

**Lawrence Derrick & Associates**

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**STOCKYARD HILL WIND FARM - INVESTIGATION OF  
POSSIBLE IMPACTS ON BROADCASTING AND  
RADIOCOMMUNICATION SERVICES**

**PHASE 1**

**[final rev 1]**

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## **BIOGRAPHY**

I hold a degree in electrical engineering from Melbourne University and am accredited by the Australian Communications and Media Authority (ACMA) to carry out the technical coordination for the issue of radio licences for all classes of radio systems

I have worked in the radio-communications and broadcasting industries for 45 years. In the last 10 years, as a Consultant, I have carried out studies of the impact of wind farms on radio-communications and broadcasting services in the vicinity of the many wind farm locations in a number of States in Australia. This has involved an extensive initial and continuing study of overseas theoretical analyses and field measurements of these effects. I have carried out pre and post wind farm construction field surveys of TV and Radio reception at residences around wind farms and have established the path to solving interference issues after confirming they were wind farm related.

### **1. BACKGROUND**

Stockyard Hill Wind Farm Pty Ltd is planning the development of a wind farm at Stockyard Hill Vic, some 45 km west of Ballarat. This will involve the construction of up to 242 wind turbines, which are anticipated to consist of tapered cylindrical metal towers of up to 80 metre in height with three blades of up to 52metres in length mounted on top. As part of the environmental study of the proposal, the potential for disruption to radiocommunications and broadcasting in the wind farm area is being assessed. Clearance distances between any point to point microwave link paths and the turbines are also required to avoid any degradation to the performance of the links. Buffer zones from radio sites within or close to the boundaries of the wind farm are also to be specified.

### **2. INTRODUCTION**

It is considered necessary to include an assessment of impacts of the wind turbines on TV and sound broadcasting reception in the general area of the wind farm from the transmitting stations utilised by residents and to determine if any of the turbines are close to microwave system paths traversing the wind farm site. This report covers the outcomes of a Phase 1 desktop study as outlined below.

### **3. INVESTIGATION PHASES**

If necessary a three phase investigation could be undertaken to determine possible impacts on broadcasting and radiocommunication services, with Phase 2 consisting of two parts:

Phase 1 - Desktop Study and Report

Phase 2 - Pre construction TV/Radio Survey of Dwellings and Validation  
of  
Communications Link Data and Report

## Phase 3 – Post Construction TV/Radio Survey of Dwellings

This Report covers Phase 1 only.

### **4. Phase 1**

In Phase 1 a desk top study has been made of the likely impact of typical wind farm turbines and their supporting towers on broadcasting and radiocommunications in the area surrounding the wind farm. This study is based on relevant International Telecommunications Union (ITU) documents and on other professional reports on overseas and Australian experience of wind farm impacts on broadcasting services in the vicinity of any wind turbine structures. For Radiocommunication services sites up to at least 50 Km need to be considered because of the length of point to point paths of up to 100 Km.

Using data from the Australian Communications & Media Authority's (ACMA) RADCOM Database, checks have been made on radiocommunication services within at least a 50 km radius of the wind farm to determine if any of the turbine towers could obstruct line-of-site paths or have any likely detrimental affect on these services. Clearance criteria for ray lines have been indicated for any point to point radio paths crossing or near the wind farm site.

### **5. BROADCASTING SERVICES IN THE AREA**

From ACMA TV and Sound Broadcasting Station listings, and from a map survey of the area surrounding the Stockyard Hill wind farm site, the following is a general summary of the broadcast transmitter site locations and radio frequency channels which cover the area.

#### **5.1 Analogue Television**

It is expected that residents in the area surrounding the wind farm location generally view analogue TV from Ballarat National and Commercial main stations located at Lookout Hill which is approx. 30 Km from the wind farm site centre. The area is also about 100 km from the Bendigo stations at Mt Alexander and some residents in the area may have alternative TV receptions from the Bendigo stations. The station utilised by individual residents for TV reception is expected to be mainly Ballarat but will depend on the least obstructed path to the transmitters and in some locations reception of more than one may be possible. Path profiles examined from Mt Alexander to selected locations for the VHF and UHF frequencies used indicate that the path are somewhat terrain obstructed and therefore the TV signals will be of low level in general. In view of possible local obstructions a field visit would be necessary to determine the individual TV station source for each resident. In addition to analogue TV channels a number of digital channels are also available from the two transmitting locations. A summary of channels available from both locations is shown in Attachment 3

#### **5.2 Digital Television**

Digital television signals are also currently being radiated from the same locations discussed in 5.1 at Lookout Hill and Mt Alexander under the current transition to digital television around Australia which started in 2001. The Government has announced that digital only transmission in metropolitan markets will begin in 2009. The Government has also announced that digital switchover in other markets will be completed by 2013. The ACMA however have indicated that “as these timeframes may not allow sufficient time for digital infrastructure and services to be rolled out across the country, the timeframe for transition will be reset to commence in 2010 – 2012.” (ACMA web site)

## **5.2 FM Sound Broadcasting**

Ballarat National services on frequencies of 105.5, 107.1 & 107.9 Mhz are located on Lookout Hill. Ballarat National, Community and commercial stations on 95.9, 97.1, 99.9, 102.3, 103.1 & 103.9 Mhz are located at Warrenheip. Bendigo National services are located on Mt Alexander on 90.3, 91.1 & 92.7 Mhz. Bendigo Community and Commercial Services are also located on Mt Alexander on 88.7, 91.9, & 93.5 Mhz. 3WWM Ararat located on One Tree Hill transmitting on 98.5 Mhz will also serve the area

## **5.3 MF Sound Broadcasting**

As indicated below, wind farm effects on MF radio are highly unlikely and therefore the stations serving the area have not been listed.

## **5.4 Satellite Pay Television**

Some homesteads in the area may have satellite pay TV service antenna installations. Unless a particular subscribers antenna reception direction and elevation is closely aligned with a turbine, which is highly unlikely, no impacts on TV reception is expected.

# **6. RADIOCOMMUNICATIONS SERVICES**

Maps generated from data in the ACMA database are shown in Attachments 4, 5, & 6. Attachment 4 shows all radio sites and point to point links within at least 50 Km of the wind farm and with operational frequencies in the range 40 – 499 MHz. Attachments 5 & 6 are similar maps in frequency ranges of 500 – 999 MHz and greater than 1 GHz respectively.

## **6.1 Point to Point**

A number of point to point links are registered for operation within 50 km of the wind farm site. As shown in maps in Attachments 4, 5 & 6 there are four links which traverse or approach the boundaries of the wind farm. Clearance requirements are required to ensure turbines are not located close to the ray lines of these links to avoid any impact on their performance.

