NEW ZEALAND ACOUSTICS

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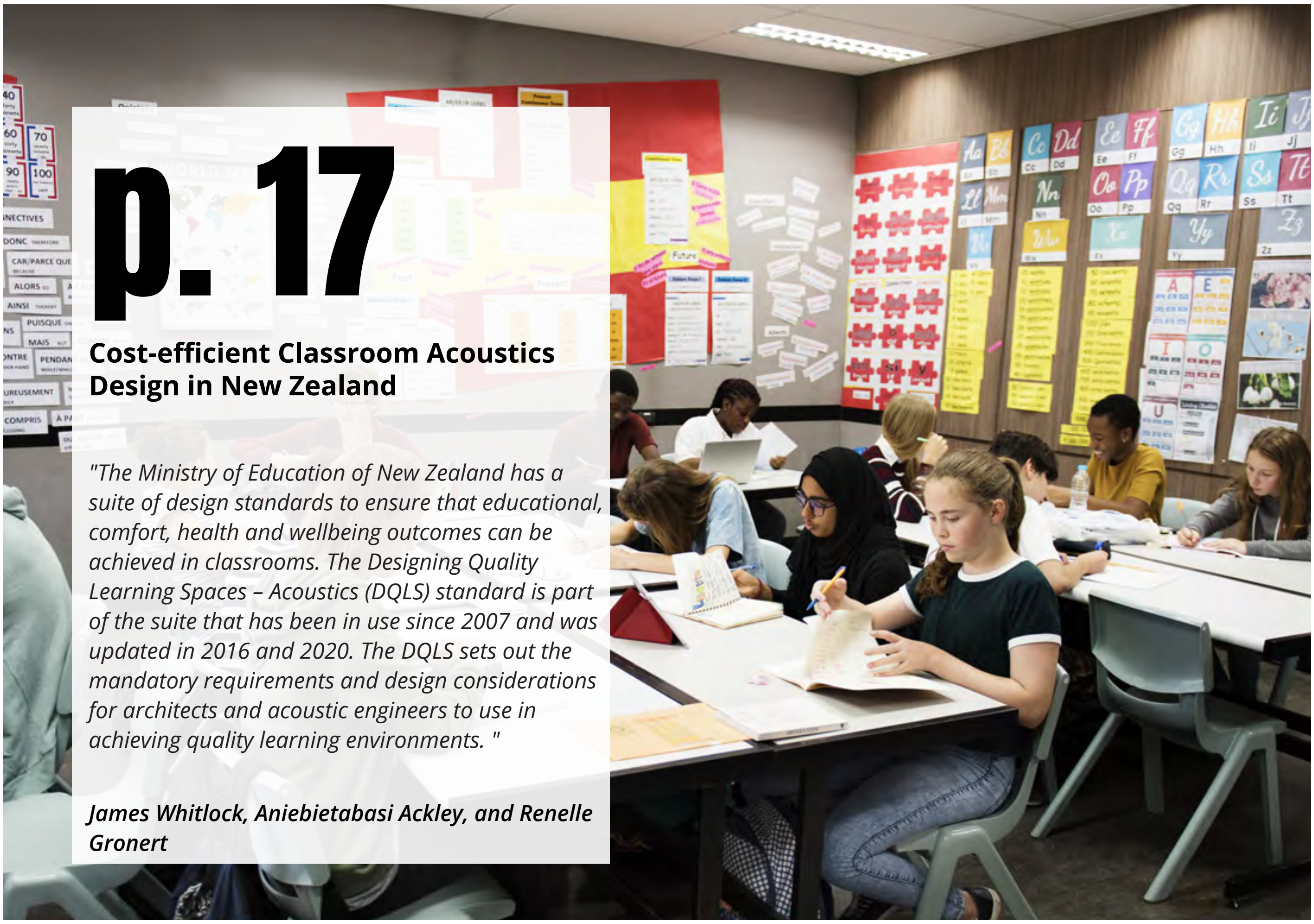
CONTENTS



p. 17

Cost-efficient Classroom Acoustics Design in New Zealand

"The Ministry of Education of New Zealand has a suite of design standards to ensure that educational, comfort, health and wellbeing outcomes can be achieved in classrooms. The Designing Quality Learning Spaces – Acoustics (DQLS) standard is part of the suite that has been in use since 2007 and was updated in 2016 and 2020. The DQLS sets out the mandatory requirements and design considerations for architects and acoustic engineers to use in achieving quality learning environments. "

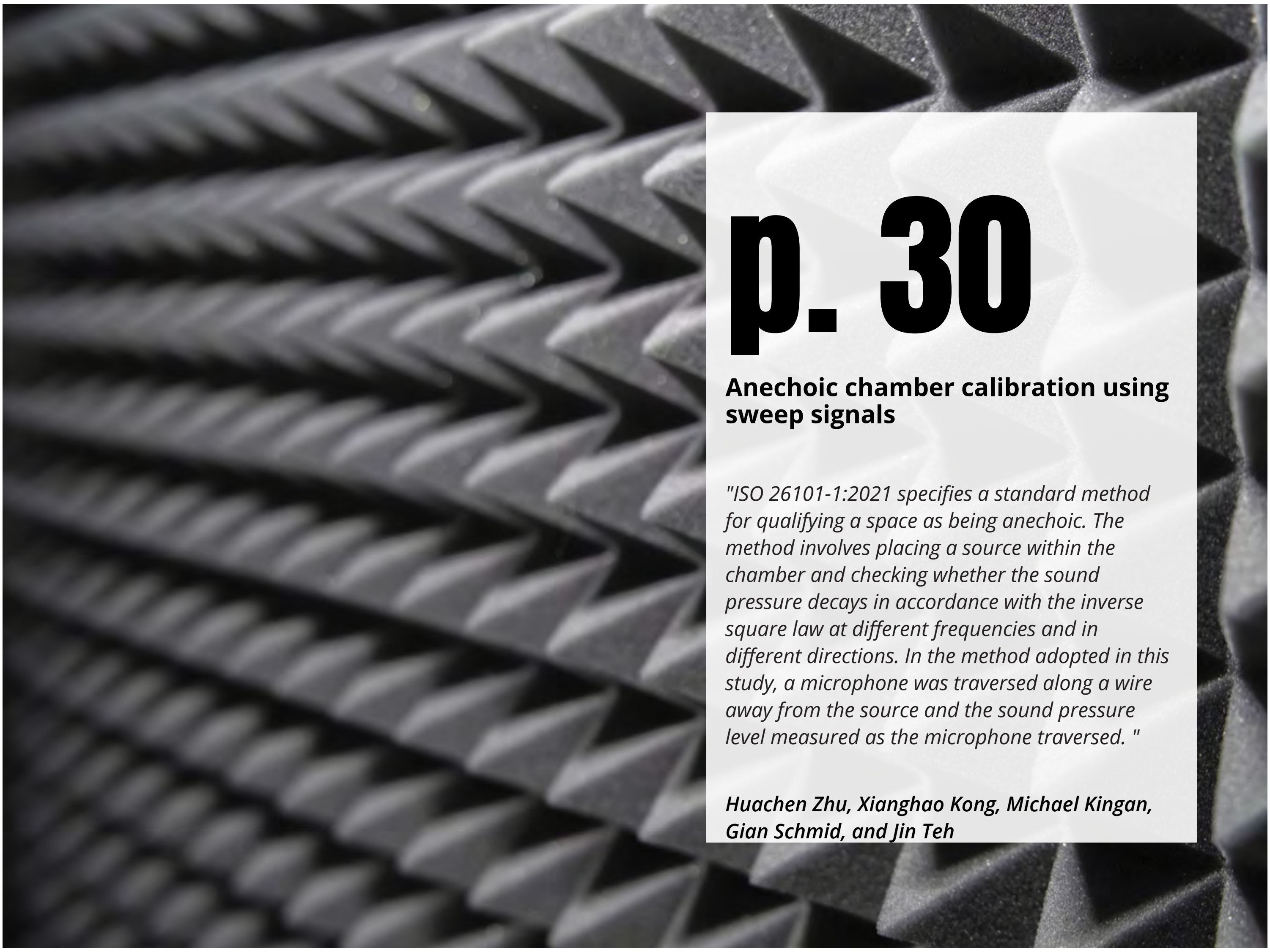
James Whitlock, Aniebietabasi Ackley, and Renelle Gronert

p. 06

Simulation of Acoustic Barriers with Air Transit Louvers

"There is an increasing need to install outdoor acoustic barriers to attenuate the noise generated by air conditioning machines, such as chillers, heat pumps, and cooling towers, etc. This type of equipment generally requires high airflow rates for heat exchange with the external environment. "

Gianfranco Quartaruolo, Silvia Motto, Roberto Zecchin, Thomas Dimasi, and Andrea Fornasiero



p. 30

Anechoic chamber calibration using sweep signals

"ISO 26101-1:2021 specifies a standard method for qualifying a space as being anechoic. The method involves placing a source within the chamber and checking whether the sound pressure decays in accordance with the inverse square law at different frequencies and in different directions. In the method adopted in this study, a microphone was traversed along a wire away from the source and the sound pressure level measured as the microphone traversed. "

Huachen Zhu, Xianghao Kong, Michael Kingan, Gian Schmid, and Jin Teh

Tracy Hilliker

President of the Acoustical Society of New Zealand Inc.

Dear Members,

Before the summer holiday break becomes more of a distant memory, I hope you all had a wonderful time with friends and family and managed some time to relax and enjoy a change in scenery. In December we hosted our annual ASNZ Christmas gatherings which were combined with our AAAC friends, with events in Auckland, Tauranga, Wellington and Christchurch. It is great that our society is growing, as is the turnout from our membership base who are making the most of these opportunities for networking and celebration amongst colleague and friends.

As it's the time for setting New Year resolutions, I've been reflecting on the strategic direction, challenges and opportunities ahead for our Society. One that is top of mind, and as we have already informed, is the proposed amendments to the ASNZ Rules (to be known as our Constitution) as we transition our governance framework to comply with the new mandatory provisions of the Incorporated Societies Act 2022. This includes updates to our Rules of Conduct and Disciplinary Measures, with the aim of strengthening our dispute resolution pathways and processes. Your Council has been working hard to finalise the proposed changes, so keep an eye on your inbox for notification of documentation that will be tabled for final review.

It is pleasing to see the increasing engagement from our community in areas where NZ acoustical standards are somewhat outdated, and that we are collaborating for change. I am aware of some fantastic work being conducted on review of the NZS 680X series, where there is the potential for advancing technical content for NZ application, to be formed through our relationship with Standards New Zealand and other major stakeholders. The formalising of the work completed can be a timely and costly process, and commitment to investment into such processes by our Society needs to be fiscally responsible. Nonetheless, I am sure we all agree the importance and necessity for the active development of NZ Standards and our profession. Furthermore, it is great to see an increase in participation by NZ companies with the AAAC. A little birdie tells me there has been a substantial amount of feedback received on the draft guidance for NZS 6803:1999 Construction Noise, and I am sure once finalised, this will become an important reference document for our industry.

My father liked to remind me that "good things take time" (that may incite memories for those of similar age of Mainland NZ Cheese Ads, sorry)! Whilst we had been optimistic that the launch of the new website would have occurred by now, there have been a few delays as we make final tweaks and enhancements. I am very hopeful that by the time you receive Volume 2 of this Journal you will be enjoying our new digital platform.

Annually, the World Health Organization promotes World Hearing Day, celebrated on the 3rd of March, to raise awareness of preventable hearing loss and promote ear and hearing care around the world. Such events are well supported by our friends at the National Foundation for Deaf & Hard of Hearing, NZ Audiological Society and Hearing New Zealand. One in every six people (or more than 880,000 New Zealanders) have some form of hearing loss, and the impacts are wide-ranging. One initiative to help raise awareness is the White Cat campaign, where pins are available for purchase to show your support. Why the White cat? White cats often have hearing loss, in about the same ratio as humans, and occasionally they are profoundly deaf, just like people. Another simple way to support this community is to download the SoundPrint App. This is a global public database for rating venue sound levels, which you can then reference to reduce your own exposure to loud sound levels and find quiet places to enjoy. The overarching aim is to identify and provide support for venues such as bars and restaurants to create a more pleasant acoustic environment and protect employee hearing who work at these venues.

Autumn will be a busy season, and we are making plans for our annual AGM which will soon be advertised, so keep an eye out for a date in mid-July. You will be welcome to join us in Auckland in person or attend via video conferencing. Your attendance is important as we need a quorum of members to be able to vote on our amended rules, so I will thank you in advance for joining us. A reminder that applications for the ASNZ Conference Fund also close on 15 May for conferences held between July and December of this year. The application form can be found on our website www.acoustics.org.nz where up to $500 can be awarded for conference attendance in NZ, and $1,500 for conferences held overseas.

