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The Measurement of Infrasound and Low Frequency Noise for Wind Farms (amended version)

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Summary

The use of dB(A) for the assessment of large industrial wind turbines does not address low frequency noise (LFN) or infrasound due to the filter characteristics of the A-weighting curve. In seeking to address infrasound noise (typically identified as between 1Hz and 20Hz) some acousticians for the wind industry have used dB(G) and dB(Z) results. Both of these weighting curves exhibit significant roll offs in the frequency domain below 6Hz that renders the use of such descriptors of no real value in addressing infrasound of wind turbine noise. In my opinion the correct procedure is to use Linear (unweighted) levels in both constant percentage 1/3 octave bands (to agree with current acoustical data) and narrow band analysis to identify the wind turbine signature. For infrasound noise it would appear consideration of the linear result over the bandwidth of 1Hz – 20Hz is appropriate and low frequency noise when considered as a separate exercise should be expressed as a linear level restricted to the bandwidth of 20 – 200Hz.

1. Introduction

Wind farm approvals in Australia to date have used the dB(A) parameter with limits typically specified at 35/40dB(A) or background +5dB(A) whichever is the greater. The dB(A) parameter when used as the sole acoustic descriptor is inadequate for low frequency noise and infrasound. The use of other acoustic parameters has been proposed to discover low frequency noise and infrasound.

Various wind developers and industry lobby groups both in Australia and around the world have been claiming that the report issued by the South Australian EPA and Resonate Acoustics [1] is a scientifically valid document that has confirmed infrasound associated with wind turbines is a non-event. A cursory examination of the document as set out below suggests that it is a document that provides incorrect conclusions to the wind industry and the community that are not supported by the data.

The primary function of the document was to compare the levels of infrasound measured within different environments including locations adjacent to wind farms. The report provides dBG result and Linear octave band levels over the infrasound region of 0.25Hz to 20Hz. The report did not quantify the human perception of

infrasound from wind farms but provided measured levels of infrasound near wind farms.
The report indicates that the use of the dB(G) parameter is an appropriate measurement of infrasound from wind farms. After selective testing of a number of sites, there is a claim that both rural and residential areas experienced dB(G) levels higher than that associated with wind turbines.
As wind farms are normally placed in rural areas (and similarly in the US so are scattered individual turbines) where ambient noise levels are relatively low, then there is a fundamental problem with utilising noise criteria issued for suburban environments where such environments are significantly higher than the background soundscape experienced in rural areas.

2. dB(G)

The authors claim in Section 2.1 (of the Resonate Acoustics report) that the dB(G) parameter is used to quantify sound that has a significant portion of its energy in the infrasonic range.
Immediately following the first paragraph of Section 2.1, a figure is provided showing the weighting characteristics of the G-filter, obtained from the ISO Standard 7196 [2]. The G-weighting function (see Figure 1) follows the procedure in the ISO Standard of referencing the attenuation with respect to a level of 0dB at 10Hz. The filter shows that there is amplification above the region of 10Hz to 25Hz, with a maximum of +9dB at 20Hz. Between 1Hz and 20Hz the filter drops off at 12dB per octave, whilst below 1Hz and above 20Hz the filter drops off at 24dB per octave.

