from the radio path where any reflected/scattered signal will be of an amplitude sufficiently smaller than the direct signal arriving at the receiver. The acceptable Carrier/Interference (C/I) ratio will depend on the modulation and coding schemes of the link. Bacon's Paper provides formulas to calculate the distance from the link path where the C/I will be below a desirable level depending on the link parameters.

The calculation of the scattering level of RF signals from turbines is complex and varies with RF frequency, physical dimensions of the turbine blades and their twist, tilt and orientation. Radar Cross-section (RCS) values are used in the Bacon paper and elsewhere to account for the scattering characteristics of individual turbines. A wide spread of values appear in the literature for typical modern turbines which makes the estimation of the scattered signal levels uncertain. It is noted that the Bacon Paper uses an RCS value of 30 m^2 whereas the SA DTEI guidelines uses a value of 480 m^2 which is the total area of the 3 blades based on an assumed width of 4 metres each and lengths of 40 metres. In another British, study Ref. 2, the RCS of turbines were modelled and validated with actual field measurements. This study was focused on the aviation radar signatures of wind farms and measurements were carried out with radar in the 1 to 3 GHz range. Peak RCS values can significantly exceed the physical area of the turbine but they will occur over narrow arcs. The wind generator nacelle and the general shape of the tower itself can make significant contributions. A 100metre tall tower with 45 metre turbine blades was estimated to have a maximum peak RCS of 25000 m^2. According to the Report this high peak was probably associated with a particular style of nacelle and tower. For the purposes of this study a peak of 1000 m^2 associated with the blades is considered appropriate. The RCS will of course vary with wind direction, blade pitch and other design factors including rotor tilt and coning angle. Multiple turbine interference from a wind farm will also be additive on a power basis due to the uncoordinated sources.

2.4 Omnidirectional Services

The Bacon paper was written for the point-to point-radio link situation and no omnidirectional system (eg mobile radio base station) was considered. The DTEI guidelines have been developed for omnidirectional mobile services from the Bacon paper by applying the formula for the point-to-point link reflection/scattering case to an omnidirectional service. It further derives another criterion for the case where the remote mobile/portable unit is located at points where a turbine is in line with the transmission path to the base station. A criterion of no more than 10% of the fresnel zone width being blocked by a blade width of 4 metres appears to have been employed to derive an exclusion zone. This purports to limit signal variations as a result of the turbine to 0.5 dB

3 RADIO SERVICES LOCATED NEAR SAPPHIRE WF

From the latest ACMA database, maps have been prepared showing registered radio sites and point-to-point links in the area. Attachment 2 shows the situation for systems with frequencies below 1000 MHz with zoomed views in Attachments 3 & 4. Attachment 5 shows the links and sites for systems operating on frequencies above 1000 MHz. Typical calculations of required clearances are shown in Attachment 6 using the formulas in Bacon's paper

3.1 Point-to-point Systems

The radio link maps have been examined and the links crossing the wind farm site and near radio sites have been identified from the ACMA data. There are 3 Point-to-point links in the 45 MHz, 400 MHz and 8 GHz bands operated by Trans Grid, Ambulance Service of NSW and Soul Pattinson Telecommunications respectively on 3 paths which nominally cross the site. Three radio sites which are located outside the wind farm boundaries but are close enough to be considered from a buffer zone point of view have also been examined. A summary of the calculated Near Field and 2nd Fresnel zone clearance at mid-path and at 1 KM are shown below. No radio sites within the wind farm boundaries were identified from an analysis of the ACMA data. The locations of the turbines for both layouts have been shown in the link maps generated in MapInfo and were used to confirm that distances from radio link ray lines and the turbine tower centrelines meet the clearance criteria.

PATH ACMA Site ID's	Total Path Dist. km	ANTENNA Dia. or Gain/ frequency	Near Field Distance M	Mid Path Fresnel Zone Distance M	1 Km Fresnel Zone Distance M
55450-6909	119	8.2dB/45 Mhz	14.7	630	115
250528-6915	64.7	14.2dB/400 MHz	6.6	156	38.4
6863-6864	56.75	2.4M/ 8GHz	461	32.6	8.6

It is interesting to note the large near field distance calculated of 461 metres for the Soul Pattinson 8GHz link which is due to the high gain antennas used. According to the Bacon paper a 360 deg. zone of this radius around each end of the link ends should be kept clear of obstructions. This seems a very conservative constraint for a high gain dish antenna where most of the energy exists in a narrow beam. However as the link sites are remote from the site boundaries this clearance is not an issue for this project.

The calculation of the reflection/scattering zone using the Bacon formula requires iteration with increasing values of the distance from the path bore sight at each distance from the terminal until the required C/I value is reached. For the three links which cross the wind farm all have terminal/repeater sites well separated from the site and the scattering effect will be negligible.

