HF Radio Frequency Noise Measurements at Quartz Hill

Background

The Quartz Hill site was originally used by the Broadcasting Corporation of New Zealand (BCNZ) to receive shortwave radio broadcast programmes from around the world, before these types of programmes could be carried by satellite and underwater cable technologies.

The Wellington Amateur Radio Club took over the site from Radio New Zealand in 1997, and developed an amateur radio station (callsign ZL6QH) which became renowned worldwide for its operations on the high frequency (HF) bands below 30 MHz. The station was dismantled in 2007 to make way for the civil works associated with Meridian Energy's West Wind project.

A low level of interference from man-made radio frequency noise was a key requirement and feature of both the broadcasting and amateur radio operations at Quartz Hill.

Members of the Wellington Amateur Radio Club visited the West Wind project site on 10 May and 15 August 2009 to measure the level of HF radio frequency noise radiated by the wind turbines. The purpose of the measurements was to help the club assess the level of interference that would be experienced if the amateur radio station was rebuilt at Quartz Hill, or at another location in the general vicinity of the wind farm.

Measurements

Figure 1 shows the layout of the turbines and the areas in which the measurements were conducted. Only the turbines highlighted in blue and a few of the G road turbines were commissioned prior to our 10 May measurements. All of the turbines to the north of turbine J01 had been commissioned by the time we conducted the 15 August measurements.

Photographs of some of the measurement locations are shown in Figures 2 to 5 at the end of this report.

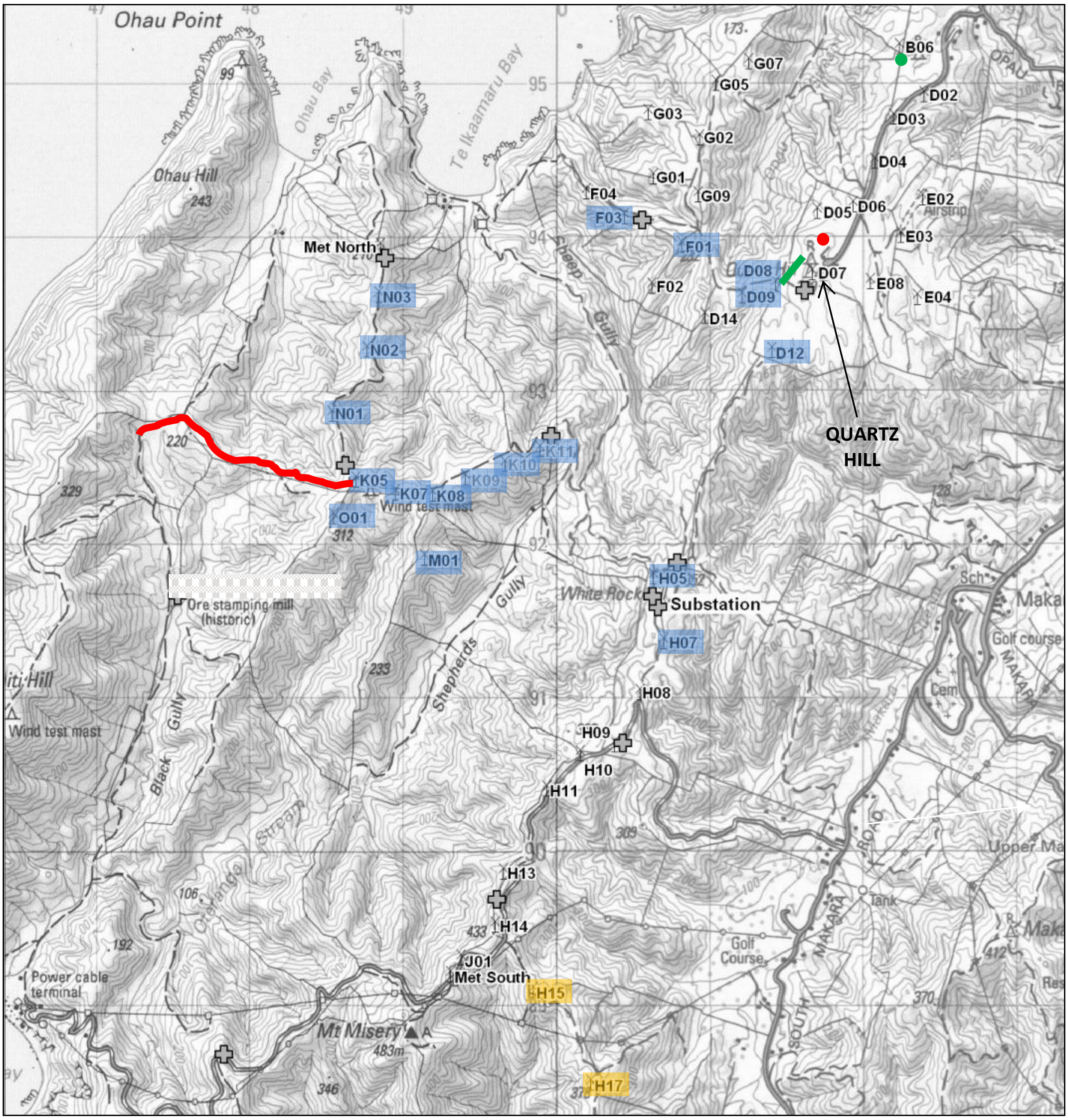
Due to the limited time available on site, the measurements were restricted to a frequency of 3.73 MHz within the 80 metre amateur band. The 80 metre band was selected because the noise from AC power sources is generally more noticeable at lower frequencies, and this band is one of the main ones used by amateur operators at the lower end of the HF spectrum. The 3.73 MHz frequency was chosen because it provided the best impedance match for maximising the transfer of the received noise power from the antenna system to the receiver[1].

