Ongoing Confirmation of Objective Criterion Predicting Annoyance Linked to Wind Turbines

William K.G. Palmer *[1]

[1]TRI-LEA-EM, Paisley, Ontario, Canada

1 Introduction

CAA Acoustics Week in Canada, 2023, introduced a criterion based on an acoustic measure to objectively predict annoyance from wind turbines.[1] That criterion predicted annoyance if (LA10-LA90) was ≤ 3 dBA, while (LZ10-LZ90) was ≥ 6 dBZ. This correlated closely with subjective identification of annoyance from residents living in the wind turbine environment. That evidence was gathered primarily at a site near constant speed, stall regulated wind turbines. This paper gives subsequent investigations of annoyance at a site with variable-speed pitch regulated turbines.

2 Method

2.1 Acoustic data gathering

Data analyzed was collected during an audit performed for the Ontario Ministry of the Environment between December 2018 and April 2019. The data was collected at a home 787 meters from the nearest wind turbine, with 3 turbines within 1000 m, and 16 within 3000 m. Residents identified 77 times for analysis. Some were examples when annoyance was perceived, primarily due to a tonal-like sound emission, characterized by the residents as ‘woo-woo-woo’. Other examples were cases when annoyance was not present. Residents filed a Freedom of Information application to obtain .wav files for 76-11 minutes sound recordings submitted to the Ministry during the audit. This paper reports on analysis of those audit files.

At the same time, recordings were made by a SAM Scribe monitoring system with two microphones, each fitted with 90 mm primary and 450 mm secondary windscreens. The SAM scribe system made a continuous record of 10 minutes .wav sound files.

Acoustic conditions were processed using the application electroacoustics toolbox version 3.9.10, on an iMac computer. This permitted calculating calibrated values of LA10, LA90, LAeq, LZ10, LZ90, and LZeq, as well as charting one-third octave band and FFT analysis.

3 Results

3.1 Correlation of SAM and Audit Data

Good correlation was demonstrated between the audit data and the SAM data, as shown in the sample Figure 1. In some cases, the audit Leq readings were slightly greater than the SAM readings. Listening to the audit data revealed a pronounced rustle at times, suspected to be due to the motion of plastic protecting the microphone from rain.

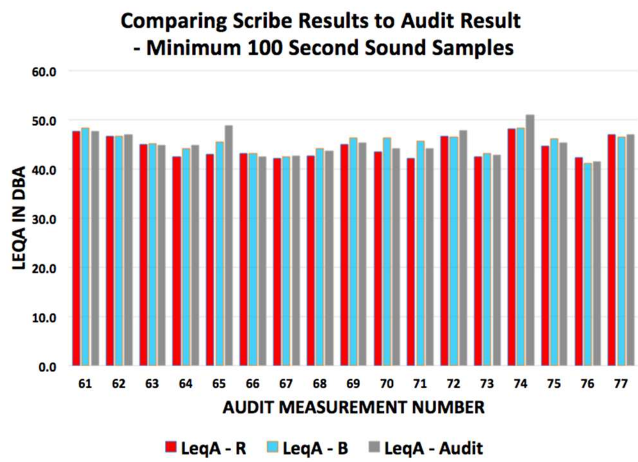

Figure 1: Comparison of red, blue, and audit microphones.

3.2 Testing for presence of annoyance criterion

Each of the 11-1 minute wav files for the 76 audit files were tested to see if the annoyance criterion identified in the previous campaign was met. That criterion predicted annoyance if (LA10-LA90) was ≤ 3 dBA, while (LZ10-LZ90) was ≥ 6 dBZ.

Figure 2 demonstrates the effect of transient contamination by road noise, wind gusts, or wildlife and correlation between the audit, red, and blue microphones on a spectrogram. Samples of at least 100 s for each available microphone were selected for analysis from time periods where the spectrograms showed insignificant contamination.

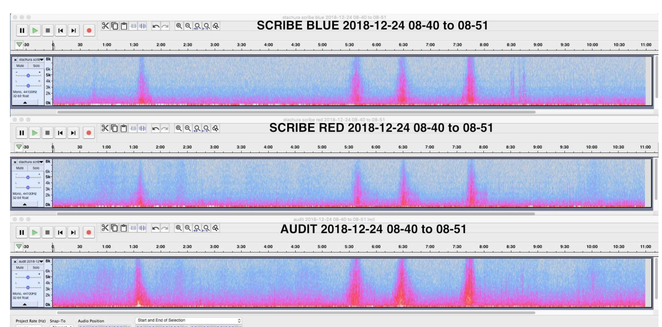

Figure 2: Spectrogram of audit, red, and blue microphones.

Table 1: Summary of samples meeting criterion.

Microphone	Samples Available	# Meeting Criterion
Red-SAM	55	24
Blue-SAM	50	14
Audit	76	14

* trileaem@bmts.com

Table 1 identifies how many of the 76 audit samples met the annoyance criterion. While residents had identified 3 of the audit periods as quiet, they identified the rest as annoying. As Table 1 identifies less than half of the samples as meeting the annoyance criterion, it suggests that the criterion is insufficient to predict all annoyance.

