Technical Note

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LOW FREQUENCY, INFRASOUND AND AMPLITUDE MODULATION NOISE FROM WIND FARMS – SOME RECENT FINDINGS

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This article reviews some recent papers describing low-frequency, infrasound and amplitude-modulation noise from wind turbines, and whether low-frequency and infrasound from wind farms is a real, measurable issue. Some of the information was included in a literature review for the MOE Ontario. Some new information on low-frequency sound and amplitude-modulation at different angular locations from wind turbines presented at Inter-Noise 2011 in Osaka are also included in this review. One proposal for low frequency noise objectives is also discussed.

INTRODUCTION

Recently, amplitude modulation, low frequency and infrasound noise from wind farms has been the subject of complaints, many different media reports and a Senate Inquiry in Australia. The Ministry of Environment of Ontario province in Canada, amongst many other regulators, has been considering a new policy on low-frequency infrasound noise from wind farms and commissioned a literature review into it in 2011. That report collated and considered many papers dealing with the audibility of low-frequency sound and noise from wind farms. Some of the papers presented at Inter-Noise 2011 in Osaka included measurements or predictions of sound levels and frequency spectra from wind turbines, including the low-frequency range and amplitude-modulation. These papers help provide some further information to acousticians dealing with wind farm noise.

Broner [1] suggested an environmental noise quality criterion for low-frequency sound, based on the C-weighted sound level. Comment is provided using comparisons of low-frequency and infrasound hearing thresholds with measured wind turbine sound frequency spectra, and amplitude-modulation sound levels from wind turbines.

LOW FREQUENCY NOISE FROM WIND TURBINES

There have been regular discussions about the existence and potential effects of low frequency and infrasound noise from wind turbines for at least the past 5 years. Studies have been undertaken by or for governments and their agencies, including the NHMRC in Australia [2] and the Ministry of Environment of Ontario in Canada [3], as well as other wind industry groups. These studies have all noted that there is no evidence to support the contentions that low frequency and infrasound noise from wind farms are injurious to health.

It is considered relevant (and hopefully helpful) to acousticians and others working in this area to be aware of studies that have compared the frequency spectrum sound levels of modern wind turbines with the hearing thresholds of otologically normal people. References in the Ontario report have been used to provide eight different low-frequency and infrasound hearing threshold levels reported between 1974 and 2008 [4-8].

One of the papers presented at Inter-Noise 2011 provided sound levels at the reference distance (hub-height + rotor radius) for five different modern wind turbines in Japan, ranging in electrical power capability from 285kW to 2MW [9]. Figure 1 compares the eight different low-frequency and infrasound hearing thresholds from the four references studies, with the measured sound levels of 5 different single wind turbine generators in Japan, over the range 1 to 50 Hz at the distance given.

The figure shows that for the frequency range below 25 Hz, which includes the infrasonic range, the sound levels from the 5 wind turbines is less than the threshold of hearing – for frequencies less than 20 Hz, this difference is at least 10 dB and increases with reducing frequency. The measurement distances range from 44 to 77 m.

Several references listed in the Ontario report describe other natural and man-made sources of low-frequency and infrasound noise and their comparison to wind turbine noise. Man-made sources include pumps, fans, boilers, ventilation plant, road, rail, sea and air transport (and travelling in them) and cooling towers. Natural sources include wind in vegetation, surf breaking and waterfalls. One study reported had sound levels inside passenger road vehicles of 90 to 110 dB at 10 Hz, (compared to the maximum 75 dB for the wind turbines shown in Figure 1).

A report by DELTA [10] compared graphically the sound levels of sources of low-frequency sounds. This showed that many of these sources had much higher levels of low frequency sound than a 3.6MW wind turbine at measured at a distance of 250m.

These reports also noted that there is no evidence that exposure to sound below the threshold of hearing can cause any damage to hearing or other physiological effects. Other naturally occurring and transport noise sources produce much higher levels of low-frequency and infrasonic sound, also without evidence of such effects.