## **6.2 Cellular Mobile Base Stations**

No cellular mobile base stations are registered at sites in the close vicinity of the wind farm. The nearest Telstra, Optus & Vodafone mobile base stations at Beaufort and Skipton are too distant to significantly affect mobile phone reception in the area.

### **6.3 Two-Way Mobile**

A number of private and Public Utility Point to Multipoint and mobile bases exist in the area surrounding the wind farm site. These bases potentially provide cover to mobiles in a 360 degree arc from their bases. No significant impact from the wind farm on base coverage beyond normal mobile operational performance is predicted in view of the geographic separation between the base antennas and the turbine structures. Of course a mobile unit communicating with a base station when the mobile is located within metres of the wind turbine structures (or indeed near any large building, silo, tower etc) may experience some very local performance change, however moving a short distance would restore performance to normal. The Country Fire Authority (CFA) have omnidirectional coverage 160 MHz band mobile base stations registered, the closest to the site being at Lake Goldsmith, Stockyard Hill and Stoneleigh. The Stockyard Hill base station is within the wind farm boundaries and could have turbines near it.

### **6.4 CB Radio**

CB radios are not individually licensed, the equipment being subject to class licensing only. Therefore no records of location or operators of CB radios exist, and the channels are shared without any right of protection from interference. No impact from the wind farm is predicted except perhaps for very local effects to portable or mobile units in the immediate vicinity of the turbines which could be avoided by a small location change of the unit.

### **6.5 Other Services**

The nearest airport at Ballarat is about 42 km away. No wind turbine impact on this site is predicted in view of the separation and type of Radio systems being operated. An Airservices radar facility at Smeaton Hill 65 km away was cleared by Airservices for a much closer wind farm at Tuki so no impact is expected from Stockyard Hill. An Airservices radio site in the area at Ben Nevis 38 km away has point to point links installed however the ray lines do not traverse the wind farm site.

## **7. EMI EFFECTS OF WIND TURBINES**

The following is an extract from Ref. 1:

"It is well known that any large structure, whether stationary or moving, in the vicinity of a receiver or transmitter of electromagnetic signals may interfere with those signals and degrade the performance of the transmitter/receiver system. Under certain conditions, the rotor blades of an operating wind turbine may passively reflect a transmitted signal, so that both the transmitted signal and a delayed interference signal (varying periodically at the blade passage frequency) may exist simultaneously in a zone near the turbine. The nature and amount of electromagnetic interference (EMI) in this zone depend on a number of

parameters, including location of the wind turbine relative to the transmitter and receiver, type of wind turbine, physical and electrical characteristics of the rotor blades, signal frequency and modulation scheme, receiver antenna characteristics, and the radio wave propagation in the local atmosphere. Other wind turbine components which have been considered to be potential causes of EMI are towers and electrical systems. However, neither of these has been found to be a significant source of interference. Thus, moving blades are the components of most importance in determining EMI levels.

Television Interference from wind turbines is characterised by video distortion that generally occurs in the form of a jittering of the picture that is synchronised with the blade passage frequency.

Effects on FM broadcast reception have been observed only in laboratory simulations."

Point to point links in microwave and lower frequency bands will be affected only if the turbine tower or turbine clearance to the line of site path to the other end of the link is within the second Fresnel zone which is dependent on the operating frequency of the link, the distance of the tower/turbine from the link antenna and the total link distance. D. F. Bacon (Ref. 8) proposes 3 potential degradation mechanisms - near field effects, diffraction and reflection or scattering. The reflection or scattering treatment in the reference suggests greater clearance requirements at positions close to the link terminals than the usually applied Fresnel Zone clearance.

## **8. DISCUSSION OF OVERSEAS EXPERIENCE**

Observations and studies have been carried for a number of years in both the USA and the UK on the effects of wind turbines on TV and other radiocommunication services. In 1976 the US Energy Research and Development Administration (ERDA) funded the RadLab at the University of Michigan for investigations into these effects and this continued for 7 years. Ref. 1 summarises the results of theoretical and field measurements.

The BBC's Research Department in the UK has also investigated this subject in some depth, and in 1983 a report was issued (Ref. 2). Another Report (Ref. 3) was issued in 1992 after the Research Department had carried out observations from test transmissions at existing wind farms in Denmark in 1991.

In 1992 the ITU issued a Recommendation (Ref. 4) on the assessment of impairment caused to television reception by a wind turbine.

In a recent exchange of emails, Mr Chris Gandy of the BBC Research Department summarised the conclusions they had come to on this subject as follows - ".....in the UK the only significant broadcast reception difficulties that have successfully been attributed to wind turbines so far have been associated with UHF analogue television, not FM radio and certainly not MF or LF radio. There may be some potential for effects on digital terrestrial television, but possibly only in cases where turbine blades are between the transmitter and the receiver - cases of reflection from the blades are much more common and in the

majority of cases should do little damage to our DTT signals because of the guard interval present in each DVB signal. Of course, there will be the odd case where reception was right on the edge of the 'digital cliff' before the turbines were built. Also we have no record of interference with our Digital Radio transmissions in Band III."

Ref 5 summarises the results of model measurements of the level of interference signals scattered by turbine blades and the supporting tower and confirms some of the backscatter estimates calculated in Ref. 4.

It is believed that metal blades were used on the earlier turbines unlike the modern ones where composite material - fibre glass, carbon fibre, plastics are used. In some cases metal exists in the composite material blades for strength reinforcing or for lightning protection. Some references indicate that the composite blades will have a reduced interference potential, however the BBC view is that at UHF TV frequencies the difference will be small.

It is also indicated in some of the reports that due to variable wind speeds and direction, the resulting changes to turbine blade pitch and turbine facing direction will modify any interference levels at a given location in the service area ie interference effects would be time variant.

From a study of the above references and others, the following general conclusions are drawn:

- (a) No turbine interference effects are expected to MF radio reception.
- (b) There is a very low probability of perceptible interference to FM radio reception, and under most situations any interference to analogue VHF TV reception would be limited to locations close to the turbines.
- (c) Some interference may be experienced to analogue TV services and particularly where the path to the TV transmitter for a given receiver location is through the wind turbine blades or where there is a partly obstructed path to the transmitter and there is a clear path to a turbine. These effects may be restricted up to a distance of about 3 km from the wind farm in forward scatter directions (receiver on opposite side of the wind farm to the TV station).
- (d) Digital TV services are unlikely to suffer degraded picture quality, eg, ghosting, where signals have a margin above threshold levels, however a reduction in service area could occur due to time varying reflected signals.

