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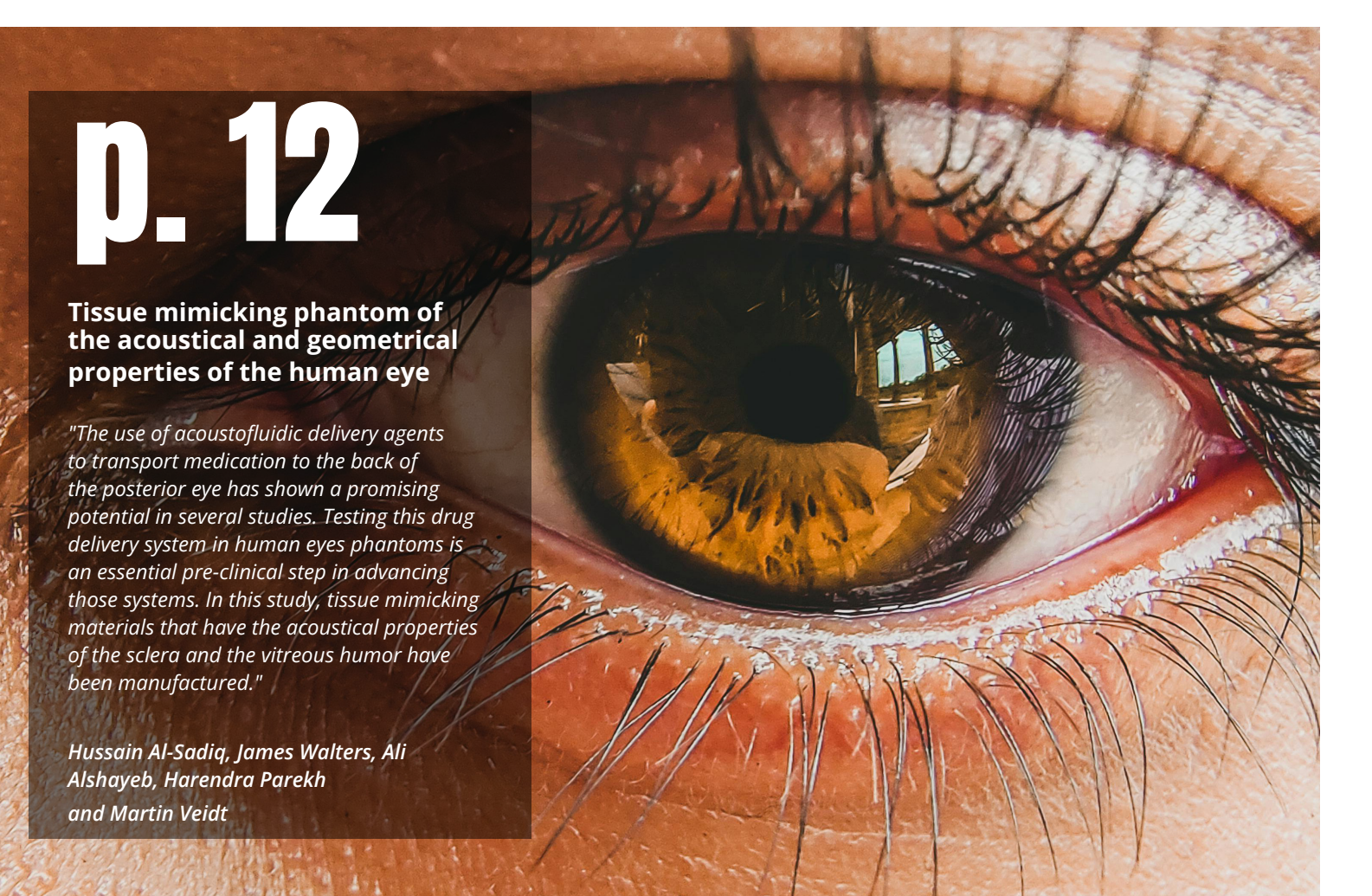
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New Zealand round robin sound absorption measurements between Canterbury Acoustic Testing Services and Acoustic Testing Services, University of Auckland

"Interlaboratory variability in sound absorption measurements is a well-recognised challenge in acoustic testing. Differences observed between results from Canterbury Acoustic Testing Services (CATS) and Auckland Acoustic Testing Services (ATS) have motivated the present investigation."

