Appendix D

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Measurement and Level of Infrasound From Windfarms And Other Sources

MEASUREMENT AND LEVEL OF INFRASOUND FROM WIND FARMS AND OTHER SOURCES

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Infrasound is generated by a range of natural and engineered sources. The measurement of infrasound at low levels requires a specific methodology, as it is readily affected by even light surface breezes on the microphone. Such a methodology, based on measurements below the ground surface in a test chamber, has been developed to measure infrasound at two Australian wind farms and also in the vicinity of a beach, a coastal cliff, the city of Adelaide and a power station. The measured levels have been compared between each source and against the infrasound audibility threshold of 85 dB(G). The measured level of infrasound within the wind farms is well below the audibility threshold and is similar to that of urban and coastal environments and near other engineered noise sources.

INTRODUCTION

Infrasound is generally considered to be sound at frequencies less than 20 Hz and is often described as inaudible. However, sound below 20 Hz remains audible provided that the sound level is sufficiently high [1]. Infrasound is generated by a range of natural sources, including waves on the coastline, waterfalls and wind. It is also generated by a wide range of engineered sources such as industrial processes, vehicles, air conditioning and wind farms. The thresholds of audibility for infrasound have been determined in a range of studies [2]. The G-weighting has been standardised to determine the human perception and annoyance due to noise that lies within the infrasound frequency range [3]. A common audibility threshold from the range of studies is an infrasound level of 85 dB(G) or greater. The audibility threshold limit of 85 dB(G) is consistent with other European standards and studies, including the UK Department for Environment, Food and Rural Affairs threshold developed in 2003 [2], the UK Department of Trade and Industry study [4], the German Standard DIN 45680 [5] and independent research conducted by Watanabe and Møller [6].

There have been concerns raised in the community regarding the generation of infrasound by Australian wind farms. The generation of infrasound was detected on early international turbine designs, which incorporated the blades 'downwind' of the tower structure [7]. The mechanism for the generation was the blade passing through the wake caused by the presence of the tower. Modern wind turbines now locate the blade 'upwind' of the tower.

Australian States presently assess the noise from wind farms under a range of Standards and Guidelines [8-12]. These Standards and Guidelines do not provide prescriptive requirements for infrasound from wind farms due to the absence of evidence that infrasound should be assessed.

A specific methodology was developed to reduce the influence that even light surface breezes can have on the infrasound results. The methodology is based on measurements being conducted below the ground surface in a test chamber that is approximately 500mm square and 500mm deep. Infrasound was measured using this below ground methodology at two Australian wind farms, Pacific Hydro's Clements Gap Wind Farm which has been operating in the mid-North of South Australia since 2010 and comprises 27 Suzlon S88 wind turbines, each with a rated capacity of 2.1 MW, and at the coastal Cape Bridgewater Wind Farm which has been operating since 2008 in south-western Victoria, and comprises 29 REpower MM82 wind turbines, each with a rated capacity of 2.0 MW. Infrasound was also measured in the vicinity of a beach, a coastal cliff, the city of Adelaide and a power station using the below ground methodology. This paper reports on the study that:

- Develops a methodology to measure infrasound that minimises the influence of wind on the microphone;
- Measures the levels of infrasound at a range of distances from a wind turbine, for two wind farms;
- Compares the results against recognised audibility thresholds; and
- Compares the results with infrasound measurements taken near natural sources, such as beaches, and engineered sources, such as a power station and general activity within the city of Adelaide.

MEASUREMENT TECHNIQUE

Equipment

All measurements were conducted with a SVANTEK 957 Type 1 NATA calibrated sound and vibration analyser. The SVANTEK 957 Type 1 meter has a measured frequency response down to 0.5 Hz. A GRAS 40AZ ½" free field microphone with a frequency response of ±1dB to 1 Hz and ±2dB to 0.5 Hz was used with the SVANTEK meter. The meter and microphone arrangement is therefore suitable for measurement of noise levels in the infrasound range to the level of accuracy required for the assessment.