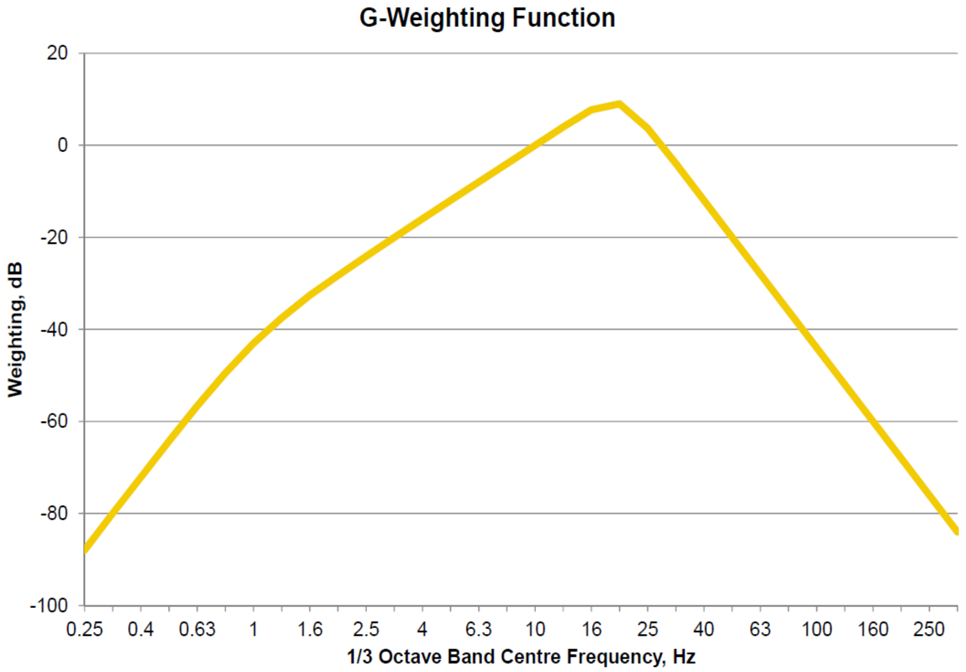


FIGURE 1: G-Weighting Filter from reference 1

At 6.3Hz, being a typical lower limit of some sound level meters that can provide 1/3 octave band results, the dB(G) filter has a value of 8dB below the reference level at 10Hz. Similarly at a frequency of 1Hz (that is typically near the blade pass frequency of modern day turbines) the filter exhibits an attenuation of 43dB below the 10Hz 0dB reference level.

Using dB level expressed in a Linear (un-weighted) format, the frequency spectrum from modern day wind turbines is predominantly elevated in the 0.7Hz to 6Hz region. For example, later in the Resonate Acoustics report (Figure 29) there is a 1/3 octave band spectrum chart limited to the frequency range of 0.25Hz to 20Hz (shown as Figure 2). With the G-weighted response placed over the measurement results it is clearly apparent from Figure 2 that the dB(G) value **does not cover the majority of the infrasound region generated by turbines**.

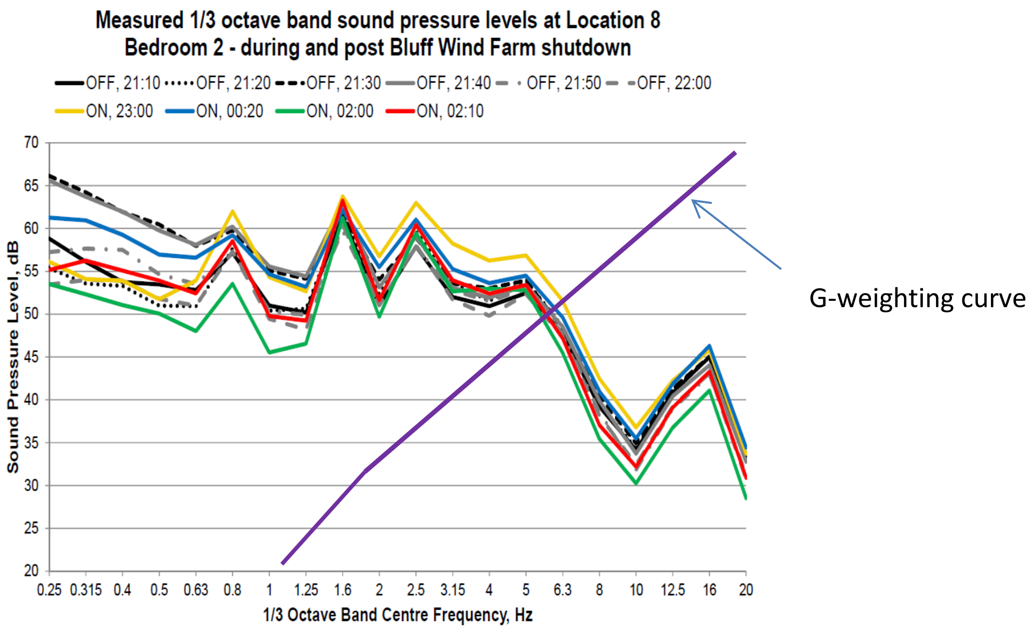


Figure 29 – Measured sound pressure levels with wind farm on and off, Bedroom 2 at house near Bluff Wind Farm

FIGURE 2: Figure 29 from reference 1

Examination of Figure 2 clearly indicates a significant degree of energy in the lower portion of the infrasound band. When the spectrum is corrected by the dB(G) function (Figure 1), the claim as to the dB(G) being a suitable descriptor for infrasound noise for wind farms is incorrect.

Using the linear (un-weighted) data in Figure 29 of the Resonate Acoustics report, that covers only the infrasound region of 0.25Hz – 20Hz, it can be seen that the peaks associated with the blade pass frequency and the first few harmonics (when measured in 1/3 octave bands) are higher than the peak at 16Hz.

