ACOUSTIC REPORT FOR DEVELOPMENT APPLICATION

ASSESSMENT OF ENVIRONMENTAL IMPACT OF NOISE FROM PROPOSED DOG BREEDING ACCOMMODATION AT 125 ELTONS RD SILVERDALE

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Report Ref: 160703 July 2016 v1.1
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Assessment of noise impact from proposed dog breeding accommodation.

1. **INTRODUCTION**

Acoustic Directions has been retained by Hamptons Property Services to prepare an acoustic assessment of noise produced by barking dogs housed within the property at 125 Eltons Rd Silverdale NSW. Acoustic Directions understands that Council has received complaints from nearby residents about excessive noise from dogs barking.

We also understand that Council has requested that owner of the property submit a Development Application for an “animal boarding or training establishment” to enable the owner to breed dogs. This report accompanies that application, examining the acoustic issues and proposing a solution.

The assessment has been conducted in accordance with the relevant standards and recommendations issued by NSW state authorities. The author, Glenn Leembruggen, is a Fellow of the Institute of Acoustics (UK) and a member of the Australian Acoustical Society. Acoustic Directions is a member firm of the AAAC.

2. **ABOUT THIS REPORT**

- Section 3 describes the site and proposed facility and identifies noise-sensitive receivers.
- Section 4 presents the sound pressure levels that were measured to establish the existing noise from dogs barking and the background noise level as well as the numerical noise criteria that have been formulated from those measurements.
- Section 5 presents the noise criteria used to assess noise from the proposed facility.
- Section 6 lists the acoustical features of the proposed solution to contain the noise from dogs barking.
- Section 7 notes the acoustic parameters used in the prediction of noise levels from barking, and presents the predicted noise impact on residential receivers.
- Section 8 describes recommendations for the acoustical components of the proposed kennel structure.
- Section 9 presents the conclusion.
- The Appendix holds the noise logger plots of ambient noise levels around the site.
- A Glossary of technical terms is provided to assist the reader understand the technical content of this report.
- For brevity, bullet points are used in parts of the report.
- The term dB represents a decibel, which is both a measure of how loud a sound is, and a relative difference between two sound levels.

3. **PROJECT DESCRIPTION**

A. **Site Description**

Currently, dogs are housed in a number of kennels and yards on the property.

B. **Proposed Operation**

The current DA proposal is seeking approval to house up to twelve dogs in a large kennel structure on the property to accommodate the owner’s dogs and breeding business. That structure is described in Sections 6 and 8.

C. **Residential Receivers**

During our site inspection, we found that the most affected residential-receivers live directly adjacent to the subject property. Of these, the residence at 115 Eltons Rd shown as Location R1 in Figure 1, is closest to the proposed kennel structure.
4. **ASSESSMENT OF EXISTING NOISE LEVELS**

There are two components of the existing noise that were assessed:

- Background noise levels
- Noise levels produced by barking dogs.

A combination of unattended and attended measurements was used to provide data to establish both the background and barking noise levels present at the receivers.

4.1. **Attended Measurement**

A. **Site Details**

An attended noise measurement was made by Acoustic Directions’ technician using a Type 1 hand-held acoustic analyser Brüel & Kjaer 2250. The measurement was made at Location L1 on Thursday June 2nd 2016 from 11 am to 11:15 am. The meter was positioned at 1.5 m above the ground and at a distance exceeding 1.5 m from building surfaces. The meter was calibrated prior to and after the noise measurements, and no significant drift in the calibration was observed.

The measurement was made on the boundary of the property at 129 Eltons Rd which is shown in Figure 1 as Location L1. The distance from the logger microphone to the nearest building was more than 10 m. This location was selected for the following reasons:

- We understand that residents are rarely at 129 and therefore there was the likelihood of less extraneous noise in the logger data.
- It was relatively close to an adjacent residence, thereby assessing the actual noise impact of the barking.
- It was sufficiently far from Eltons Rd to reflect the background noise experienced by adjacent residents.
The sound during the attended measurement consisted of vehicular traffic, birds, dogs barking and cattle braying. The day was fresh and dry with no cloud cover and no wind. Weather conditions at the time of the measurements did not affect the measurements results.