The submission period has now closed for The Resource Management (Consenting and Other System Changes) Amendment Bill. The Bill will amend existing provisions in the Resource Management Act (RMA) relating to infrastructure and energy, housing growth, farming and the primary sector, natural hazards and emergencies, and system improvements. This will fundamentally change how resources are managed in NZ, which will impact planning and the way we interact with District and City Councils. Hopefully we see a holistic approach such that we don't prioritise short-term growth at the expense of long-term sustainable development. As they say, the devil will be in the detail, and I look forward to seeing how this is rolled out this year, and understanding what impact it will have on our environmental acoustic sector.

I confess that I am a rugby fan, and with the start of Super Rugby Pacific season there has been some awesome games to watch. Recently, we saw the Highlanders play the Blues, with the large Dunedin crowd paying an emotional tribute to the late Connor Garden-Bachop before kick-off. Instead of the customary moment's silence, there was a more unique moment of celebration. The family had asked for a minute of noise, resulting in fans signing John Denver's "Take Me Home, Country Road" at the top of their lungs to be as loud as they could be. Many of us work in a daily realm where we are dealing with the negative connotation of noise, chiefly that unwanted sound. However, I thought it was wonderful to see so many people embrace noise for a change, where it was intentional, loud, and wanted – even if only for a short time. What song, or even sound, would you want to be remembered by?

As we stare into the face of Autumn, I am sure the routine of work, school, sports trainings and other hobbies are back to normal rosters. The current economic recession can weigh heavily on us, so please make sure and take time to care for your own wellbeing first. As the saying goes, "you can't pour from an empty cup". This year, I have resolved to take more time for myself, commit to better health, and surround myself with comfort. I challenge you all to do the same.

Ngā manaaakitanga,

Tracy Hilliker

President of the Acoustical Society of New Zealand Inc.


Lindsay Hannah and Wyatt Page

Principal Editors

Greetings, talofa and nau mai haere mai

Welcome to the first issue of New Zealand Acoustics for 2025 (Volume 38, Issue #1). As we finalise this issue, the cooler weather has started to settle in across the country. Autumn is showing off its colours, and winter is slowly but surely on its way. This is our usual edition with news, updates, and a great selection of papers. In this issue, you'll find a hands-on look at simulating acoustic barriers with air transit louvers, an insightful piece on cost-effective acoustic design for classrooms, and a technical deep dive into calibrating anechoic chambers using sweep signals. We hope you'll take the time to check them all out—each paper brings something unique to the table.

Alofaaga and Ngā mihi.

Lindsay Hannah & Wyatt Page
Principal Editors

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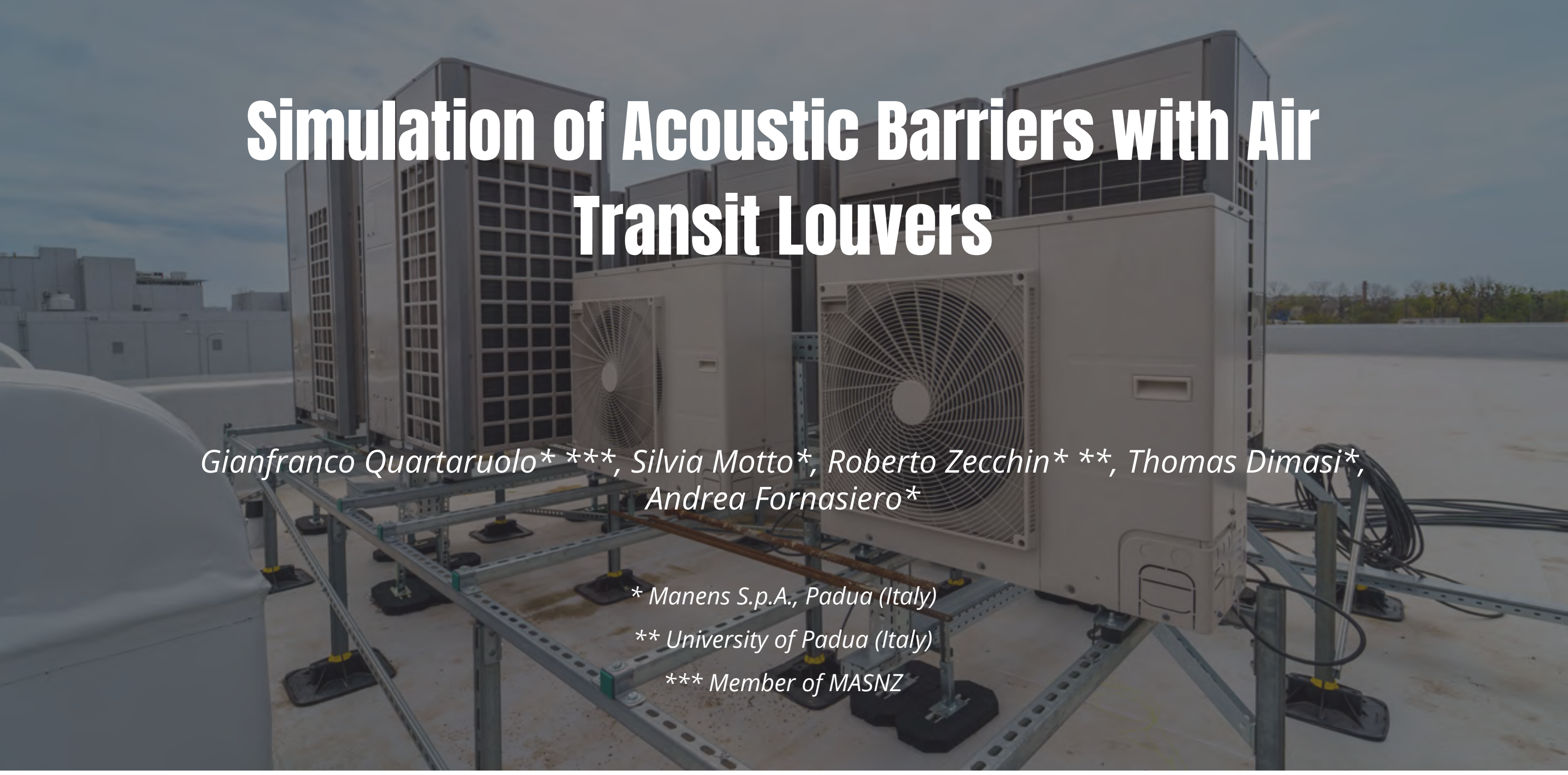

Simulation of Acoustic Barriers with Air Transit Louvers

Gianfranco Quartaruolo ***, Silvia Motto*, Roberto Zecchin* **, Thomas Dimasi*, Andrea Fornasiero**

** Manens S.p.A., Padua (Italy)*

*** University of Padua (Italy)*

**** Member of MASNZ*

Summary

There is an increasing need to install outdoor acoustic barriers to attenuate the noise generated by air conditioning machines, such as chillers, heat pumps, and cooling towers, etc. This type of equipment generally requires high airflow rates for heat exchange with the external environment. The proximity of the barriers necessary to optimize their acoustic performance can penalize air circulation and therefore the thermal efficiency of the system. The insertion of soundproofed air transit louvres can be a good solution to ensure the necessary airflow, but it can generate a significant loss of acoustic attenuation, which must be appropriately considered in the noise calculation.

The purpose of this study is to define a methodology that can correctly simulate the real-world case when ventilation is required, and an acoustic louver or a mixed louver/solid barrier is installed, in cases where the simulation software adopted does not allow associating these elements with their corresponding transmission loss.

State of the art

Today, mechanical engineering practice is increasingly oriented towards the use of systems that require installation in an outdoor environment, such as air conditioning and refrigeration.

From an acoustic point of view, these machineries are intrinsically noisy and, in the case of installation in densely populated sites, can cause a disturbance to the nearest buildings (noise-sensitive receptors). The need to attenuate the generated noise therefore arises and the most frequently adopted solution is the installation of extensive acoustic barriers. Often, these barriers can surround the machineries, forming a real enclosure. In these cases, impervious acoustic barriers to the passage of air can be problematic, as the lateral flow of air is obstructed, resulting in a loss of efficiency and functionality.

A technique that achieves an adequate compromise between acoustic insulation and ventilation, is the use of acoustic louvres.

Acoustic louvers are elements consisting of fins mounted on a suitable support frame, where the upper part of the fin is made of solid sheet metal, and the lower part is made of perforated sheet metal with a sound-absorbing material placed inside. These louvers can be made of one or two rows of fins (see Figure 1), with the second type providing better acoustic performance but generating greater pressure drops, which significantly reduce the airflow passage.

The design of acoustic barriers is mainly carried out by software that implements mathematical models based on UNI ISO 9613-2[1] standard "Attenuation of sound during propagation outdoors" and since the results of these models are usually used to show compliance with laws and regulations, the use of these software is largely used.

Figure 1: Examples of acoustic louvres (source www.duco.eu)

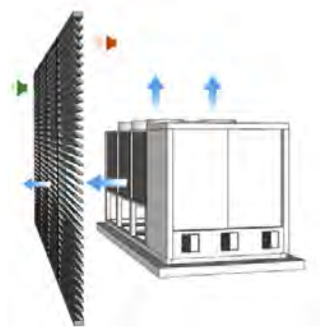

Figure 2: Example of installation of an acoustic louvre as an acoustic barrier

[1] *The new 2024 version technically revised the original 1996 version, with no impacts to the outcome of this study.*

The reference legislation

The purpose of the UNI ISO 9613-2 is to provide an engineering method for calculating sound attenuation in the outdoor environment. The basic equation, reported by UNI ISO 9613-2 and implemented in the acoustic software is as follows:

$$L_{fT}(D_W) = L_W + D_c - A \quad [1]$$

where:

- *L_{fT} (D_W): is the equivalent continuous sound pressure level, by octave band, in decibels,) at a noise sensitive receptor in the wind direction D_W (D_W is calculated for the eight octave bands with centre frequencies between 63 Hz and 8 kHz)*
- *Lw*: is the sound power level by octave bands, in decibels, generated by the single sound source and calculated to a reference sound power of 1pW;
- *DC*: is the directivity correction, in decibels
- *A*: is the attenuation by octave bands, in decibels, that occurs during propagation from the point sound source to the receptor

The attenuation term A is expressed by the following equation:

$$A = A_{div} + A_{atm} + A_{Gr} + A_{bar} + A_{Misc} \quad [2]$$

where:

- A_{div}: attenuation due to geometric distance;
- A_{atm}: attenuation due to atmospheric absorption;
- A_{gr}: attenuation due to the effect of the terrain;
- A_{bar}: attenuation due to barriers;
- A_{misc}: attenuation due to other effects.

The conditions for considering an object as a shield are the following:

- the surface density of the object is at least equal to 10 kg/m^2;
- the object must have a uniform and compact surface;
- the horizontal size of the object normal to the acoustic propagation is greater than the wavelength of the nominal band under consideration.

A_{bar} attenuation due to an obstacle is designated by insertion loss. Diffraction along the top edge and around a lateral vertical edge can be calculated (in decibels) with:

$$A_{bar} = D_z - A_{gr} > 0 \quad [3]$$

and that of diffraction around a vertical edge with:

$$A_{bar} = D_z > 0 \quad [4]$$

where:

- D_z: is the attenuation due to the obstacle for each octave band;
- A_{gr}: it is the attenuation of the ground in the absence of the barrier.