The measurement receiver was a Kenwood TS120V radio (with 2.4 kHz IF filter) powered from a battery. Table 2 shows the outcome of the calibration measurements used to translate the receiver S meter readings into received power (dBm). The antenna was a half wave 'inverted vee' wire dipole antenna, approximately 40 metres long. A length of RG58 coax cable (up to 30 metres long) was used to connect the antenna to the receiver input.

Measurements were conducted with the dipole antenna wire orientated to be either in line with the direction of the nearest 'reference' turbine (0 degrees) or perpendicular to this direction (90

[1] The VSWR of the antenna system at 3.73 MHz was less than 1.5:1.

degrees). The centre of the antenna was supported at a height of 5 metres above ground level, except in the case of the 15 August measurements at Quartz Hill (Location 6) where a 22 metre steel pole was used to support the antenna at various heights between 5 metres and 20 metres.



XNN	Turbines that were commissioned prior to 4 May 2009
XNN	Turbines that were commissioned after 4 May and prior to 15 August 2009
XNN	Turbines that were NOT commissioned at 15 August 2009
	Location of 15 August measurements
	Location of 10 May measurements

Figure 1: Map Showing the Turbine and Measurement Locations[2]

[2] Map source: June 2009 Kordia report 'Investigation of Wind Turbine Emissions in the HF Band'

Results

The measured data is summarised in Table 1, and plotted in Chart 1, to show the relationship between the level of received noise and distance from the nearest turbines.

Tuning the measurement receiver across the range between 3.5 MHz and 4 MHz confirmed that the noise sounded like manmade electrical 'hash' and was broadband in nature, i.e., there were no significant peaks or nulls in the level of noise across this frequency range.

Audible monitoring confirmed that the measurement frequency was not impacted by any transmissions from local or distant HF stations, and the only atmospheric noise was in the form of intermittent lightning crashes which peaked up to near the -110 dBm level when making measurements later in the afternoon on 10 May at Location 5.

As shown in Chart 1, the trend of the data as a function of distance is best approximated by a straight line, with the measured noise level decreasing at a rate of approximately 20 dB per decade (or 6 dB per octave) when moving away from the nearest turbines. This result indicates that the measured noise is emanating from the turbine installations and not from other background noise sources in the environment. Furthermore, during our 10 May measurements, the nearest operational turbine (D08) stopped on several occasions due to insufficient wind. When it stopped we were able to observe, and hear, a significant reduction in the level of received noise.

It also seems unlikely that our measurements were effected by any radiation from the buried high voltage transmission cables that connect each turbine to the sub station. The majority of the measurements were conducted at locations remote from the cable routes. In particular, the 15 August measurements at Locations 7 to 13 were conducted along a road which is not associated with any high voltage cables.