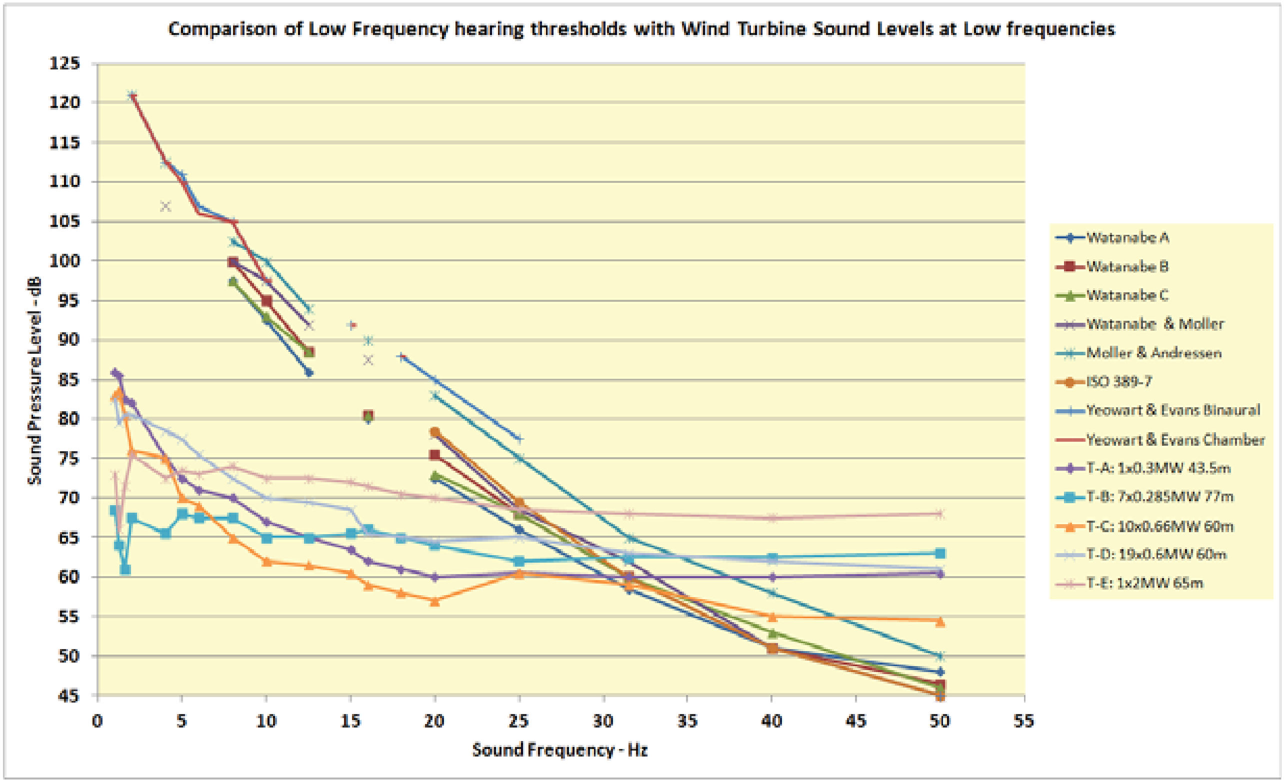

Figure 1. Hearing thresholds and spectrum sound levels from 5 wind farms in the low and infrasonic region

MODULATION SOUND LEVELS FROM WIND TURBINES

Other recent work presented at Inter-Noise 2011 has identified that the amplitude-modulation of sound from the blade pass – the modulation depth (the difference in sound level between the minimum sound level) is highest at the +210º to 240º downstream measurement locations, and can be discernible at relatively long distances from the turbine [9, 11]. This indicates that predictions of sound levels from wind farms could include modulation depth and consider these in the assessment of potential impacts at residential receiver locations. NZS 6808:2010 [12] requires this to be done as part of the assessment of Special Audible Characteristics (SACs), and this method is required for assessment of wind farms in Victoria. Assessment of SACs is also included in the Draft NSW Planning Guidelines: Wind farms [13] (along with tonality and low frequency noise), and a limit of 4 dB modulation depth is proposed.

Miyazaki et al. [9] measured sound levels at 12 equal angled reference distance locations around five different wind turbines to provide measurements for all wind directions. The directionality graph is shown in Figure 2 and shows the higher level locations are away from the centreline and are explained by the directivity of the moving source – this and other papers have shown that the rotor trailing edge is a source of high noise emission, directed forwards from the rotor in the direction of travel in the rotor plane. The reasons for different directivity curves between different types of turbines is not discussed, but could be related to blade profile or wind conditions.