Since the residents had identified a tonal-like quality of the sound, all of the samples were analyzed for tonality. The IEC-61400-11 method [2,3] identified no tonality in the samples. Figure 3 shows the energy of most of the critical band is not considered as tone. In this example, even though two peaks are more than 5 dBA above the average of higher or lower bands, no points meet the tonality criteria.

IEC 61400-11 has been revised to use the ISO/PAS TS 20065 method [4] of tonality test but both describe the tonality as inaudible. The ECMA74 tonality assessment [5], supports the psychoacoustic principle identified by Zwicker and Fastl [6] that humans group sound within critical bands.

In figure 4 the ECMA74 assessment shows samples of audit critical bands with a tonal-like peak more than 3 dBA above the higher or lower bands. This is an audible change. As a further test, one-third octave analysis of a sample is shown in Figure 5. The snapshots taken one second apart, demonstrate the 500 Hz one-third octave rising and falling by 5 dB. This confirms the 'woo-woo-woo' emission.

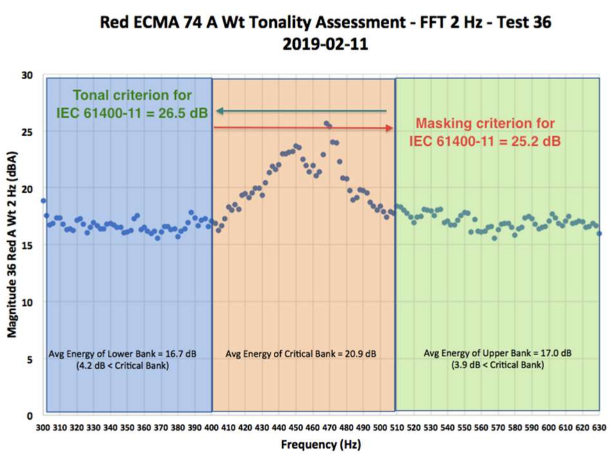

Figure 3: IEC 61400-11 (Ed. 3) treatment misses tonality.

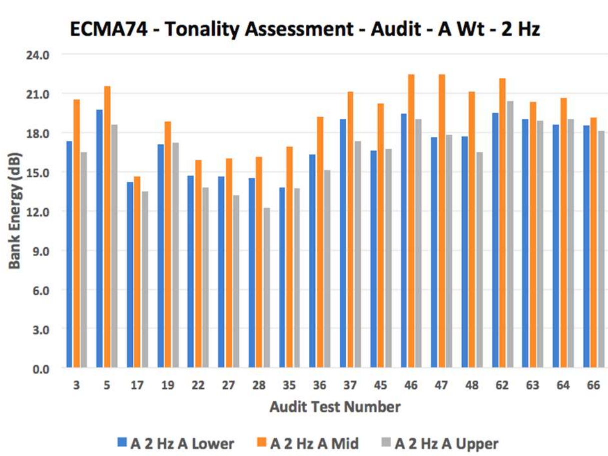

Figure 4: ECMA74 analysis shows critical band higher.

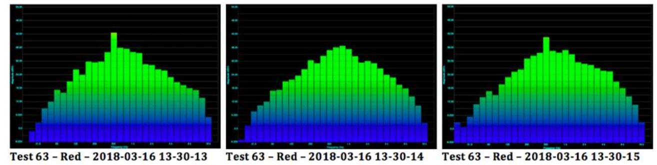

Figure 5: One-third octave analysis – 1 second apart.

4 Discussion

Audit examples might not pass the tonality test of the IEC or ISO standards, but describing the results as inaudible does not meet psychoacoustic principles of perception. Both the ECMA74 test, and one-third octave analysis confirmed critical band differences that were clearly audible.

5 Conclusion

This paper identifies that while some of the samples identified as annoying met the previously identified annoyance criterion, others did not. An additional factor impacting annoyance was a tonal-like characteristic where the critical band exceeded higher and lower bands by 3 dB, an audible difference. It is a weakness in that accepted standards identify clearly audible examples as inaudible.

Acknowledgments

Residents had to pay to acquire the Audit test data through a Freedom of Information request and paid to purchase the SAM Scribe Mk-II monitoring system.

References

[1] W.K.G. Palmer, Lessons Learned Monitoring Near and Further from Wind Turbines, Canadian Acoustics 51(3), 172-173 (2023).

[2] International Electrotechnical Commission, Technical Standard, 61400-11-2 Wind energy generation systems – Part 11: Acoustic noise measurement techniques, Edition 3 (2012).

[3] International Standards Organization, Technical Standard, 20065, Acoustics-Objective method for assessing the audibility of tones in noise – Engineering method, ISO/TS (20065:2022).

[4] G. Arivukkodi, D. Solomon, K. Balaraman, L. Stefi, Tonality Analysis of Wind Turbine Noise Based on IEC Standard, IJRASET, 10 (IX), 1305-1316 (2022-09).

[5] ECMA74, Standard 20th edition – Measurement of Airborne Noise Emitted by Information Technology and Telecommunications Equipment, ECMA International, Geneva, Switzerland (2022, 12).

[6] E. Zwicker, H. Fastl, Psychoacoustics: Facts and Models, 2nd edition, Springer, Kindle Edition (2013).