

## Subjective perception of wind turbine noise - The stereo approach

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## Subjective perception of wind turbine noise - The stereo approach

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The conduct of stereo measurements for both playback in high-quality headphones and in a hemi-anechoic room has been undertaken for a number of wind farms and other low-frequency noise sources as an expansion of the material previously presented at the Boston ASA meeting. The results of the additional monitoring, evaluation, and subjective analysis of this procedure are discussed and identifies the benefits of monitoring noise complaints and assessments of wind farm noise in stereo. The laboratory mono subjective system was used to reproduce the audio wave file obtained in a dwelling. The test signal, being inaudible, was presented as a pilot double blind provocation case control study to 9 test subjects who have been identified as being sensitized to wind turbine noise and low frequency pulsating industrial noise. All test subjects could detect the operation of the inaudible test signal. The use of a stereo manikin to investigate detected inaudible "hotspots" is discussed.



## 1.0 INTRODUCTION

The subjective assessment of wind turbine noise, and in particular the perception of amplitude modulation, have been undertaken using a mono noise source that may be generated by multiple speakers mounted on a baffle [1], [2] or use of a three-sided speaker located in a corner of the room as an extension to the use of that speaker for the generation of synthesised infrasound [3], where in the main the source being reproduced is an external signal.

Reproduction of an internal signal has tended to use a synthesised signal (rather than an actual signal recorded inside a dwelling) with an assumption of building attenuation and disregarding the influence of room mode or building element resonances.

In relation to the accurate reproduction of wind farm noise over the infrasound region and the low frequency region the use of actual wave files is preferred, once one overcomes the technical challenges that are presented [4].

Having conducted measurements and assessments at residential premises in proximity to wind farms, on a subjective basis our experiments have found a significant difference on comparing the reproduced signals to the actual sound of wind turbines observed in the field.

Our previous paper on this topic presented at the Boston ASA meeting [5] identified an overwhelming support by test subjects for the use of stereo recordings for the subjective evaluation of external wind turbine noise.

The use of line array speakers in a hemi-anechoic room for a mono signal (from a precision sound level meter) versus a stereo signal from precision microphones set 1.9 m apart found a dramatic difference in the perception of external wind turbine noise. For the test subjects that have experienced the comparison there is 100% agreement that one must use stereo assessment for subjective assessment of wind turbine noise and in particular when evaluating special audible characteristics.

Further evaluation of special audible characteristics and/or subjective assessment of wind turbine noise has been undertaken using headphones with a frequency response of 4Hz – 45 kHz [6] and a D Class amplifier. The previous presentation postulated the concept of using manikins to be superior to two microphones orientated 180° apart (back to back). The principal basis of the hypothesis was the omnidirectional characteristics of precision microphones versus the directional characteristics that occur for humans (and manikins), due to the attenuation of the head with respect to the individual ears/microphones.

Having an individual in a stationary position whilst listening to a person moving 360° around that individual, and continuously talking with the speaker's mouth oriented towards the listener is a simple method to identify the difference in the sound that an individual hears where that sound comes from different directions.

## 2.0 OBTAINING THE STEREO SOUND FIELD

The cost of professional head and torso systems used for the acoustic evaluation of headphones or room acoustics [7] is not one that lends itself to fieldwork with respect to unfunded investigations.

A cost-effective solution utilised hollow manikins with Type 1 precision microphones mounted in each pinna, utilising a microphone extension rod from older precision sound level meters (rather than an expensive 90° adapter), with preamplifiers on the end of each extension rod, is a practical solution (see Figures 1 & 2).

Field testing was undertaken of microphone set ups using two microphones spaced 1.9 m apart pointed directly towards the noise source, two microphones in line but 180° apart and parallel to the wavefront from the noise source of the investigation, and the stereo manikin concept identified in Figure 1. In all cases the microphones used are GRAS 40AZ with B & K 2669 preamps to a LANXI multichannel Pulse System with a sample recording rate of 113 kHz per second. The stereo wave file signals were compared directly with a wave file from a B & K 2250 Sound Level Meter using a B & K 4193 microphone. All system combinations permit full-spectrum monitoring down to and including the infrasound region.

Comparison of the stereo measurements versus the single mono channel measurement have for every test subject found the stereo material (when compared to mono) to be superior whether utilising speakers or headphones.