The equation that describes the effect of the screen is as follows:

$$D_z = 10\log[1 + (2 + (C_2/\lambda) \cdot C3 \cdot z)\, K_{Met}] \quad \text{for } z > z_{Min} \quad [5]$$

Where

- *zmin = -2λ / (C_2 C3)*
- *C2*: is equal to 20 and includes the effect of reflections on the ground; if, in special cases, the reflections on the ground are calculated separately from image sources, *C2* = 40;
- *C3* = 1 for single diffraction;
- *C3 = [1 + (5λ/e)^2] / [(1/3) +(5λ/e)^2]* for double diffraction; where *e* is the distance between the two edges of diffraction, in the case of double diffraction
- *λ* is the wavelength of sound, in meters, at the central frequency of the band of the octave considered;
- *z* is the difference between the travel length, in meters, of the diffracted sound and the direct sound;
- *Kmet* is the correction factor from weather effects:

$$K_{met} = exp\left\{-(1/2000)\sqrt{[max(d_{ss}, d_{sr}) + e] \cdot min(d_{ss}, d_{sr}) \cdot d / [2(z - z_{min})]}\right\} \quad [6]$$

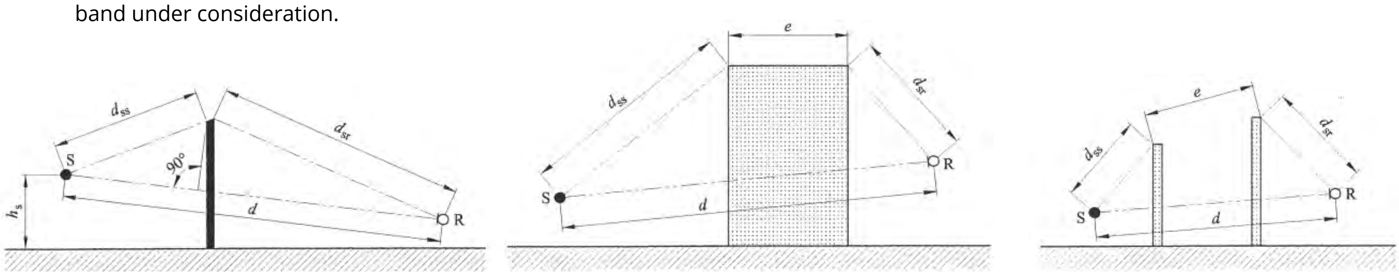

Figure 3: Geometric quantities for the determination of the difference in the length of the path, for single diffraction and double according to UNI ISO 9613-2

It should be noted that the attenuation of the parameter Dz in any octave band, according to the standard, should not be considered greater than 20 dB, in the case of single diffraction (i.e., on thin obstacles), and greater than 25 dB, in the case of multiple diffraction (with the parameter e > 0 in Fig. 3).

The standard does not consider the component of noise passing through the barrier, as it refers to a minimum value of the surface mass equal to 10 kg/m². For this surface mass (kg/m2), the amount of acoustic energy through the barrier compared to the diffracted component is negligible.

The simulation of acoustic barriers containing openings

Concerning the acoustic modelling of shielding elements, the most common software does not allow any deviation from the UNI ISO 9613-2 standard, and do not allow addition of customized values of transmission loss for the considered barrier. This can create difficulties in the correct representation of the phenomenon, as the design practice often requires mitigation systems which need proper ventilation (e.g. acoustic louvres). In such cases it is essential to be able to consider the actual transmission loss of the shielding elements, since the acoustic louvres ensure the necessary passage of air (unlike the barriers considered by UNI ISO 9613-2), they attenuate noise differently in the different frequency bands.

To overcome the limitations of the software, a method has been developed that allows the actual soundproofing properties of the shielding elements to be considered. This method consists of placing a virtual vertical area source on the outer side of the barrier with a sound power level equal to that actual transmitted by the barrier itself; in this way both the diffracted and transmitted noise path are evaluated.

This sound power level is determined by reducing the sound level incident the barrier by the transmission loss of the elements composing it according to the following equation, rather than to an undefined transmission loss, as most commercial software generally does.

$$L_{W,out} = L_i - R_w + 10log\ (S/S_0) \qquad [7]$$

where:

- $L_{w,out}$ is the sound power level coming out of the element under consideration, in decibels;
- L_i is the sound intensity level incident to the element, in decibels;
- R_w is the soundproofing power of the element, in decibels
- S is the area of the element, in square meters;
- S_0 is the reference area, in m^2; S_0 = 1 m^2.

In accordance with UNI ISO 9613-2, the equations to be used for the calculation of the outdoor noise propagation are those to the distance attenuation of a point source. As a starting point for the calculation of sound propagation, the extended area sources on the outer side of the barrier must therefore be divided into elementary areas that can be represented by a virtual point source in the centre. (see Fig. 4).

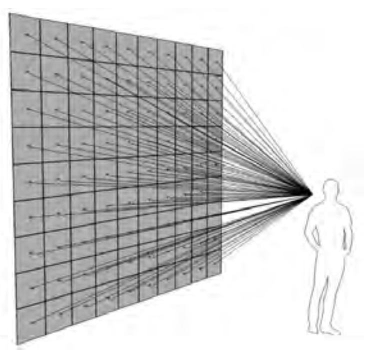

Figure 4: Principle of subdivision of an area source

Application mode

Implementing the procedure presented in this study the goal is to calculate the sound pressure level generated by a machinery, protected by an acoustic louvre, 12 meters long and 5 meters high, in correspondence with a receptor placed 2 meters away from the centre.

The following sound power level of the source, Tab. 1, has been assumed in this simulation to show the methodology.

Frequencies [Hz]	63	125	250	500	1000	2000	4000	8000	LwA [dB(A)]
Lw [dB]	100	100	100	100	100	100	100	100	107

Table 1: Sound power level of the sound source

The first step is to create the model of the barrier with the desired geometric characteristics.

The amount of the sound level incident on the barrier is carried out by dividing the entire surface into elementary areas, assuming the uniform sound field over the entire area of the single element.

On each centre of the virtual area, a receptor is placed to allow the calculation of the sound intensity level (in outdoor calculations the sound pressure level incident a surface can be assumed equal to the sound intensity level), assuming a high fictitious sound absorption such as to make negligible the component reflected by the object under consideration.

It should be noted that the acoustic field inside an open technical plantroom is not always completely free of reverberance and therefore this acoustic field, if present, must be calculated separately to characterise the reverberant component of the intensity level incident on the shielding element.

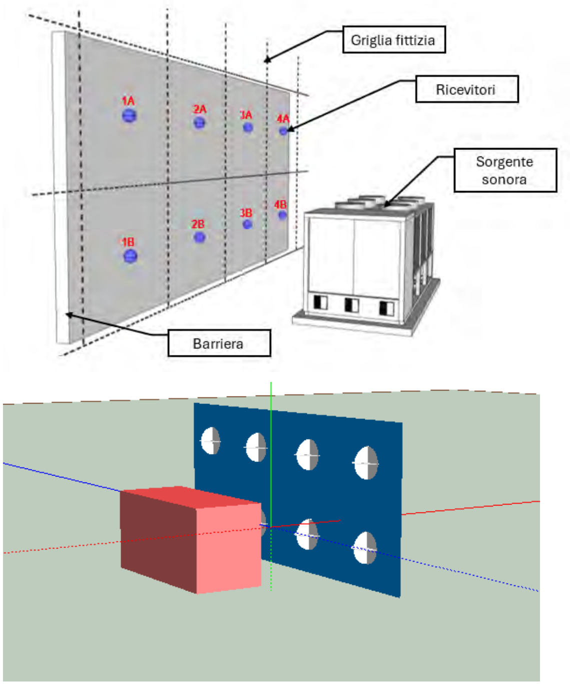

Figure 5: Division of the shielding into elementary areas and association of receptors – Extract of the calculation model

The sound intensity levels on the inner side of the shielding element, calculated as a result of the procedure described above, are shown in Table 2.

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Frequencies [Hz]	63	125	250	500	1000	2000	4000	8000	L_i [dB(A)]
Step 1A	78	75	75	76	76	76	76	76	83
Point 1B	80	77	76	75	76	76	75	75	82
Step 2A	80	78	78	78	79	79	79	78	86
Point 2B	82	79	78	78	78	78	78	78	85
Step 3A	80	78	78	78	79	79	79	78	86
Point 3B	82	79	78	78	78	78	78	78	85
Step 4A	78	75	75	76	76	76	76	76	83
Point 4B	79	76	75	75	75	75	75	74	82

Table 2: Sound intensity levels calculated at individual checkpoints

The noise emitted from the outer surface of the shield is simulated with the use of area sources, equal to the dimensions of the already defined elementary areas. The specific sound power [dB/m2] of each areal source is calculated using the formula [7]. The transmission loss of a 100 mm thick acoustic louvre is shown below.

Frequencies [Hz]	63	125	250	500	1000	2000	4000	8000	Rw [dB]
R [dB]	5	4	5	6	9	13	14	13	10

Table 3: Transmission loss of the acoustic louvre

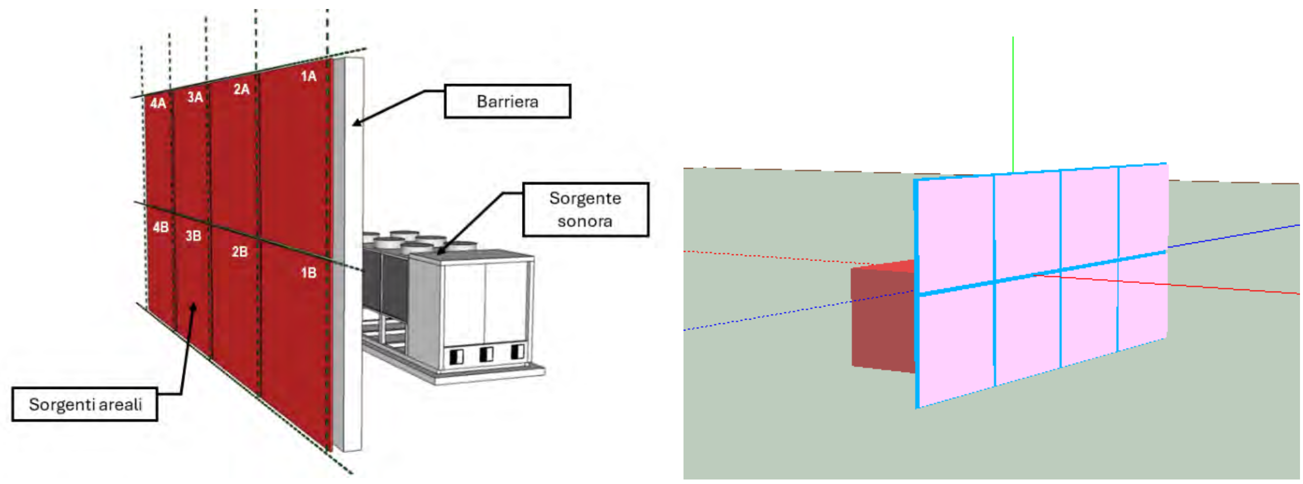


Figure 6: Division of the shielding into elementary areas and association of areal sources – Diagram and extract of the calculation model

The sound power applied to the individual area sources [dB/m2] reduced by the transmission loss is shown in Table 4.

Frequencies [Hz]	63	125	250	500	1000	2000	4000	8000	LwA [dB(A)/m2]
Lw area 1A [dB/m2]	73	71	70	70	67	63	62	63	73
Lw area 1B [dB/m2]	75	73	71	69	67	63	61	62	72
Lw area 2A [dB/m2]	75	74	73	72	70	66	65	65	75
Lw area 2B [dB/m2]	77	75	73	72	69	65	64	65	75
Lw area 3A [dB/m2]	75	74	73	72	70	66	65	65	75
Lw area 3B [dB/m2]	77	75	73	72	69	65	64	65	75
Lw area 4A [dB/m2]	73	71	70	70	67	63	62	63	72
Lw area 4B [dB/m2]	74	72	70	69	66	62	61	61	72

Table 4: Calculated sound power level of individual area sources

The values calculated at the receptor located at 2 meters from the acoustic louvre and at 1.5 m from the ground calculated using the UNI ISO 9613-2 algorithms, are shown in Table 5:

Frequencies [Hz]	63	125	250	500	1000	2000	4000	8000	Lp [dB(A)]
Lp [dB]	77	73	70	69	67	64	63	63	73

Table 5: Sound pressure level at the receptor – Situation with aphonic grilles

For comparison the same simulation has been carried out using the standard barrier model included in the UNI ISO 9613-2 algorithm. The sound pressure level at the receptor results is shown in Table 6.

Frequencies [Hz]	63	125	250	500	1000	2000	4000	8000	Lp [dB(A)]
Lp [dB]	70	65	61	58	57	57	56	56	64

Table 6: Sound pressure level at the receptor – Standard barrier situation

A comparison of the results in tables 5 and 6 above are illustrated in the following figure 7 using the contour map provided by the used software. The sound pressure level in the case of the developed procedure is significantly higher than the one evaluated by the standard UNI ISO 9613-2.

