The article is related to sound power levels not the impact of wind turbine sound.

The article requires a second part in relation to the impact on people.

Sound Power Level

There is an expectation that a larger surface area at the same noise level will cause an increase in the sound power level.

The fundamental problem with the wind turbine data is that the concept of sound power level is a total energy from the noise source under investigation.
In acoustic Standards the preferred method is to conduct measurements over the radiating surface and compute the sound power in terms of the average level and the total surface area of the measurements.

The method of assessing the sound power level in IEC.61400-11 Wind turbine generator systems – Part 11: Acoustics noise measurement techniques is to use measurements at ground level with the microphone at the centre of a flat hard board with the axis of the microphone pointing towards the turbine.

The Standard identifies in plan view the microphone measurement positions.

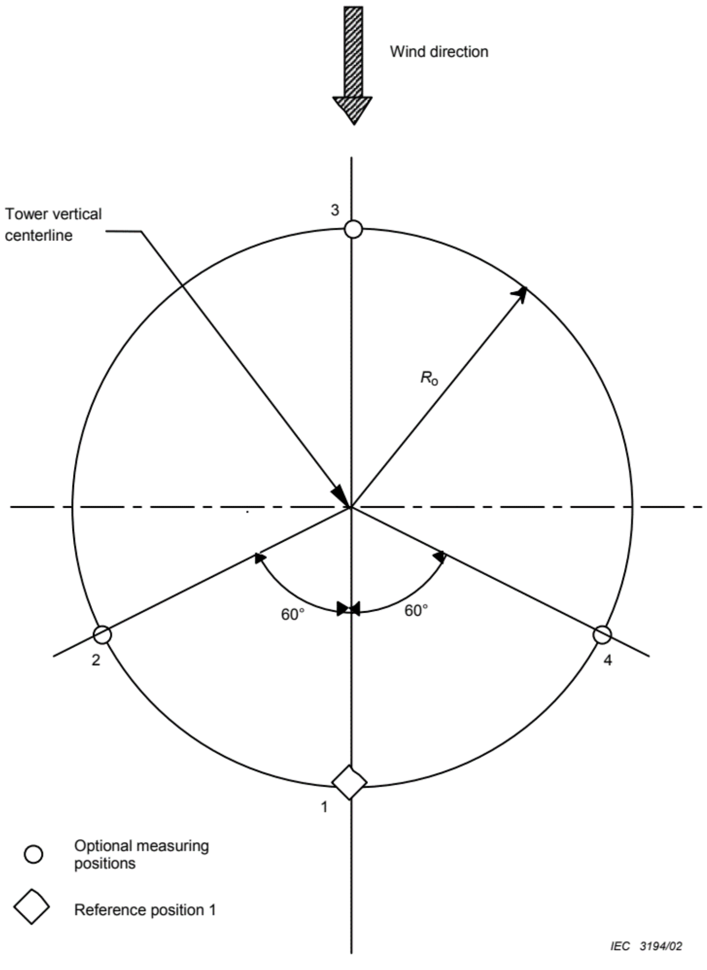

Figure 3 – Standard pattern for microphone measurement positions (plan view)

Oerlemans has shown the radiation pattern of a wind turbine in both plan and side elevation views is a dipole. That means there is a directivity of the radiated sound.
For horizontal axis turbines in elevations the microphone locations are presented in IEC 61400-11 for distance R_0 = hub height + ½ (diameter of the swept path) out from the centre of the tower. The additional of a dipole propagation identifies a focussing of the radiation of sound. Hence the measurement location is in a shadow zone.

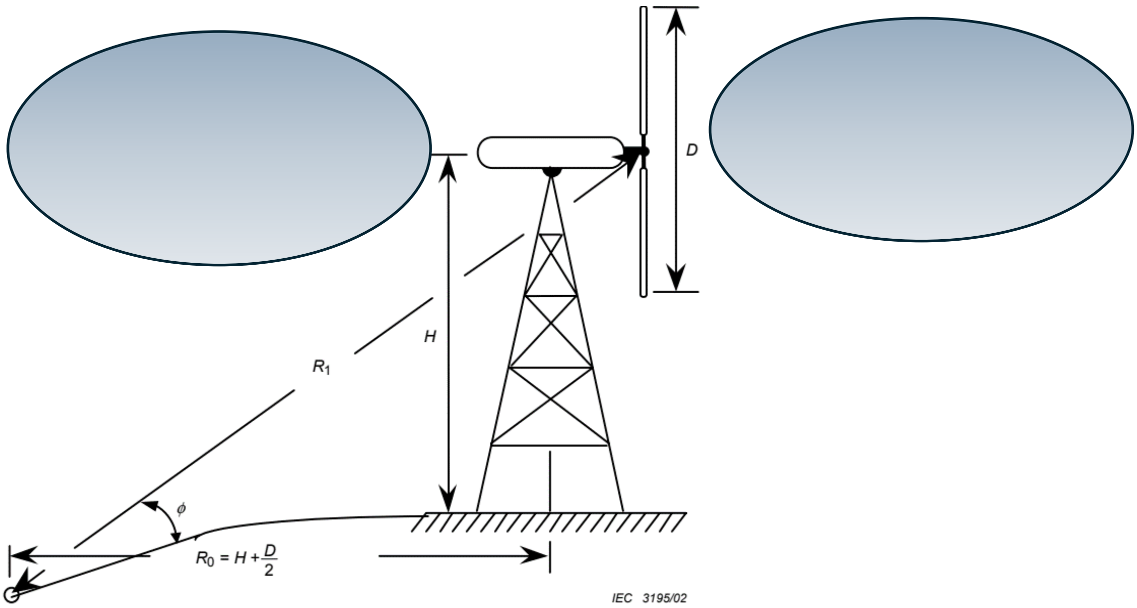

Figure 4a – Horizontal axis turbine

As identified by Oerlemans that correct procedure for determining the directional sound power level is to utilise an array of microphones in the sound field.