Figure 1 View of Microphone set up

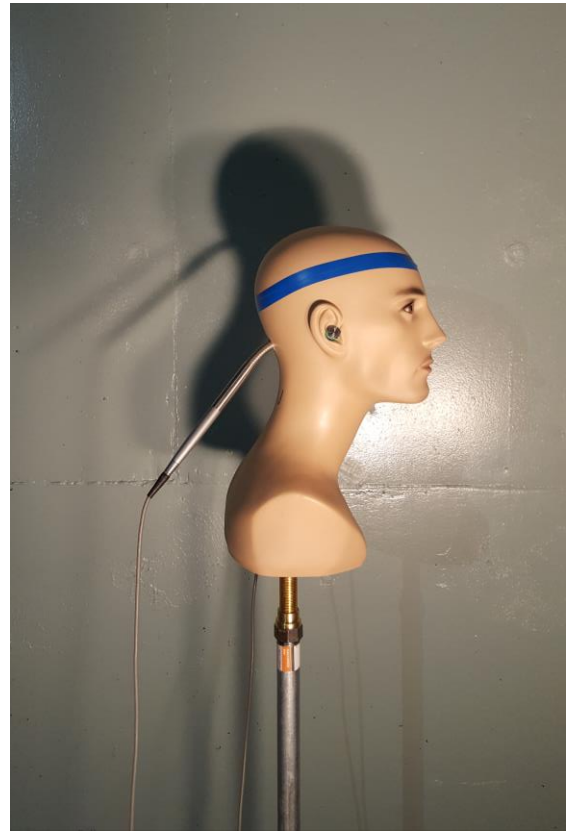


Figure 2 Manikin mic in ear and preamp on extension rods

Utilising the headphones for playback, the manikin measurements were found in the opinion of all the test subjects to be superior in terms of its presentation of the stereo image, and the degree of subtle differences that did not arise from the use of omnidirectional precision microphones where there is no separation in terms of directivity from sound from the other side of the sound field that is present.

Table 1 presents the rankings from the subjective assessment of wind turbines using headphones versus the line arrays.

Ranking	Headphones	Line Arrays in Hemi-Anechoic Space
1	Manikin	Spaced mics towards source
2	Spaced mic towards source	Mics 180° apart
3	Mics 180° apart	Manikin
Do not use	2250 (mono)	2250 (mono)

Table 1: Stereo Subjective Assessment Recommendations for External Noiiie Sources

### 3.0 SENSATION INVESTIGATION

Because of a presentation by Dr Michaud at the ASA Salt Lake Meeting Wind Turbine Session in relation to the Health Canada investigations [8], discussions from other presentations [9] [10], and the session attendees, it appeared that several of the houses in the two study areas had been abandoned by residents, citing the issue of disturbance from wind turbines. Therefore, not all persons who may be considered sensitive to wind turbine noise were included in the Health Canada study [11].

Dr Michaud indicated to the attendees that in light of discussions in the Wind Turbine Session he would propose to Health Canada to undertake additional investigations of persons who had resided in the two study areas but had abandoned their houses because of disturbance, where such a study would be undertaken with the assistance of the community to obtain access to those individuals. The results of the suggested study had not been presented and as such, still left a question as to the relevance of sensitised people in terms of their ability to sense the operation of wind turbines.

To address the perception of persons who may be considered sensitised to wind turbine noise and examine the claim of residents sensing the operation of the turbines without actually hearing the noise, a series of experiments were undertaken utilising persons in Australia who have been identified as being sensitive to wind turbine noise, and low-frequency noise that exhibits pulsations occurring at an infrasound rate (“test group 1”).

In 2013 Schomer proposed the possibility that a limited number of residents subject to noise from wind turbines may be experiencing motion sickness and suggested the construction of a test facility that utilise special transducers to extend down to very low frequencies (0.05 Hz or lower) [12]. Schomer proposed to undertake sensing tests that could then lead to further medical examinations on animals to develop an understanding why the phenomenon seems to affect some residents near wind farms and establish who are affected by wind turbine infrasonic emissions in various ways.