3.2 Nearby TV & FM Broadcasting Stations at Glen Innes, Inverell Emmaville.l

Nearby low power TV and FM Broadcasting stations for Glen Innes are located on Carpenters Hill (ACMA Site ID's 9955 & 151348). and the sites are about 12.5 km from the nominal eastern site boundary. Low power TV/FM Sites also exist to serve the Inverell area from sites 6831 and 150296 and for Emmaville from site 151357. All of these sites are separated from the wind farm by sufficient distances to not require any further buffer zone requirements

3.3 Air Services Facilities

There are no registered Air Services Radar sites within line of site of the turbines. Non Directional Beacons (NDB's) are located at sites 6827 and 6830 in the Inverell area and there is a ground to air communications base at site 6931 at Glen Innes. Due to the separation distance from the wind farm boundaries of these sites no addition buffer zones are required

3.4 Other Radio Sites

The following table lists sites which are adjacent to the wind farm site boundaries and need to be considered from a buffer zone point of view

Site/Service	Antenna Gain/frequency	Near Field Distance M	Scattering Clearance M
6837/ 80 MHz Dept of Enviro. & Conserv. Mobile Radio Base	Omnidirectional 2.2 dBi gain, 80MHz/	2.1	200*
6864 / 160 MHz Telstra Mobile Radio	Omnidirectional 5.2 dBi gain, 160 MHz	2.1	200*

Base			
6864 / 3.4 GHz P to MP Telstra base	Omnidirectional 10 dB gain, 3400 MHz	0.3	300**
9004089/ 148 MHz CCA Paging Service Base	Omnidirectional 2.2 dBi gain, 148MHz	1.2	200*

* C/I of >26 dB
**C/I of >30 dB

As the scattering clearance calculated is much less than the separation of these sites from the wind farm boundaries no further clearance is required

4 DISCUSSION

The Calculations for the scattering cases summarised above are based on a reasonable high RCS for the turbines and represent a peak level, bearing in mind that the scattering from a turbine will vary with its orientation which changes with wind direction and speed. For the near field calculations a conservative factor of 3 has been applied as suggested by Bacon. Also the Bacon suggested second Fresnel zone clearance has been used which is also reasonably conservative, although Ref. 6 has suggest that 3 times the first Fresnel zone distance could be applied. No account has been taken of the topography of the area including possible obstructions to either the wanted signal or turbine locations at specific locations where portable or mobile units may be used or where FM broadcast receivers in cars or residences may be operated.

The Telstra SA – GRN Guideline has an additional criteria for omnidirectional services which covers the case of mobile or portable radio units being operated in a situation where the path to/from the base station has a turbine in the first Fresnel zone on the radio path. This of course applies to both ends of the link ie near the base station and near the mobile/ portable unit. The 1200metres zone proposed in the guideline would equally apply throughout the mobile service area which could be 30 Km in radius. The outcome of this is that operation of the terminals would need to be protected within 1200 metres from each turbine wherever it was located in the mobile service area. A clearance zone from a base station site for this criteria is therefore not considered feasible A review of a number of reports available on radio system clearances to wind farm have not considered this issue. For example two reports, Refs 4 & 5 which considered base station clearances to turbines derived the clearances required using the scattering criteria. In one (Ref 5, BCL NZ) a clearance of 600 metres was derived for VHF mobile base stations and the other (Ref 4, Kordia NZ) 320 metres for both VHF and UHF mobile bases. Differences in assumptions about turbine RCS and safety margins appear to account for the differences in distance in these two reports.

4.1 Point-to-point Links

The clearance distance from the link sites can be theoretical controlled by the near field distance for example one link on site 6864 requires a buffer zone of 641 Metres which according to Bacon applies to in all angles of azimuth. As shown in the table above link paths require Fresnel zone clearance of between 33 and 630 metres at mid path of the link depending on path length and operating frequency. The Fresnel zone clearance is tapered, increasing from 0 at both ends of the links with the maximum at the mid path points. The systems on two of the paths which nominally cross the boundaries of the wind farm site are single channel analogue or low capacity data links in the VHF or UHF bands. From the path profiles shown in attachments 7 and 8 the VHF path does not have 1st Fresnel clearance and the UHF path appears to be terrain obstructed. Although it is accepted that a second Fresnel turbine clearance should be applied to higher frequency microwave links of multi-channel capacity and is desirable for the low frequency links it could be argued that it is not essential to apply it to the VHF or UHF links on the grounds of small impact on these links. If the application of these calculated corridor widths significantly reduces the utility of the site because of reduced number of turbines possible these clearances should be reviewed in conjunction with the link operators. The third link is a multichannel microwave link in the 8 GHz band and the full clearance should be maintained

4.2 TV & FM Broadcasting Services

These are omnidirectional services and have similar requirements to mobile base stations with regard to clearance zones for scattering. Based on the controlling scattering criteria a clearance of 300 metres is estimated as having negligible impact on the service coverage. For TV there is the possibility of ghosting or other effects occurring over a significant part of the service area from close spaced towers or turbines to the transmitters. For the local low power TV and FM stations mentioned above there is sufficient spacing to the nearest turbines to have negligible effects. There will however be a potential to have TV reception impaired at residences close to the turbines from the main and local station(s) serving the residences in area around the wind farm.

4.3 Mobile Base Stations

Once again the controlling criteria is the Scattering mechanism. 200 metres has been calculated for the Mobile and Paging base stations. A higher C/I ratio has been used for the Telstra P to MP base station resulting in a 300 metre clearance.

5 RECOMMENDATIONS

5.1 Point-to-point Links

As there are three paths which cross or are very close to the site, horizontal corridor clearances for those are summarised below. Path profiles are shown in Attachments 7, 8 and 9. These horizontal clearances are specified on the basis that a similar vertical clearance is not achieved over the tip of the turbine blades at the turbine locations. Although the Fresnel zone clearance requirement is tapered, increasing from low values near the link ends to maximum at mid path it is proposed that that a simple fixed width corridor be defined. Corridor widths of the mid path clearances should be employed which will cover the scattering clearances which apply close to the link end points and are larger than the Fresnel clearances at these end locations. For the two links the following corridor clearances should be maintained: Please note the comments in 4.1 above regarding a review of the clearance distances if they are too restrictive on the site layout.