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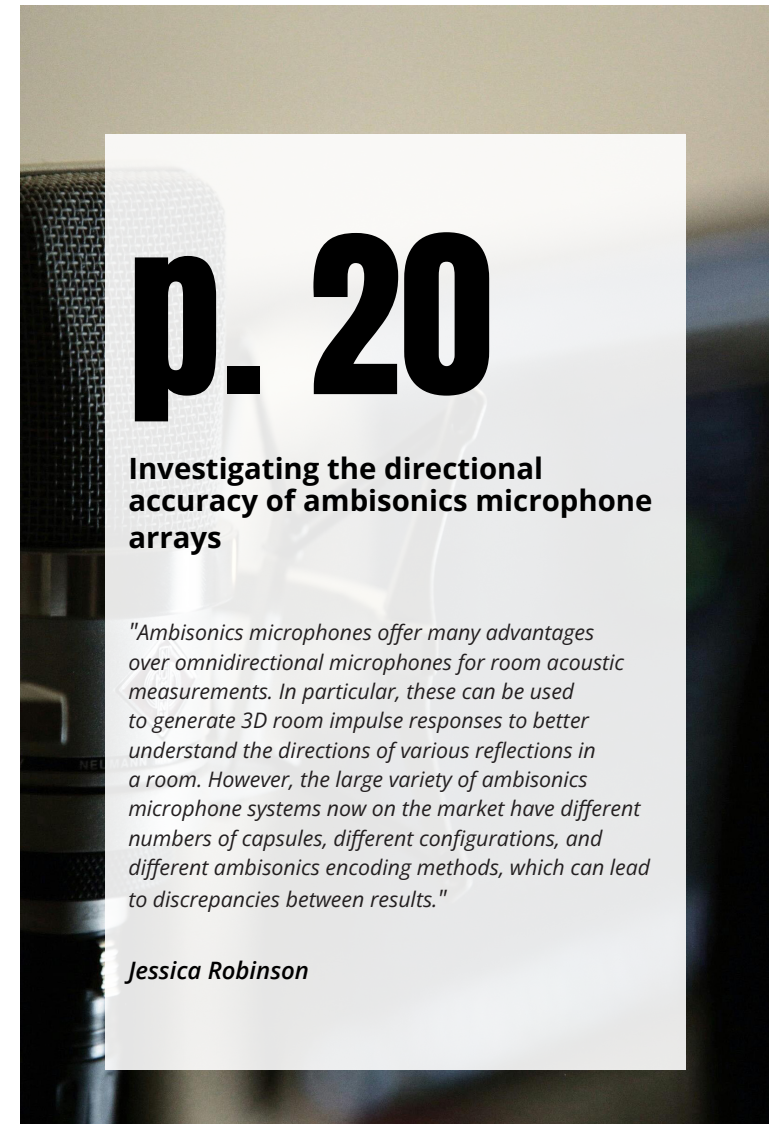


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Tissue mimicking phantom of the acoustical and geometrical properties of the human eye

"The use of acoustofluidic delivery agents to transport medication to the back of the posterior eye has shown a promising potential in several studies. Testing this drug delivery system in human eyes phantoms is an essential pre-clinical step in advancing those systems. In this study, tissue mimicking materials that have the acoustical properties of the sclera and the vitreous humor have been manufactured."