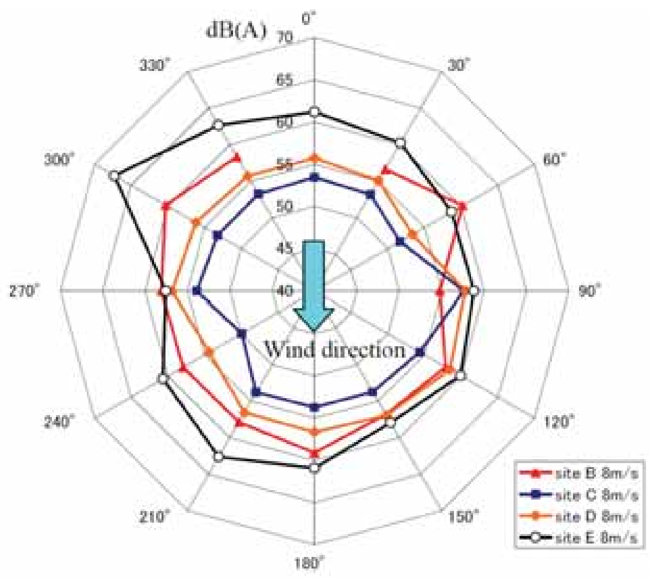

Figure 2. Sound levels at reference distances from 5 wind turbines [9]. Note some locations were affected by background noise

Lee et al. [11] predicted the acoustic pressure for a 2.5 MW wind turbine with 82m hub height and 93m rotor diameter and 15.4 rpm. Sound levels were predicted at the reference positions used in IEC 61400-11:1998 [14], and then at distances out to 1000m. While the sound levels at 1000m were higher along the direct 0° axis than off the axis (37 dBA compared to 30 dBA), and amplitude modulation was not identified at the 0° position, for the 60° off axis position, amplitude modulation was identified. Their study also identified that while the overall sound pressure level decreased with distance, the modulation depth was consistent with distance. This is shown in Figure 3.

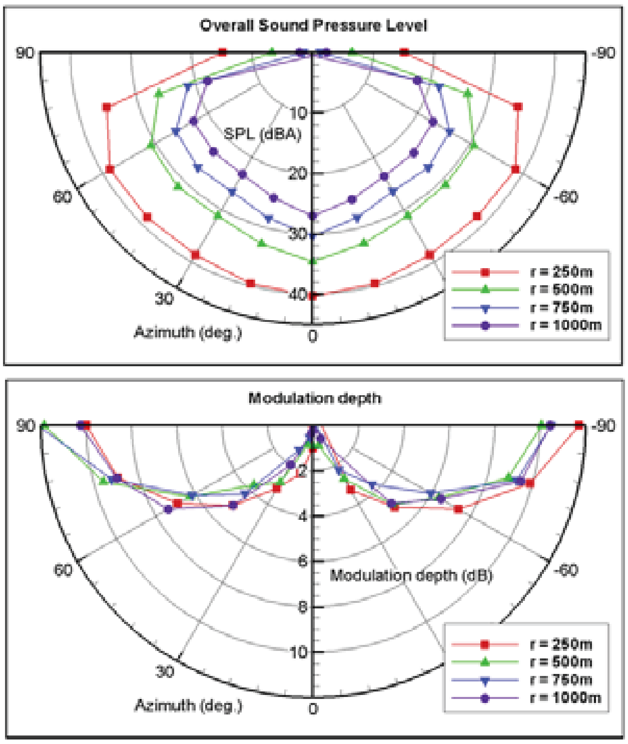

Figure 3. Results of predicted sound levels at increasing distances from a 2.5MW wind turbine, for overall sound levels and modulation depth [11]

Taking these two items together, it may be relevant to consider amplitude modulation as an addition to the predicted overall sound level at receiver locations for comparison with environmental noise quality objectives. This approach would assist in reducing the potential for annoyance that could occur from wind turbines.

LOW-FREQUENCY AND INFRASOUND ENVIRONMENTAL NOISE CRITERIA

Broner [1] discussed different approaches to regulating low-frequency and infrasound noise from industrial sources, including wind turbines. After a detailed review, he recommended a desirable objective external sound level for residential receivers of 60 dBC for night-time. The author's experience with other industrial sources of low-frequency noise indicates that this is a reasonable objective to minimise the potential for noise annoyance.

A benefit of this objective is that it would allow use of most currently used and available Class 1 or Type 1 sound level meters. Other reports have suggested use of the ISO G-weighting for measurement of infrasound. This has the difficulty of having to either find a meter with such a weighting built in, or making one-third octave band measurements in the frequency range 10 to 25 Hz and then converting it. In any case, some development of appropriate methods to measure sound accurately in the low-frequency and infrasound range will be necessary. Such things could be included in revisions to either Australian Standards AS 1055 Acoustics - Description and Measurement of environmental noise, or AS 4959 Acoustics – measurement, prediction and assessment of noise from wind turbine generators.

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