## **9. STOCKYARD HILL WIND FARM SITUATION**

From overseas experience, calculations using the University of Michigan method and the topography of the area:

9.1 No interference from the wind farm is expected to the MF and FM sound broadcasting services in the area.

9.2 Theoretical estimates outlined in Attachment 8, of reflections of the typical analogue VHF and UHF TV transmissions from Lookout Hill and Mt Alexander by

the turbine blades indicate that some possibility of TV picture degradation exists at times for dwellings located such that wind turbines exist within a +/- 20 degree sector (Ref. 6) from the TV antenna nominal direction of reception, and up to about 3 km from the turbines. Estimates of typical scattering from the blades are based on available data for three blades each have a one sided projected surface area of 67 sq. metres (44 metres long), that the turbine towers will be tapered steel columns about 80 metres high and on using the method outlined in Ref.1. The turbines proposed may have longer blades and the towers are taller and so will have a nominal increase in reflected signal level. These measurements overseas indicate that the calculations using the alternative ITU method (Ref.4) over estimate the scattering /reflection so this method has not been used. It is also difficult to estimate the additive effects of a number of turbines distributed over some distance and on the effect of the undulating terrain on the ratio of the reflected signal to the main wanted TV signal. Some properties are predicted to have some probability of perceptible TV picture degradation for a percentage of time depending on the direction and speed of the wind. At some unfavourably located properties within about 3 km of turbines there is a probability of perceptible analogue TV picture degradation for a percentage of time depending on the direction and speed of the wind.

9.3 As shown in Attachment 2 a number of houses surround the wind farm and some are located within the boundaries. As TV reception from Ballarat is received from Lookout Hill which is on a bearing of about 350 degrees any houses which have turbines to the north and close to them have a risk of TV interference occurring. Houses to the North of the wind farm would not be expected to be affected. Some residents may be able to receive the "out of area" Bendigo TV stations from Mt Alexander. As Mt Alexander is on a bearing of about 55 degrees, dwellings with turbines to the North East of them may experience interference to these TV stations

9.4 As indicated above, digital television is not subject to ghosting degradation in high signal strength areas, however some reduction of service area could result from reflected unwanted signals at the limits of the service area The Lookout Hill stations are high power UHF main stations and are about 30 km from the centre of the wind farm. It is therefore expected that the general wind farm area will be in a high signal strength zone. There may be some isolated areas which are shadowed by local hills resulting in reduced signal levels however it is difficult to predict whether digital reception will be impaired in specific locations.

9.5 There are no TV rebroadcast stations listed in the area surrounding the wind farm. The turbines will, therefore, have no impact on rebroadcast signal quality.

9.6 For satellite pay TV services in the area of the wind farm no interference to these services is likely to occur unless the required pointing of their dish antennas to the serving satellite is also in line with a turbine.

9.7 The ACMA RADCOM database has been studied for services within at least 50 km of the wind farm to determine if any point to point services will have their paths obstructed by the wind turbine blades or the supporting towers. Maps derived from the ACMA database showing radio sites and links in the general area surrounding the site are shown in Attachments 4, 5 & 6. Three Radio links

have been identified as crossing or close to the boundary of the wind farm site and one is in the vicinity of the northern site boundary. Attachment 7 shows the calculated clearances required between the link ray lines and any part of a turbine

9.8 The CFA should be consulted for their view on the need for a buffer zone around the 160 MHz mobile base station on Stockyard Hill which may have turbines in close proximity to it

9.9 No impact on Airservices radio facilities at Ben Nevis, Smeaton Hill or at the Ballarat Airport is predicted. The Smeaton Hill Radar was the subject of correspondence with Air Services Australia concerning a closer wind farm at Tuki. As Air Services had no objection in that case the more distant Stockyard Hill turbines are not likely to be an issue.

## **10. FORTUITOUS RECEPTION OF BROADCAST SIGNALS**

On some previous projects Responsible Authorities have imposed conditions such as:

"if the qualitative survey establishes any detrimental increase in interference to reception or transmission measures must be taken to mitigate the interference to return the affected reception or transmission to pre-construction quality" (Waubra Vic Planning Permit No PL-SP/05/0150),

This raises two issues, the first being the criteria for interference assessment and the second being the protection of reception of some services outside their designed coverage area - termed fortuitous reception. For analogue television reception which is the most vulnerable service for turbine interference it is proposed to use the ITU grade 4, of a 5 grade impairment scale as the limit of acceptance, which is described as "perceptible but not annoying". On the second point, the ACMA's attitude to protection of reception outside designed service areas is understood to be that the reception is fortuitous and will not be protected. They will therefore plan for reuse of frequencies for new stations which in future may impair reception in areas where it is currently acceptable or useable, often for at least part of the time.

This is, of course, difficult for individuals to accept who, due to their particular location, cannot receive an acceptable service from their planned station. Others may use distant stations to avail themselves of diverse programs. It is not reasonable to attempt to protect these services which are likely to be of low signal level and may vary in quality of reception depending on time of day, weather patterns and season. It is therefore not recommended to mitigate any reception which may be impacted by turbine effects where the receivers are clearly outside the ACMA planned coverage area for the particular service being received.

## **11. MITIGATION TECHNIQUES**

For individuals who experience a degraded FM or TV broadcasting service due to identified interference from the wind farm, possible techniques to reduce the interference to acceptable limits include:

1. Replacement of receiving antenna system with a higher gain more directive model,
2. Reposition antenna in height or horizontally on the dwelling,
3. Install an antenna elsewhere on the property and cable to dwelling,
4. Change the orientation of antennas to receive an alternative station if available, e.g. Bendigo instead of Ballarat .
5. Use available digital TV Channels instead of analogue (requiring a digital Set Top Box or digital TV set), and
6. Provision of an alternative satellite service eg, Austar Pay TV Service.
7. Where feasible, consideration could be given to the installation of a TV or FM Repeater station to provide service to groups of residents in a shadow zone.

Potential point to point system and mobile base coverage conflict is not predicted with turbines being located with recommended clearance zones from radio sites or point to point ray lines. There is only one identified link passing the turbines and final micro siting adjustments of 1 turbines will avoid any impacts.

Any minor affects to MF broadcasting would occur within 10's of metres of the turbines only and with a buffer zone of at least 500m to any dwelling, no corrective action will be required.

## 12. CONCLUSIONS

Interference to MF and FM sound broadcasting is not expected.

No potential conflicts between point to point radio systems and the wind turbines have been identified which cannot be avoided by using adequate clearances.

Mobile radio and other radiocommunication services in the area are not expected to be significantly impacted by the wind farm or its operation.

TV reception at dwellings within about 3 km of the wind farm turbines and with antennas having turbines located with +/- 20 degrees angle of their reception direction will have some probability of noticeable ghosting at times. Any ghosting experienced may be time variant depending on wind direction and speed.