We have previously utilised one of our reverberation test chambers (having a volume of 126 m<sup>3</sup>) with twelve 15” sub-woofers mounted on in the aperture between the reverberation chambers to investigate threshold of sensation versus threshold of hearing in the infrasound region [13], investigations into the ‘infrasound signature’ from wind turbines [14], [15] & [16]. Those investigations were undertaken using pure tones or external (free-field) noise measurements of wind turbine noise.

The chamber has been used to investigate the generation of recorded wind turbine noise versus field measurements to identify the issue of pulsations across the entire spectrum and that the synthesis method that has been proposed for creating the source signal over a wide band of frequencies [17] and a concept of synthesising a digital signal from analysed Leq FFT results but limited to just the infrasound region [18]. Those investigations found the synthesised results did not agree with our analysis of the original external source data that has been obtained in the field. Utilising a synthesised signal from an averaged (Leq) FFT to produce a steady signal lacks the on/off transitions, transients and variations that existed in the original time record.

For the subject study the original wave files obtained at house 87 from the Cape Bridgewater study [19] was used with a focus on the region of 30 Hz – 1250Hz. The source wave file signal obtained from measurements inside dwelling 87 at Cape Bridgewater, that have been used by several authors as a reference FFT Leq spectrum, was reproduced in the chamber utilising the sound system described above and provided the 1/3 octave band spectra shown in Figure 3. For the frequency range of interest the reproduced signal approximated the original signal as a 10 minute Leq level.

As a pilot study, 9 persons identified as sensitive to wind turbine noise or pulsating low-frequency industrial noise (test group 1) have attended our test chambers to participate in an experiment along the lines of the sensing tests in the format described by Schomer. A control group of 9 persons not previously exposed to turbine noise or pulsating low-frequency industrial noise (including 4 acousticians) participated in the same tests.

The reverberation room, with the addition of acoustic absorption treatment, satisfies the requirements of European Broadcasting Union Technical Document 3276 *Listening Conditions for the Assessment of Sound Programme Material: Monophonic and Two-Channel Sound* [19]. The maximum noise level under that standard for a mono signal is set at 85 dB(A). The distribution of absorption around

the perimeter of the reverberation room leads to the absence of lateral reflections from wall surfaces. As the walls of the chamber are core filled blockwork, from sound intensity and vibration measurements it was established that neither the walls, floor or ceiling of the chamber are generating structure borne noise from the speakers mounted on the baffle in the aperture.