As the noise from dogs’ barking was continually present at location L1 and affecting the measurement of the $L_{A90}$ background level, our technician measured the background noise level at the front boundary of 135 Eltons Rd by the road (Location L2). At this location, noise from the dogs was inaudible.

B. Analysis

a) Using acoustic analysis software, the $L_{A90}$ level was computed from the measured data to provide the background noise level during the measurement period.

b) The recording was listened to and loud instances of the sound of dog(s) barking were isolated in the analysis software. The total $L_{Aeq}$ level of the combination of the isolated barking segments was then computed.

c) Table 1 shows the levels measured at L1. It is evident that the noise from barking dogs is more than 20 dB above the background noise

<table>
<thead>
<tr>
<th>Noise Type</th>
<th>Parameter</th>
<th>Overall dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background (location L2)</td>
<td>$L_{A90}$</td>
<td>32.8</td>
</tr>
<tr>
<td>Dogs barking L1 (location L1)</td>
<td>$L_{Aeq}$</td>
<td>53.1</td>
</tr>
</tbody>
</table>

Table 1 Levels measured at attended measurement at L2.

4.2. Unattended Measurements

Unattended measurements were made over a continuous 24-hour period for seven days using an ARL noise logger that was also able to record the audio. The logger was also placed at Location L1. The logger measurement was made between Thursday June 2nd and Thursday June 9th 2016 and recorded the $L_{A90}$, $L_{Aeq}$ and $L_{A10}$ levels in fifteen minute periods.

4.2.1 Background Noise Levels

The recorded graphical $L_{A90}$ values from the noise logger are shown in Appendix 1. The $L_{A90}$ graphs were analysed to determine the 10th percentile value to use as the Assessment Background Level (ABL) for each time period. The median of the ABL values was then used for the Rating Background Level (RBL). The methods used to find these two parameters are in accordance with Table 3.1 in the NSW Industrial Noise Policy.

The ABL and RBL data for the day, evening and night periods are shown in Table 2.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Computed RBL dBA</th>
<th>Assessment Background Levels dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thrus</td>
<td>Fri</td>
</tr>
<tr>
<td>Daytime 7:00 am to 6 pm</td>
<td>32.3</td>
<td>31.7</td>
</tr>
<tr>
<td>Evening 6 pm to 10 pm</td>
<td>33.3</td>
<td>28.4</td>
</tr>
<tr>
<td>Night 10 pm to 7 am</td>
<td>27*</td>
<td>26.3</td>
</tr>
</tbody>
</table>

Table 2 ABL and RBL data obtained from noise logger

* see text
Although the actual RBL of the logged night-time data is 32.1, we consider that the true RBL for this period would be approximately 27 dBA, it is likely that the inclusion of additional nights would yield a RBL of around 27 dBA.

4.2.2 Noise from Dogs Barking

The LA10 data in each fifteen-minute period from the noise logger was ranked according to level. For those periods showing high LA10 levels, the audio recording for the corresponding time period was examined for the presence of barking noise. We found many instances in which barking noise was the primary noise sound in the fifteen-minute period.

Of the instances selected, the L\text{Aeq} levels over the fifteen-minute periods ranged between 53 and 62 dB A. Occurrences of the noise were found during right through the day and night from 7:00 am up 00:15 am. Noise levels recorded were unexpectedly high and far exceeded acceptable levels for neighbour amenity.

5. NOISE CRITERIA

It appears that Wollondilly Shire Council do not include noise criteria in the 2016 Development Control Plan.

In the absence of such criteria, we have used the criteria given in the document NSW Noise Guide for Local Government prepared by DECCW.

However, given the subjective annoyance that noise from barking dogs can cause to residents, we have allowed for an ample safety margin for this criterion.

5.1. DECCW NSW Noise Guide for Local Government

The NSW Noise Guide for Local Government essentially deals with noise from commercial and industrial operations that are not required to hold a license from the EPA.