Using the red line for ON at 2.10 AM inside the bedroom 2 for location 8 the data appears to provide the results set out in Table 3 to reveal a Linear level of 67 dB, whilst the dB(G) level is 53dB.

TABLE 1: Weighted Results for Figure 2

Weighting	1/3 Octave Band Centre Frequency (Hz)														
	0.8	1	1.25	1.6	2	2.5	3.15	4	5	6.3	8	10	12.5	16	20
Linear	58	49	49	63	57	60	53	52	53	45	35	33	38	43	33
Z weight	28	24	26	43	40	46	41	41	48	38	31	30	36	42	32

Comparison of the Linear spectrum versus the G-weighted spectrum in Figure 2 (from the Resonate Acoustics report) and Table 2 shows the inadequacy of the dB(G) value to address infrasound from wind turbines.
The use of an overall level using Linear weighting over the infrasound region of 1 – 20Hz for the measurement of turbine noise covers the energy produced by turbines in the infrasound region, whereas the dB(G) result does not reflect the significant portion of the energy in the very low frequency infrasound range as shown by the comparisons having little difference in the dB(G) value, whereas on a Linear basis there is a significant difference.

Impulse response durations for 90% magnitude 1/3-octave filters in time domain		
Center frequency	4^{th}-order	6^{th}-order ANSI S1.11
1.00 Hz	3294 ms	4989 ms
1.25 Hz	2616 ms	3963 ms
1.60 Hz	2078 ms	3148 ms
2.00 Hz	1651 ms	2500 ms
2.50 Hz	1311 ms	1986 ms
3.15 Hz	1042 ms	1578 ms
4.00 Hz	827 ms	1253 ms
5.0 Hz	657 ms	995 ms
6.3 Hz	522 ms	791 ms
8.0 Hz	415 ms	628 ms
10.0 Hz	329 ms	499 ms
12.5 Hz	262 ms	396 ms
16.0 Hz	208 ms	315 ms
20.0 Hz	165 ms	250 ms
25.0 Hz	131 ms	199 ms
31.5 Hz	104 ms	158 ms
40.0 Hz	82.7 ms	125 ms
50 Hz	65.7 ms	99.5 ms
63 Hz	52.2 ms	79.1 ms
80 Hz	41.5 ms	62.8 ms
100 Hz	32.9 ms	49.9 ms
125 Hz	26.2 ms	39.6 ms
160 Hz	20.8 ms	31.5 ms
200 Hz	16.5 ms	25.0 ms
250 Hz	13.1 ms	19.9 ms
315 Hz	10.4 ms	15.8 ms
400 Hz	8.28 ms	12.5 ms
500 Hz	6.57 ms	9.96 ms
630 Hz	5.23 ms	7.91 ms
800 Hz	4.16 ms	6.28 ms
1000 Hz	3.30 ms	4.99 ms
1250 Hz	2.62 ms	3.96 ms
1600 Hz	2.09 ms	3.15 ms
2000 Hz	1.67 ms	2.50 ms
2500 Hz	1.32 ms	1.99 ms
3150 Hz	1.06 ms	1.57 ms
4000 Hz	0.84 ms	1.25 ms
5000 Hz	0.68 ms	1.00 ms
6300 Hz	0.51 ms	0.79 ms
8000 Hz	0.40 ms	0.63 ms
10000 Hz	0.33 ms	0.50 ms
12500 Hz	0.26 ms	0.40 ms
16000 Hz	0.22 ms	0.31 ms
20000 Hz	0.16 ms	0.25 ms

TABLE 2: Impulse response durations from reference 4

In light of the above, the claim that the G-weighting function **"is used to quantify sound that has a significant portion of its energy in the infrasonic range"** is wrong for turbine noise. That position and a number of issues relating to the Resonate Acoustics report were discussed at a technical meeting of the NSW Division of the AAS in March 2013 [3].
The G-weighting filter impulse response time is only about 120ms which is adequate for measuring around 1Hz but the time constants for 1/3 octave bands below 6.3Hz are much longer (see Table 2). Using 1/3 octave band results to derive a dB(G) value is automatically incorrect due to the too long a time constant for industrial wind turbines with blade-passing periods of approximately 1 second (BT=1). Similarly G-weighting when derived from 1/3 octave band results is completely inappropriate when coupled with longer integration times (of 10 seconds) [4] [5].
At the present time ISO 7196 indicates the dBG may be appropriate for the measurement of infrasound, although the Standard does not refer to wind turbines in the bibliography. Swinbanks [5] has suggested that the overall slope of the G function below 10Hz does reflect the sensitivity of the inner hair cells to initial external pressure excitation at the eardrum and therefore follows the threshold of hearing perception referenced in the bibliography of ISO 7196.