Microphone Mounting Method

A microphone mounting method is provided in IEC 61400-11 [13]. The method was developed to minimise the influence of wind on the microphone for the measurement of noise in frequencies higher than those associated with infrasound. This is achieved by mounting the microphone at ground level on a reflecting surface and by protecting the microphone with two windshields constructed from open cell foam. The method was not developed specifically for the measurement of infrasound, and wind gusts can be clearly detected when measuring in the infrasound frequency range using the above method. Therefore, this study has developed an alternative method to reduce the influence of wind on the microphone that would otherwise mask the infrasound from a particular source. A below ground surface method was developed based on a similar methodology [14]. This method has been adapted for this study, and includes a dual windshield arrangement, with an open cell foam layer mounted over a test chamber and a 90mm diameter primary windshield used around the microphone. The microphone mounting arrangement is depicted in Figure 1.

Verification of Technique

The below ground technique was analysed at a remote site away from wind farms, transport corridors and other appreciable noise sources and in very still conditions. The aim of the analysis was to determine the level of transfer of infrasound from outside to inside the chamber. The following procedure was used:

- A constant level of infrasound was generated using a tone signal generator and sub-woofer speaker (B&W Type ASW CDM), mounted 1m above the ground at a distance of 10m horizontally from the chamber. The lowest frequency that could be generated by the signal generator was 8 Hz and therefore the infrasound was generated at a number of discrete frequencies between 8 and 20 Hz.
- The infrasound was measured using the IEC 61400-11 above ground technique;
- The infrasound was measured using the below ground technique;
- The infrasound was measured without the tone signal generator operating to determine the ambient level of infrasound.

The measurement results are summarised in Table 1. The measured levels inside and outside of the chamber were consistent at all of the frequencies produced by the signal generator. The measurement of a constant source of infrasound in still conditions is the same above the ground as in the chamber using the technique described above.

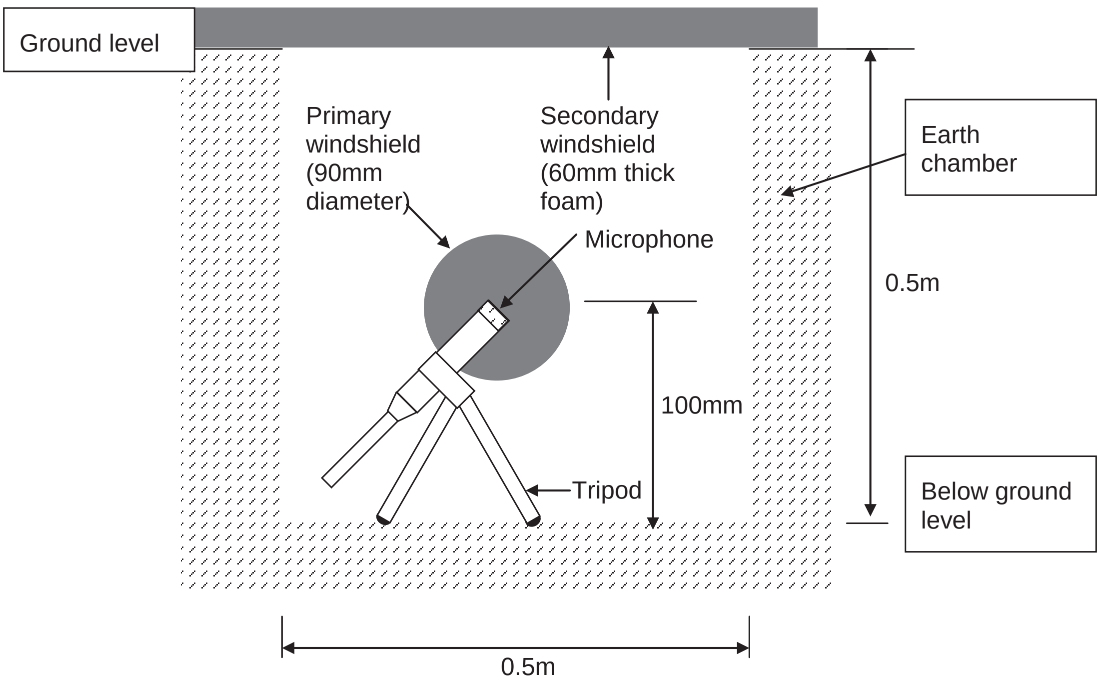

Figure 1. Schematic diagram of the microphone position (not to scale)