Some modelling for wind turbines is based on point source calculations whilst some calculations are based on helispherical source calculations and give rise to different results.

The article assumes similar characteristics for the larger turbines but noting the likelihood of a reduced speed - which in turn will reduce the blade pass frequency. In a general sense the lower speed reduces the timing of the beat of the audible noise. Under Zwicker and Fastl the infrasonic rate of the beat is defined as ‘fluctuation’ and is not heard but sensed.

With the larger area of disturbed air is a critical issue with respect to the depth of modulation of the pulses. This has not been discussed.

The 1/3 octave band spectrum are not relevant to the operation of turbines that have an inherent characteristic that has been described as Amplitude Modulation.

The article has not discussed wake turbulence impacts as a result of downwind turbines being in disturbed air (wakes) from upwind turbines. It has been identified with wake turbulence there is potential for higher levels of modulation that can give rise to a significant enhancement of the pulsations through multiple turbines.

Figure 15 refers to the addition of serrations of five wind turbine types without any comment or results of the benefit of such serrations to the “beat”.

Acoustic Impacts

The article has not discussed the annoyance characteristics of the noise emitted from current wind turbines and penalties to apply for tonal or modulation effects. The use of compliance testing by L90 measurements and a regression curve (under the ETSU-R-97 method) does not in itself appear in the L90 levels.

The principal author’s earlier work identified the beat of turbines was getting louder, where that work was based on small turbines (when compared to current models) or the proposed larger models.
The article refers to dose curves but fails to identify the dose reposes were based on predicted levels absent noise measurement data corresponding to the noise received by residents.

There are court rulings around the world in relation to noise nuisance from wind turbines irrespective of acoustic compliance.

With the general concept of averaged L90 levels as a basis of compliance there is no correlation with noise nuisance or sleep disturbance.

There appears to be a lack of assessment of wind turbine noise levels to identify what level of noise will not give rise to disturbance.

The last paragraph on page 2 is incorrect. The frequency spectrum creates peaks that show up in the infrasound spectrum. That does not mean it creates infrasound as sound waves. The peaks in the infrasound region of an FFT analysis are a result of the presence of the periodic function in the time domain that relates to impulses occurring at the blade pass frequency (say every 1.2 seconds) that are actually described in paragraphs 1-5 in section 2.1.

Using the work of Zwicker and Fastl (referenced the beat is getting louder paper) the modulation (variation in the sound level) at the blade pass frequency is identified as “fluctuation” which is not heard but sensed.

The reaction/sensing of the fluctuation is a function of the modulation depth and the frequency of the modulation.

For the blade stall, the angle of the blade (the pitch) relative to the wind speed changes and leads to greater levels of modulation depth of the sound.

The term Amplitude Modulation to describe the effect of the variation of the periodic sound of turbines. Technically AM is incorrect because in engineering terms it is the mixture of the modulating frequency onto a carrier frequency of a much higher frequency. In acoustics for audiometric testing, they are using tones that are modulated at a much lower frequency.

But in wind turbines what you get is a modulation of the broad band sound at the blade pass frequency. So technically this is not AM.

It has been shown the greater level of modulation the greater level of annoyance.

In the UK they have now defined AM (Amplitude modulation) and the modulation of the overall noise of turbines at the blade pass frequency. In the UK they use normal AM (NAM), Other AM (OAM) and Enhanced/Excessive AM (EAM).

On wind turbines with gearboxes there can be an audible tone from the outputs shaft of the gearbox in the region of 25 Hz that exhibits classical amplitude modulation where in the narrow band frequency spectra there are side bands that are related to AM n(in the correct engineering sense).

Smith et al under the WiTNES pilot study, found reported sleep disturbance for wind turbine noise with strong AM.

CONCLUSION

Residents around the world that are in proximity to wind turbine installations do not react to averaged noise levels set out in permits but are reacting to nuisance/sleep disturbance.

The article requires amendments and needs to address the AM component of larger turbines so as to identify whether the larger swept rotor area (with or without serrations) will reduce the annoyance/nuisance component of wind turbines or will be causing a greater impact.

Oerlemans, S. *An explanation for enhanced amplitude modulation of wind turbine noise*, report NLR-CR-2011-071, National Aerospace Laboratory NLR, https://www.ref.org.uk/Files/RUK-A1.pdf

Smith M, Ogren M., Thorsson P., Hussain-Alkhateeb L., Pedersen E., Forssen J., Morsing J.A., Waye K.P. *Wind Turbine Noise Effects on Sleep: The WiTNES study*, 12th ICBEN Congress on Noise as a Public Health Problem, Zurich June 2017.

van den Berg, G.P. The Beat is Getting Stronger: The Effect of Atmospheric Stability on Low Frequency Modulated Sound of Wind Turbines. *J. Low Freq. Noise Vib. Act. Control* **2005**, *24*