The procedure to assess a commercial noise source that operates during daytime has three main elements:

- controlling the impact of intrusive noise
- dealing with the offensiveness of the noise
- assessing the amenity level of the noise

A. Intrusiveness Criterion

The intrusiveness of a commercial noise source is generally considered acceptable if the equivalent continuous (energy-average) A-weighted level of noise from the source (represented by the L\text{Aeq} descriptor), measured over a 15-minute period, does not exceed the background noise level measured in the absence of the source by more than 5 dB.

The intrusiveness criterion can be expressed as follows:

\[
\text{L}_{\text{Aeq}, \text{15 minute}} \leq \text{rating background level} + 5 \text{ dB (RBL+5dB)}
\]

where \text{L}_{\text{Aeq}, \text{15 minute}} represents the equivalent continuous (energy average) A-weighted sound pressure level of the source over 15 minutes. This is to be assessed at the most-affected point on or within the residential property boundary.

The \text{rating background level (RBL)} is the short-term background noise level to be used for assessment purposes. For this project, the RBL is represented by the \text{L}_{\text{A90, 15 minute}} descriptor.

The RBL is to be found for the relevant time period of the day; viz. daytime (7 am to 6 pm), evening (6 pm to 10 pm) and night-time (10 pm to midnight).

If the intrusive noise contains impulsive or tonal components, adjustments must be applied to the measured noise level to reflect the increased subjective annoyance of the noise. These adjustments are listed in the NSW Industrial Noise Policy.
B. Penalty for tonal sounds

The INP states that if tonal components are significant characteristics of the measured external noise levels, a penalty should be applied to the measured A-weighted sound pressure level before comparing the measurement with the recommended noise levels. The reason for this is that prominent tones can become easily “annoying” or “offensive” for a sensitive receiver and are considered undesirable.

As the barking sound of a dog has no dominant tonal components, this penalty does not apply.

C. Transient Noise Sources

Table 4.2 of the Industrial Noise Policy (INP) issued by the NSW EPA gives adjustments to the measured noise level of a transient noise source based on its duration. However, these adjustments can only be used for one event in a 24-hour period.

As noise from the kennel operation will be intermittent, this adjustment for transient noise is not relevant and therefore we need to use the LA_{eq,15 min} parameter to assess the noise level of day-to-day operations of the property.

D. Penalty of Intermittency

If the noise during the night-time period only varies by more than 5 dB, then a penalty of 5 dB is to be applied to the noise.

As the 7 am to 8 am period on Sunday morning is classed as night-time, this penalty should be applied to the dog noise in this time period.

E. Maximum penalty

Where more than one penalty could be applied to the noise, the penalty is limited to a maximum of 10 dB.

5.2. Offensive Noise

The concept of offensive noise is applied in both the POEO Act and the Noise Control Regulation. Offensive noise is defined in the POEO Act as being noise:

a) that, by reason of its level, nature, character or quality, or the time at which it is made, or any other circumstances:

   (i) is harmful to (or is likely to be harmful to) a person who is outside the premises from which it is emitted, or

   (ii) interferes unreasonably with (or is likely to interfere unreasonably with) the comfort or repose of a person who is outside the premises from which it is emitted, or

b) that is of a level, nature, character or quality prescribed by the regulations or that is made at a time, or in other circumstances, prescribed by the regulations.

To ensure that noise from the dogs will not cause annoyance to residents, we consider that noise from the dogs should be at least 7 dB below the background noise level at all times. This level will ensure virtual inaudibility of the barking noise at nearby residential buildings.

5.3. Adopted Noise Criteria

The estimated octave-band L_{90} levels for each time period were used to form the criteria levels for the noise emissions from the kennel operation. The penalty of 5 dB for intermittent noise during the night period is used to reduce the criterion to background noise.

The levels of the criteria are listed in Table 3.
<table>
<thead>
<tr>
<th>Period</th>
<th>Type</th>
<th>Overall dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime</td>
<td>RBL</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Criteria</td>
<td>37</td>
</tr>
<tr>
<td>Evening</td>
<td>RBL</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Criteria</td>
<td>38</td>
</tr>
<tr>
<td>Night</td>
<td>RBL</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Criteria</td>
<td>27</td>
</tr>
</tbody>
</table>

Table 3: Adopted background noise levels and criteria at the property boundary

If compliance is achieved at the most-affected residences, all other residential properties surrounding the site will also comply with the criteria.