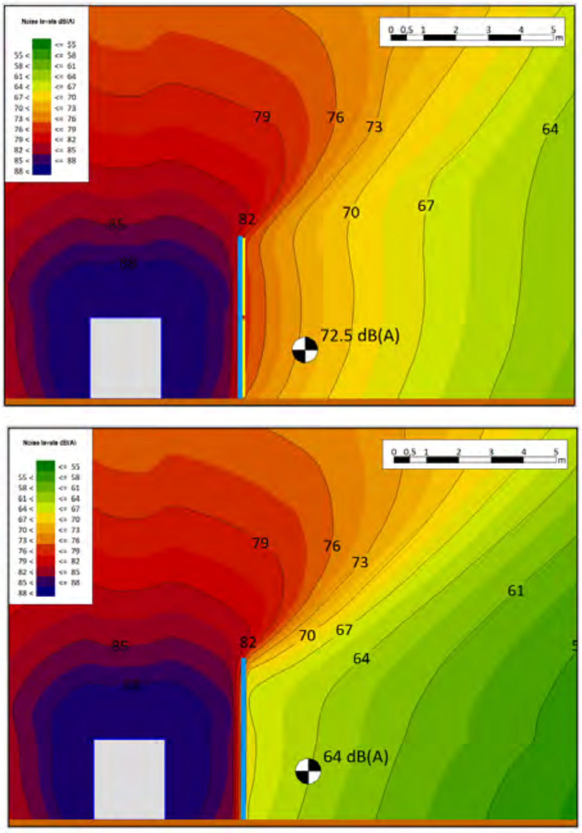


Figure 7 – Cross-sections of the distribution of the sound pressure level considering the effect of the acoustic louvre according to the proposed implementation (top) and calculating the effect of the solid barrier according to UNI ISO 9613-2 (below).

A real case study

The method presented in this work has been applied to evaluate the shielding effect of a heat pump to be installed on the roof of a new building trough an acoustic louvre, a solid barrier, and a mixed (50% acoustic louvre – 50% solid barrier). The urban context in which the building under study is located is densely built; in fact, 15 meters away is a four-storey residential receptor is located, directly exposed to the noise emissions of the heat pump. According to the Council Noise Regulation of the territory, the receptor is located within class IV "Areas of intense human activity" with a noise limit of 60 dBA for the daytime period and 50 dBA for the nighttime period. It is assumed that the heat pump can also operate during the nighttime at 100% of the load for practicality.

The spectrum of the sound power generated by the machine is shown in Table 7.

Frequencies [Hz]	63	125	250	500	1000	2000	4000	8000	Global [dB(A)]
Lw [dB]	86	85	89	91	92	80	69	61	94

Table 7 – Sound power level of the sound source

The first step is the evaluation of emissions by simulating direct propagation, without any type of shielding. In this case, the level calculated at 15 m (LAeq at receptor P3: 60 dB) exceeds the Council oise Regulation and it is therefore necessary to provide a shielding system.

Three potential types of mitigation have therefore been hypothesized:

1. 4 meter height full solid barrier;
2. 4 meter height full acoustic louvre;
3. Mixed system (2 meter solid barrier and 2 meter acoustic louvre).

The simulation of the case 1 with a full solid barrier, has been carried out using the specific module "barrier" of the used software, which considers an attenuation in accordance with the provisions of the UNI ISO 9613-2 standard, without considering the real transmission loss of the barrier. This is not an actual problem given the totality of noise is bypass the barrier from the top side.

The noise generated by the heat pump is completely shielded from the receptor (LAeq at receptor P3: 48 dB) providing full compliance with the Council Noise Regulation both during the day and during the night. However, this solution is not adequate from an engineering point of view, since the machine, positioned at a close distance from the barrier, can experience operating problems due to insufficient ventilation.

Case 2 considers a full height acoustic louvre, 300 mm thick and with a specific transmission loss, as shown in Table 8:

Frequencies [Hz]	63	125	250	500	1000	2000	4000	8000	Rw [dB]
R [dB]	5	5	7	12	18	21	16	16	17

Table 8 – Transmission Loss of the acoustic louvre

The acoustic louvre modelling process was carried out following the method described above, i.e. dividing the barrier into elementary areas and associating each of them with a sound power [dB/m²]. In this configuration, the heat pump benefits from adequate ventilation thanks to the openings however from an acoustic point of view, this solution is not providing sufficient sound reduction at the receptor (LAeq at receptor P3: 55 dB). The grille, allowing excessive sound transmission, does not guarantee compliance at the receptor with the Council Noise Regulation during the night-time (LAeq 55 dB > LAeq 50 dB).

Case 3 shows a hybrid situation which typically is less expensive compared to the case 2 and more often used. The shielding element is made by a lower part made with acoustic louvres, which allows adequate ventilation to the heat pump, and an upper part made by a solid barrier. The transmission through the louvre has been simulated using the calculation method described above.

Compared to case 1, the noise transmitted by this hybrid solution is higher, now complying with the Council Noise Regulation (P3: LAeq 49 dB < LAeq 50 dB).

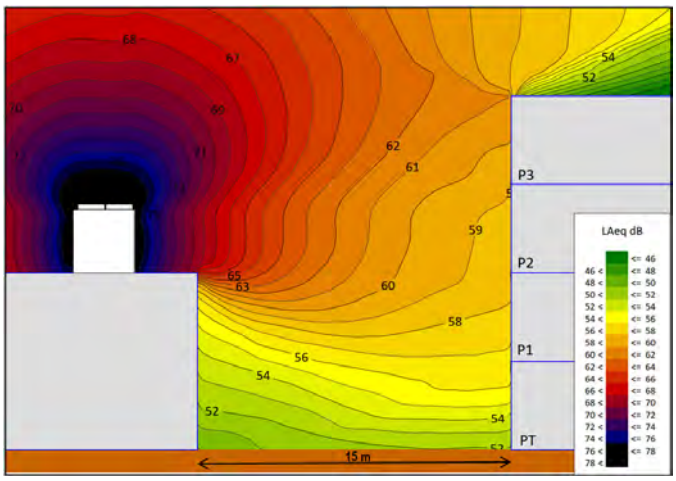


Figure 8 – Cross-section of sound level distribution, without mitigation

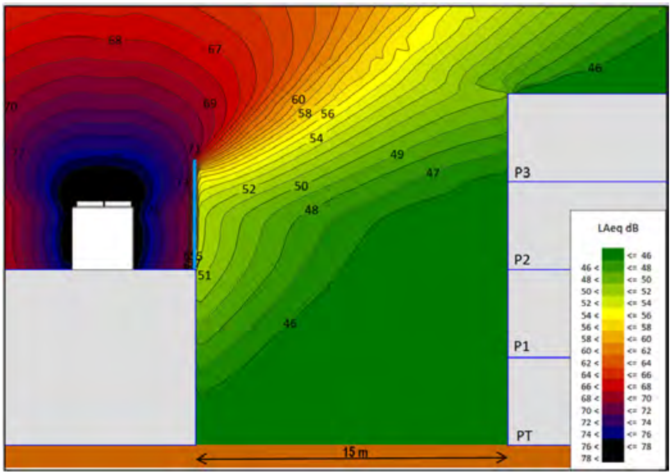


Figure 9 – Cross-section of the sound level distribution, with full high solid barrier

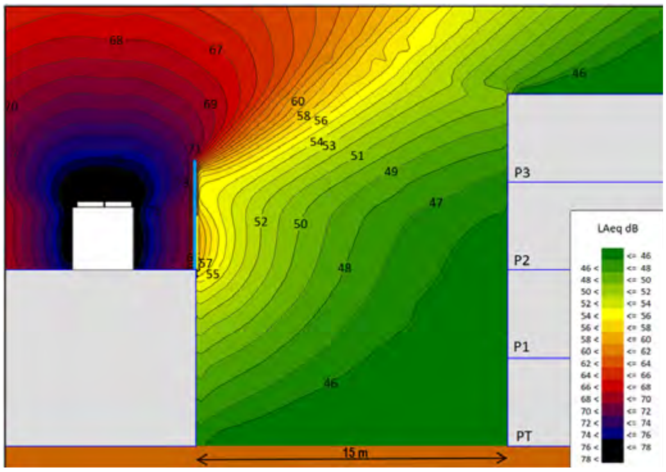


Figure 11 – Cross-section of sound level distribution, with a mixed solution (50% grilles + 50% solid barrier)

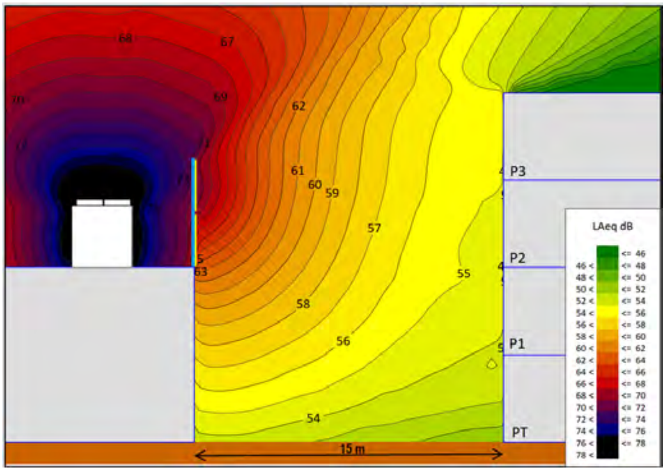


Figure 10 – Cross-section of the sound level distribution, with a full height acoustic louvre

Conclusions

This study highlights the importance of an accurate design of noise mitigation systems by using barriers made of partial or full acoustic louvres, often essential for the correct functioning of the equipment requiring high air flow rates for heat exchange with the external environment.

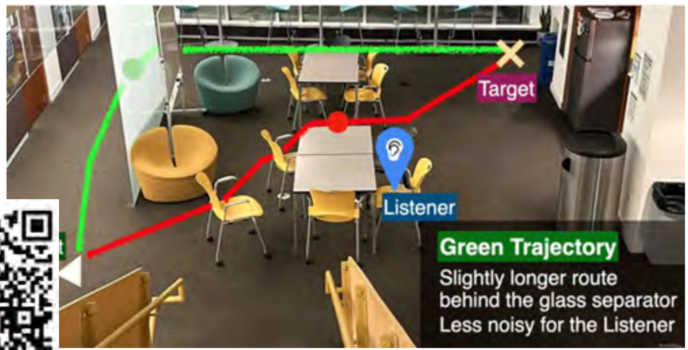
Their configuration requires a specific modelling methodology that goes beyond the procedure set out in the UNI ISO 9613-2 standard, relating to solid barriers and used by most acoustic calculation software.

An empirical model has therefore been developed for the analysis of this type of acoustic mitigation, which evaluates the contribution of noise transmission through a shield in relation to the specific transmission loss of the element. The proposed method has been presented to provide accurate estimates of the sound pressure level reaching the receiver where the typical procedure based on the ISO 9613 would not give correct results.

The results obtained in the design case, given as an example, show that this calculation methodology can also be extremely useful to more precisely define mixed systems, in which louvred elements are combined with solid barriers, achieving within acoustically restrictive contexts, a cost-effective noise control solution associated with adequate ventilation of the equipment.

ACOUSTICS IN THE NEWS AND MEDIA

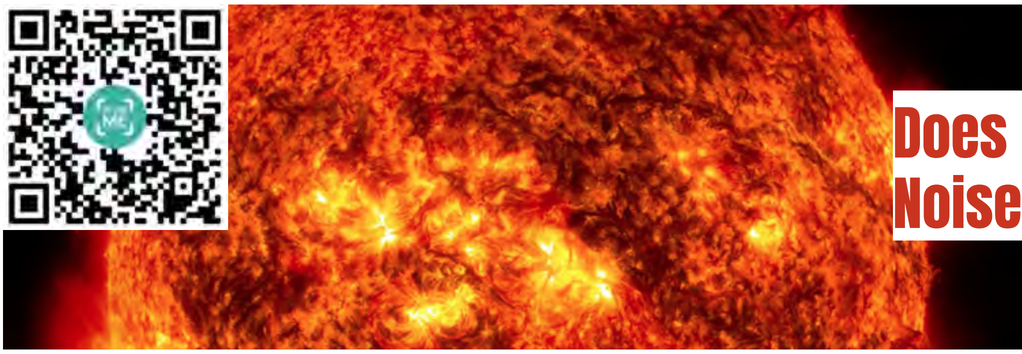
Acoustic Awareness ANAVI Framework Addresses Robot Noise Levels [1]



Acoustic cognitive map-based navigation in echolocating bats [2]