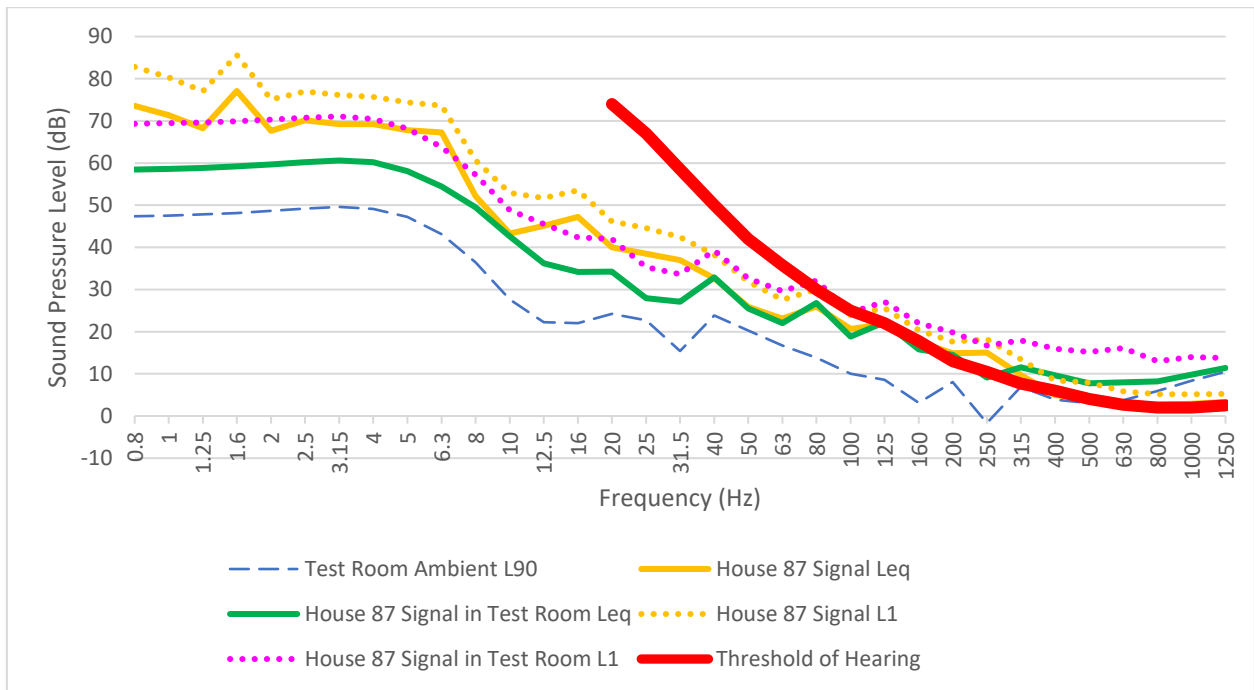


Figure 3: Spectra of Test Sample

The levels that were generated in the room approximate the 1/3 octave band levels obtained in house 87 (in the Cape Bridgewater study) [20] over the range of 40 – 1250 Hz. The response that falls off below 16 Hz reflects the absence of any graphics or parametric equalisation, and the limitations of the A-D convertor.

Table 2 presents the measured sound levels of the generated and ambient levels in the test chamber, with the derived sound level contributions in both the Leq level and the L90 level.

By any of the general measurement parameters used for wind farm assessments, the test signal contribution is at or below the ambient level. Of relevance to researchers of wind turbine noise, the testing had the wind turbine noise contribution as an Leq level of 12 dB(A) in a background level of 23 dB(A).

Weighting	Parameter	Ambient	Test Signal	Test Signal Contribution
Linear	Leq	69	69	60
	L90	57	57	49
dB(A)	Leq	24	24	12
	L90	23	23	9
dB(A) LF	Leq	8	10	8
	L90	-1	7	6
dB(C)	Leq	41	41	36
	L90	31	34	30

Table 2: Measured Levels and Derived Contributions of Test Signal



For the levels that were generated, the testing was undertaken in accordance with Australian Standard AS 1269.4 *Occupational Noise Management, Part 4: Auditory Assessment* [21] and the testing conducted in accordance with the *ASA Ethical Principles of the Acoustical Society of America for Research Involving Human and Non-Human Animals in Research and Publishing Presentations* [22]. An observer was present in the reverberation room during the testing.

The testing was conducted as multiple blind study tests. At no point in time were any of the participants advised what signal (if any) was being applied.

After a period of between 45 seconds to 3 minutes, all the 9 people in test group 1 could sense the presence of the wind turbine signal on 100% of the occasions in which the signal was presented, even though they were unable to hear the signal. At no point in time did any of these test subjects detect any audible signal.

One test subject (from the test group 1) identified a disorientation in the room where there was a perception of a tilt in the floor of about 20°.

The control group were exposed to the same test set up. After a period of some two minutes 2 people (including one a very distinguished Australian acoustician) could identify sensation, whilst the remainder of the control group never detected any sensation.

### 3.1 Observed Differences in the Sound Field – Hotspots

All the test group 1 subjects were requested to move around the room and identify any hotspots where there was a perception of a greater impact.

Two general areas were identified on either side of the radiating pattern for the baffle speaker systems (see Figure 4).

The test subjects identified the sensation that they were experiencing occurred in different parts of the body.

Seven people from test group 1 noise identified sensation in the back of the neck or the back of the head, and in four subjects there was also a tingling in the legs.

All the people from test group 1 were requested to rotate 360° to identify whether there was any position at which the sensation became stronger.