Digital TV is not susceptible to visible ghosting degradation where the signal level is above a minimum threshold The area surrounding the wind farm is expected to be a high to medium level signal area however there may be individual houses located in shadow areas who will require other mitigating technique to be applied...

For any confirmed wind farm analogue interference problems where TV receiving antenna system improvements are unsuccessful, the use of a set top box with

reception of the available digital channels may be the best solution. Existing Digital TV services are expected to provide unimpaired picture to any houses near the turbines which may have experienced picture quality problems as a result of ghosting on analogue TV services from the turbines as long as the signal levels have a margin above a threshold level. In view of the transition to Digital TV in Australia as indicated above analogue transmissions will cease by 2013. Provision of digital TV solutions to any degraded analogue reception is simply advancing an inevitable transition to digital reception.

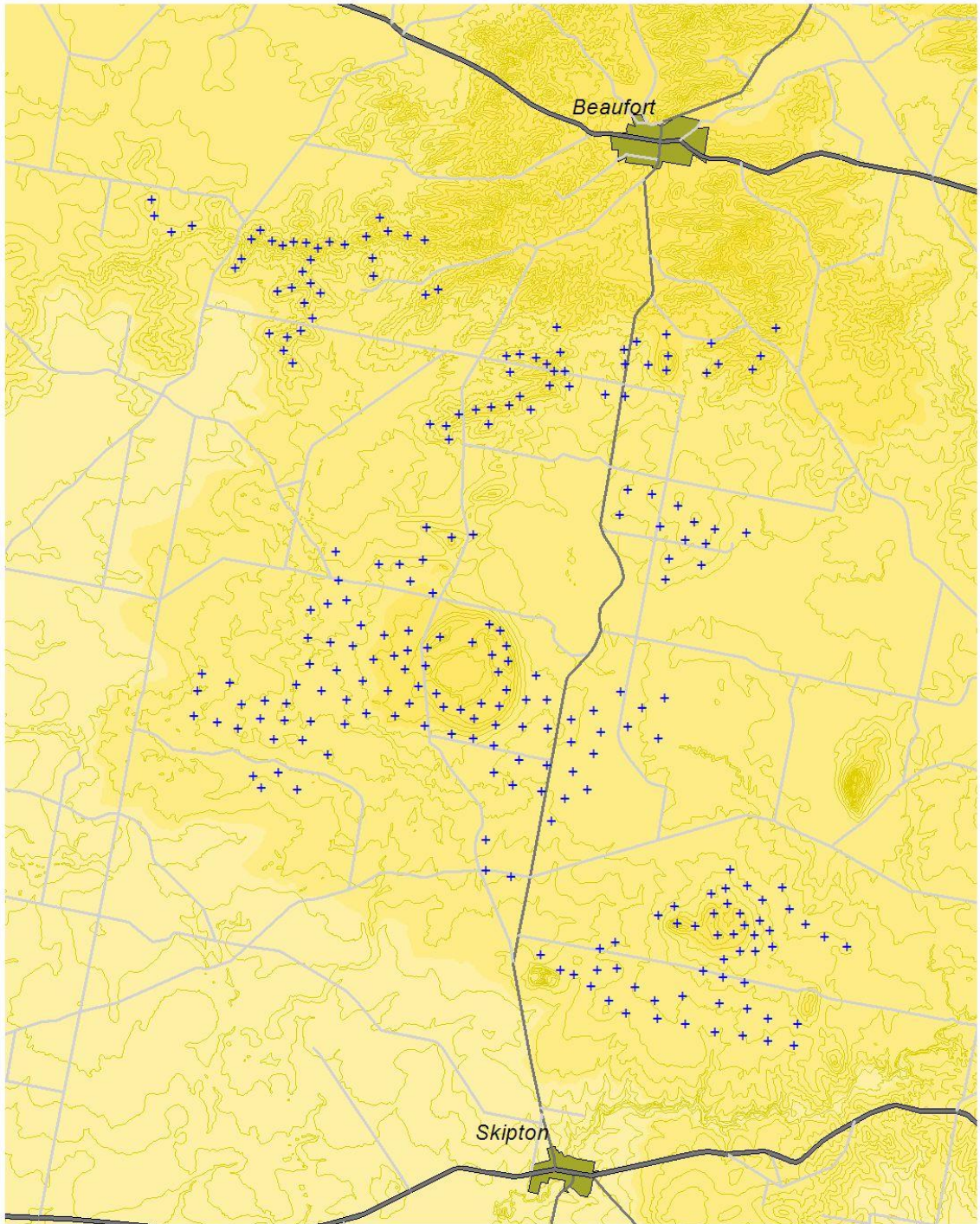
Alternatively a satellite service could be considered if digital TV reception be unsatisfactory in individual cases.

Overseas experience indicates that EMI produced by the wind farm generators and controls is not a problem with reputable world class wind turbine manufacturers and therefore no electrical noise measurements from the electrical generators are warranted.

## REFERENCES

1. David E Spera, Wind Turbine Technology, Chapter 9 ASME Press 1994
2. J.L. Eaton, R.I. Black, G.H. Taylor, Interference to Television Reception from Large Wind Turbines, BBC Research Department Report 1983/2
- 3 D.T. Wright, Effects of Wind Turbines on UHF Television Reception, Field Tests in Denmark Nov 1991, BBC Research Department Report 1992/7
4. ITU, ITU-R Recommendation BT805 Assessment of Impairment Caused to Television Reception by a Wind Turbine 1992
5. C. Salema, C. Fernandes, L. Fauro, TV Interference From Wind Turbines Conferencia de Telecomunicacoes April 2001 Portugal
6. ITU, ITU-R, Recommendation BT 419-3 Directivity and Polarisation Discrimination of Antennas in the Reception of Television Broadcasting 1992
7. BC, Radiocommunications Agency, Independent Television Commission, UK, The Impact of Large Buildings and Structures (Including Wind Farms) on Terrestrial Television Reception
8. D. F. Bacon, A Proposed Method for Establishing an Exclusion Zone around a Terrestrial Fixed Link outside of which a Wind Turbine will cause Negligible Degradation of the Radio Link, Radiocommunications Agency UK Report Ver 1.1, 28 Oct 2002