LINK A – B (ACMA Link ID's)	**TOTAL CORRIDOR WIDTH Metres Note 1**	**SITE A COORDS AMG 66 Z56**	**SITE B COORDS AMG 66 Z56**
55450-6909	1260m*	E315220 N6783350	E372915 N6679480
250528-6915	312m	E359788 N6748135	E330600 N6690360
6863-6864	65m	E365950 N6707332	E309241 6705419N

* If this clearance corridor is a significant impediment to the deployment of turbines on the site it should be reviewed. The link involved is operated on a low VHF frequency and the impact of a turbine in the clearance zone may be very small.

Note 1 No part of a turbine should protrude into the corridors. With a turbine rotor diameter of say 80 metres the centre line of the turbine towers should be at least 1260/2 + 80/2 = 670 metres from the 1st listed Link ray line.

The radio link paths in relation to the turbine layouts superimposed on the MapInfo maps showed that the required clearance above are met for 2 of the radio links which traverse the wind farm site for both the 80 metre and 110 metre diameter rotor alternatives .However in relation to the NSW Ambulance link one turbine is located within the clearance zone for both layouts as summarised in the table below:

Radio Link & Turbine Layout	Nearest Turbine Tower & Dist from Path	2nd Nearest Turbine Tower & Dist. From Path	1st Fresnel Radius	Total Blade Area* in Fresnel Zone Area %
NSW Ambulance 80 m Rotor	T155 – 21 m	T157 – 186 m	110 m	<1%
NSW Ambulance 110 m Rotor	T120 – 21 m	T121 – 237 m	110 m	1%

*Estimated planform area of 3 blades of approx. 390 m²

Given the low frequency of operation of this link and the area of the blades in the Fresnel zone area at that location being approximately 1% of the first Fresnel zone area it is considered unlikely that there will be any detrimental effects on the link performance. It is recommended however that written agreement be requested from NSW Ambulance to accept this situation.

5.2 General Buffer Zones

Taking into account all omnidirectional services scattering zone requirements and the near field clearances required for the longer distance Links a clearance circle centred on the radio towers of radius 461 metres is the clearance zone required from the worst case (sites 6863 & 6864) theoretical calculations. However due to the uncertainty in the turbine RCS assumptions and allowing for multiple turbine contributions to interference to any location it is proposed to increase the clearance radius to a recommended 1000 metres. All radio sites are greater than 1000 metres from the wind farm nominal boundaries so no buffer zones are required.

5.3 Possible Interference to Television reception

The area around the wind farm is in the Northern New South TV1 Licence area. The Upper Namoi Main Television stations at Mt Dowe would generally service the area with lower power translator stations at Glen Innes, Inverell and Emmaville.

The operators are:

- ABC
- SBS
- NBN Ltd
- Prime Television (Northern) Pty Ltd
- Northern Rivers Television Pty Ltd

It is recommended that these organisations be advised of the wind farm proposal and be requested to comment on any issues they have from a TV coverage impact point of view.

6 REFERENCES

[1] Fixed-Link wind-turbine exclusion zone method, Version 1.1, 28 October 2002, D.F. Bacon, UK Radio Communications Agency,

[2] Guidelines for Minimizing the Impact of Wind Farms on the SAGRN, Issue 1, 22 October 2003, Rohan Fernandez, Telstra SA, Document TR049-SA

[3] Wind Farms Impact on Radar Aviation Interests-Final Report, September 2003, FES W/14/00614/00/REP, Contractor QinetiQ Prepared by Gavin J Poupart.

[4] Mahinerangi Wind Farm, Compatibility with Radio Services, 3 April 2007, Anton Pereira & Richard Brown, Kordia NZ

[5] Project Hayes, Compatibility with Radio Services, 7 July 2006, Duncan Chisholm, BCL NZ