6. **OVERVIEW OF PROPOSED SOLUTION**

Given the sound levels produced by a barking dog and the relative proximity of residents, the solution to containing the noise is to house the dogs in a sound-isolated large kennel structure.

An acoustic design for this structure has been prepared, which is embodied in the drawings of the structure accompanying the DA. The kennel houses eight pens with capacity for twelve dogs. A partly open roof is provided to allow daylight and weather into the kennel structure.

There are a number of acoustical features of the design of the kennel:

a) An exercise yard with daylight is provided for the animals.

b) The edges of the open roof form acoustic barriers for the sound in all directions.

c) To maximise the losses due to the acoustic barrier effect, the height of roof apex points is 5 m which is as high as allowed by Council regulations.

d) The edges of the opening to the roof are lined with high-performance sound absorption material. Such lining has been shown in research to increase the barrier attenuation.

e) The roof opening is segmented using blades to a form a series of side-by-side sound wells, which provides two functions:
   • It maximises the barrier attenuation by maximising the vertical angle that sound from the dogs impinges on the barrier. To reach nearby residents, sound will need to bend or diffract through an angle exceeding 90 degrees.
   • The blades are lined with high-performance sound absorption material over their 1.5 m length, allowing the walls of the well to function as a lined duct. Lined ducts are able to provide substantial acoustic absorption.

f) Through-ventilation for the enclosure is provided by acoustic louvres located at each end of the enclosure. These louvres will provide up to 27 dB of sound transmission loss.

g) The ceiling and sections of the walls are lined with high-performance sound absorption material, which will significantly reduce the amount of reflected sound leaving the open roof.

h) The lower internal areas of the enclosure have hard surface finishes to enable cleaning and hosing.
7. **PREDICTED NOISE LEVELS AT RECEIVERS**

7.1. **Acoustic Parameters in the Calculations**

7.1.1 **Sound Power of Barking Dog**

To enable a calculation of noise breakout from the kennel, the sound power produced by a barking dog is required. It appears that there is little specific data available about the noise levels produced by barking dogs. We have therefore estimated the level at 1 m based on the measured attended level as follows:

a) The dog that was primarily barking during the attended measurement was located 100 m from the measurement point, resulting in a loss of 40 dB.

b) As the dog was just shielded from line of sight to the measurement position by the house on the subject property, we have assumed that the house provided a barrier loss of 5 dB.

c) A reflection from the ground is assumed to have added 3 dB to the measured level.

d) The spectrum of the dog barking at the attended location was analysed in octave bands.

e) As the size of a dog’s head is commensurate with the size of a human head, we have assumed that barking sounds will emanate in a similar directional pattern to the human voice.

f) The sound power levels in octave bands were the computed and are shown in Table 4. From this data, the sound pressure level at 1 m from the dog is calculated to be 101 dBA, which lies at the upper end of levels noted on the internet for a dog bark.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Leq in Octave Frequency Bands (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>125</td>
</tr>
<tr>
<td>Sound Power Level L_{Weq}</td>
<td>99.1</td>
</tr>
</tbody>
</table>

Table 4: Sound power levels for a barking dog in free space.

7.1.2 **Calculation Method**

Our mathematical predictions of the sound levels reaching residential locations are based on information presented by the proponent and our site inspection of the site and surrounds. The predictions have included the following parameters:

a) The structure of the building as shown in the accompanying drawings.

b) The primary leakage paths of noise from the enclosure to nearby receivers are the open (segmented) roof and the acoustic louvres.

c) The level of direct and reflected sound impinging on the sound wells and the louvres.

d) Eight dogs are assumed to be standing anywhere in the enclosure and barking simultaneously. (N.B. Up to twelve dogs could be present in the enclosure).

e) The distribution of sound levels throughout the enclosure and the expected reverberation times resulting from the surface finishes.

f) The sound transmission loss through the building walls, open and closed sections of the roof.

g) Sound attenuation provided by the NAP 600 H-Line acoustic louvres.

h) Attenuation over the 75 m distance to the nearest residence.

i) The barrier attenuation for Receiver provided by the open roof.

j) To account for diffraction effects that cannot be predicted, the maximum attenuation provided by the open roof is limited 25 dB.

k) Ground reflections.
I) Reflection from the façade of the receiver’s house.