# ATTACHMENT 1 – STOCKYARD HILLS WIND FARM TURBINE LAYOUT



## Stockyard Hill Wind Farm

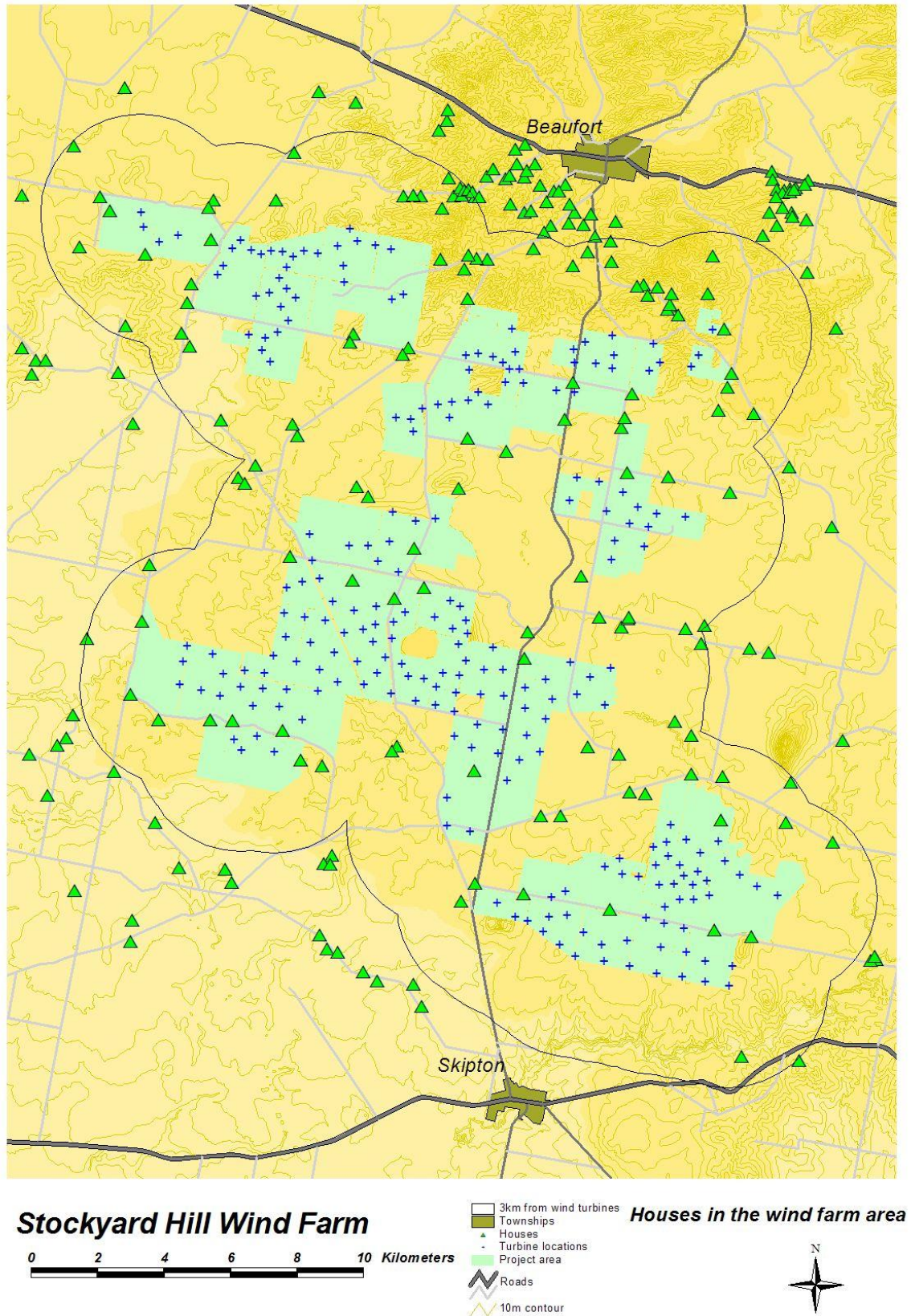


- + Wind turbine location
- Roads
- Contour
- Townships

## Wind farm layout



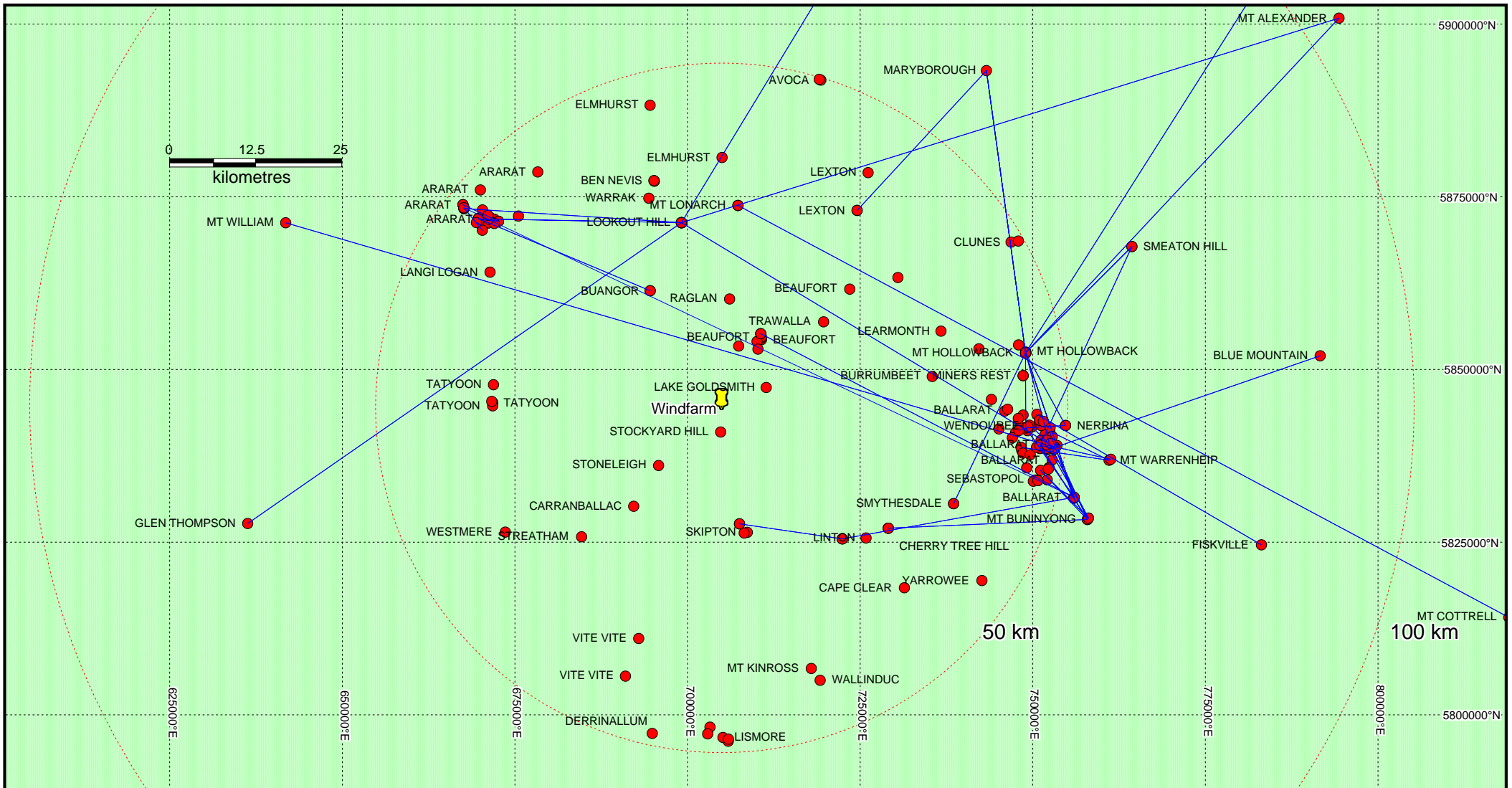
## ATTACHMENT 2 - LOCATION OF HOUSES IN WIND FARM AREA



**ATTACHMENT 3****TELEVISION STATIONS & CHANNELS - BALLARAT / BENDIGO AREA**

<b>Transmitter Location/service</b>	<b>Operator</b>	<b>Analog Channels</b>	<b>Digital Channels</b>	<b>Comment</b>