Whether the dB(G) scale, which is based on single steady tones and not fluctuating levels with harmonics, is suitable for wind turbines is not addressed in Resonate Acoustics report as it was not a study into the perception of infrasound or specifically wind farm noise.

However, residents detect the impact of turbines (presence of pressure in various parts of the body) at levels below the "threshold of hearing". Salt and Lichtenham [6] have highlighted the outer hair cells, which are connected through a separate nervous path, are not associated with "direct" hearing. Professor Salt has argued (and has measured) the response of the outer hair cells and found they are more sensitive to infrasound than the inner hair cells, particularly to very low-frequency sounds [7].

As the dB(G) function significantly attenuates the majority of the energy produced by turbines in the infrasound region the use of the overall Linear level for 1 – 20Hz bandwidth is an appropriate measure of turbine infrasound levels and may be the appropriate mechanism to address the inability of the dB(G) "hearing threshold" to correlate with complaints re turbine noise (Appendix D of reference [8]).

3. dB(Z)

The April 2012 issue of the Acoustics Australia was a special issue on wind turbine noise [9].

In relation to infrasound commencing on page 45 of reference 9 is a paper *Measurement and Level of Infrasound from Wind Farms and Other Sources* ("the Sonus paper") [10]. Statements have been regularly made by wind industry representatives in Australia that the Sonus paper is a peer reviewed paper and as such has been fully reviewed for its technical content [11].

The material contained in the paper is extracted from a report prepared in November 2010 by Sonus for Pacific Hydro [12] (the "infrasound report") in that the graphs set out in the paper are direct extracts from that report. My review [13] of the infrasound report has identified a significant number of errors and omissions that cannot be expanded upon in this article. Examination of Figure 3 (from reference 12) identifies turbine 27 and a 'cliff' measurement location that is suggested to be a natural infrasound environmental location. However Figure 4 is a Google earth map for 3 months before the measurements in reference 12 that identifies a significantly greater number of turbines near the 'cliff' measurement location than shown in Figure 3 contained in the infrasound report. Attendance in the 'cliff' measurement location found the location impacted by turbines not identified in Figure 3 yet as shown in Figure 4 existed at the time of the 'cliff' measurements.

Map 1: Cape Bridgewater Wind Farm Measurement Locations

Figure 3: Sonus report identifying one turbine

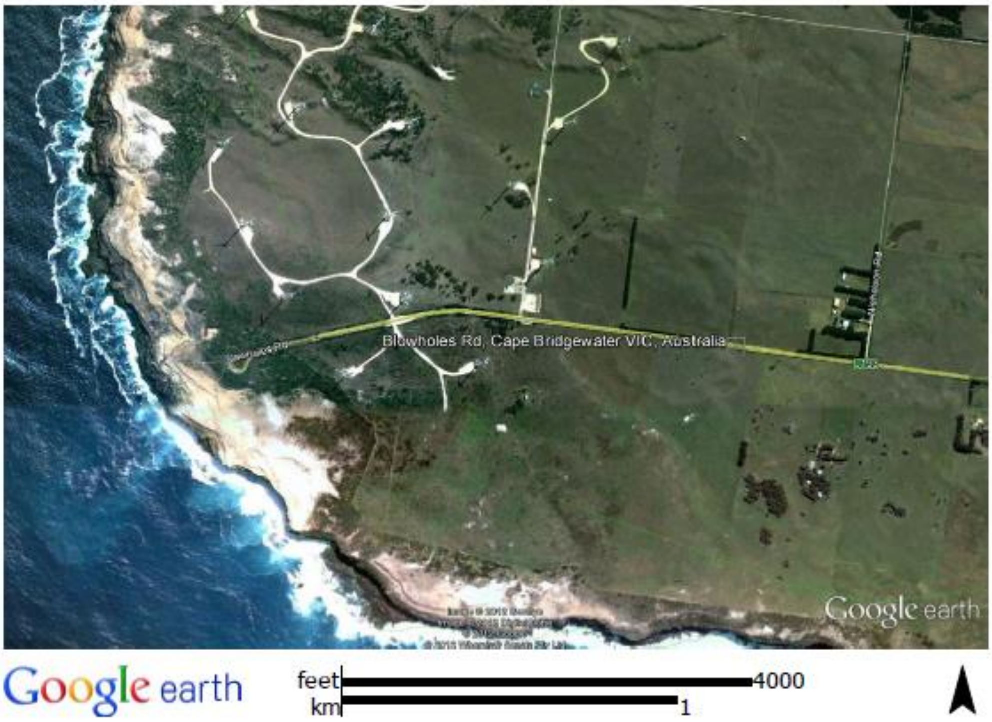


Figure 4: Google Earth, Map 1 three months prior to Sonus measurements

To identify the errors in describing what was tested, where and under what conditions as well, as the above photos that do not show all the turbines that exist at one wind farm, the reader is referred to reference [13].