Table 1. Measurement at approximately 10m from the controlled source with no wind

Frequency (Hz)		8.00	10.0	12.5	16.0	20.0
Noise Level (dB)	Inside chamber	47	50	54	60	63
	Outside chamber	47	50	54	60	63
	Ambient level	39	38	39	39	37

RESULTS

Infrasound was measured at the Clements Gap Wind Farm and the Cape Bridgewater Wind Farm, using the below ground methodology. In addition, the level of infrasound was measured in the vicinity of a beach, a coastal cliff, a city and a power station using the same methodology. At Clements Gap Wind Farm, the infrasound was measured at distances of 85m, 185m and 360m from the base of a turbine in a downwind direction. The testing was conducted between approximately 7pm and 11pm on Tuesday 11 May 2010, under a clear night sky with a light breeze. Operational data indicates that the turbines were subject to hub height wind speeds of the order of 6 to 8m/s during the period of the testing. The wind speed at ground level was not measured.

At Cape Bridgewater Wind Farm, the infrasound was measured at distances of 100m and 200m from the base of a turbine in a downwind direction. The testing at the wind farm site was conducted between approximately 4am and 6am on Wednesday 2 June 2010, under a clear night sky with a light breeze. During the testing, the operational status of the turbines was constantly observed and confirmed. Measurements were conducted with both the turbines operational and with the turbine blades stationary.

To determine the level of infrasound from natural sources, measurements using the below ground method were made at Cape Bridgewater 25m from the high waterline of a beach, at approximately 250m inland from a coastal cliff face and at 8km inland from the coast. To determine the level of infrasound from other engineered noise sources, measurements using the below ground method were conducted at a distance of approximately 350m from a gas fired power station as well as within the city of Adelaide at least 70m from any major road. The measured levels of infrasound are summarised in Table 2 and are shown graphically in one third octave bands in Figures 2, 3, 4 and 5.

Table 2. Measured levels of infrasound

Noise Source	Measured Level (dB(G))
Clements Gap Wind Farm at 85m	72
Clements Gap Wind Farm at 185m	67
Clements Gap Wind Farm at 360m	61
Cape Bridgewater Wind Farm at 100m	66
Cape Bridgewater Wind Farm at 200m	63
Cape Bridgewater Wind Farm ambient	62
Beach at 25m from high water line	75
250m from coastal cliff face	69
8km inland from coast	57
Gas fired power station at 350m	74
Adelaide CBD at least 70m from any major road	76

DISCUSSION

At the Clements Gap Wind Farm, the level of attenuation with increasing distance from the turbine is consistent with the theoretical reduction of 6dB for each doubling of the distance due to “hemispherical spreading” of the sound wave. This observation confirms that the measured levels were predominantly produced by the turbine. At the Cape Bridgewater Wind Farm, higher ambient noise levels (without the turbines operating) were encountered than at the Clements Gap Wind Farm and therefore the same attenuation with increasing distance was not observed. This indicates that the measured levels included a significant contribution of infrasound from the turbine at 100m but at a distance of 200m, the infrasound from other sources was at least as significant. The levels of infrasound from waves at a beach (in light swell conditions) and in the vicinity of a coastal cliff were in the same order of magnitude as the infrasound measured close to the wind turbines.

At 8km from the coast, the level of infrasound was significantly lower than levels observed in close proximity to the beach and the coastal cliff. The levels of infrasound in the city of Adelaide and in the vicinity of a gas fired power station were greater than the levels observed close to the wind turbines. The measured levels of infrasound from the wind turbines and all other natural and engineered sources were well below the 85dB(G) threshold of audibility.

CONCLUSIONS

A method for measuring infrasound from wind turbines has been successfully demonstrated. The method shows that wind turbines generate infrasound and that close to wind turbines, the level of infrasound is well below the audibility threshold of 85 dB(G). An attenuation rate of 6dB per doubling of distance from a single turbine was also demonstrated. Infrasound is prevalent in urban and coastal environments at similar levels to the level of infrasound measured close to a wind turbine.

ACKNOWLEDGEMENTS

Pacific Hydro commissioned Sonus to conduct a study with the aim of gaining a better understanding of the levels of infrasound from wind farms and more generally in the environment.