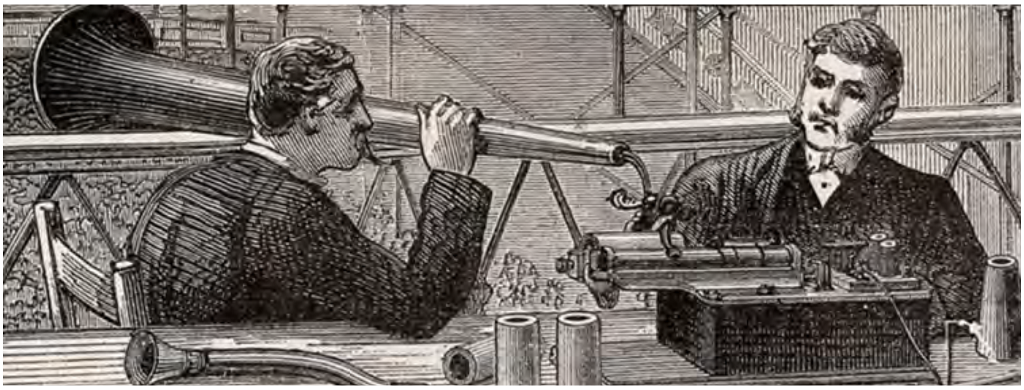
Acoustic Monitoring of Whales and Dolphins in the Cook Straight Region [3]

Daily harmful noise exposure affecting thousands [4]



Does the Sun Make Noise? [5]

Task Force Noise [6]



Infertility risk linked to traffic noise and air pollution [7]

Male bowerbirds build acoustics into their love shrines [8]

1. https://www.ri.cmu.edu/acoustic-awareness-anavi-framework-addresses-robot-noise-levels-in-the-home/
2. https://www.science.org/doi/10.1126/science.adn-6269https://www.youtube.com/watch?v=CXr9AQiJB-9g&list=WL&index=2&t=13s
3. https://niwa.co.nz/oceans/acoustic-monitoring-whales-and-dolphins-new-zealands-cook-strait-region
4. https://www.rnz.co.nz/news/national/522737/daily-harmful-noise-exposure-affecting-thousands-study-shows
5. https://www.popsci.com/science/does-the-sun-make-noise/
6. https://pro.europeana.eu/project/heritage-acoustics-task-force
7. https://www.news-medical.net/news/20240909/Long-term-exposure-to-traffic-noise-and-air-pollution-linked-to-increased-infertility-risk.aspx
8. https://www.science.org/content/article/male-bowerbirds-build-acoustics-their-love-shrines

Invisible Sound

Sound whispers softly through the air,
Vibrations dance, but we’re unaware.
It travels far, a hidden song,
But never where our eyes belong.

It hums in air, it shakes the ground,
A rhythm felt, but not unbound.
With waves that move both fast and slow,
Invisible, they come and go.

The light we see is not the same,
Its colors bright, they know no shame.
But sound, it speaks in secret tones,
In waves too long for eyes to own.

We cannot catch its fleeting grace,
Its voice exists in silent space.
Yet still we hear its quiet call,
A song that vibrates through us all.

Shannon Lidyah 2025

Cost-efficient Classroom Acoustics Design in New Zealand

James Whitlock [(1)], Aniebietabasi Ackley [(2)], Renelle Gronert [(3)]

[(1)] Marshall Day Acoustics, Tauranga, New Zealand. james.whitlock@marshallday.co.nz

[(2)] Ministry of Education, Wellington, New Zealand. aniebietabasi.ackley@education.govt.nz

[(3)] Ministry of Education, Auckland, New Zealand. renelle.gronert@education.govt.nz

ABSTRACT

The Ministry of Education of New Zealand has a suite of design standards to ensure that educational, comfort, health and wellbeing outcomes can be achieved in classrooms. The Designing Quality Learning Spaces – Acoustics (DQLS) standard is part of the suite that has been in use since 2007 and was updated in 2016 and 2020. The DQLS sets out the mandatory requirements and design considerations for architects and acoustic engineers to use in achieving quality learning environments. Following feedback received from the Ministry's design reviews, finding the right balance between good acoustic performance and cost efficiency has proved challenging – notably the Sound Transmission Class (STC) ratings of walls has tended towards over-design. This informed the need for a pragmatic construction approach and practical applications that support affordable outcomes while still ensuring classroom acoustics are fit-for-purpose. This paper provides a coherent summary of current classroom acoustic standards and recommendations from various countries around the globe, detailing how these standards were adapted to the New Zealand context. It also includes cost review exercises that have led to more economical and pragmatic design solutions, and the resulting changes to New Zealand school building acoustic standards. This paper provides valuable insights for acoustic engineers, architects, designers, property managers, and facility planners involved in the design of New Zealand school buildings, as well as policymakers, educators, and researchers.

1. INTRODUCTION

Every building has a function, and some functions (more than others) require good acoustic control. Learning is a function that requires good acoustic control – particularly reverberation time (RT) and background noise level i.e., controlling intrusive noise from adjacent spaces with Sound Transmission Class (STC)-rated walls.

In learning environments, it is crucial for students to clearly hear and understand a teacher's verbal communication to process the information presented. According to Mikulski & Radosz [1], speech clarity in these spaces is influenced by various factors, including acoustic properties. These properties depend on the room's volume, shape, the materials used for its surfaces, and the equipment within the room.

Many studies [2], [3], [4], [5], [6], [7], [8], [9], [10] have emphasized that poor classroom acoustics can affect students' speech understanding, attention, concentration, reading and spelling ability, behaviour in the classroom and learning outcomes. Poor acoustics are also of great concern to teachers. In New Zealand, A survey by Valentine et al. [8] found that 71% of teachers considered noise within the classroom to be a problem, and over a third reported needing to speak at a volume that strains their voices.

Until 2016, acoustic design in New Zealand schools was not mandatory – it was a 'nice to have' and was often cut during value engineering. In 2016, the Ministry of Education of New Zealand ('the Ministry') released Designing Quality Learning Spaces [11] v2.0. This second-generation document contained mandatory requirements that meant acoustic design could no longer be ignored. New Zealand schools' acoustic standards evolved in 2020 with the release of DQLS [12] v3.0, and now acoustics is recognised by designers and schools as one of the four key Internal Environmental Quality (IEQ) elements to ensure that learning spaces are fit for purpose – the other three being lighting [13], indoor air quality and thermal comfort [14].

Achieving good IEQ comes at a price. The cost of New Zealand buildings has been increasing year on year, particularly given the supply chain demand issues encountered as a result of COVID-19 [15]. Statistics New Zealand indicates that the cost of constructing a building has surged by 41 percent since 2019, further exacerbating the issue of building affordability in New Zealand [16].

Following feedback received from the Ministry's design reviews of numerous projects, finding the right balance between good acoustic performance and cost efficiency has proved challenging – notably the Sound Transmission Class (STC) ratings of walls has tended towards over-design. This informed the need for a pragmatic construction approach and practical applications that support affordable outcomes while still ensuring learning spaces are fit-for-purpose.

This paper provides a review of national and international classroom acoustic standards and research literature, a summary of the cost review exercise that the Ministry has undertaken to inform more economical and pragmatic design solutions, and the resulting changes to the DQLS [17] to ensure cost-efficient and fit-for-purpose acoustic requirements.

2. REVIEW OF STANDARDS IN DIFFERENT COUNTRIES

Internal noise level and reverberation time (RT) are traditionally the key acoustic considerations when designing learning spaces. For example, noise from external noise sources such as traffic, nearby flight paths or indoor noise transferring from adjacent spaces, and from Heating, Ventilation and Air-Conditioning (HVAC) systems can pose acoustic issues for schools [1]. Room properties like RT can exacerbate the impact of activity noise. Reviews by Mealings [9, 18] reported that many learning spaces have long RTs due to the building materials and overall design used.

This section examines national and international standards on RT, sound transmission between rooms, and noise level recommendations, as well as live classroom measurements, to determine what is appropriate for learning spaces.

2.1 Recommended Reverberation Time (RT) Standards in Different Countries

A significant acoustic barrier that affects speech perception in a classroom is reverberation. The reflection of sound from the floors, walls, and ceiling in learning spaces, causes the prolongation of sound and occurrence of The Café Effect [19].

Table 1 presents the acceptable RT values in learning spaces according to the standards of various countries, including Australia, New Zealand, UK, USA, Finland, Spain, Sweden, Denmark, and Canada respectively.

These references indicate that recommended maximum RTs in schools vary by country, ranging from less than 0.4 to 0.8 seconds, with the majority of standards falling between 0.4 and 0.6 seconds.

2.2 Recommended Internal Ambient Noise Level Standards in Different Countries

In learning spaces, high levels of ambient noise and/or reverberation create auditory disturbances, impairing speech clarity and detracting from learning. Ambient noise, also referred to as background noise, is the average sound level produced by any combination of nearby noise sources as measured within the learning space of interest. It comes from a range of internal and external sources such as traffic, aircraft, industrial, chatter, noise in adjacent rooms, mechanical noise, etc. While low levels of ambient noise are tolerable, high levels can be significantly disruptive to student concentration.

Table 1 also summarises the recommended internal ambient noise levels published by the WHO, the Ministry, and the national standards of 17 other countries. These standards largely suggest that internal ambient noise level should not exceed 45 dB LAeq within learning spaces, during class to avoid effects on speech intelligibility, disturbance of information extraction, and message communication. However, most of these standards are specifically not intended to assess or prescribe acceptable recommended noise levels for transient or variable noises originating outside the building, such as aircraft noise.

The WHO ambient noise guideline of 35 dB LAeq serve as targets for reducing noise in areas already affected. They aim to maintain speech intelligibility when listening to complex messages by ensuring that normal vocal efforts (at 50 dB LAeq) are at least 15 dB louder than the ambient internal noise level. This guideline is broadly applied to all spaces in schools and does not account for the differing requirements of various learning spaces.

The American National Standards Institute (ANSI) Standard recommends maximum noise levels for learning spaces is dominated by unsteady background noise from sources such as aircraft. The recommendations specify maximum levels of 35 dB LAeq (1 hour) for core learning spaces smaller than 566 m³ and 40 dB LAeq (1 hour) for larger core learning spaces.

The Ministry's DQLS was developed by a panel of acoustic experts and, similar to the UK Building Bulletin 93, outline mandatory internal ambient noise and reverberation requirements for various learning spaces in new and refurbished school buildings. It includes a comprehensive set of metrics, accommodations for learners with special needs, different space typologies, requirements for demonstrating compliance, and design guidelines. The primary goal is to create high-quality learning environments that support teaching, learning, and the well-being of the occupants. The DQLS internal ambient noise level requirement is similar to that of AS/NZS 2107:2016, ANSI S.12.60-2010, AAAC and the UK Building Bulletin 93.

Country	Standards / Guideline document	RT (s)[1]	Internal Ambient Noise L_{Aeq} (dB)
World Health Organization	WHO guideline for community noise [21]	<0.6	<35
New Zealand	Designing Quality Learning Spaces v3.1 [17]	<0.4-0.6	<40
Australia/ New Zealand	Standard AS/NZS 2107:2016 [22]	<0.4–0.5	<35-45
South Australia	Education facilities design standards [23]	<0.4-0.6	<35-50
Australia	American Academy of Audiology [24]	<0.4-0.6	<35-40
United Kingdom	Building Bulletin 93 [25]	< 0.6-0.8	<35-40
USA	Standard ANSI/ASA S.12.60-2010 [26]	<0.6-0.7	<35-40
USA	American Speech-Language-Hearing Association [37]	< 0.4	
USA	American Academy of Audiology [38]	0.6	<35
Japan	Architectural Institute of Japan [27]	< 0.6	<40
Denmark	Danish Building Regulations (2015) compiled from [28], [29], [30]	<0.6	<35
Canada	Standards and guidelines for school facilities [31]	<0.6	<35
Italy	UNI 11532 (2017) compiled from [32], [33]	<0.7	<34
Czech Republic	ČSN 73 0527 (2005) compiled from [28], [30]	<0.7	<45
Finland	Standard SFS 5907 (2022) compiled from [34]	<0.6–0.8	<35
Poland	Polish acoustic standard PN-B-02151-4:2015-06 compiled from [35], [36]	<0.5-0.8	
Spain	Compiled from [30]	<0.7	<35
South Africa	South African National Standard [39]	-	<35
Columbia	Resolucion 8321 (1983) compiled from [28]	-	<55
Sweden	Standard SS 25268: 2023 [40]	<0.5–0.6	-
France	Compiled from [30]	<0.4–0.8	<35
Belgium	Compiled from [30]	<0.8	<35

[1] Values are generally $T_{mf,}$ – mid-frequency reverberation time in s

Table 1: Recommended guidelines for RT and indoor ambient noise levels in core learning spaces

2.3 Pre- vs Post-treatment RTs in Learning Spaces

In learning spaces, acoustic improvements to RT and activity noise levels are typically accomplished by installing absorbers and/or diffusers on the ceiling and walls to improve students' listening, learning, and well-being.