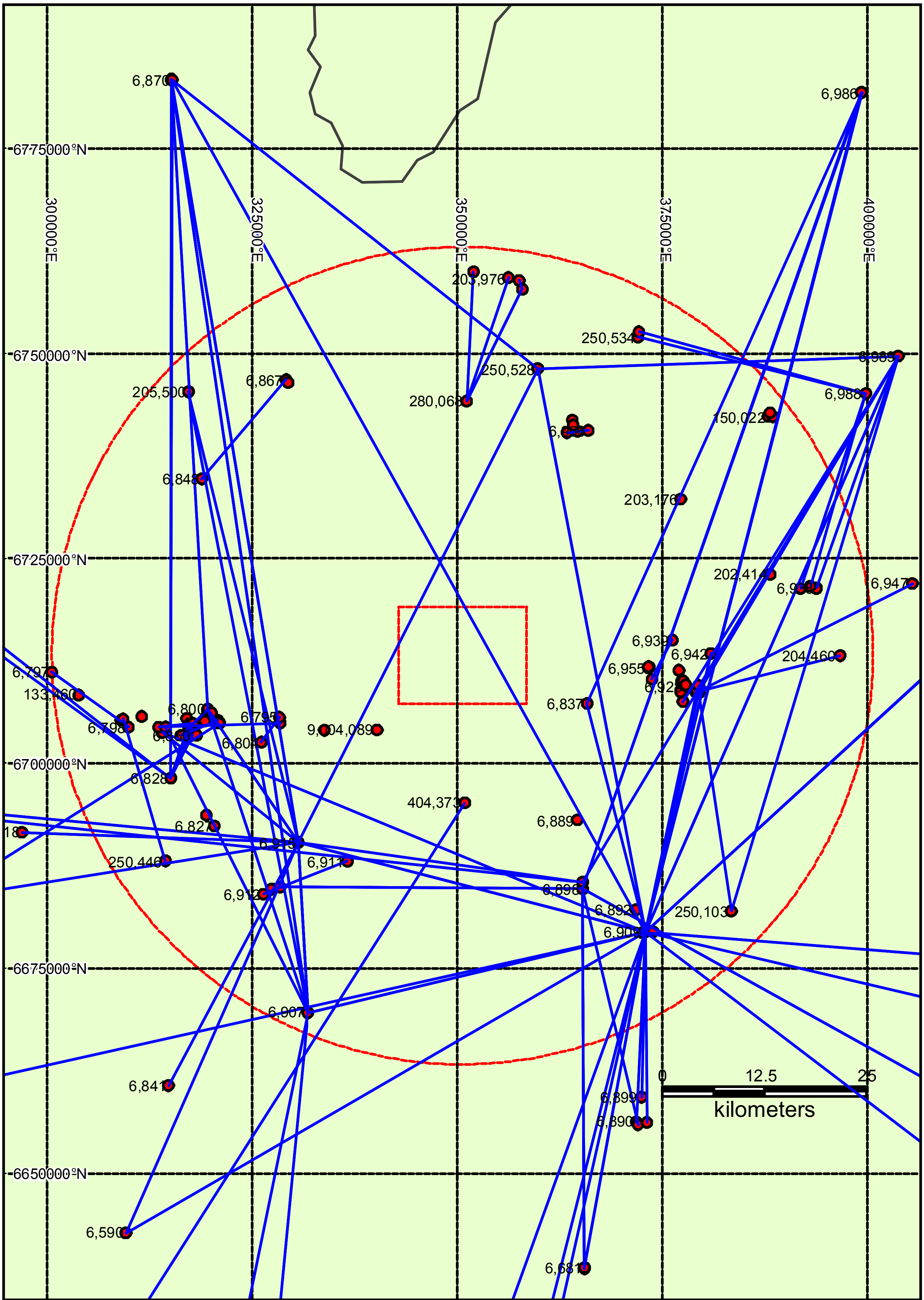
[6] Electromagnetic Interference from Wind Turbines, Sengupta & Senior, Chapter 9, Wind Turbine Technology Ed. David E. Spera ASME Press 1994

ATTACHMENT 1

WIND FARM SITE MAP SAPPHIRE

ATTACHMENT 2

MAP OF RADIO LINKS & SITES OPERATING BELOW 1000 MHz



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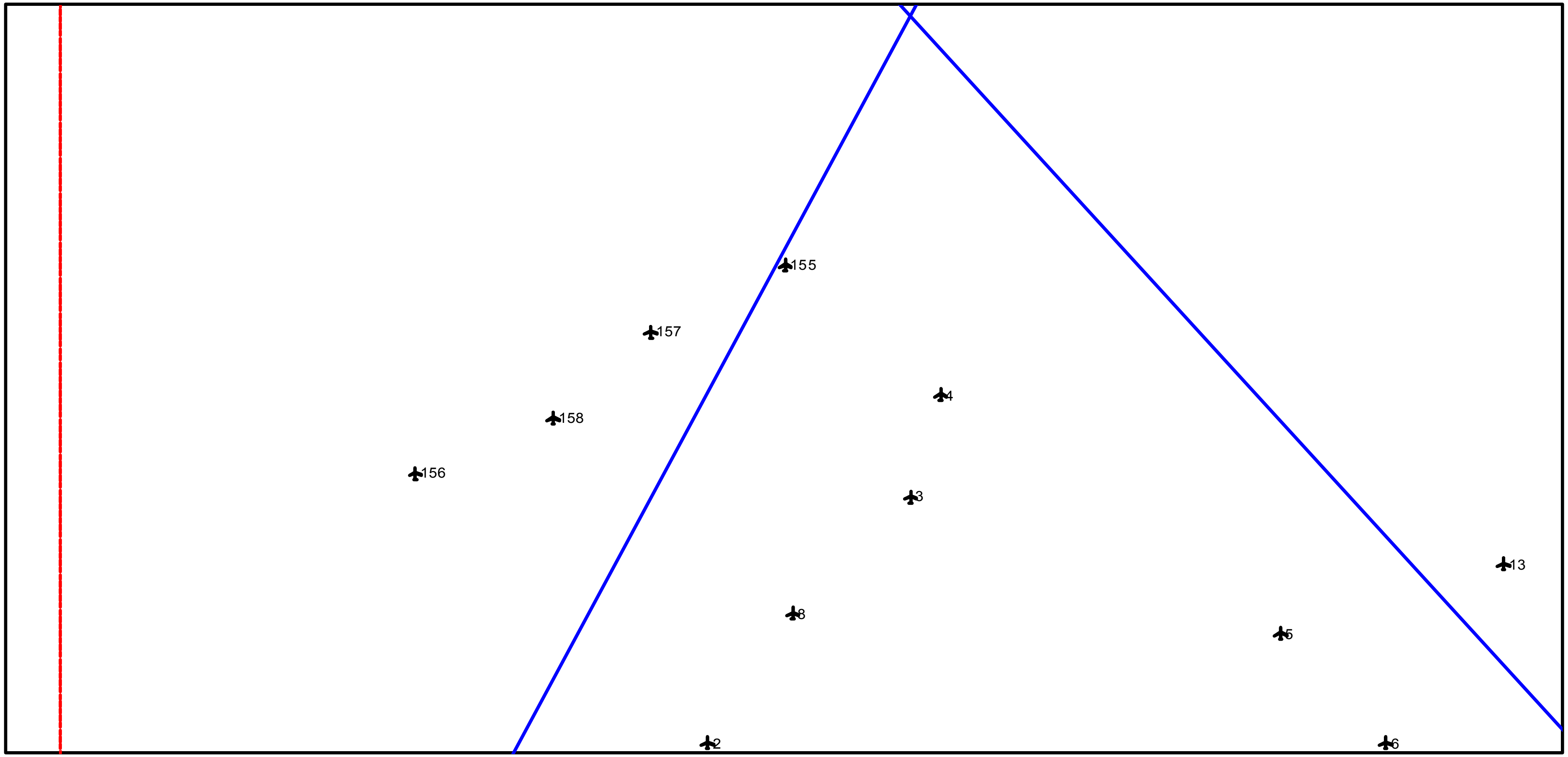
TITLE:
40-999 MHz Assignments
As Extracted from RRL Database