Our club had significant experience in operating an HF radio station at Quartz Hill over the 10 year period from 1997 to 2007, involving more than 170,000 contacts with overseas stations on frequencies between 1.8 MHz and 30 MHz. Many of these contacts involved weak signals close to the noise floor of the receivers. Generally there was no evidence of interference from local man made noise emissions during these contacts. The only exception was some low level noise emanating from the Transpower High Voltage DC transmission line, and this was only noticeable when using high gain beam antennas aimed towards the direction of the line.

After considering the above, we are confident that the observed radio frequency noise is a result of the wind farm development and mainly emanating from the vicinity of the turbine structures.

The West Wind turbines use a Siemens 2.3 MW variable speed design. It is likely that most of the radiated noise is created by the water cooled electronic power converter that translates the variable voltage and frequency output from the generator to the fixed voltage and frequency of the national grid[3].

Chart 1 shows that the noise levels measured on 15 August are approximately 10 dB greater than those measured on 10 May. It seems likely that this shift is mainly due to the greater number of

[3] The club conducted some HF radio frequency noise measurements at the Meridian Energy Te Apiti wind farm in October 2005 but could find no evidence of any significant noise being radiated by the turbines, even at locations within 100 metres of the nearest turbines. Unlike the West Wind turbines, the Te Apiti turbines are a fixed speed design and do not require a separate power converter unit.