7.2. Predicted Noise Levels

With the parameters listed above, the predicted noise level at the receiver is 24 dBA.

Table 5 compares the predicted level of barking noise reaching the façade of R1 with the time-based criteria. Increasing positive numbers represent increases in the safety margin. Ample safety margin is available during the day and evening periods.

At night-time, the level at the receiver façade with eight dogs barking simultaneously is 1 dB below the criterion and typically-lowest evening background noise and will be faintly audible outside the residence. In the more likely scenario of only two dogs barking at night, the levels would fall by 6 dB. At the resulting level of 20 dBA, other sounds such as breathing and normal domestic noise from appliances would render the noise inaudible within a bedroom with an open window.

<table>
<thead>
<tr>
<th>Period</th>
<th>Criterion dBA</th>
<th>Predicted Level dBA</th>
<th>Margin for Criteria dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime</td>
<td>37</td>
<td>26</td>
<td>11</td>
</tr>
<tr>
<td>Evening</td>
<td>38</td>
<td>26</td>
<td>12</td>
</tr>
<tr>
<td>Night</td>
<td>27</td>
<td>26</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 5: Exceedance levels of criterion in dB at Receiver R1 with eight dogs barking simultaneously

8. ACOUSTIC RECOMMENDATIONS

For the proposed commercial kennel to achieve compliance with the noise criteria, the recommendations listed in this section should be implemented.

8.1. Operational Conditions

a) Dogs are only allowed within the kennel enclosure.

b) All current dog-related structures and holding yards are to be removed.

c) Up to 12 dogs can be housed in the kennel structure.

8.2. Structure of Enclosure

The structure of the floor/ceiling system shall be:

a) Walls to be concrete block.

b) Glass blocks in the walls are to provide light.

c) 0.5 mm BMT Colourbond roofing material over 100 mm rafters.

d) 9 mm thick fibre cement sheet lining to underside of rafters.

e) Each sound well requires a solid internal panel, such as 10 mm waterproof plywood or 1 mm thick galvanised steel.

f) All gaps around the eaves and the sound wells to be sealed with flexible sealer.

g) All insulation is to be 100 mm thick polyester CSR Martini Absorb HD100.

h) The insulation should be faced with a waterproof, open weave scrim.

i) Where it is exposed to rain, adequate drainage is to be provided for the installation.
j) Acoustic louvres to be NAP 600 H-line. Louvres should be sized to ensure the required airflow up to a maximum area of 1.8 sq m.

k) The entry door is to be solid core 35 mm or thicker with a self-closing mechanism.

9. CONCLUSION

An assessment of the environmental noise impact of a commercial kennel operation at 125 Eltons Rd Silverdale has been conducted by Acoustic Directions at nearby residential receivers. The assessment has determined the background noise levels applicable to the situation and assessed the existing noise levels from barking dogs.

Measurements have shown that the existing noise levels far exceed the background noise levels.

An acoustic enclosure has been proposed to house the dogs, and incorporates a number of elements designed to maximise noise attenuation whilst providing a semi-outdoor area for the dogs.

Sound levels from this enclosure reaching the nearest residence have been predicted, and were based on a number of operational conditions and acoustic construction details.

The predicted level of noise at the nearest receiver with eight dogs barking simultaneously complies with noise criteria based on the NSW Industrial Noise Policy with noise penalties applied where necessary.