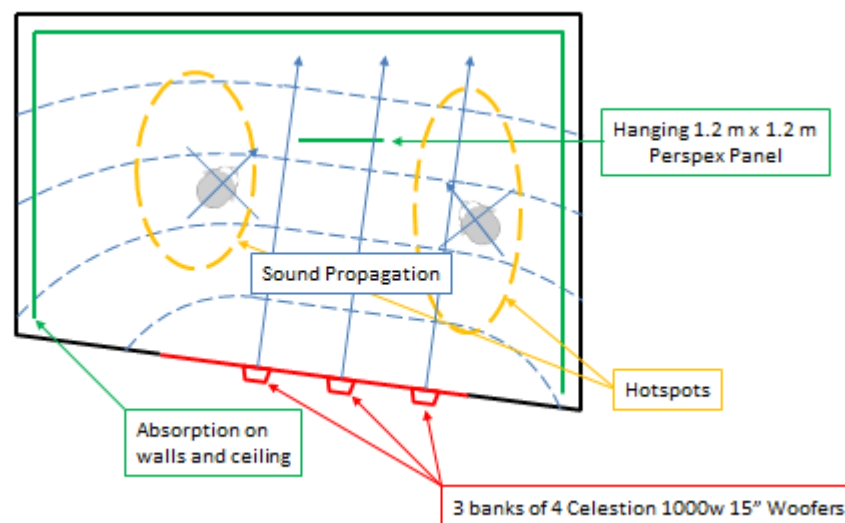


Figure 4 – Hotspots

In all cases except for two women (one person who has a hearing impairment), the test subjects identified that the greatest sensation occurred for an orientation where the back of the head was towards the speaker baffles but the body was turned at an angle of 45° so that the ear adjacent the baffle propagating sound field was closer to the speakers (see Figure 4).

The test subjects were then presented with audio headphones [6] that provide an SLC 80 attenuation of 11 dB, and then a set of hearing protectors [23] providing an SLC 80 of 26dB.

All test subjects (except the two women noted above) identified there was a difference in the perception of sensation in their head, but had difficulty expressing what that difference was. Both women identified the test signal produced a sensation across the forehead. The headphones provided a slight difference but when using the ear muffs both participants felt the onset of nausea and the experiment was terminated. Does this result support the observation by Salt [24] of a greater Guinea pig ear response when there was less high frequency masking?

### 3.2 Manikin Investigation of Hotspots

The use of the manikin in the main chamber at the hotspots (identified by the subjects from test group 1) found no timing difference in terms of the arrival of pulsations for either ear, but that the orientation that produced the greatest level of disturbance to the test subjects revealed a slight pressure difference either side of the head.

For the two hotspot regions and the most sensitive angle to the sound field ( $135^\circ$  for the LHS and  $225^\circ$  for the RHS – where  $0^\circ$  is facing the speakers, as shown in Figure 5) the differences were noticeable in the mid band region of 250Hz – 2000 Hz.



*Figure 5: Manikin at RHS hotspot set at  $0^\circ$  position (facing speaker baffle)*

A one third octave band analysis of the test signal revealed the following polar plots for the manikin (see Figure 5). This Leq pressure differential between the two ears as a result of the pulsating 2signal may be an area for further research (by others) as suggested by Schomer [11].