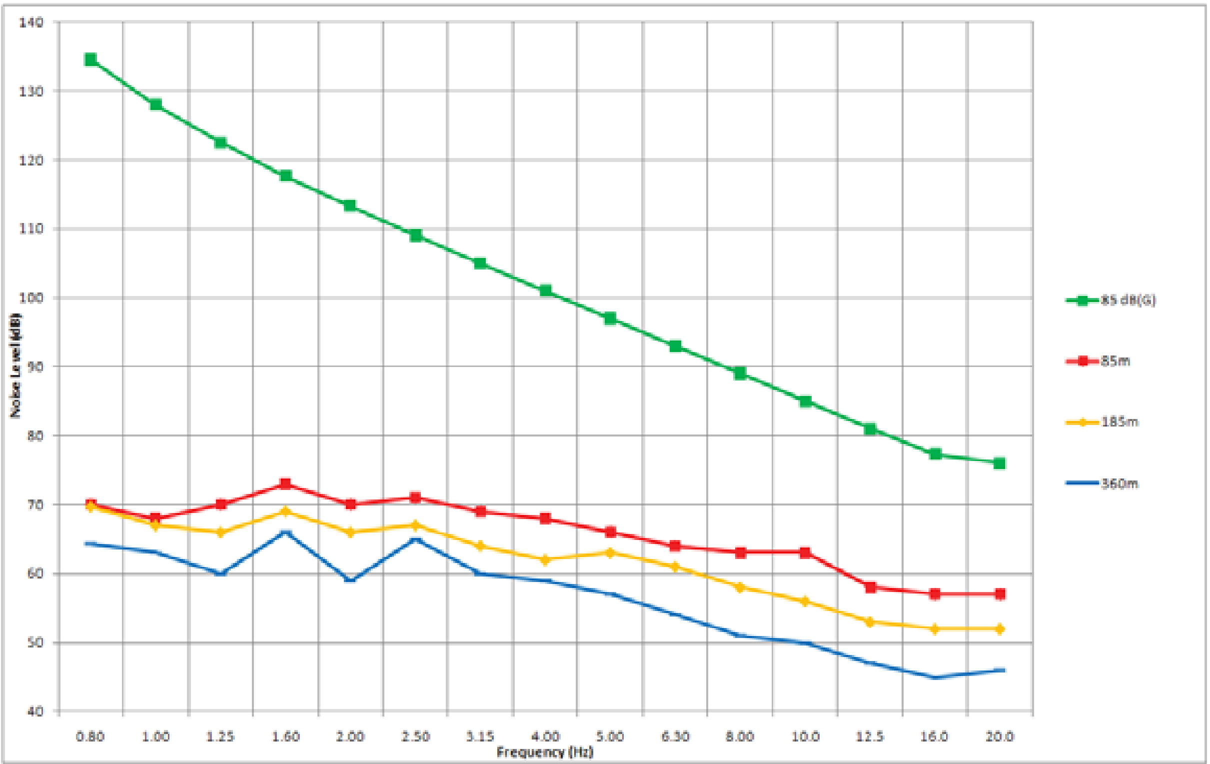

Figure 2. Measured levels of infrasound at Clements Gap Wind Farm

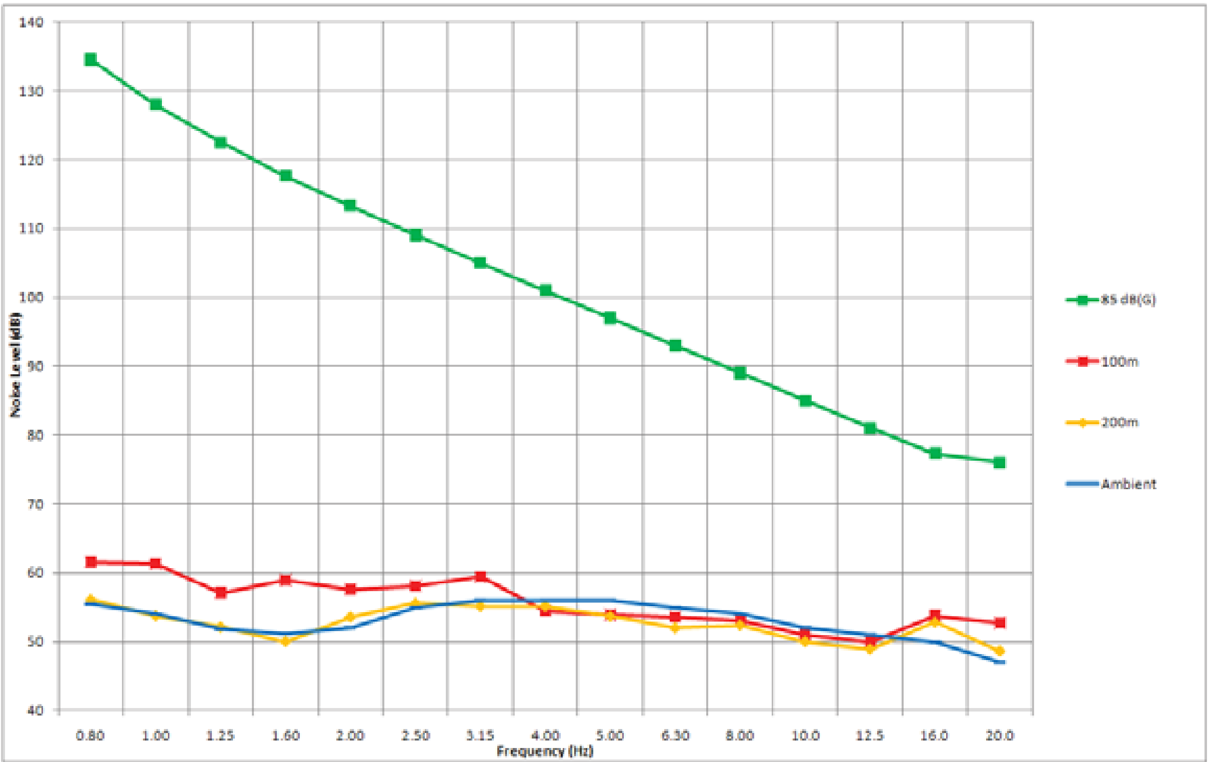