Table 2 summarizes the acoustic treatment and corresponding RTs in empirical studies that evaluated speech intelligibility in learning spaces, including before and after acoustic treatment.

In summary, while Table 1 shows the established RT standards in 17 countries, Table 2 presents studies from various countries that have examined the acoustical environment in learning spaces through acoustic measurements and subjective speech intelligibility assessments.

It is not surprising that the measured RT values differ from one study to another, likely due to variations in the learning spaces involved, such as volume, surface finishes, furniture, and equipment in the rooms.

Overall, a general conclusion can be drawn that both the studies referenced in Table 2 and reference standards listed in Table 1 agree that an RT between 0.4 and 0.8 seconds is suitable for learning spaces.

This largely aligns with similar studies [1], [29], [42] which summarised acoustic standards for learning spaces in various countries. These RT values are based on typically developing children with normal hearing, but they also take into account the needs of children with hearing impairments or language delays who require more favourable listening conditions [29]. To achieve an RT of 0.4-0.8 seconds, Table 2 suggests that a Noise Reduction Coefficient (NRC) > 0.60 and a Ceiling Attenuation Class (CAC) of >20 is required. NRC and CAC are discussed further in Section 3 below. The comparison of pre-and post-acoustic treatment RT indicates that achieving an optimal RT is challenging without the use of sound-absorbing materials on ceilings and walls.

Country/ Authors	Acoustic Treatment	Reverberation time (s) Speech transmission index (STI) Background noise level (dBA)
Sweden [20]	**Configuration 1:** • Ceiling-only treatment (52 m^2) **Configuration 2:** • Ceiling-mounted porous 40 mm absorbers were installed on two perpendicular walls, covering an area of 9 m^2. **Configuration 3:** • Ceiling-mounted diffusers designed to diffuse high frequencies and absorb low frequencies were installed, covering an area of 9 m^2	Acoustic treatment in configurations 2 and 3 decreased RT: o **Configuration 1:** 0.8–0.95s o **Configuration 2:** 0.45–0.95s o **Configuration 3:** 0.5–0.75s Decrease in background noise level: o **Configuration 1:** 1–5 dBA o **Configuration 2:** 1–8 dBA o **Configuration 3:** 2–7 dBA
New Zealand [8]	**Option 1:** • Echophon Master F– beta finish (40mm thick) ceiling tiles were directly fixed to the central area of the ceiling, covering approximately 35 m^2 of treatment in total. **Option 2:** • Rockfon Arktic mineral fiber ceiling tiles were installed with a 200 mm air gap in the central area of the ceiling, covering approximately half of the total ceiling area treated (35 m^2) **Option 3:** • Softboard acoustic ceiling tiles were applied to the underside of the trusses, covering the entire ceiling area.	**RT:** o Pre (Poor Rooms): 0.69 o Post: 0.43 The solutions were directly derived from RT measurements of relocatable classrooms that had already been treated in this manner and were rated as satisfactory in the survey questionnaire.
China [43]	The ceiling was smooth and painted concrete before the sound absorption treatment. **Type:** • Mineral-fiber acoustic ceiling tiles with a thickness of 1.5 cm were utilized, featuring a Noise Reduction Coefficient (NRC) > 0.60 and a Ceiling Attenuation Class (CAC) of 33. **Positioning:** • Installed on the ceiling with a 53 cm high cavity above the ceiling tiles.	**RT:** o Pre: 1.1–1.7 o Post: 0.5–0.9 **STI:** o Pre: 0.55–0.58 o Post: 0.74–0.75 **Background noise level:** o Pre: 41–43 dBA o Post: 38–41 dBA
Poland [35]	**Type:** • Glasswool tiles with a thickness of 100 mm were used. **Positioning:** • Tiles covering approximately 43.4% to 50.6% of the ceiling area were installed around the perimeter of the rooms. • Tiles covering approximately 12.4% to 14.1% of the total wall area were mounted on two rear walls and one side wall, with panels covering the entire available surface of these walls higher than 2 meters.	**RT:** o Pre: 0.8–2.5 o Post: 0.5–0.8 **STI:** Pre: 0.47–0.52 Post 0.70–0.72
Italy [44]	**Type:** • Panels made of rock-wool and plaster board. **Positioning:** • Rock-wool panels were positioned on the ceiling and the upper sections of the rear and side walls. • Plaster board panels were installed on the lower sections of the walls. • A plaster board panel measuring 7m^2 was inserted into the flat absorbing ceiling above the teacher's desk to enhance early speech sound reflections.	**RT:** o Pre: 1.6 o Post: 0.4
China [41]	**Type:** • Mineral-fiber acoustic ceiling tiles with a thickness of 1.5 cm were utilized, featuring a Noise Reduction Coefficient (NRC) > 0.60 and a Ceiling Attenuation Class (CAC) of 33. **Positioning:** • Installed on the ceiling with a 53 cm high cavity above the ceiling tiles.	**RT:** o Pre: 0.8–1.4 o Post: 0.5–0.8 **STI:** o Pre: 0.55 o Post: 0.74

Table 2: Pre vs Post Acoustic Treatment and Corresponding Reverberation time (RT)

2.4 Sound Transmission Class (STC)-rated Walls

The STC ratings of various construction elements are of considerable interest to architects and acoustical engineers [45]. In New Zealand, the amount of sound isolation a wall assembly provides is measured by its STC rating. This rating system assesses the level of noise reduction offered by the assembly, weighted across a range of frequencies, resulting in a single numerical rating [46].

STC ratings assist in evaluating building materials and acoustical products for sound reduction. By understanding these ratings, designers can determine how effectively the materials will block sound from passing through. Generally, the higher the STC rating, the better the material's ability to block sound transmission.

In light-weight wall assemblies, "the STC rating is influenced by several factors: the type of studs used (wood or metal), the number of studs used (single or double stud walls), the number of layers of gypsum board in the wall assembly, the amount of insulation in the stud cavities, and the type of isolation elements used (such as resilient channels), if any" [47].

Table 3 provides a comparison between STC ratings and the perception of sound complied from multiple sources including Mehta's book on Architectural Acoustics: Principles and Design [48], and international organizations [26], [49], [50], [51].

Table 3 suggests that (with the recommended classroom background noise level of 35 dBA – refer Table 1) an STC rating of 45 is where privacy between spaces begins and this could be considered a baseline for preventing sound transmission as it is a level where conversations won't be understood through the walls. Someone in a quieter room on the other side may be able to hear that a conversation is happening, but they wouldn't be able to understand it without focussing on the voices, and it wouldn't be considered disruptive.

An STC rating of 50 is sufficient for people to feel adequately insulated from noise. Research in Canada demonstrated that an STC rating of 50 significantly reduces noise-related complaints, as speech cannot be heard through the walls and loud sounds are only faintly audible [52].

Sound Source	Wall STC	Receiver's Perception (Background Noise 35 dBA)
Conversational sound levels	25	Soft speech can be heard and understood
	30	Normal speech can be heard and understood
	35	Sentences can be understood
	40	Effort to understand words and phrases; sound perceived
Raised speech sound levels (classrooms)	45	Loud speech can be heard, but not understood (privacy begins)
	50	Effort to hear loud speech, but are very faint
	60+	Loud speech not heard (good soundproofing begins)

Table 3: Comparison between STC ratings and the perception of sound. Source: [26], [49], [50], [51]

Table 4 reviews the comparable American National Standards, Canadian standard, and New Zealand school acoustic standard regarding STC ratings between core learning spaces. In summary, the STC ratings from all four standards agree on the appropriate measures for preventing sound transmission between different learning spaces. However, the DQLS goes further by distinguishing between connected and non-connected spaces, recognizing that achieving a high level of sound privacy is not required between spaces where the learning activities are co-ordinated. Figure 1 below provides an illustrative example of the DQLS v3.1 [17] mandatory requirements, as applied in a typical learning hub.

STC rating is determined through laboratory testing by the ASTM E90 standard [57]. In practice, the STC rating of the laboratory sample represents the ideal condition and is seldom attained in real construction. The variation between the apparent STC, tested in the field, and the laboratory STC is typically due to leaks and flanking [50]. A -5dB allowance is made for this in the NZ Building Code, which is reflected in the Acoustic Verification section of DQLS [17].

Spaces	[1]American National Standard [26]	LEED for Schools (53)	[2]Alberta Guidelines [31]	[3]New Zealand DQLS [17]	
				Connected	Non-Connected
Classrooms	50	50	50	45	50
Music rooms	60	60	60/65	-	60
Offices	45	45	45	-	45
Corridors	45	45	-	40	50
Gymnasium	-	-	60	-	60
Libraries	-	-	50	45	45

[1]" Doors between music rooms must have an STC 40, exterior windows must have an STC 35, STC 30 for classroom doors, excepting doors to corridors, office spaces, and conference rooms and offices around spaces of critical privacy the minimum composite STC is 50."

[2]" Require full height construction for all walls with a rating of STC 50 or greater and a double plumbing wall between washrooms and learning spaces and ensure that piping is attached to studs on washroom wall only."

[3]" Acknowledges that sound travels more easily between connected spaces, and this is acceptable if the activities are acoustically compatible i.e., all quiet or all noisy at the same time, or there is an ability for coordination of activities between space users."

[3]" Walls between connected spaces are permitted to have lower STC ratings because learning activities occur in both spaces and are physically connected to each other by a door, corridor or opening (i.e., one can walk between them without going outside), and their use is under the control of the same teacher(s) so learning activities can be coordinated (e.g., open learning environments)."

Table 4: Summary of STC ratings in the comparable American National Standard, Canadian, and New Zealand school acoustic standards

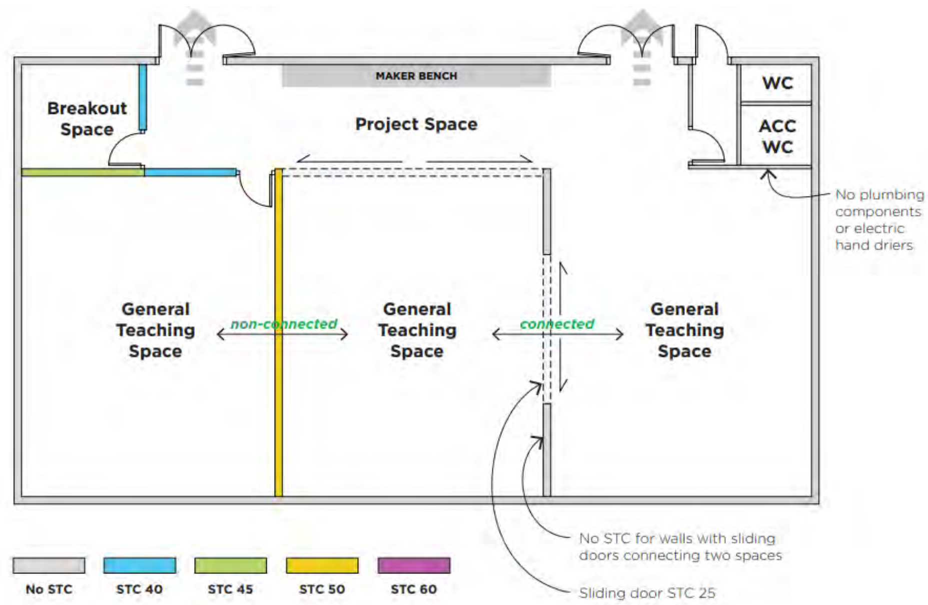


Figure 1: DQLS [17] STC plan wall mark-up of a typical learning hub

3. NEW ZEALAND CLASSROOM ACOUSTIC REQUIREMENTS

To improve classroom acoustics, it's essential to prioritise acoustic performance and requirements right from the beginning of the project. This is the focus of the DQLS v3.1 amendment [17] – to ensure cost effective and fit-for-purpose acoustic performance standards for New Zealand schools. This section summarises the cost analysis and salient areas that have been improved in the DQLS.

3.1 School Buildings must be Cost-Efficient

As a government agency, the Ministry of Education of New Zealand is funded by tax dollars that are subject to fixed parameters in the parliamentary budget. If school buildings are expensive to build, then fewer learning spaces can be provided in each budgetary term.

The Ministry's School Property Strategy 2030 [54] (p.13) notes, "over time, school property management has become more complex. This is because of changes in legislative requirements in areas such as health and safety, as well as in design considerations, technologies, and supplier markets."

The rising cost of living and New Zealand's repayment of COVID-related borrowing has further added pressure on already limited resources, diminishing the purchasing power of money. This situation, coupled with a deteriorating global economy has altered spending patterns and diminished the Government's tax revenue. Additionally, a series of weather events, such as Cyclone Gabrielle, along with ongoing population growth, have further complicated the challenges associated with managing school property.