FILENAME:	40-999 MHz Table Top New	DATE:	17/1/2011
PROJECT:	Sapphire New	SCALE:	N/A
DRWG NO:	1 of 2	BY:	SEA

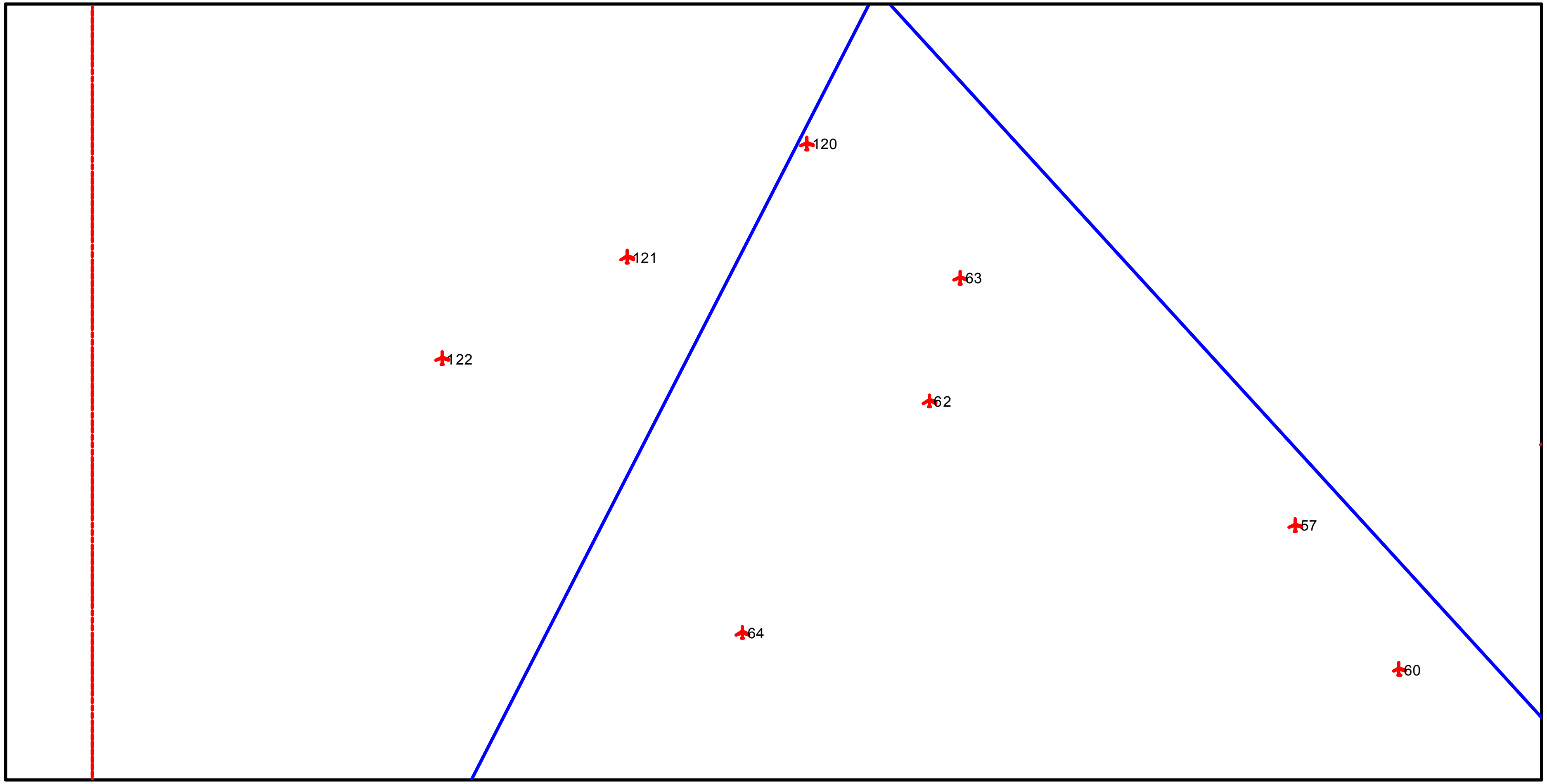
ATTACHMENT 3

MAP OF RADIO LINKS OPERATING BELOW 1000 MHz –DETAIL 80 METRE ROTOR LAYOUT



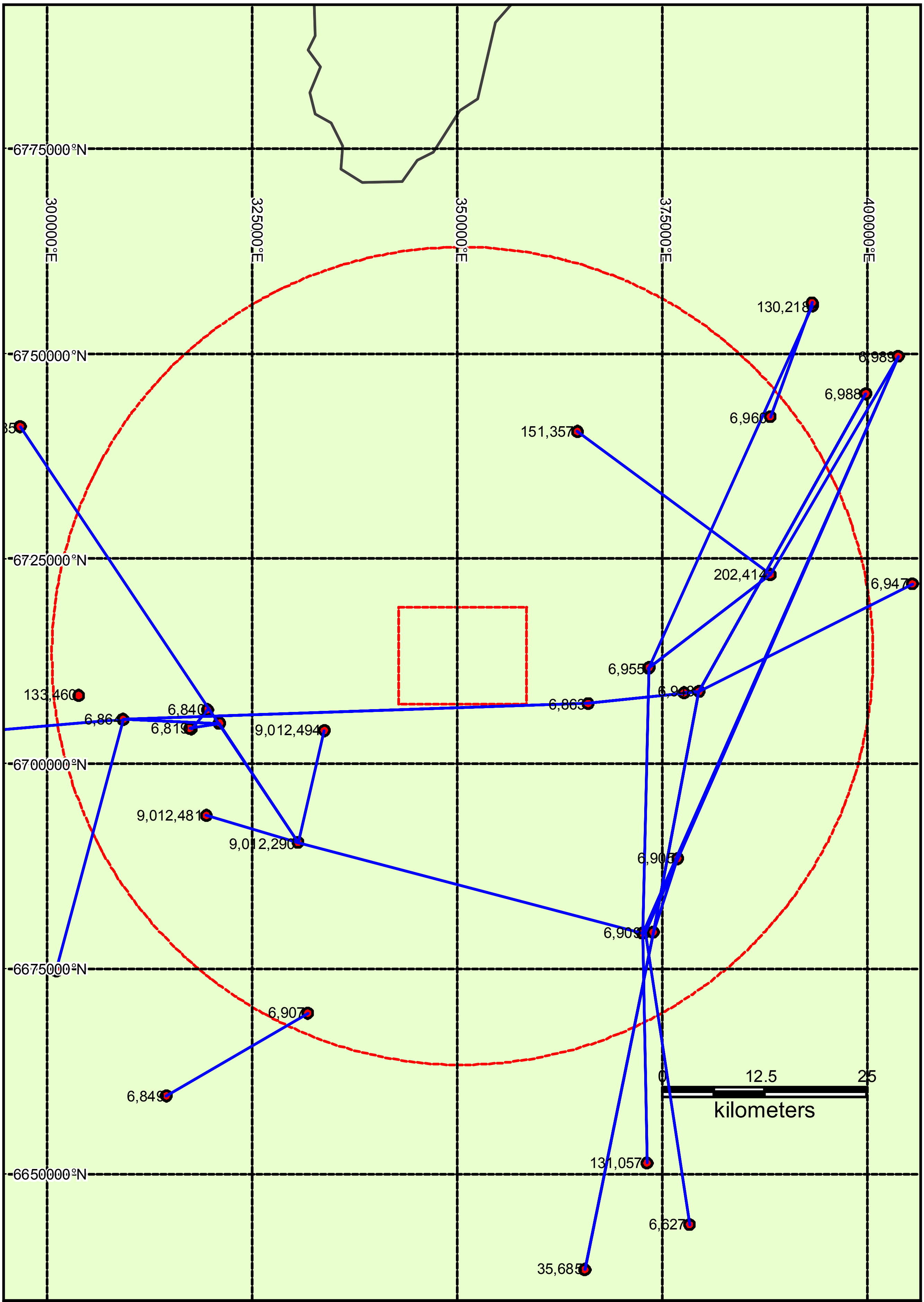
ATTACHMENT 4

MAP OF RADIO LINKS OPERATING BELOW 1000 MHz – DETAIL 110 METRE ROTOR LAYOUT



ATTACHMENT 5

MAP OF RADIO LINKS & SITES OPERATING ABOVE 1000 MHz



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TITLE:	**Above 1 GHz Assignments As Extracted from RRL Database**		
FILENAME:	Above 1 GHz Table Top New	DATE:	17/1/2011
PROJECT:	Sapphire New	SCALE:	N/A
DRWG NO:	2 of 2	BY:	SEA

ATTACHMENT 6 - SAMPLE CALCULATIONS OF CLEARANCE ZONES

The calculations below are examples for near field, second Fresnel zone and scattering clearances for the point-to-point and omnidirectional services.. The results of all calculations are in tables in the body of the Report. The formulas used are taken from Ref. 1