Figure 3. Measured levels of infrasound at Cape Bridgewater Wind Farm

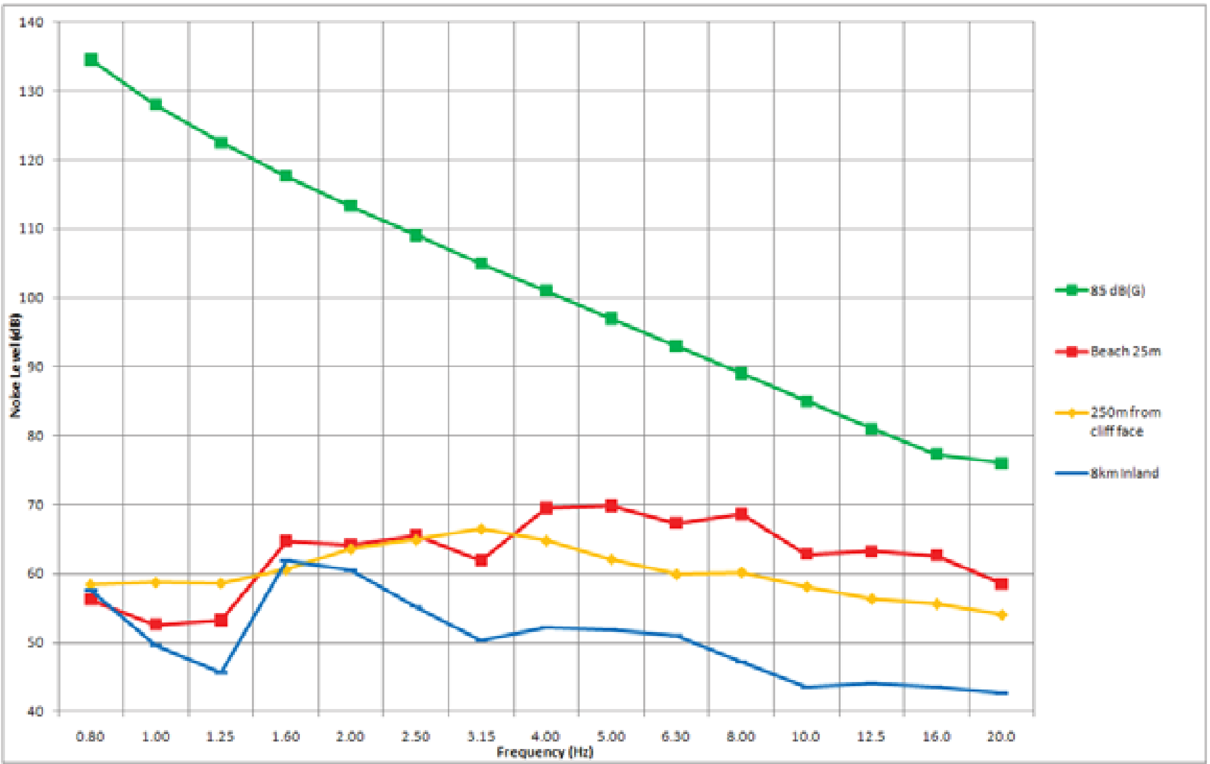

Figure 4. Measured levels of infrasound from natural sources