Significant school funding goes to roll growth projects i.e., adding extra learning spaces in an existing school. In order for the required number of learning spaces to meet the demands of population growth, school buildings must be cost-efficient but also satisfy the fitness-for-purpose requirements. This is a difficult challenge.

In the last decade, school building designs have been largely bespoke and in some cases over engineered. The average cost per m2 for learning spaces has varied depending on the design and can be high, which is not sustainable in the current financial climate.

3.2 Standardised/Repeatable Designs with Approved Solutions Narrow the Design Scope

Adopting standardised design (also known as reference or repeatable design at scale) is part of the Ministry's strategy to achieve cost-efficient school buildings [56]. This approach, along with approved solutions is an effective way of reducing cost because they narrow the scope of acoustic design. Designers can simply adopt the approved solutions and achieve good acoustic outcomes, without the need for detailed acoustic advice.

Essentially, the acoustic expertise is front-loaded into robust solutions that will (in most cases) achieve suitable target criteria. Acoustic engineers will still be involved in school building projects, but their role will be reduced to addressing the more complex projects and aspects, or spaces with special acoustic needs like auditoria, music rooms and recording spaces.

Another solution for providing consistent design is offsite manufactured buildings (OMBs). These buildings are assembled in factories and brought to schools on a truck, with minimal building works required once on site.

Modular school buildings are a type of OMB that enable larger spaces to be built by connecting a number of separate truck-transportable modules together. The Ministry has engaged OMB manufacturers to develop modular learning spaces, and with the right acoustic input they too can meet the DQLS standards.

3.3 Learning Spaces are the Priority

Schools have a range of spaces, not all of which are for learning. Offices, meeting rooms, staff rooms, resource rooms and toilets all had mandatory RT and STC requirements in DQLS v3.0 [12], which added cost to projects.

The Ministry's focus is providing fit-for-purpose learning spaces, so they should take priority in a project budget. Of course, those other spaces still need to be functional and fit for purpose, but they are less likely to be compromised by reverberation or background noise and standard constructions will in many cases be appropriate.

3.4 DQLS (2020) v3.0 has been Amended to v3.1

The DQLS v3.1 [17] changes the mandatory criteria and adopts the cost-efficiency opportunities discussed above.

DQLS – Acoustics Amendment

Standard:	*Designing Quality Learning Spaces (DQLS) – Acoustics*
Version:	V3.1, 2020
Section:	Section 1 (Reverberation Time (1.1), Sound Transmission and Impact Insulation (1.2) and Indoor Noise Levels (1.3))
Effective From:	May 2024 for all projects (including projects currently in design)

Amended Section 1 Mandatory Requirements for Acoustics

This section sets out the Ministry's mandatory requirements and approved solutions for acoustic performance in schools. All new buildings and major refurbishments must be designed to achieve these mandatory requirements. Compliance checks are done using the verification methods in **Section 3** of *DQLS - Acoustics*.

Tables 3 to 6 provide approved solutions for controlling reverberation time (RT), sound absorption, sound insulation and impact insulation. Alongside the approved solutions are performance requirements that alternative designs (i.e., different from the approved solutions) must comply with.

This guidance addresses typical learning and ancillary spaces arrangements, but it cannot cover all design options. If a particular space is not listed, designers are to apply the limits for the space that is most relevant in terms of size and function.

Figure 2: DQLS v3.1 Amendment

The amendment has made changes to DQLS in five key areas:

1. Inclusion of approved solutions for reverberation control, with target RTs
2. Greater clarity on 'connected spaces'
3. Inclusion of approved solutions for wall and floor constructions, with target STC ratings
4. Provision of example STC mark-ups of typical classroom layouts
5. Inclusion of a list of typical roof build-ups, with reduced rain noise requirements i.e., lower CAC ratings

Each of these changes delivers cost-efficiencies through one of the following mechanisms:

- Requiring simpler construction details with cheaper materials
- Identifying and removing expensive acoustic solutions
- Reducing the need for expert involvement
- Limiting the range of acoustic products, which enables bulk buying in larger quantities
- Clarifying some aspects of DQLS v3.0 that have led to overdesign
- Prioritising learning spaces for acoustic treatment

3.5 Finding cheaper ways to build STC-rated walls

A costing exercise of STC-rated walls was carried out by experienced school design Quantity Surveyors during the amendment drafting stage. Any STC value can be achieved using a range of materials, but the higher the STC requirement, the more specialised (and heavyweight) the build-up has to be.

Most plasterboard suppliers have a range of boards that usually include standard and high-density options, as well as fire or moisture-rated boards for certain walls that require them. Each board type comes in multiple thicknesses too, resulting in a wide range of board options.

Constraining the number of board types used in school building projects has two advantages. The first is that buying larger quantities of a one board type can lead to bulk discounts (and the Ministry is most definitely a bulk buyer). The second advantage is in streamlining the building process on site. Less potential for confusion over which board is needed for which wall i.e., easier oversight and better quality assurance.

DQLS v3.1 [17] has reduced some STC ratings compared with v3.0 [12], but still provides appropriate acoustic separation between the spaces that need it.

3.6 Wall Cost Rules-of-thumb for Acoustic Engineers

The costing exercise provided some useful insights into pricing of STC-rated walls. Below are some rules-of-thumb that will allow acoustic engineers to appreciate some of the cost aspects of the walls they design:

- Double stud walls cost 30-40% more than single stud walls
- Staggered stud walls cost 15% more than single stud walls
- Steel studs are 10-20% cheaper than timber studs
- Rubber isolation clip systems with furring channels increase the cost of a single stud wall by 120-140%
- Uprating wall from 10 mm standard plasterboard to 13mm high-density plasterboard increases the cost of a single stud wall by 10-15%
- Doubling the number of linings increases the cost of a single stud wall by 30-40%
- Increasing a wall's performance by 5 STC points will cost around $20 per m2 (up to STC 55)
- Increasing a wall's performance from STC 55 to STC 66 will cost around $30 per m2

These figures are provisional only, and subject to change over time. They were based on Auckland pricing (the most expensive of NZ regions) and included the cost of labour and fixings.

3.7 Rain Noise is an Intermittent Issue

The impact of rain noise is an important factor to consider with lightweight roof membranes, as it can generate excessive reverberant noise levels within learning spaces. Rain falling on the lightweight roof system can generate a drumming noise within the space, especially in areas of high rain intensity. The primary concern for building occupants is the sound level within the room caused by rainfall. According to a study by Chiu et al. [58], an external mass layer (12 kg/m^2) backed with 100 mm mineral wool insulation (minimum density 48 kg/m^3) covering 80% of the roof area would result in an anticipated internal ambient noise level of 53 dB(A) for occupants.

DQLS v3.0 [12] had approved roof-ceiling solutions for three rainfall rate categories, with each region in New Zealand placed in the appropriate category. The rainfall rates (in mm/hr) were based on an average occurrence of 5 minutes per month. This meant that expensive roof systems were being built to protect classroom occupants from a noise source that occurs quite infrequently.

High rain intensity occurs intermittently i.e. minutes at a time, not for an entire day, and not all times during a teaching day are highly noise-sensitive (such as didactic teaching). Typical roof systems provide a reasonable level of rain noise control in most cases, which the Ministry deems appropriate for learning spaces. The amendment states that the Ministry considers a typical roof system to be:

- A profiled steel warm roof system and a CAC 30 ceiling system
- A profiled steel warm roof system with a mass layer (solid board or high-density material with a weight of at least 10kg/m^2), and a CAC 20 ceiling system
- A profiled steel cold roof with fibrous insulation in the cavity and 13 mm standard plasterboard ceiling or a CAC 40 ceiling system

Table 5 below provides insights from a comparison of the Canadian and South Australian Standards with the DQLS (New Zealand's) Noise Reduction Coefficients (NRC) and Ceiling Attenuation Class (CAC), to support the DQLS v3.1 requirement.

NRC is the average whole-ceiling performance of four mid-frequency octave bands (250Hz, 500Hz, 1kHz and 2kHz). Each ceiling tile or ceiling panel has its own NRC value, but the total coverage of the product must be considered. For example, if an NRC 1.0 tile covers the whole ceiling, the average whole-ceiling value will be NRC 1.0. But if the same tile only covers 70% of the ceiling (with the remainder being a hard material like plasterboard), the whole-ceiling value will be around NRC 0.7.

Table 5 shows that the DQLS NRC requirement is generally higher than other similar standards (which aligns with its RT criteria being at the low end of the range – refer Table 1), and the CAC requirements are in agreement. This means the DQLS outcomes will be fit-for-purpose.

Spaces	[1]Canadian [31]	[2]South Australia [55]	[3]New Zealand [17]
Learning spaces	0.55	0.7	0.85
Gymnasiums	0.70	-	0.7
Music	0.80	-	Specialist design
Offices	0.55	0.5	0.7
Common areas (corridors and circulation)	0.55	0.5	0.7

[1]Recommends an acoustic ceiling board with CAC 40 rating when it is not possible to have full height construction for wall assemblies with STC 45 rating and greater.

[2]Recommends a CAC between 30 to 45 rating depending on room type.

[3]Recommends a CAC between 20 to 40 rating depending on rooms with high noise tech, hard floors or type of roof system used.

Table 5: Noise Reduction Coefficients and Ceiling Attenuation Class ratings comparison with similar standards

3.8 The DQLS Amendment will bring Cost Savings

The costing exercise carried out as part of the DQLS amendment showed the following cost savings for a typical storey four classroom block with toilets, breakout spaces, teacher workroom etc:

- 17% saving on typical internal wall costs from the STC, RT and internal noise level amendments (1% of overall building cost)
- 38% saving on typical roofing costs from the roof/ceiling amendments (3% of overall building cost)

CONCLUSION

The DQLS v3.1 amendment [17] aims to retain the same quality of classroom design, just to build the same projects more cost-efficiently. But the ways in which DQLS has evolved over 17 years suggest that changes in pedagogy, design trends, economic pressures, and sustainability goals all impact how schools are built. And school building design will most likely continue to evolve.

Standardised/Reference designs will provide robust solutions. The last decade has seen bespoke school building designs, but the associated cost is not sustainable. The Ministry has been reviewing and modelling multitude learning space typologies and working with design experts to develop standardised designs [56] with robust solutions that ensure school buildings can withstand the range of New Zealand climates. The amended DQLS requirements will be tested as part of the standardised design modelling to further provide assurance and inform areas for future improvement for the forthcoming update and renaming of the DQLS suite.

The review of various national standards and scientific articles revealed a consensus that the optimal reverberation time (RT) in learning spaces is between 0.4 to 0.8 seconds. Additionally, the ambient noise level should be around 35 dB (and below 45 dB in any case), depending on the type of activities and the age and specific needs of the students. An STC rating of 45 marks the threshold for speech privacy, whereas an STC rating of 50 ensures good sound reduction.

The costing exercise offered valuable insights into the pricing of STC-rated walls and established some rules of thumb that will help acoustic engineers better understand the cost implications of the walls they design.

Therefore, it can be concluded that the DQLS requirements largely align with acoustic expectations in other comparable countries and provides cost-effective methods (approved solutions) for ensuring the acoustic quality of learning spaces.