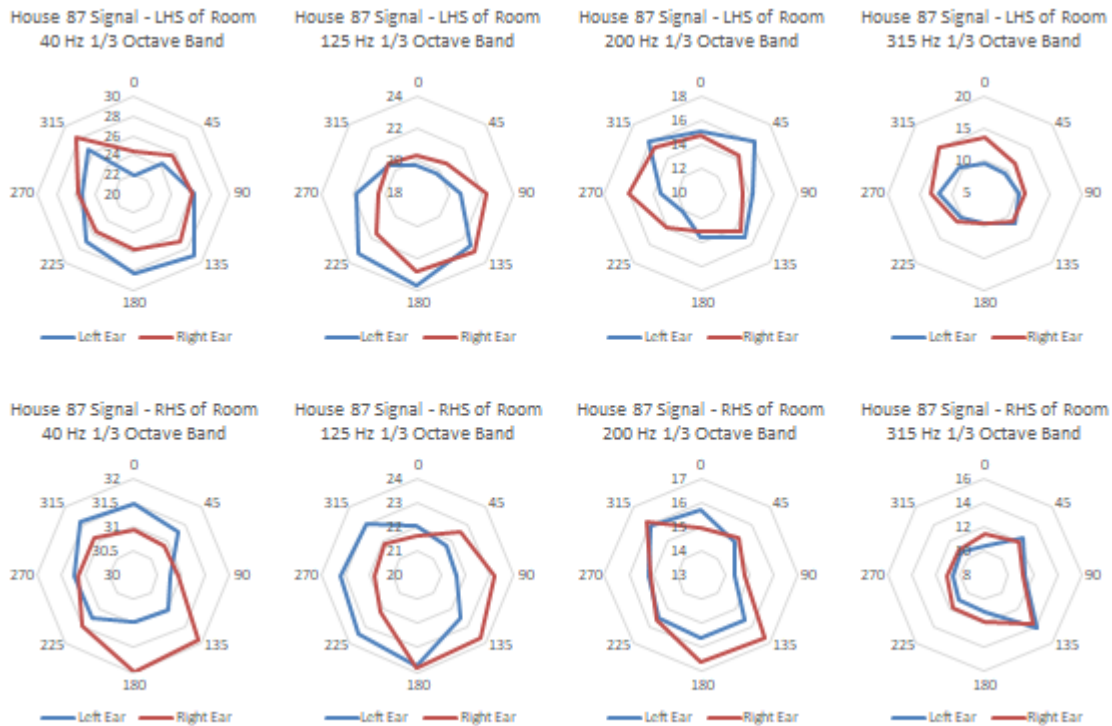


Figure 5 – Manikin at hotspots (degrees represent angle of nose to speakers)

### 3.3 Vibration on Hanging Perspex Panel

Testing of vibration levels inside dwellings in the Cape Bridgewater study, to evaluate whole-body vibration criteria, found insignificant levels of vibration with respect to the relevant Australian or British Standards [25] [26] that may be transmitted to the body.

If sensations are not just restricted to the inner ear and can also include response of the vestibular system of the body, a question arises as to the degree of vibration that may be induced into the body by way of the sound pressure field from turbines.

A perspex panel was suspended off the roof of the test chamber and could be seen to respond to the movement of people in the room and/or closing the nearest door to the panel. The panel required a long settling time (6 – 9 minutes) to return to a stationary position.

Observation of the panel with the application of the test signal found no perceptible vibration. However, examination of the shadow of the panel outline on the floor (from an elevated light) showed movement of the bottom of the panel.

Normal accelerometers cables used for vibration monitoring were found to be microphonic for the sound generated in the room (either by use of charge amplifier or voltage amplifier inputs). Higher sensitive accelerometers used for low-frequency seismic measurements were also found to have cables that resulted in pickup of the inaudible sound generated by the test signal and excessive mass that affected the damping of the panel, thereby presenting difficulty in obtaining vibration measurements using standard instrumentation.

However, the use of DC response accelerometers (Bruel & Kjaer Type 4575) [27] overcame that issue and found vibration levels obtained at the bottom of the swinging perspex panel were less than  $1/50^{\text{th}}$  of the 31.5 Hz acceleration level and  $1/20^{\text{th}}$  of the 4Hz acceleration levels suggested for the protection of the comfort of individuals subject to low-frequency vibration [25].

Further investigation into the response of the physical pressure wave on individuals is outside our expertise, and may be an area of interest to other researchers with access to the appropriate persons and instrumentation.

## 4. CONCLUSIONS

Testing of the response of individuals to audible wind turbine noise in recent years has typically utilised a mono noise source with a large bank of speakers in a modified reverberation room or listening environment.

Other testing purporting to assess the impact of infrasound from turbines, has not actually used the infrasound signal but has used either pure tones [28] [29] or a synthesised signal based a result of an FFT Leq analysis of the original signal and incorrectly claimed such noise sources as being “wind farm infrasound”.

Analysis of wind farm noise using wave files of actual wind farm noise (rather than any synthesised format or digitally designed signal) has found the typical FFT acoustical analysis is incorrect in terms of the fundamental formula of  $BT=1$  for frequency analysis. That is, a finer resolution or small B requires a large T, and therefore a low temporal resolution to make the result valid. In the infrasound region the pulses are not present long enough to satisfy  $BT=1$ .

A modification of the Infrasound Logger from Huson Associates (Mark II) incorporates a modified filter and increased sample rate to address signal droop and obtain a faithful wave file to 150Hz.

Analysis of the wave files recorded at Cape Bridgewater reveals the presence of a dynamically pulsed amplitude modulation of the signal that occurs across the entire audible frequency band. The dominant bands where such noise is audible are in the low and mid frequency region.

All our field work to date that provides FFT or 1/3 octave band measurement data in relation to wind turbine infrasound, identified levels well below the nominal threshold of hearing. The limitation of instrumentation and sampling rates to provide an accurate and valid spectrum measurement in the infrasound region has been questioned ( $BT=1$ ).