We are satisfied that if the conditions and recommendations stated in this report are implemented, the noise resulting from the kennel operator will comply with the noise criteria and not cause annoyance to nearby residents.
10. **APPENDIX 1**  NOISE LOGGER PLOTS
Existing Ambient Noise - Wednesday-08-June-2016

Existing Ambient Noise - Thursday-09-June-2016
11. **GLOSSARY OF TERMS**

11.1. **Index to Terms**

The glossary is arranged alphabetically to assist readers to find the required information by clicking on the link.

*Assessment Background Level (ABL)*

*A-Weighted Sound Level dBA*

*Clarity Ratio*

*C-Weighted Sound Level dBC*

*Decibel (dB)*

*DnT,w*

*Equivalent Continuous Sound Level (Leq)*

*Equivalent Acoustic Distance*

*Frequency Response*

*LA1,(T)*

*LA10,(T)*

*LA90,(T)*

*Lmax,T - Maximum Sound Level*

*Rating Background Level (RBL)*

*Reverberation Time*

*Rw*

*Sound*

*Sound Absorption*

*Sound Absorption Coefficient*

*Sound Insulation*

*Sound Level Indices*

*Sound Power*

*Sound Pressure Level*

*Sound Reduction Index*

*STI*

*Vibration*

*Z-Weighted Sound Level dBZ*
11.3. Glossary

**CLARITY RATIO**

The clarity ratio is a metric that is used to assess the degradation in speech intelligibility due to the temporal effects of reverberation and echo. It is defined as the ratio of the sound energy of early-arriving sound that is useful for intelligibility to the energy of late-arriving sound which is not useful. Early-arriving sound consists of the direct sound and some reflections, while late arriving sound consists of reverberation and echoes.

Early-arriving sound consists of sound that arrives between the start of an extremely short pulse (an impulse) up to 50 ms after the start of the pulse, while late arriving sound is the total sound energy arriving later than 50 ms after the start of the pulse.

The following figure shows a typical impulse response and illustrates the dividing period of 50 ms between early and late arriving sound, which is used to compute the $C_{50}$ clarity ratio.

Typical impulse response illustrating how the clarity ratio $C_{50}$ is computed.

As the ear and therefore subjective intelligibility is sensitive to the amount of reverberation and echo at different frequencies, the $C_{50}$ ratios must be as high as possible at all frequencies to maximise intelligibility.

**STI - SPEECH TRANSMISSION INDEX**

The Speech Transmission Index (STI) is one of the better available metrics to assess the capability of a transmission system to transmit intelligible speech. STI is a single number that ranges between 0 and 1. It attempts to assess the degradation in intelligibility caused by reverberation/echoes and background noise by measuring the reduction in modulation of the speech-like waveform. Phonemes in speech are produced by modulating vocal sounds in a specific pattern, and when perfect transmission of the modulation pattern is present at a listening location, the clarity is perfect. When modulations are corrupted by reverberation or noise, the time pattern of the phonemes is changed and the clarity is degraded.

However, STI has three fundamental weaknesses:

i) It is almost blind to the effects of tonal balance on intelligibility.

ii) It is partially blind to the effects of echo on intelligibility.

iii) It reduces many complex factors (frequency/level/time) into a single number, thereby concealing important and audible components that contribute to the degradation of speech intelligibility.

To accommodate these weaknesses in STI, Acoustic Directions uses two other metrics (clarity ratios and frequency response) in conjunction with STI to assess speech intelligibility produced by a sound system.
The STI value is computed from weighted MTI values, which represent the loss of modulation in each octave-wide frequency range. When assessing STI performance, it is instructive to assess the loss of modulation in each frequency range by inspecting the associated MTI values.

Given that the majority of speech sounds occur in the 250 Hz and 500 Hz frequency ranges, the MTI values in these frequency ranges are a direct indicator of the smearing or degradation in vowel sounds. In turn, this indicates the extent to which long vowel sounds will subjectively mask sounds with higher frequency content such as consonants.

**SOUND**

Sound is an instantaneous fluctuation in air pressure over the static ambient pressure, and is transmitted as a wave through air or solid structures.

**SOUND PRESSURE LEVEL**

Commonly known as “sound level”, the sound pressure level in air is the sound pressure relative to a standard reference pressure of 20μPa (20x10^-6 Pascals) when converted to a decibel scale.