Lookout Hill/Ballarat	SBS	30H	43H	UHF
	ABC	42H	41H	UHF
	AMV	33H	46H	UHF
	BCV	39H	40H	UHF
	VTV	36H	37H	UHF
Mt Alexander/Bendigo	ABC	1V	48H	VHF/UHF
	SBS	28H	29H	UHF
	AMV	32H	31H	UHF
	BCV	8V	38H	VHF/UHF
	VTV	35H	54H	UHF

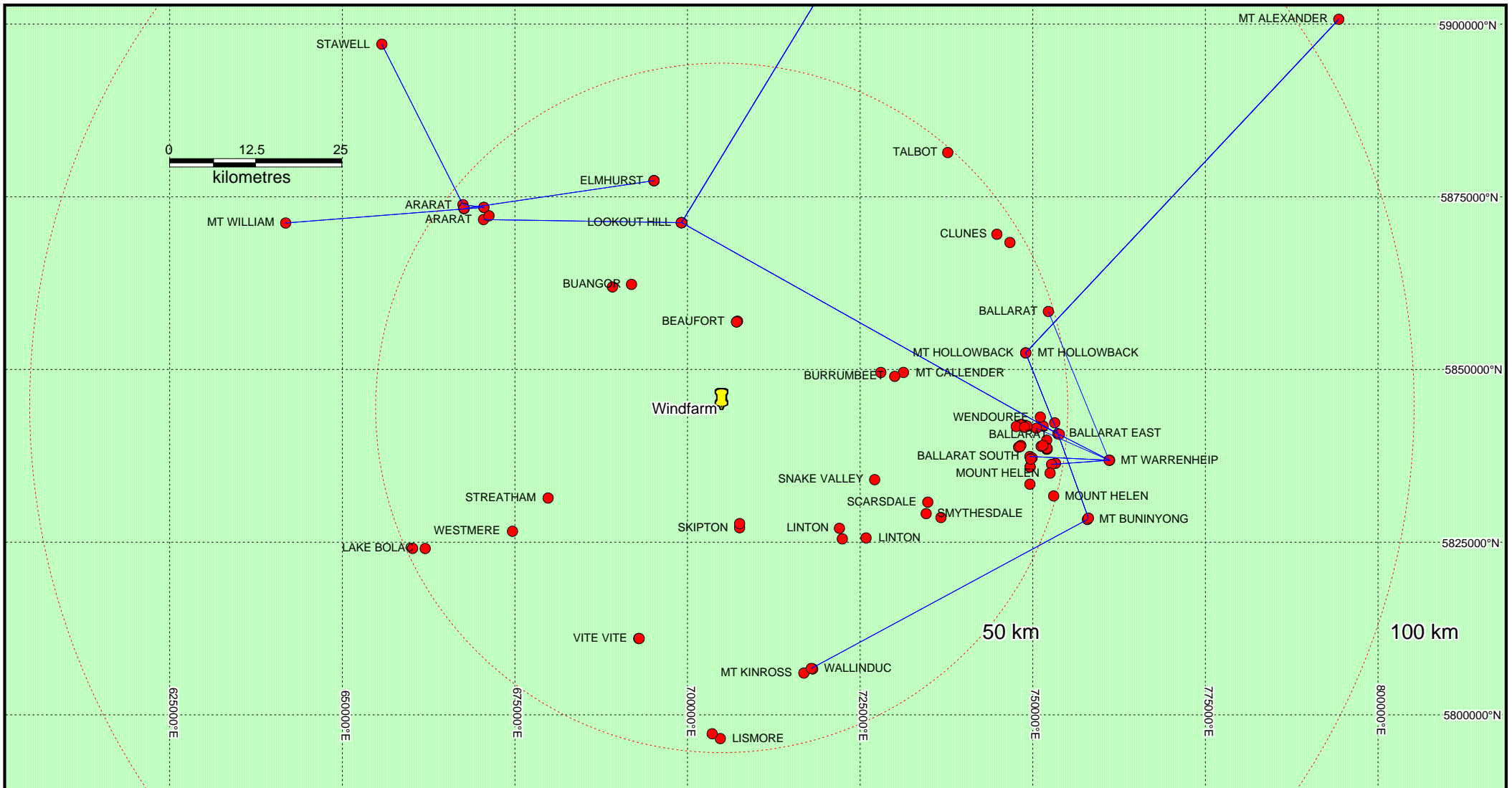
**ATTACHMENT 4 - Radio Link Map 40- 499 MHz Frequencies**



<b>TITLE:</b>	
<b>40-499 MHz Assignments As Extracted from ACMA RRL Database</b>	
FILENAME:	40-499 MHz
DATE:	11/6/2008
PROJECT:	Windfarm
SCALE:	N/A
DRWG NO:	1
BY:	Spectrum Eng.