On page 47 of the Sonus paper measured levels utilising the G-weighting curve are provided. The paper claims (as does the infrasound report) that there are various natural and man-made sources which give rise to higher levels of infrasound than that of wind farms when utilising the dB(G) curve.

However on going to the actual infrasound report it can be established that is not the case by examining the 1/3 octave band results that have been graphed (to identify individual frequencies) with some locations presented in tables.

If one plots the inside and outside noise levels set out in Tables 8 and 9 respectively of the infrasound report (on the basis of the material that has been provided) it can be seen that for frequencies below 3Hz the inside noise levels are **greater** than the outside noise levels (see Figure 3), yet on a dB(G) basis it is claimed that the outside level of 56dB(G) is reduced to an inside level of 50dB(G). The graphs indicate that there are frequencies below 20Hz inside the dwelling where a significant portion of the energy is below 6.3Hz. Utilising the reported results from Table 8 and 9 the 1/3 octave band data for 1Hz to 20Hz provides the levels set out in Table 3.

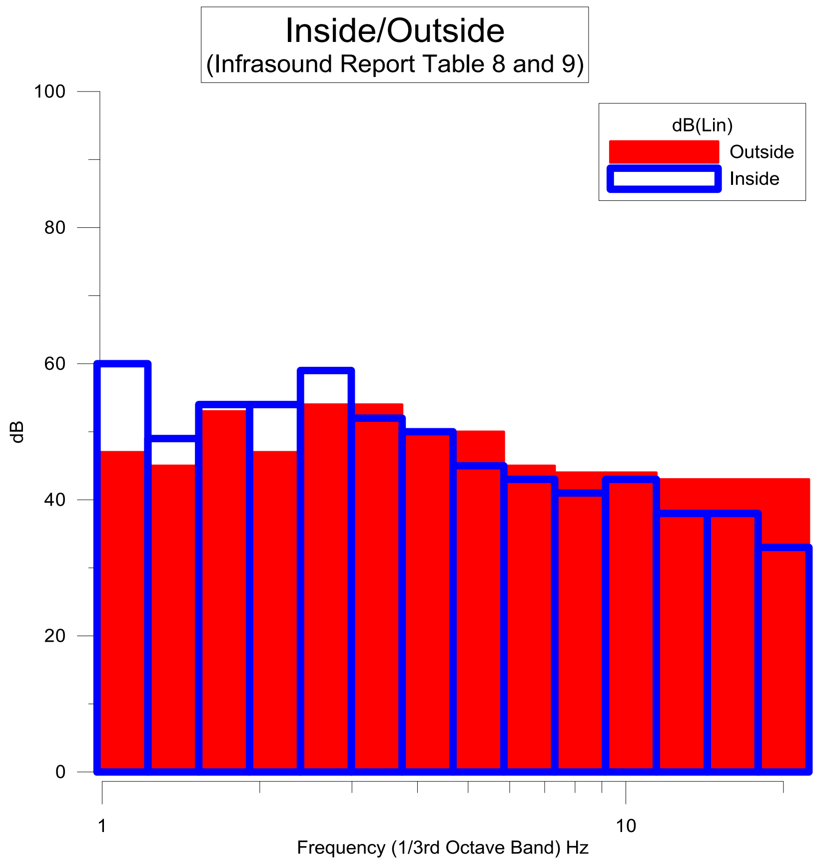


FIGURE 5: Inside/Outside results from reference [12]