1. Point-to-point Link 55450 to 6909 TransGrid

(a) Near Field Zone

Frequency 45 MHz

Antenna Gain 8.2 dB

$$D_{nf} = 0.1\ 10^{0.1G} / f$$
$$= 0.1 x\ 10^{0.1 \times 8.2} / 0.045$$
$$= 14.7 \text{ metres}$$

Second Fresnel Clearance

Path Distance 119km

Mid Path distance 59.5km

$$R_{2F} = \sqrt{\frac{\lambda\ d_2 d_1\ 2}{d_2 + d_1}}$$

= √ 59)550/x003(2x1/190095 x

....=630. metres (mid path)

= √ 10)004/ 003(x 2 1/190081 1

= 115 metres @ 1km from tower

(b) 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:

$$R_{ci} = 71 + S + 20 \log (s_1 s_2) - 20 \log (D_p) + G_1(0) + G_2(0) - G_1(\theta_1) - G_2(\theta_2) \quad \text{(dB)}$$

where:

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

For each pair of $d_{1,2}$ values, equations above are used to evaluate R_{ci} for D_s incremented from zero (from a non-zero but small distance in the vicinity of the terminals) upwards in suitably small increments until the required value of C/I ratio, given by R_{ci}, is obtained. A guide as to a suitable increment for D_s is that the resulting zone should be defined by a smooth curve.

Antenna Type Scalar Y103 – 203 Vert

Turbine Radar Cross Section (RCS) assumed 1000 metres²

C/I Ratio required >40dB

An Excel spread sheet was set up to with the formulas above implemented to carry out the iteration required for d_1, d_2 values for increasing values of D_s. At 1.0km from the tower a C/I value of 40 dB was achieved at <100 metres off the rayline. Beyond 1 km the C/I value is achieved even on boresight. These indicates that scattering can be ignored 1 km and beyond the end sites. The published Radiation Pattern Envelope (RPE) for the antenna types for the actual link was used in the calculation

2. **Telstra Point to Multipoint Radio Base Stations – Omnidirectional Coverage**

(a) Near Field Zone

Frequency 3.4 GHz

Antenna Gain 10dB

$$D_{nf} = 0.1\ 10^{0.1G} / f$$

$$= 0.1x\ 10^{0.1x10}/3.4$$

$$= 0.3 \text{ metres}$$

(b) Reflection/Scattering Clearance Zone

Turbine RCS = 1000 m²

Wanted C/I >30dB

The C/I ratio is:

$$r_{ci} \quad \frac{l_i}{l_d} = \frac{4\pi s_1^2 s_2^2 \, g_1(0) g_2(0)}{D_p^2 \, g_1(\theta_1) g_2(\theta_2) \, \sigma}$$