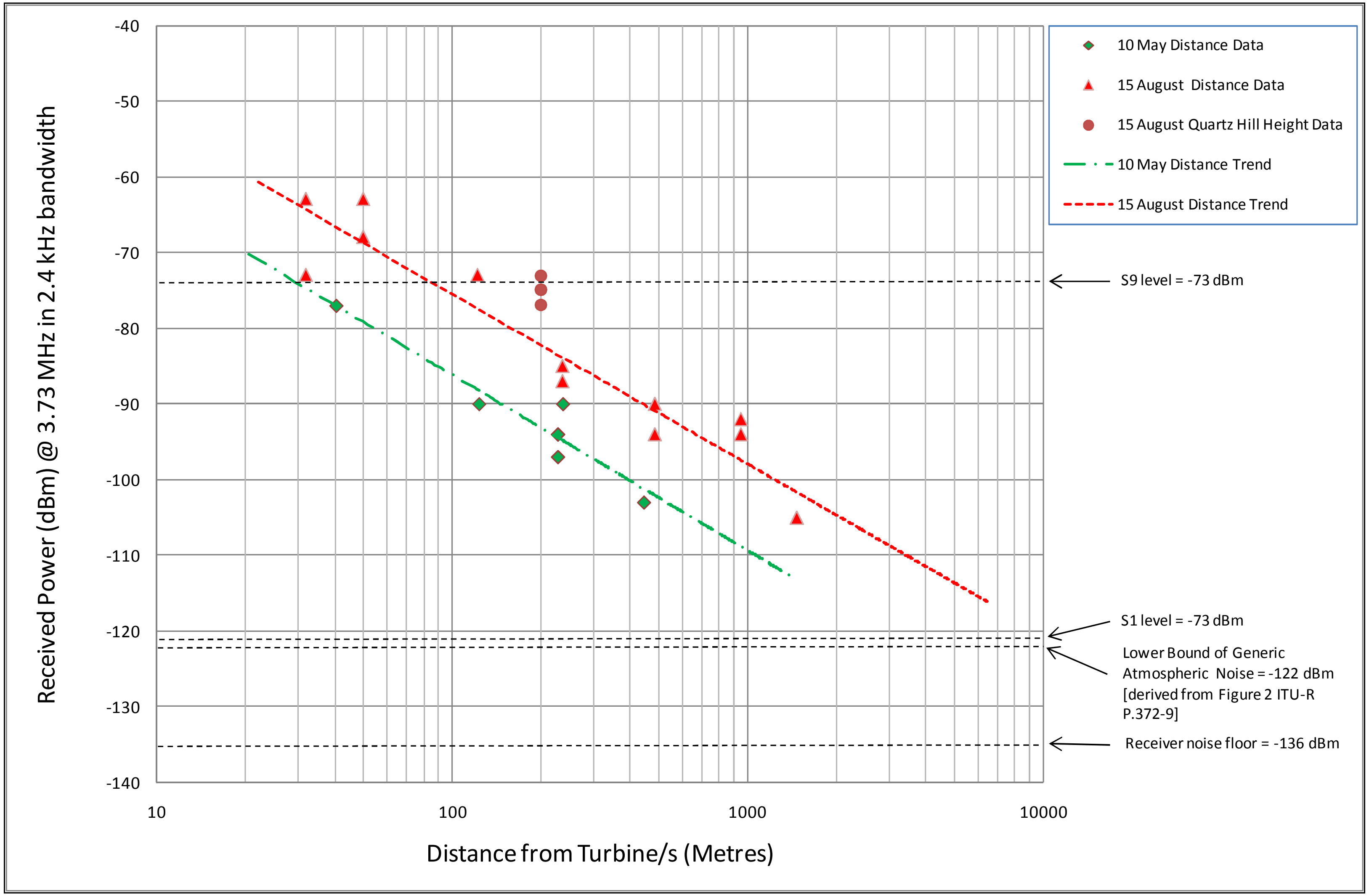


Chart 1: Measured Noise as a Function of Distance from the Nearest Project West Wind Turbine/s[4]

[4] Siemens 2.3 MW variable speed machines

turbines that were operating on 15 August, noting that the received noise level is the sum of the respective noise powers received from each of the individual turbines

In order to effectively receive weak amateur radio signals, the club requires a level of man-made noise that is comparable to or less than the level of emissions from natural noise sources in the HF range. Curve B in Figure 2 of Recommendation ITU-R P.372 plots the lower bound of the values of atmospheric noise that are exceeded for 99.5% of time. The calculation in Table 3 shows that the lower bound of atmospheric noise at 3.73 MHz is -122 dBm in a 2.4 kHz band width. Our previous experience at Quartz Hill confirms that an HF amateur radio station operating with weak signals needs to be capable of receiving signals down to near the -122 dBm level.

The information in Chart 1 shows that the received noise is significantly greater than the -122 dBm objective. On 15 August this objective was exceeded by up to 50 dB in the Quartz Hill area (Location 6) and 17 dB in an area (Location 13) approximately 1.5 kilometres from the nearest turbines.

Extrapolation of the straight line trend beyond 1.5 kilometres for the 15 August data in Chart 1 suggests that an amateur radio station would need to be located at a distance of ten or more kilometres from the nearest turbines in order for the noise to be attenuated to levels that are comparable to the -122 dBm objective.

It is recognised that a prediction based on a simple extrapolation of the straight line trend may not be appropriate. This is because the main mode of propagation is likely to be a surface wave which initially travels for a short distance as through free space with an attenuation rate of 20 dB per decade, but beyond this distance it moves into the Sommerfeld zone where the attenuation rate increases and eventually reaches 40 dB per decade. The distance at which the Sommerfeld zone commences is not easily predicted and depends on various factors including the frequency, ground conductivity and geometry of the path. However, even an overly optimistic scenario, in which the attenuation rate jumps to 40 dB per decade beyond 1.5 kilometres, would still require an amateur radio station to be located several kilometres away from the nearest turbines in order to meet the -122 dBm objective.

Furthermore, it should be noted the above predictions are conservative as they do not take into account the factors of antenna polarisation and gain. These factors are likely to contribute to the actual noise level received by an amateur radio station being greater than that observed in the measurements.

An inverted vee dipole, like that used in the measurements, is most effective at receiving horizontally polarised radio waves and in the direction perpendicular to the wire, but it also provides some limited response to vertically polarised waves in the direction of the wire. The measured data shows that the level of measured noise was generally greatest (by a margin of several dB) when the antenna wire was orientated in line with the direction of the nearest 'reference' turbine rather than in the perpendicular direction. This observation indicates that the noise emissions are mainly vertically polarised, and therefore the received noise is likely to be greater than the measured levels when using antennas that are designed for the effective reception of vertically polarised waves.[5]

The antennas at a permanent amateur radio station can be expected to have more gain than the dipole antenna used in the measurements, due to a combination of their greater elevation and directivity. This additional gain is also likely to result in more noise being received.[6] The effect of

[5] Vertically polarised antennas are typically used for amateur radio communications at lower frequencies (below 4 MHz) where they are often more effective than horizontally polarised antennas for long distance communications.