The previous work by the authors that identified the analysis/signature of pulses that occur at an infrasound rate, leads investigators to view the signal in the time domain and examine/describe/review the method of modulation with dynamically pulse amplitude modulation suggested as a more accurate description.

In endeavouring to reproduce an accurate signal in the time domain we have raised the issue of much higher sampling rates than normally encountered [31].

There are also issues with the creation of wind turbine “infrasound” in the laboratory [4].

The authors are of the opinion that experimental research limited to just wind turbine “infrasound”, whether tones or synthesised digital signals, is a waste of research time and money.

Reproducing and analysing the wind turbine signal including the audible range is an easier and simpler task to undertake and permits the essential work of identifying what creates sleep disturbance and physical impacts from wind turbine noise. Such research should be undertaken inside dwellings (in the field) and (subject to qualification of the sound field) may be undertaken in the laboratory.

Utilising wave files and playback of such signals at inaudible levels without requiring reproduction of infrasound is an easier and simpler task to undertake. The benefits of using a stereo signal for subjective assessment is clearly a superior method and a logical approach for any serious investigation into wind turbine noise.

Our previous paper into the stereo effect [2] found microphones spaced 1.9 metres apart for recording the signal and playback in a hemi anechoic space using line array speakers to be the preferred method by all test subjects for the subjective assessment of external wind turbine noise.

For utilising headphones, the recent testing has confirmed that the use of a stereo head torso (or in this exercise a cheaper version identified as a manikin) is the appropriate mechanism for undertaking further investigation into the subjective effects of wind turbines.

The application of the manikin to support the investigation of the subjective response of wind turbine affected persons in a mono generated sound field, utilising inaudible wind turbine noise, identified slight differences between the “ears” at the position identified by the test group as the hotspots (i.e. a greater perception of sensation with their backs to the sound source and one ear on an angle of  $45^\circ$  to the sound source).

The sensation perceived by the specific sensitive people (rather than the control group) was significantly stronger in the sound field exposed to the entire body when compared to just utilising headphones.

The results of the sensitivity testing require the expertise of other disciplines to explain the mechanisms by which the test subjects perceive the wind turbine noise to their entire body [30] and should be of interest to other researchers.