For the omnidirectional case $g_1(0) = g_1(\theta)$ & $g_2(0) = g_2(\theta)$

It can also be assumed that S_1 will approx equal D_p

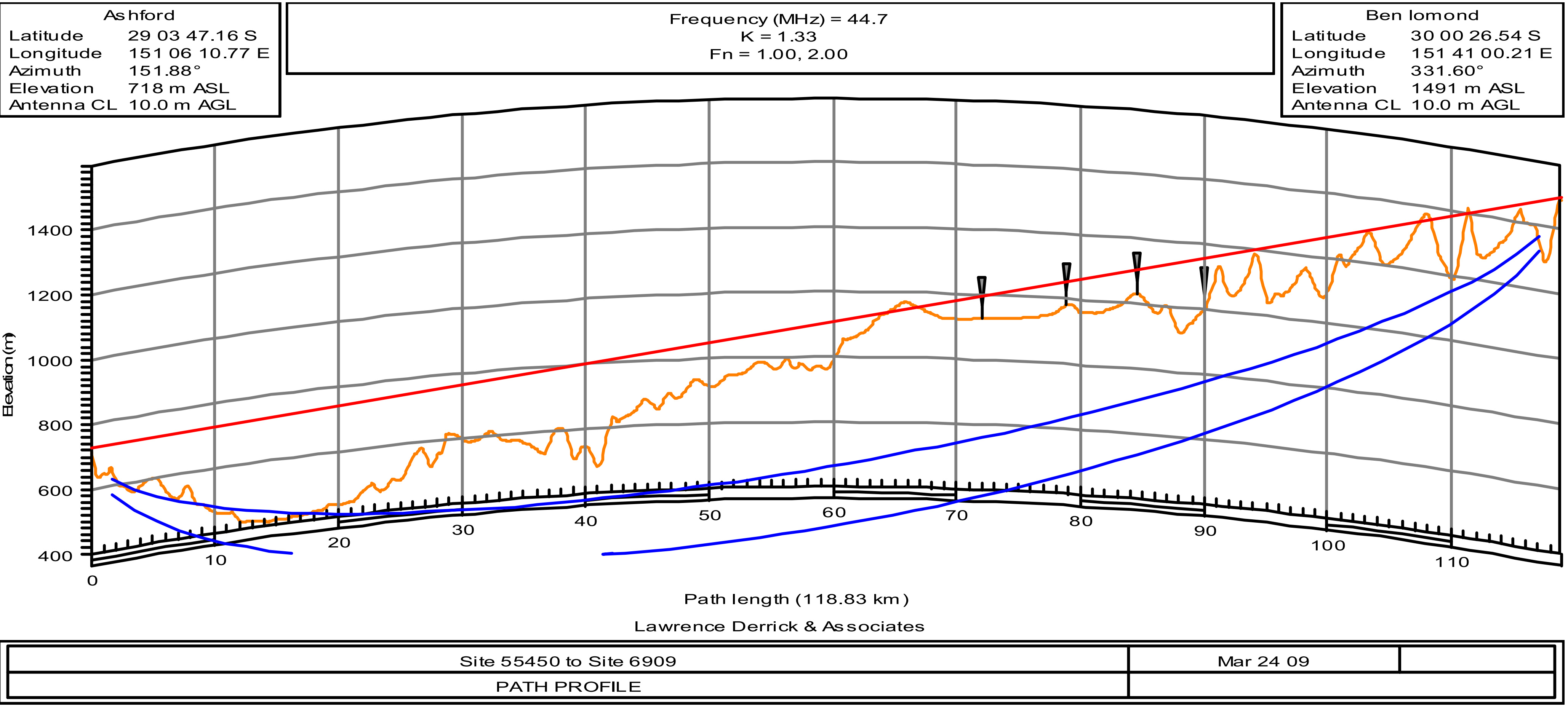
then

$$r_{ci} \quad \frac{l_i}{l_d} = \frac{4\pi S_2^2}{\sigma}$$

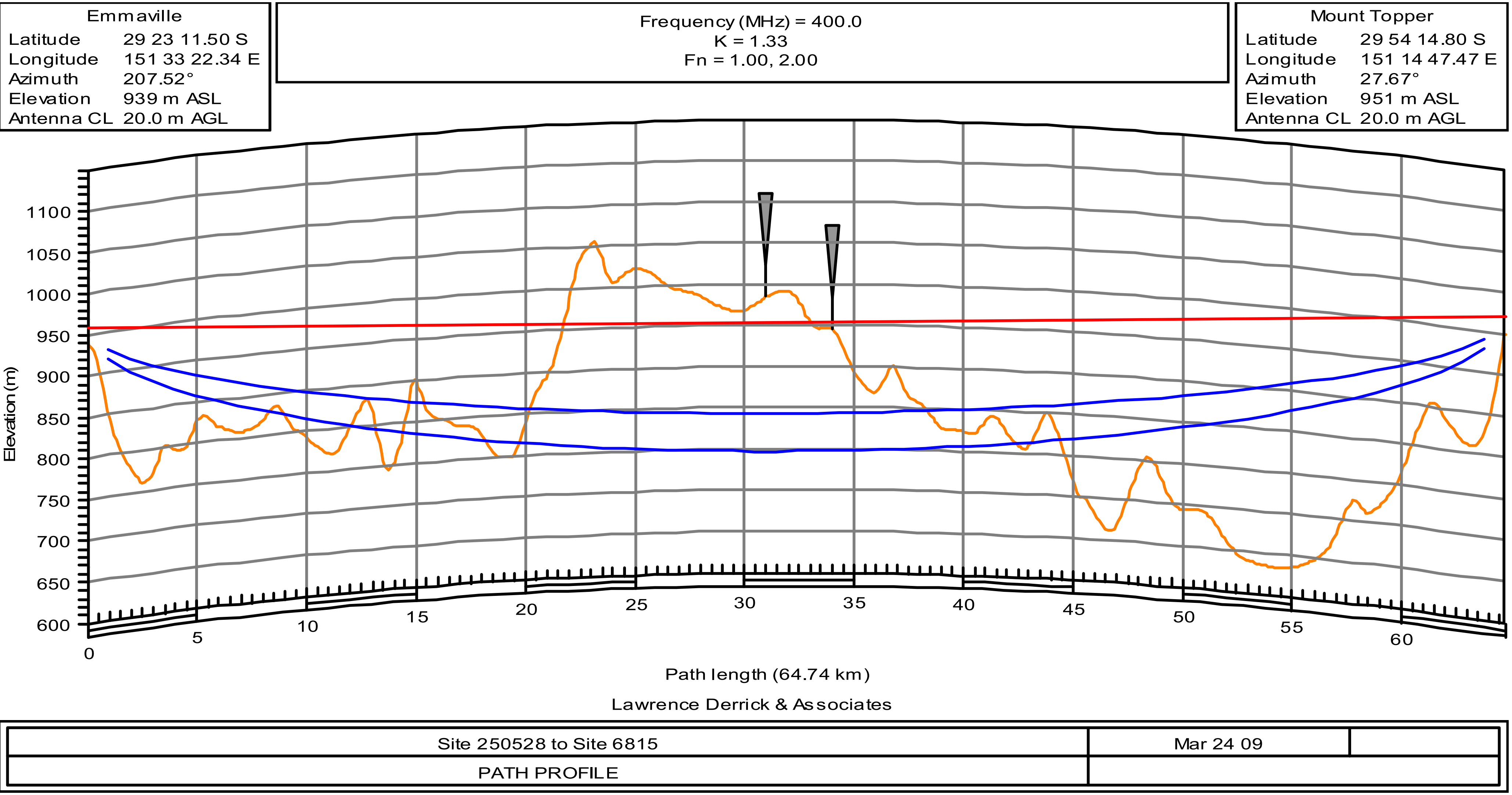
$= 4x\ \pi\ x\ 300^2/1000$

=1130 or 30.5dB at 300 metres

ATTACHMENT 7 – PATH PROFILE SITE 55450 to 6909



ATTACHMENT 8 – PATH PROFILE SITE 250528 TO 6915



ATTACHMENT 9 - PATH PROFILE SITE 6863 – SITE 6664