Postal: P.O. Box 3213, BELCONNEN ACT 2617  
 Telephone: 02 6253 2555  
 Facsimile: 02 6253 2800

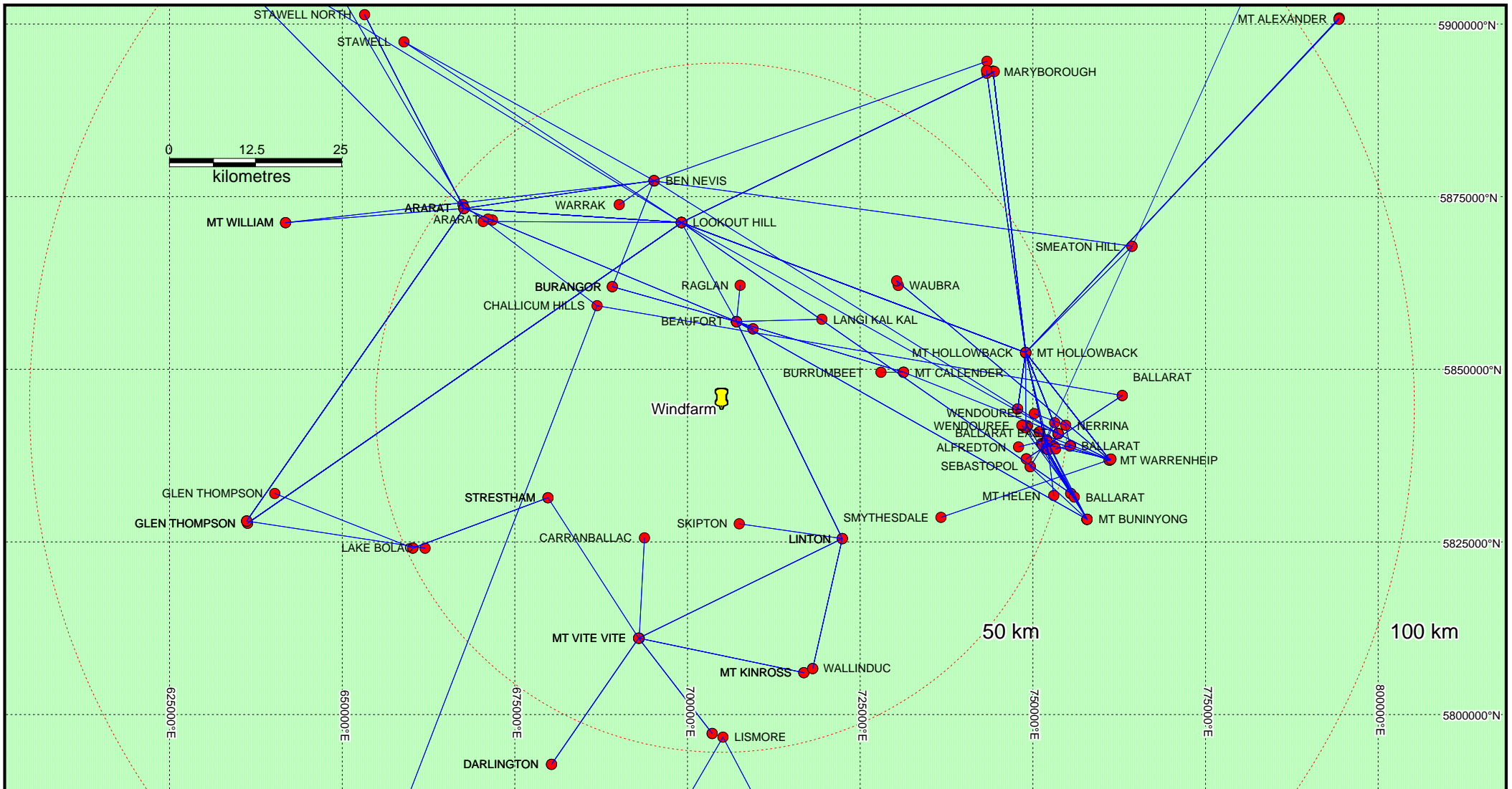
**ATTACHMENT 5 - Radio Link Map 500 – 999 MHz Frequencies**



Postal: P.O. Box 3213, BELCONNEN ACT 2617  
 Telephone: 02 6253 2555  
 Facsimile: 02 6253 2800

TITLE: <b>500-999 MHz Assignments As Extracted from ACMA RRL Database</b>	
FILENAME: 500-999 MHz	DATE: 11/6/2008
PROJECT: Windfarm	SCALE: N/A
DRWG NO: 2	BY: Spectrum Eng.

**ATTACHMENT 6 - Radio Link Map above 1 GHz Frequencies**



<b>TITLE:</b> Above 1 GHz Assignments As Extracted from ACMA RRL Database	
FILENAME: Above 1 GHz	DATE: 11/6/2008
PROJECT: Windfarm	SCALE: N/A
DRWG NO: 3	BY: Spectrum Eng.

Postal: P.O. Box 3213, BELCONNEN ACT 2617  
 Telephone: 02 6253 2555  
 Facsimile: 02 6253 2800

## ATTACHMENT 7 – RADIO LINK DATA AND CLEARANCES

A search of the AMCA Radcom Data Base indicates that there are four UHF or Microwave Point to Point Links which require consideration in maintaining adequate clearance to the wind turbines and their towers for the proposed Stockyard Hill wind farm layout.

In the event of a point to point system passing near a turbine the recommended clearance from link ray line to turbine blade tip is the Second Fresnel zone radius calculated using the following formula:

$$Y_{\min} = \sqrt{2\lambda D_1(1 - D_1/D_2)} \quad (\text{Ref. 1})$$

### 1. Site 1 Ararat to Site 2 Ballarat Link

Operator: Link Communications  
 Frequency Band 450 MHz  
 Calculated Path Length : 97.77 km  
 Calculated Bearing From Site 1 : 114.23°T  
 Mid Path 2<sup>nd</sup> Fresnel Clearance D1

$$\begin{aligned} D_1 &= \text{SQRT}(2 \times \lambda \times d_1 \times d_2 / (d_1 + d_2)) \\ &= \text{SQRT}(2 \times (300/450) \times 48610(1 - 48,610/9,720)) \\ &= 180.5 \text{ metres} \end{aligned}$$

### 2. Site 1 Mt William to Site 2 Ballarat North Link

Operator: Rural Ambulance  
 Frequency Band 400 MHz  
 Calculated Path Length : 116.03 km  
 Calculated Bearing From Site 1: 105.31°T  
 Mid Path 2<sup>nd</sup> Fresnel Clearance D1

$$\begin{aligned} D_1 &= \text{SQRT}(2 \times \lambda \times d_1 \times d_2 / (d_1 + d_2)) \\ &= \text{SQRT}(2 \times (300/400) \times 58,015(1 - 58,015/116,030)) \\ &= 208.6 \text{ metres} \end{aligned}$$