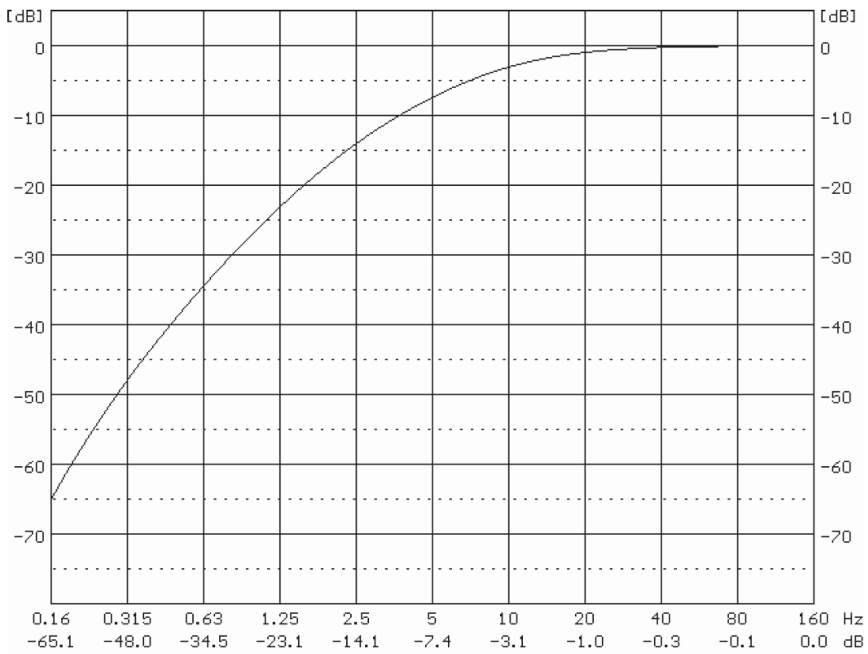
TABLE 3: Calculated levels – Tables 8 & 9 of Infrasound report (Reference 12)

Noise Source	Measured Level dB(G)	Measured Level dB(Lin)	Measured Level dB(C)	Measured Level dB(A)
Inside Dwelling	50	64	35	-14
Outside Dwelling	56	61	41	-6

The report does not identify the blade pass frequency. If one assumes the frequency relates to a speed of 16 - 17 rpm then the blade pass frequency will be below 1 Hz. The above results do not go below 1 Hz as the meter is unable to measure 1/3 octave bands below 1 Hz.

The material provided in the infrasound report and the aforementioned Sonus paper in Acoustics Australia [11] identified the meter was a Svantek 957 meter with a Gras 40 AZ microphone having a frequency response of ±1dB to 1Hz (page 45 of reference 13). Some older Svantek meters (such as the 912 and 912AE) provide a Linear spectrum but not the 957 meter used for the Sonus paper.

The meter used for measurements has the capability for selecting spectra for analysis utilise A-weighting, C-weighting or Z-weighting. For analysis purposes the 957 meter has two Z weighting curves. One curve for the broadband level (figure 6) and a relatively flat curve (Flat) for 1/3 octave band analysis.



Low band frequency characteristics of Z filter implemented in the instrument

FIGURE 6: Z-weighted – characteristics from reference 14

The Z-weighting filter shown in Figure 6 (from reference 14) for the SVAN 957 meter is for the broadband dBZ measurement and provides an attenuation that shows the start of a roll-off around 70 Hz (-0.1dB at f_1 at 80Hz) and whilst only being 1 dB down at 20 Hz, it is 23 dB down at 1.25 Hz. His contradicts the text in the manual (Appendix D9) that indicates the 0.1 dB down point is at 27 Hz.

Therefore if using the dBZ overall value to describe the noise then like the dBG filter curve an overall dBZ value will underestimate the contribution for the blade pass frequency and the lower harmonics of that frequency.

Sonus have advised [15] that the 1/3 octave band graphs from the meter utilise a different curve to that shown in Figure 6 that provides a flat response from about 0.8Hz and required a notation of that fact in the presentation.

There is no identification in either the Sonus paper or the infrasound report of the meter settings.

However there also another set of correction curves in the sound mode to address the sound field and extension cables (as compensation filters) that would appear to change the frequency response curves by an additional “digital filter when compensation filter is engaged” [16].

In other sound level meters there can be a flat Z weighting for a limited frequency range and compensation adjustments for extended frequency response or different microphones. Similarly in using direct analysis processing (such as Pulse) it is necessary to be aware of the High Pass filter settings (22.4Hz, 7Hz, 0.7Hz or DC).

From the above discussion there can be problems in assuming a flat response from the measurement instrumentation. Therefore in reporting on infrasound measurements it becomes necessary to identify the instrumentation setup and any compensation filters that may be used.

The above discrepancy in the response curves leads to an identification that *International Standard IEC 61672-1 Electroacoustics – Sound level meters – Part 1: Specifications* [17] only provides a Z weighting filter correction of 0 dB down to 10Hz. The Standard does not present a frequency response below 10Hz. Furthermore the allowable tolerance of the Z weighting at 10 Hz is larger than at higher frequency.

It is suggested that these aspects of the IEC Standard for the frequency range below 10 Hz for the measurement of wind farms needs to be addressed.