[6] More noise is captured in the direction of maximum gain but there is also greater rejection of noise in other directions.

increasing antenna height is demonstrated in the 15 August measurements at Location 6 (Quartz Hill) where there was a noticeable increase in noise level (approximately 3 dB) as the height of the centre of the antenna was increased from 5 metres to 20 metres above ground.

Conclusion

The measurements conducted on 10 May and 15 August 2009 confirm that it will not be possible to operate an amateur radio HF station in the vicinity of Quartz Hill due to the high level of radiated noise interference from the wind turbine infrastructure. At 3.73 MHz, the measured level of radiated noise is approximately 50 dB greater than that sought for weak signal HF amateur radio communications. Our analysis of the measurement data suggests that an amateur radio station would need to be separated from the nearest turbines by a distance of at least several kilometres, and possibly up to more than 10 km, in order to reduce the interference to the desired level.

Acknowledgments

The club is grateful to:
- Meridian Energy Limited for facilitating access to the West Wind site for the noise measurements.
- Ralph Sutton ZL2AOH, Bob Vernall ZL2CA, Doug McNeill ZL2AOV and Brian Miller ZL1AZE for their assistance with the measurement work.

Report prepared by:
Brian Miller ZL1AZE
Chair of Quartz Hill Committee
Wellington Amateur Radio Club Inc
13 December 2009

RF Noise Measurements at Project West Wind		
Date	10-May-09	15-Aug-09
Weather	Fine, light winds caused some intermittent turbine operation	Fine and cloudy, until the onset of a rain shower during the measurements at location 13
Club Personnel	ZL1AZE, ZL2AOV, ZL2AOH, ZL2CA	ZL1AZE, ZL2AOV, ZL2AOH
Operational Turbines	Except for D12 (stopped in light wind) all of the turbines commissioned prior to 4 May were turning. A few turbines along the G road were also observed to be turning.	All of the turbines commissioned prior to 15 August were turning
Measurement Receiver	Kenwood TS120V powered from a battery, 2.4 kHz SSB filter	
Measurement Antenna	Inverted vee half wave 'inverted vee' dipole tuned for a nominal resonant frequency of 3.7 MHz. The centre was supported by a 5 metre pole, except at location 6 where the height was varied from 5 to 20 metres	
Transmission cable	RG58 coax - up to 30 metres in length	
Measurement Frequency	3.73 MHz	