**DECIBEL (dB)**

A scale for comparing the ratios of two quantities, including sound pressure and sound power.

The ratio of sound pressures which we can hear is a ratio of 106:1 (one million to one). To measure this huge range in pressure, a logarithmic measurement scale is used with the associated unit being the decibel (dB).

An increase or decrease of approximately 10 dB corresponds to an approximate subjective doubling or halving of the loudness of a sound. A change of 2 to 3 dB is subjectively a small change and may sometimes be difficult to perceive.

As the decibel is a logarithmic ratio, the laws of logarithmic addition and subtraction apply to dB values.

The difference in level between two sounds \( s_1 \) and \( s_2 \) is given by \( 20 \log_{10} \left( \frac{s_1}{s_2} \right) \). The decibel can also be used to measure absolute quantities by specifying a reference value that fixes one point on the scale. For sound pressure, the reference value is 20μPa.

**FREQUENCY RESPONSE**

Subjective tonal balance is measured as a system’s frequency response at each location. As the ear is very sensitive to the direct sound field (the first-arriving part of the sound before reflections arrive), the response of the direct field with speech must be as consistent as possible over the listening area in the frequency range of 100 Hz to 12 kHz.

**EQUIVALENT ACOUSTIC DISTANCE**

By amplifying a talker’s speech, a sound system reduces the apparent acoustic distance between a talker and distant listener. The equivalent acoustic distance defines the resulting acoustic distance between the talker and listener and is a direct measure of the amount of voice amplification that the system can provide before the onset of acoustic feedback. Feedback is often heard as a strong colouration to the voice or howling sound.

We are accustomed to holding conversations in relatively close proximity, and to produce similar conditions in a courtroom and allow soft talkers to be heard, the EAD should be less than 2.2 m and typically 1.8 m without any trace of feedback or tonal ringing in the sound.

EAD is associated with speech intelligibility as it directly relates to the amount of speech amplification that the system can provide in order to deliver a satisfactory level of speech signal above the noise to each listener.

Factors affecting the EAD include:

- The number of microphones switched on at any time.
- The relationships between the directional response characteristics of the microphone and loudspeaker.
- The sound level reaching the audience at the critical mid and mid-high frequencies.
- Room acoustic behaviour.
FREQUENCY

Frequency is the rate of repetition of a sound wave. The subjective equivalent of frequency in music is pitch. The unit of frequency is the Hertz (Hz), which is identical to the number of cycles per second. A thousand hertz is often denoted kiloHertz (kHz), e.g. 2 kHz = 2000 Hz.

Human hearing ranges from approximately 20 Hz to 20 kHz.

OCTAVE BAND

The most commonly used frequency bands are octave bands, in which the mid frequency of each band is twice that of the octave band below it. In subjective terms, it corresponds to a doubling of pitch.

For design purposes, the octave bands ranging from 31.5 Hz to 8 kHz are generally used. For more detailed analysis, each octave band may be split into three one-third octave bands or, in some cases, narrow frequency bands.

A-WEIGHTED SOUND LEVEL dBA

The unit of sound level, weighted according to the A scale, which takes into account the increased sensitivity of the human ear at some frequencies. The unit is generally used for measuring environmental, traffic or industrial noise is the A weighted sound pressure level in decibels, denoted dBA.

A weighting is based on the frequency response of the human ear at moderate and low sound levels and has been found to correlate well with human subjective reactions to various sounds.

Sound level meters usually have an A-weighting filter network to allow direct measurement of A-weighted levels.

C-WEIGHTED SOUND LEVEL dBC

As the sound level increases, the ear is better able to hear low frequency sounds, The C-weighting filter allows low frequencies to contribute to the measurement much more than the A weighting filter.

Z-WEIGHTING dBZ

The Zero-weighting is equivalent of non-frequency shaping or weighting the measured sound level, and as no filter is applied to the sound before measurement, it is sometimes referred to as “linear” weighting.