TABLE 4: AAS Paper – Table 2 Data (reference 12)

(Limited 1/3rd Octave Bands 1-20Hz)

Noise Source	Measured Level dB(G)	Measured Level dB(Lin)	Measured Level dB(C)	Measured Level dB(A)
Clements Gap Wind Farm at 85m	75	100	61	9
Clements Gap Wind Farm at 185m	70	97	56	4
Clements Gap Wind Farm at 360m	65	93	51	-2
Cape Bridgewater Wind Farm at 100m	68	89	53	5
Cape Bridgewater Wind farm at 200m	66	83	51	2
Cape Bridgewater Wind Farm ambient	65	83	51	0
Beach at 25m from high water line	78	91	64	13
250m from coastal cliff face	72	90	57	7
8km inland from coast	61	86	47	-5
Gas fired power station at 350m	75	90	60	13
Adelaide CBD at least 70m from any major road	78	91	62	15

Accordingly as the infrasound report concentrated on dB(G), the comparison of man-made and wind farm infrasound will be different as discussed above.
The Sonus paper only provided a table of dB(G) values. If one is seeking to compare infrasound from wind farms, and the dB(G) does not identify the majority of the turbine infrasound, the use of the dB (Lin) parameter band limited to 0.5 Hz to 20 Hz.

In some instances resident complaints attributed to wind farms are related to low frequency noise, which is not a matter that is covered either by dB(G) or dB Linear when the results are just band limited from 1Hz to 20Hz. To address low frequency noise should another measure of wind farm noise cover 20 Hz to 200Hz as a Linear level?

Low frequency noise has recently been shown by Nobbs et al. [17] to be directly associated with specific symptoms under the label of "annoyance" and the severity of those symptoms correlated precisely with the "dose" or SPL of sound energy present in those frequencies at the time. It is noted that reference [17] provides levels in dB(Z) but limited to above 10Hz.

A repeat exercise but to include frequencies below 10Hz was being undertaken at the time this paper was being prepared.

4. Narrow Band Spectra

It is noted that in relation to the matter of addressing infrasound and low frequency noise from wind farms, other acoustic consultants both here and in Australia have looked to narrowband measurements to identify the signature of the turbines to find a fundamental frequency associated with the blade pass frequency and multiple harmonics all to lie in the infrasound region.

A report issued in late 2012 with respect to the Shirley Wind Farm in Wisconsin [8] confirms the results of similar measurements conducted in Falmouth, Massachusetts [19] and measurements in Australia [7]. The Shirley Wind Farm monitoring involved a number of acoustical consultancy firms where assessments were conducted both in terms of 1/3 octave's and also narrowband analysis.

The Wisconsin report identifies residents were able to perceive low frequency noise being below the nominal threshold of hearing and the penultimate paragraph of the conclusion states:

> "The four investigating firms are of the opinion that enough evidence and hypotheses have been given here in to classify LFN and infrasound as a serious issue, possibly affecting the future of the industry. It should be addressed beyond the present practice of showing that wind turbine levels of magnitude is below the threshold if hearing at low frequencies."

One of the firms involved in the Wisconsin study included Dr Paul Schomer, who for experienced practitioners in acoustics would be well aware of his experience in acoustics, particularly with respect to socio-acoustics and regression analysis for various forms of noise sources.

Dr Schomer in his report (attached as Appendix D to the main Wisconsin report) identifies that the implications of the measurements (of the Shirley Wind Farm) are:

1. The measurements support the hypothesis developed in (I) that the primary frequencies are very low, in the range of several tenths of a Hertz up to several Hertz. The coherence analysis shows that only the very low frequencies appear throughout the house and are clearly related to the blade passage frequency of the turbine. As Figure 5 shows, the house is acting like a cavity and indeed at 5Hz and below, where the wavelength is 200 ft or greater, the house is small compared to the wavelength.

In the section of Descriptors for Wind Turbine Emission, Dr Schomer states:

1. Currently the wind turbine industry presents only A-weighted octave band data down to 31Hz. They have stated that wind turbines do not produce low frequency sound energies. The measurements at Shirley have clearly shown that low frequency infrasound is clearly present and relevant. A-weighting is totally inadequate and inappropriate for description of this infrasound. In point of fact, the A-weighting, and also the C and Z-weightings for Type 1 sound level meter have a lower tolerance limit of -4.5dB in the 16Hz one-third octave band, a tolerance of minus infinity in the 12.5Hz and 10Hz one-third octave bands, and are totally undefined below the 10Hz one-third octave band. Thus, the International Electro-technical Commission (IEC) standard needs to include both infrasonic measurements and a standard for the instrument by which they are measured.