### 3. Site 1 Beaufort to Site 2 Linton Link

Operator: Optus  
 Frequency Band 8 GHz  
 Calculated Path Length: 35.01 km  
 Calculated Bearing From Site 1 : 152.66°T  
 Mid Path 2<sup>nd</sup> Fresnel Clearance D1

$$D_1 = \text{SQRT}(2 \times \lambda \times d_1 \times d_2 / (d_1 + d_2))$$

$$= \text{SQRT} ( 2x (300/8000) x 17465(1- 17,465/34,930)$$

$$= 25.6 \text{ metres}$$

#### 4. Site 1 Chalicum Hills to Site 2 Ballarat Link

Operator: Powercor  
 Frequency Band 1500 MHz  
 Calculated Path Length: 77.14 km  
 Calculated Bearing From Site 1: 98.42°T  
 Mid Path 2<sup>nd</sup> Fresnel Clearance D1

$$D1 = \text{SQRT} (2 x \lambda x d1 x d2/(d1 + d2))$$

$$= \text{SQRT} ( 2x (300/1500) x 38,570(1- 38,570/77,140)$$

$$= 87.8 \text{ metres}$$

### SUMMARY OF CLEARANCE REQUIREMENTS

LINK	TOTAL CORRIDOR WIDTH Metres Note 1	Bearing from Site 1 °T	Co-Ordinates of Site 1 WGS 84 Zone 54
Ararat- Ballarat	361	114.23	E667724 N5873588
Mt William- Ballarat N.	417.2	105.31	E641925 N5871413
Beaufort – Linton	51.2	152..66	E707223 N5857058
Chalicum Hills - Ballarat	175.7	98.42	E687020 N5859377

Note 1 No part of a turbine should protrude into the corridor. For example for the third link listed, with a turbine rotor diameter of 103 metres the centre line of the turbine tower should be at least  $25.6 + 103/2 = 77.1$  metres from the link ray line

Link path No 3 passes through the wind farm site. The other link paths are outside the nominal site however the clearances are provided to ensure any turbine relocations can be checked for sufficient clearance.

## ATTACHMENT 8 – PREDICTED INTERFERENCE LEVELS TO TELEVISION RECEPTION

The estimates below of reflection of TV signals from generator blades use the formulas in Ref.1 and the details of a Suzlon S88 generator has been used. This is a three bladed 44 metre radius rotor on a tower of 80 metres in height. Information from Suzlon Energy Australia suggests that the blades have the following details:

Planform Area of each Blade approx 67 m<sup>2</sup> (calculated)  
 Coning Angle 4.3 degrees  
 Twist of Blade 9.9 degrees  
 Lightning Protection bus inside Blade 60mm<sup>2</sup> stainless steel

Signal Scattering Efficiency  $\eta_s$

$\eta_s = 0.8 \times 0.41 \times \exp(-2.3\Delta\beta)$  for non-metallic blades

$\Delta\beta = \text{total blade twist} = 9.9/180 \times \pi$

$\eta_s = 0.8 \times 0.41 \times 0.67206$

$= 0.2204$

lightning protection 60mm<sup>2</sup> cable could increase efficiency by 20% so

$\eta_s = 0.264$

For VHF TV at on say Channels 7 & 9 ( 190 Mhz)

Effective Number of Blades for receiver in the back scattering zone

$$B_e = 1 + \sin c \left\{ \frac{2\pi R}{\lambda} \sin(2\theta) \cos(k) \right\} \leq B_e \text{ max}$$

$k = \phi_{RT} / 2$  for backward scatter zone

$k = 2\phi_{RT}$  for forward scatter zone

$$B_e = 1 + \sin c \left\{ \frac{2\pi 44}{300/190} \sin 2 \times 4.3 \right\}$$

$$= 1.8672$$

where  $B_e \text{ max} = 1 + \frac{\lambda R}{A_p}$  (Note 1.)

$$= 1 + 300/190 \times 44/67 = 2.0369$$

therefore  $B_e = 1.8672$  is applicable

$$Z_I = \eta_s \frac{B_e A_p}{\lambda D} \cos(k)$$

$$= 0.264 \times 1.8672 \times 67 \times 190 / (300 \times 1000) \text{ for } D = 1\text{km for the maximum}$$

directions

$$= 0.020917$$

$$= -33.6\text{db}$$

$$\begin{aligned}
 &= 0.264 \times 1.8672 \times 67 \times 190 / (300 \times 250) \text{ for } D = 250\text{m for the maximum} \\
 \text{directions} \\
 &= .083668 \\
 &= -21.5\text{db}
 \end{aligned}$$

The required wanted to unwanted signal ratio for a just perceptibly degraded TV picture as a function of the time difference between the wanted and unwanted signals is shown in Fig. 2 of Ref. 4 and varies between 28db (<1 $\mu$ s delay) and 34db(>5 $\mu$ s delay). If it was assumed that the wanted signal strength at the residents' TV antennas was the same as at the generator centre, from the above signal scatter ratio estimates perceptible TV picture degradation would occur up to near 500 metres from generators in the forward scatter area. No TV receiving antenna discrimination is possible in the forward scatter case. As, in fact, the signals at the lower height TV antennas in the close in areas will be lower than at the 80m generator height by, for example 6 db, perceptible interference up to 1.0 Km is predicted.

Similar estimates have been made for other UHF channels. The signal scatter ratios for representative UHF channels are summarised below:

Channel 65 (765 MHz) at 1Km  $Z_I = -26.8\text{db}$

Channel 34 (570 MHz) at 1Km  $Z_I = -29.5\text{db}$

The calculations also show that at 250m

Channel 65,  $Z_I = -14.8\text{db}$ .

Channel 34,  $Z_I = -17.5\text{db}$ .

These figures indicate that there is a potential for interference for the UHF channels up to and beyond 1.5 Km from the generators in the forward scatter region.

Scatter from multiple generators would be additive to some degree at each receiver.

*Note1. The formula for  $B_{e,\text{max}}$  was established for a 3 bladed generator in a recent exchange of emails with Prof. Sengupta, of the University of Michigan, USA, one of the Authors of Ref. 1.*

## ATTACHMENT 9 - GLOSSARY OF TECHNICAL TERMS

VHF	Very High Frequency
UHF	Ultra High frequency
EMI	Electromagnetic Interference
VHF Channels	TV Channels 0 to 12 (45 - 230 Mhz)
UHF Channels	TV Channels 28 - 46 (526 - 820 Mhz)
Band 111	VHF TV Channels 5A - 12
First Fresnel Clearance	Clearance to obstructions from the ray line on a radio Path which does not produce any additional loss above free space loss
FM	Frequency Modulation
MF	Medium Frequency
LF	Low Frequency (not used for sound broadcasting in Australia)
GSM	European Digital Cellular Mobile System
CDMA	Code Division Multiple Access Cellular Mobile System
ITU	International Telecommunications Union
ACMA	Australian Communications & Media Authority
CB Radio	Citizens Band Radio