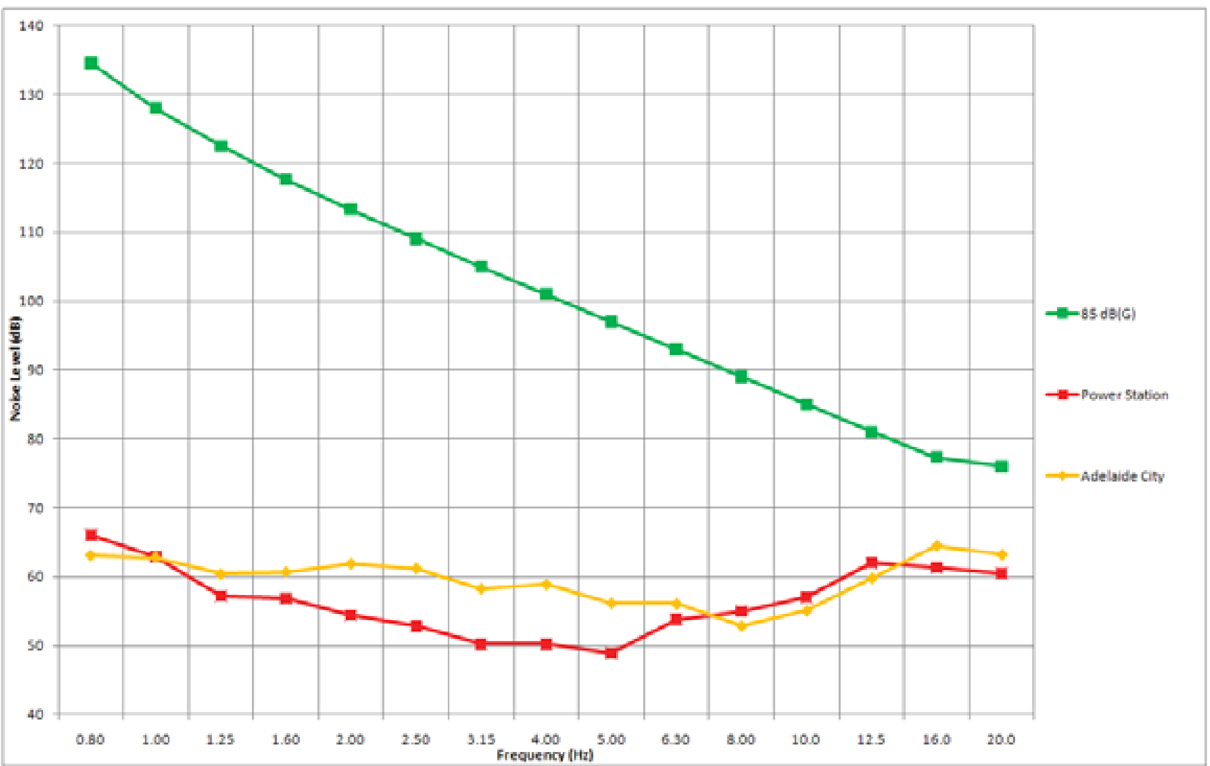

Figure 5. Measured levels of infrasound from engineered sources

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