Date	**Time**	**Reference Turbine Location**			**Measurement Location**			**Dipole Orientation**	**Distance**	**Location Description**	**TS120V S Meter**		**Comment**
		Turbine	Grid N	Grid E		Grid N	Grid E	Degrees	Metres		S Units	dBm	
10-May-09	1431	D08	5993696	2651431	1	5993723	2651461	90	40	40 metres NE of D08	S8	-77	
10-May-09	1447	D08	5993696	2651431	2	5993802	2651494	90	123	120 metres NE of D08	S5	-90	
10-May-09	1504	D08	5993696	2651431	3	5993872	2651576	90	228	230 metres NE of D08	S4	-94	
10-May-09	1507	D09	5993617	2651209	3	5993872	2651576	90	447	450 metres NE of D09	S2	-103	D08 stopped in light wind
10-May-09	1511	D08	5993696	2651431	3	5993872	2651576	0	228	230 metres NE of D08	S4	-94	
10-May-09	1513	D08	5993696	2651431	3	5993872	2651576	90	228	230 metres NE of D08	S3	-97	
10-May-09	1542	D08	5993696	2651431	4	5993627	2651658	90	237	240 metres E of D08	S5	-90	
10-May-09	1612	D08	5993696	2651431	5	5995605	2652312	90	2102	2100 metres NE of D08	<S1	< -110	Could hear atmospheric and turbine noise, and a S1 SSB overseas station on 3800 kHz
15-Aug-09	1234	D07	5993767	2651669	6	5993938	2651771	0	199	200 metres NE of D07	S9	-73	Dipole centre @ 20 metres AGL
15-Aug-09	1236	D07	5993767	2651669	6	5993938	2651771	90	199	200 metres NE of D07	S9	-73	Dipole centre @ 20 metres AGL
15-Aug-09	1242	D07	5993767	2651669	6	5993938	2651771	90	199	200 metres NE of D07	S8.5	-75	Dipole centre @ 10 metres AGL
15-Aug-09	1244	D07	5993767	2651669	6	5993938	2651771	0	199	200 metres NE of D07	S8.5	-75	Dipole centre @ 10 metres AGL
15-Aug-09	1249	D07	5993767	2651669	6	5993938	2651771	0	199	200 metres NE of D07	S8	-77	Dipole centre @ 5 metres AGL
15-Aug-09	1249	D07	5993767	2651669	6	5993938	2651771	90	199	200 metres NE of D07	S8.5	-75	Dipole centre @ 5 metres AGL
15-Aug-09	1415	K05	5992408	2648694	7	5992419	2648664	90	32	30 metres E of K05	S9	-73	Noted a few dB variation in noise level as K05 blades rotated.
15-Aug-09	1421	K05	5992408	2648694	7	5992419	2648664	0	32	30 metres E of K05	S9+10	-63	
15-Aug-09	1430	K05	5992408	2648694	8	5992408	2648644	0	50	50 metres E of K05	S9+10	-63	
15-Aug-09	1431	K05	5992408	2648694	8	5992408	2648644	90	50	50 metres E of K05	S9+5	-68	
15-Aug-09	1440	K05	5992408	2648694	9	5992374	2648577	0	122	120 metres E of K05	S9	-73	
15-Aug-09	1448	K05	5992408	2648694	10	5992470	2648466	0	236	220 metres E of K05	S6.5	-85	
15-Aug-09	1449	K05	5992408	2648694	10	5992470	2648466	90	236	220 metres E of K05	S6	-87	
15-Aug-09	1500	K05	5992408	2648694	11	5992385	2648209	0	486	480 metres E of K05	S5	-90	
15-Aug-09	1507	K05	5992408	2648694	11	5992385	2648209	90	486	480 metres E of K05	S4	-94	
15-Aug-09	1520	K05	5992408	2648694	12	5992628	2647770	90	950	950 metres E of K05	S4	-94	
15-Aug-09	1522	K05	5992408	2648694	12	5992628	2647770	0	950	950 metres E of K05	S4.5	-92	
15-Aug-09	1535	K05	5992408	2648694	13	5992680	2647251	90	1468	1500 metres E of K05	S1.5	-105	
15-Aug-09	1536	K05	5992408	2648694	13	5992680	2647251	0	1468	1500 metres E of K05	S1.5	-105	

Table 1: Measurement Data

TS120V Meter Calibration @ 3.73 MHz (0dB = approx 50 uV at input to TS120V receiver)		
Level	dB	dBm
S9+10	10	-63
S9+5	5	-68
S9	0	-73
S8.5	-2	-75
S8	-4	-77
S7	-9	-82
S6.5	-12	-85
S6	-14	-87
S5	-17	-90
S4.5	-19	-92
S4	-21	-94
S3	-24	-97
S2	-30	-103
S1.5	-32	-105
S1	-34	-107

Table 2: TS120V Receiver Calibration

Rec. ITU-R P.372-9 Calculations			
$P_n = F_a + B - 204$	where:	$P_n =$	10 log p_n : available power (W)
		$B =$	10 log b , and –204 = 10 log $k\ t_0$.
		b :	noise power bandwidth of the receiving system (Hz)
<u>Lower Bound of Atmospheric Noise - Curve B in Figure 2</u>			
Frequency	3.73E+00	MHz	
b	2.40E+03	Hz	
B	3.38E+01	dB	
Fa	18	dB	
Pn	-1.52E+02	dBW	
Pn	-1.22E+02	dBm	

Table 3: ITU-R P.372-9 Noise Calculations

Figure 2: 10 May 2009 - Measurements to the North East of D08

Figure 3: 10 May 2009 - Measurement Location 5, 2100 metres to North East of D08

Figure 4: 15 August 2009 – Height Measurements at Location 6 (Quartz Hill)

Figure 5: 15 August 2009 – Measurement Location 13, 950 metres to West of K05