1. Yokoyama S, Kobayashi T, Sakamoto S & Tachibana H “Subjective experiments on the auditory impression of the amplitude modulation sound contained in wind turbine noise”, International Meeting on Wind Turbine Noise, Glasgow 2015.
2. Kelley N.D, “A Proposed Metric for Assessing the Potential of Community Annoyance from Wind Turbines Low-Frequency Noise Emissions”, Windpower '87, San Francisco, October 1987
3. Walker B, Celano J, “Progress Report on Synthesis of Wind Turbine Noise and Infrasound”, 6<sup>th</sup> International Meeting on Wind Turbine Noise, Glasgow 2015.
4. Cooper S, “Reproduction of wind turbine infrasound and low frequency noise in a laboratory”, Acoustical Society of America Meeting, Boston, June 2017
5. Cooper S, “Subjective perception of wind turbine noise”, Acoustical Society of America Meeting, Boston, June 2017, ASA POMA Vol 30/10.1121/2.0000639
6. Audio-Technica, “ATH-M79x Studio Monitoring Headphones”, <http://audio-technica.com.au/products/ath-m70x/>
7. Bruel & Kjaer., “Sound Quality Head and Torso Simulator Type 4100”, <https://www.bksv.com/-/media/literature/Product-Data/bp1436.ashx>
8. Michaud D, “An evaluation of how nightly variations in wind turbine noise levels influence wrist actigraphy measured sleep patterns”, Acoustical Society Meeting, Salt Lake City, May 2016
9. Nissenbaum MA, “Industrial wind turbines and adverse health effects: Where we are, where we need to go, and the need for regulations and predictive models to recognize human physiology” Acoustical Society Meeting, Salt Lake City, May 2016
10. McMurty R.Y, “Patient Centered Medicine and Soundscape – A bridge between clinicians and acousticians”, Acoustical Society Meeting, Salt Lake City, May 2016
11. Health Canada, Wind Turbine Noise and Health Study: Summary of Results”, <https://www.canada.ca/en/health-canada/services/environmental-workplace-health/noise/wind-turbine-noise/wind-turbine-noise-health-study-summary-results.html>
12. Schomer P.D, Erdreich J, Boyle P & Pamidighantam P, “A proposed theory to explain some adverse physiological effects of the infrasonic emissions at some wind farm site”, 5th International Conference on Wind Turbine Noise, Denver August 2013
13. Cooper S, “Threshold of hearing v threshold of sensation for low frequency and infrasound”, Acoustical Society of America Meeting, Salt Lake City, May 2016, ASA POMA vol 26/10.1121/2.0000432
14. Cooper S, “Reproducing wind farm infrasound for subjective testing – Just how accurate is the reproduced signal?”, Acoustical Society of America, Salt Lake City, May 2016
15. Coper S, “Wind Farm Infrasound – Are we measuring what is actually there or something else? (part 2)”, Acoustical Society of America Meeting, Salt Lake City, May 2016
16. Cooper S, Chan C, “Can inaudible and audible low level infrasound and low frequency noise be an acoustic trigger of the startle reflex?”, Acoustical Society of America Meeting, Hawaii, December 2016
17. Hansen K, Walker B, Zajamsek B & Hansen C, “Perception and annoyance of low frequency noise versus infrasound in the context of wind turbine noise”, 6<sup>th</sup> International Meeting on Wind Turbine Noise, Glasgow April 2015
18. Tonin R & Brett J, “Response to Simulated Wind Farm Infrasound Including Effect of Expectation, International Meeting on Wind Turbine Noise, Glasgow 2015.
19. The Acoustic Group, “The Results of an Acoustic Testing Program, Cape Bridgewater Wind Farm”, Dec 2014 <http://waubrafoundation.org.au/resources/cooper-s-acoustic-group-results-cape-bridgewater-acoustic-investigation/>
20. European Broadcasting Union Technical Document 3276 “Listening Conditions for the Assessment

- of Sound Programme Material: Monophonic and Two-Channel Sound, 1998
21. Australian Standard AS 1269.4 “Occupational Noise Management, Part 4: Auditory Assessment”, Standards Australia, 2005.
  22. Acoustical Society of America, “Ethical Principles of the Acoustical Society of America for Research Involving Human and Non-Human Animals in Research and Publishing and Presentations”, [http://acousticalsociety.org/for\\_authors/ethical\\_principles](http://acousticalsociety.org/for_authors/ethical_principles)
  23. “EMLU 60 Hearing Protector”,  
<https://www.scotssafety.com/en/anzip/DocumentandMedia1/Protector%20EMLU60%20HB%20Ear%20muffs%20Datasheet%20ANZ.pdf>
  24. Salt A. “Perception-based protection from low frequency sounds may not be enough”, Internoise 2012, New York
  25. Standards Australia, “AS 2670.2-1990, Evaluation of human exposure to whole-body vibration, Part 2: Continuous and shock-induced vibration in buildings (1 to 80 Hz)”, Standards Australia 1990.
  26. British Standard 6472-1992 “Guide to evaluation of human exposure to vibration in buildings (1Hz to 80 Hz)”. British Standards Institute
  27. Bruel & Kjaer, “DC Response Accelerometer Type 4575”, <https://www.bksv.com/-/media/literature/Product-Data/bp2170.ashx>
  28. Crichton F, Dodd G, Schmid G, Gamble G & Petrie K, “Can Expectations Produce Symptoms From Infrasound Associated With Wind Turbines?”, *Health Psychology*, 33(4), 360-364 (2014)
  29. Crichton F, Dodd G, Schmid G, Gamble G, Cundy T & Petrie K, “The Power of Positive and Negative Expectations to Influence Reported Symptoms and Mood During Exposure to Wind Farm Sound?”, *Health Psychology*, American Psychological Association 2013
  30. Cooper S.E., “Can inaudible and audible low level infrasound and low frequency noise be an acoustic trigger of the startle reflex?”, Acoustical Society of America Meeting, Hawaii, December 2016
  31. Cooper S.E., “Are Sample Rates for Wave File Recordings Too Low for Transient Signals?”, Acoustical Society of America Meeting, Boston, June 2017