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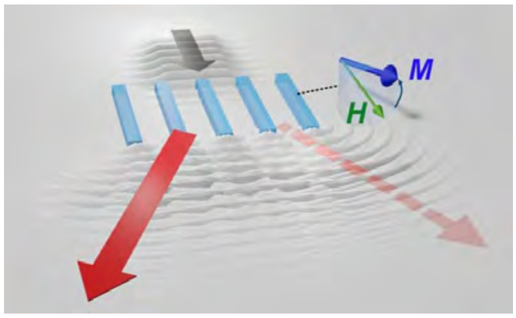
ACOUSTICS IN THE NEWS AND MEDIA

Meteorite over South Island causes massive sonic boom [9]

New acoustic wave phenomenon discovered [10]



Excessive Noise Cameras in Action [11]

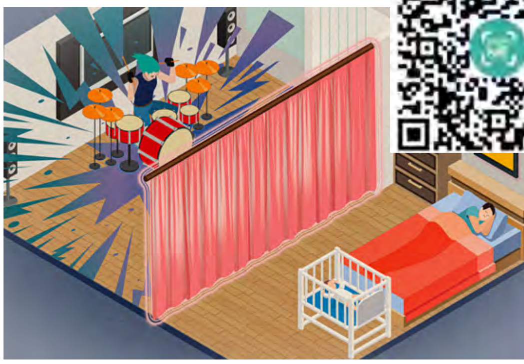
Noise pollution can harm birds even before they hatch [12]

Preserving Sound of Notre Dames Acoustics [13]

Rifle Range Noise Battle [14]

Acoustic Rock Art [15]

How Silk Can Create Quiet Spaces [16]



SPHEREx Undergoes Acoustic Testing [17]

Traffic Noise Diminishes Benefit of Calming Natural Sounds [18]

9. https://www.nzherald.co.nz/nz/meteorite-over-south-island-causes-massive-sonic-boom/TWWA4F4X5RAZDFVLT3G6Q4EZOI/

10. https://phys.org/news/2025-01-acoustic-phenomenon.html

11. https://www.nbcwashington.com/news/local/montgomery-county-to-install-noise-cameras-to-catch-excessively-loud-cars/3742075/

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13. https://www.rfi.fr/en/science-and-technology/20250115-preserving-the-sound-of-history-how-scientists-safeguarded-notre-dame-s-acoustics

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15. https://theconversation.com/rock-art-acoustics-south-african-study-suggests-that-a-distinct-echo-attracted-ancient-artists-back-to-one-site-241953

16. https://news.mit.edu/2024/sound-suppressing-silk-can-create-quiet-spaces-0507

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18. https://www.technologynetworks.com/applied-sciences/news/traffic-noise-blocks-out-the-benefits-of-nature-sounds-393820

Anechoic chamber calibration using sweep signals

Huachen Zhu [1], Xianghao Kong [1], Michael Kingan [1], Gian Schmid [1], Jin Teh[1]

[1] The University of Auckland, Auckland

gzhu357@aucklanduni.ac.nz

ABSTRACT

ISO 26101-1:2021 specifies a standard method for qualifying a space as being anechoic. The method involves placing a source within the chamber and checking whether the sound pressure decays in accordance with the inverse square law at different frequencies and in different directions. In the method adopted in this study, a microphone was traversed along a wire away from the source and the sound pressure level measured as the microphone traversed. The standard recommends using pure tones at the centre frequencies of the standard one-third octave bands as the noise signal. In order to speed up testing, multiple tones can be played simultaneously. However, using multiple tones which includes tones at harmonics of others results in beating which affects the measured sound pressure level over the short period required when using a traversing microphone. This article describes how a swept sine signal was used instead during the calibration of the anechoic chamber at the University of Auckland. The results obtained using the proposed method were compared with those obtained using single pure tones and the results were observed to be consistent. It is also noted that the measured cut-off frequency of the anechoic chamber at the University of Auckland is below 50 Hz.

INTRODUCTION

The precision of measurements made within an anechoic chamber are dependent on its proximity to ideal free-field acoustic conditions. ISO 26101-1:2021 [1] specifies a standard method for qualifying an anechoic chamber as providing an anechoic/free-field environment. This method involves positioning an omnidirectional sound source within the chamber and then measuring the sound pressure level at varying distances from the source. In order for the chamber to qualify as anechoic, the sound pressure level should decay in accordance with the inverse square law (in which the rms pressure is inversely proportional to the distance from the centre of the sound source to the microphone). Evaluating deviations from this inverse square law across multiple directions and frequencies enables an assessment of the free-field environment within the chamber as a function of both frequency and direction. In the method employed in this study, a microphone was traversed at a constant slow speed along a wire away from the sound source whilst the acoustic pressure measured by the microphone was recorded. The sound pressure level at a particular location was then calculated from the recording using data collected whilst the microphone was in close proximity to the nominal measurement position. The standard method advocates for the use of pure tone signals to be used during testing. Because of the number of tests which are required, it is tempting to employ multiple pure tone signals simultaneously. However, this can lead to errors at harmonics of the low-frequency tones when using a traversing microphone because of beating which affects the level of the measured signal over the short measurement period required when using the traversing microphone method to calculate the sound pressure level at a point.

In this study, it is shown that a swept sine signal can be used as an alternative signal to calibrate an anechoic chamber when using a traversing microphone. The method allows relatively quick measurements of the sound pressure level at very high spatial resolution which is a significant advantage over manually moving a static microphone to a limited number of measurement points. The results obtained using the proposed method were compared with those obtained using single pure tones. It is also noted that the calibration of the chamber using this method showed that the cut-off frequency of the anechoic chamber at the University of Auckland was below 50 Hz.

Figure 1: Speaker mounted in anechoic chamber with traversing microphone.

METHODOLOGY

The measurements described in this paper were performed in the anechoic chamber at the University of Auckland. A photograph of this chamber is shown in Figure 1.

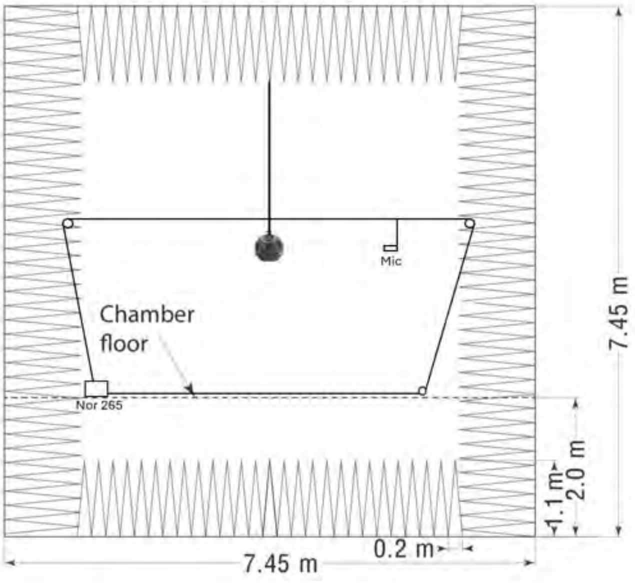

Figure 2: Schematic of the calibration test setup.

The chamber has the form of a large 0.5 m thick concrete box with all inner surfaces covered in wedges made from open-cell foam. These wedges measure 1100 mm in length, have a square cross-section of 200 mm × 200 mm at their base (attached to the wall) and a cone angle of 14 degrees to a sharp edge (away from the wall). The chamber is isolated on springs and boasts internal dimensions of 5.25 m × 5.25 m × 5.25 m (from wedge tip to wedge tip), as shown in Figure 1. Additionally, it includes an acoustically transparent wire mesh floor suspended above the wedges on the floor of the chamber. The chamber has an entrance/exit with dimensions of 2 m × 1 m. The entrance/exit is fitted with a heavy metal door and during testing, the entranceway can be covered internally using a moveable wall of wedges.

The experiments used a Norsonic Nor276 omnidirectional sound source which is omnidirectional between 50 Hz and 5000 Hz. The speaker was placed at the centre of the chamber as recommended in A.3.1 of [1].

The traversing system, illustrated in Figure 2, employed a polyethylene wire with a diameter of less than 0.5mm. This wire was strung between two pulleys and the microphone was hung off this using a specially constructed holder such that its axis pointed directly towards the speaker whilst traversing. The wire was connected to the top of a Norsonic Nor265 turntable which was used to accurately move the microphone along its traversing path. The microphone was a RODE Lavalier lapel microphone which was connected to a computer via a Roland OCTA-CAPTURE system. The signal from the microphone was sampled at 44100 Hz. The sound source was also connected to the OCTA-CAPTURE system using a Yamaha XMV 4140 amplifier to enable simultaneous playback and recording. The microphone's distance from the sound source was calculated as the product of the microphone's speed and the duration for which the turntable was active. Furthermore, the initiation of both the microphone data recording and the traverse system occurred simultaneously, thereby ensuring a precise calculation of the distance from the microphone to the source point based on the recorded data. The method allowed very high spatial resolution measurements – with the sound pressure level being calculated at 1.6 mm intervals. In total 1062 sound pressure level measurements were made for each traverse which spanned a distance of 0.6 m to 2.3 m from the sound source - significantly exceeding the 10 measurement points mandated by ISO 26101-1:2022 [1]. This high-resolution data is very useful for judging the accuracy of the inverse square law decay of the measured sound pressure level.

In this experiment, a log sine sweep signal was used as the sound source signal. The start frequency of the sweep signal was 2 Hz, the end frequency was 6000 Hz, the sweep duration was 0.8s, and the gap duration was 0.2s. The sweep signal was repeated during the measurement as the microphone traversed. Each cycle of the sine sweep was identified from the output signal using cross-correlation with the input sine sweep. The distance corresponding to each cycle was calculated based on the turntable's speed and the cycle's timestamp. The distance corresponding to each cycle was calculated based on the rotation speed of the turntable and the timestamp of the cycle. As the duration of each cycle was 1s, the nominal position of the microphone is taken to be the location of the microphone at the midpoint of each cycle. The error associated with this change in distance during the measurement is negligible.

ANALYSIS METHOD

ISO26101 states that the measured sound pressure level should satisfy the inverse square law which requires that [2]

$$L_p = L_{p,0} - 20\log_{10}(r_0 + \Delta r) \qquad (1)$$

where L_p denotes the sound pressure level at a distance □□ from the acoustic centre, $r = r_0 + \Delta r$ denotes the distance from the microphone to the centre of the speaker, r_0 is the distance from the microphone to the centre of the speaker at the start of the traverse and Δr denotes the distance the microphone has travelled since the start of the traverse. $L_{p,0}$ is the sound pressure level at distance r equal to 1 m.

EXPERIMENT RESULTS

The SPL was calculated from the measured pressure signals with a frequency resolution of 1 Hz. Figure 3 plots the peak deviation in the measured sound pressure level from that expected measured during a traverse plotted against frequency.

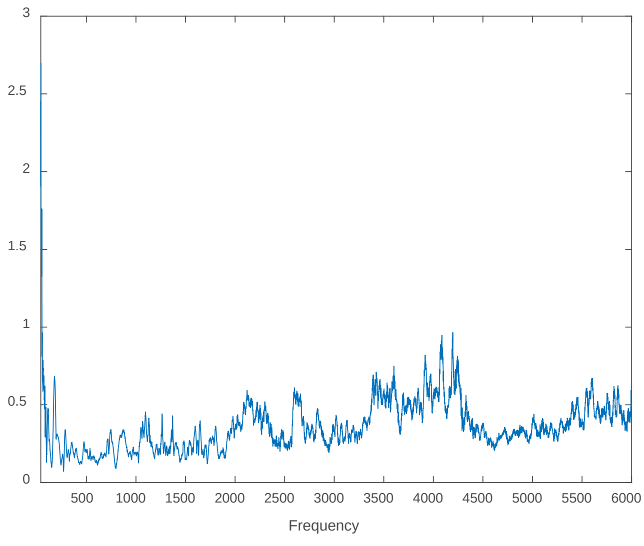

Figure 3: The peak deviation calculated using the swept sine signal method

The experiments were repeated using single tones generated at the centre frequency of one-third octave bands between 40 Hz and 5000 Hz. It was found that the peak deviations obtained using the two methods were similar.

According to the criteria given in ISO 26101-1:2021 [1] and the results obtained during testing showed that the anechoic chamber at the University of Auckland has a cut-off frequency of less than 50 Hz.

CONCLUSION

This study proposes an alternative method for calibrating an anechoic chamber utilising a traversing microphone and a swept sine signal. The method allows very high spatial resolution measurements of the inverse-square law decay of the measured sound pressure level. Experimental results obtained using a swept sine signal and a single pure tone signal experiment were compared and found to be consistent. It was also noted that the measured cut-off frequency of the anechoic chamber at the University of Auckland is below 50 Hz.

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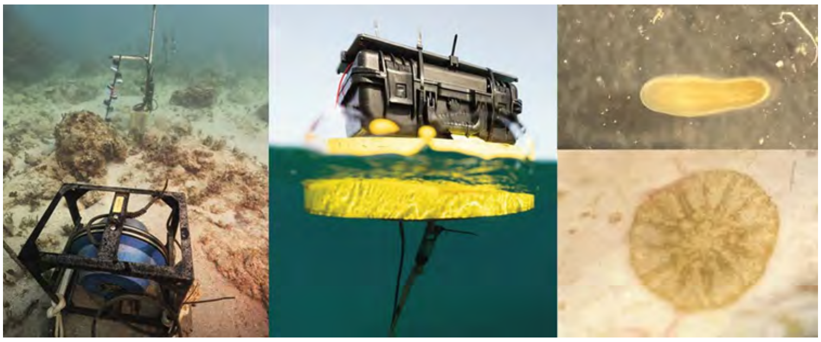
Travis Scott concert at Auckland's Eden Park racks up 21 noise complaints [19]



Waiheke's Cable Bay Wine convicted, fined $50k over noise limits [21]

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Noisy hospo venues are an ear-bashing, and risk permanent hearing damage [19]


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