5. Filter Limitations

The preceding extract identifies the levels below 10Hz are undefined for the normal filter curves. It would appear that there are different “Linear” frequency responses for different meters and there are different Z filter responses for various meters. Many Type 1 sound level meters do not cover the full range of the spectrum needed for assessing turbines.

Our measurements have utilised the full spectrum capabilities of the Bruel & Kjaer Pulse system with early measurements using the default 22.4Hz high pass filter, then measurements using the 7Hz high pass filter (-3dB @ 0.7Hz), and now 0.7Hz filter (-3dB at 0.07Hz) with unfiltered data being obtained for real time and post-processing.

We have found the frequency response of the microphones has been the first limitation, then the dynamic range of the microphones. This had led to extensive testing of noise floors and frequency range of the various microphones for the Pulse system and comparison with other meters to confirm the measurement results (particularly indoors) are above the thermal/electrical floor of the instrumentation. Such testing has identified a “sensitivity” floor of the microphone (above the electrical noise floor) where the microphone starts to provide an output having overcome the mechanical inertia of the diaphragm.

Swinbanks [5] identifies wind-turbine infrasound can be impulsive with a well-defined array of tonal harmonics below 10Hz. He notes that, *“for impulsive sound, the harmonics are all phase-correlated; so that they do not add together randomly in mean square to form the maximum amplitude, but rather they add together in a linear fashion, with their individual maxima all coinciding. Thus, for an impulse having 10 equal amplitude harmonics each of unity amplitude (say), the mean square level is +10dB, but the peak level is +20dB”.*

Because the peak levels for wind turbine noise could be considerably higher than for wind noise, Swinbanks [5], James & Bray [4] and Rand & Ambrose [19] utilise unweighted time waveforms as an essential part of their assessment where significant crest factors can be identified.

6. Conclusions

The concept of utilising dB(G) to describe infrasound levels associated with wind turbines at residential receivers has a fundamental flaw due to the definition of the G-weighting curve which can be obtained by reference back to International Standard ISO 7196:1995.

Due to the specific frequency weighting characteristics of the G function, whilst the proportion of energy below 6.3Hz is evident in a linear format for such measurements, such energy in not reflected in the dB(G) value.

The relevance of using dB(G) to determine the human perception of infrasound from turbines has not been established or whether in fact the suggestion of a hearing threshold based on dB(G) is appropriate for turbine noise.

There is danger in utilising or presenting material as Linear levels when using instrumentation that has a dB(Z) weighting that may have different frequency responses below 5Hz and potentially different compensation filters that need to be identified.

Not all meters have the same dB(Z) filter or even true Linear spectrum results, nor do most consultants or calibration facilities have the ability to calibrate complete systems across the full infrasound spectrum.

It would therefore appear that in seeking to investigate infrasound measurements the appropriate method is to present the linear (unweighted) results. In our experience in addition to generalised 1/3 octave band information, narrowband analysis should be provided which by its very nature is able to identify the presence of tones at a lower level than one can see by use of 1/3 octave band analysis.

Investigations into the infrasound issue associated with the wind turbines also require consideration of the noise levels inside buildings. In some cases the internal noise levels are higher than external, whilst for other sites the internal levels are marginally below that recorded externally – but not to the extent as the reduction in dB(A) values.

Apart from the issue of secondary windscreens or microphones in holes in the ground, there is an issue in terms of the instrumentation that is used for measurements where matters have been raised by various parties as to the noise floor of the microphone (and the instrumentation) and also the frequency response for the levels being measured. The frequency response of microphones is usually tested at levels much higher than encountered inside residences. Testing in our anechoic room showed the frequency response is not linear across the dynamic range [21] and one has to ensure the system can measure the actual noise – hence requiring specialised instrumentation.

Investigation and measurement of infrasound is for most acousticians a new area of investigation and as well as being somewhat expensive to investigate, it is also quite interesting. It is hoped that the above matters lead to further discussion as to the appropriate measurements and consistency in terms of methodologies so as to permit the health studies and similar that would enable investigating noise from wind turbines can be undertaken from a more solid and consistent basis with respect to the noise level measurements.

7. Acknowledgements

The author acknowledges the contribution from Rob Rand, Rick James, Stephen Ambrose and Les Huson for technical editing of the article, and in particular the material provided by Dr Malcolm Swinbanks to educate us all about filters.

The amended version of the original paper is different to that contained in the conference proceedings following advice from Mr Turnbull of errors in the original paper concerning the Z weighting of the 1/3 octave bands in the SVAN 957. The author in the presentation acknowledged the error and gave an undertaking to those present to re-issue the paper.

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