SOUND LEVEL INDICES

Noise levels usually fluctuate over time, so it is often necessary to consider an average or statistical noise level. This can be done in several ways, so a number of different noise indices have been defined, according to how the averaging or statistics are carried out.

Examples of sound level indices are Leq,T, Lmax, L90, L10 and L1, which are described below. The reference time period (T) is normally included, e.g. dBLA10, 5min or dBLA90, 8hr.

EQUIVALENT CONTINUOUS SOUND LEVEL (Leq)

Another index for assessment for overall noise level is the equivalent continuous sound level, Leq. This is a notional steady level, which would, over a given period of time, deliver the same sound energy as the actual time-varying sound over the same period. This allows fluctuating sound levels to be described as a single figure level, which assists description, design and analysis.

The Leq is often A-weighted to remove the contribution of low frequencies, which may be less audible and is written as LAeq. It can also have no weighting as LZeq or C-weighting as LCeq.

Lmax,T - MAXIMUM SOUND LEVEL

A noise level index defined as the maximum noise level during the measurement period duration T. Lmax is sometimes used for the assessment of occasional loud noises, which may have little effect on the overall Leq noise level but will still affect the noise environment. Unless described otherwise, it is measured using the ‘fast’ sound level meter response.
LA90(T)
A noise level index. The LA90 is the sound pressure level measured in dBA that is exceeded for 90% of the time over the measurement period T. In other words, the measured noise levels during the period were greater than this value for 90% of the measurement time period.

L90 can be considered to be the “average minimum” noise level and in its A weighted form is often used to describe the background noise a LA90.

LA10(T)
A noise level index. The LA10 is the sound pressure level measured in dBA that is exceeded for 10% of the time interval (T). In other words, the measured noise levels during the period were only greater than this value for 10% of the measurement time period.

This is often referred to as the average maximum noise level.

LA1(T)
Refer to the sound pressure level measured in dBA, exceeded for 1% of the time interval (T). This is often used to represent the maximum noise level from a period of measurement, but is not the same as LAmax.

RATING BACKGROUND LEVEL (RBL)
A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey.

ASSESSMENT BACKGROUND LEVEL (ABL)
A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background LA90 noise levels – i.e. the measured background noise is above the ABL 90% of the time.

SOUND POWER
The sound power level (Lw) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level (Lp) varies as a function of distance from a source or other factors such as shielding. However, the sound power level is an intrinsic characteristic of a source.

VIBRATION
Vibration may be expressed in terms of displacement, velocity and acceleration. Velocity and acceleration are most commonly used when assessing structure borne noise or human comfort issues respectively. Vibration amplitude may be quantified as a peak value, or as a root mean squared (rms) value.

Vibration amplitude can be expressed as an engineering unit value e.g. 1mms-1 or as a ratio on a logarithmic scale in decibels:

Vibration velocity level, LV (dB) = 20 log (V/Vref),
(where the preferred reference level, Vref, for vibration velocity = 10-9 m/s).

The decibel approach has advantages for manipulation and comparison of data.

SOUND ABSORPTION
This is the removal of sound energy from a room or area by conversion into heat.
SOUND ABSORPTION CO-EFFICIENT

Sound absorption co-efficient indicate the extent to which the material absorbs sound power at a specific frequency, and is expressed on a scale of 0 to 1, with a value of 1 representing the maximum possible absorption.

SOUND INSULATION

The sound insulation is the capacity of a structure such as a wall or floor to prevent sound from reaching a receiving location.

SOUND REDUCTION INDEX

This parameter is used to describe the sound insulation properties of a partition, and is the decibel ratio of the airborne sound power incident on the partition to the sound power transmitted by the partition and radiated on the other side. It is usually measured in specific frequency bands, such as octave or one-third octave.

DnT,w

The single number quantity that characterises sound insulation between rooms over a range of frequencies with airborne sound.

Rw

Single number quantity that characterises the sound-insulating properties of a material or construction element over a range of frequencies with airborne sound.

Reverberation Time

The time in seconds required for the sound at a given frequency to decay away (or reduce to) to one-thousandth of its initial steady-state value after the sound source has been stopped. This degree of reduction is equivalent to 60 decibels.