Hussain Al-Sadiq, James Walters, Ali Alshayeb, Harendra Parekh and Martin Veidt

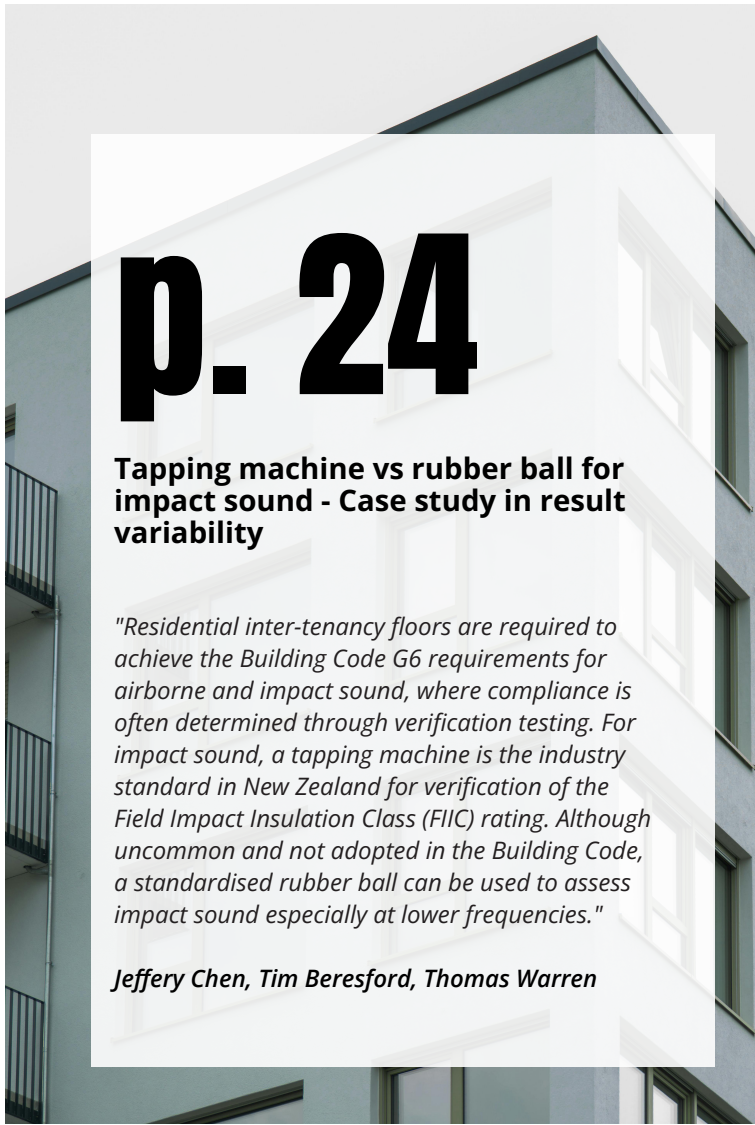


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Investigating the directional accuracy of ambisonics microphone arrays

"Ambisonics microphones offer many advantages over omnidirectional microphones for room acoustic measurements. In particular, these can be used to generate 3D room impulse responses to better understand the directions of various reflections in a room. However, the large variety of ambisonics microphone systems now on the market have different numbers of capsules, different configurations, and different ambisonics encoding methods, which can lead to discrepancies between results."

Jessica Robinson



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Tapping machine vs rubber ball for impact sound - Case study in result variability

"Residential inter-tenancy floors are required to achieve the Building Code G6 requirements for airborne and impact sound, where compliance is often determined through verification testing. For impact sound, a tapping machine is the industry standard in New Zealand for verification of the Field Impact Insulation Class (FII) rating. Although uncommon and not adopted in the Building Code, a standardised rubber ball can be used to assess impact sound especially at lower frequencies."

Jeffery Chen, Tim Beresford, Thomas Warren



Tracy Hilliker

President of the Acoustical Society of New Zealand Inc.

Dear Members,

With summer behind us and autumn underway, this quarter has been one of momentum and consolidation for our Society. I am pleased to share several important updates that reflect the collective efforts of our Council, volunteers, and our wider membership.

I am delighted to confirm that our new **ASNZ website** is now live. This long-anticipated project delivers improved navigation, enhanced member-only content, streamlined CPD submission, and easier access to key resources such as journal archives, events and society documentation. My sincere thanks go to Tim Beresford, Mathew Legg and James Whitlock, and all those involved in bringing this platform to fruition. I encourage all members to visit www.acoustics.org.nz, reset your password, and check that your contact details to ensure you receive all communications, including this Journal. We welcome your feedback as the site continues to evolve.

In further positive news, MBIE has initiated work to update **NZBC Clause G6** through its Healthier and More Energy Efficient Buildings programme. The first stage of this work will define the scope of future changes to G6, focusing on improving the acoustic environment in buildings. ASNZ has been appointed by MBIE to support this process and has convened a subcommittee of Members who are collaborating to review existing research, identifying gaps and overlaps with other standards, and develop recommendations to guide future technical analysis and code drafting for the NZBC 2031 update cycle. The outcome will be

a well-defined roadmap for modernising G6 to better address acoustic comfort and health in buildings.

Planning is well underway for our upcoming **ASNZ Conference** in Tauranga in early November, which will feature a strong technical programme, professional development opportunities, and networking events. These events are a cornerstone of our Society, providing valuable opportunities to share knowledge, connect with colleagues and exhibitors, and celebrate excellence within the acoustics community. Highlights include a technical tour, and an NZTA Workshop covering recent NZS 6806 developments for road-traffic noise prediction and measurements. Early-bird registration and abstract submissions are open at www.asnzs2026.co.nz. Members are also reminded of the **ASNZ conference support fund**, where \$5,000 is offered annually to assist members with conference attendance costs. Submissions for attendance at our ASNZ Conference in November, or Internoise in Adelaide in August, need to be received by the 15 May.

Thank you to our Council members, volunteers, and various working group contributors for your continued dedication, and to all members for your ongoing support and engagement. I look forward to connecting with many of you in the coming months.

Ngā manaakitanga,

Tracy Hilliker

President of the Acoustical Society of New Zealand Inc.

Student Prizes: Update

The Acoustical Society continues to provide support to students studying acoustics throughout New Zealand. Last year, a group of two fourth-year undergraduate Mechanical and Mechatronics Engineering students – Zongxi Li and Jayden Sin – were awarded a \$500 prize for a project investigating “Vibration and Sound Attenuation Using Metamaterials Through Machine Learning Enabled Design”. In addition, three PhD students were each awarded \$500 prizes for their outstanding research outputs produced during their studies. A brief biography and summary of these students’ research is given below.

Jin Xuan Teh: Jin completed his Master of Engineering in Mechatronics Engineering at the University of Southampton in 2018. From 2019 to 2022, he served as a Senior Operations Modelling Engineer at Micron Semiconductor in Singapore. Since 2023, he has been pursuing a PhD in Mechatronics Engineering at the University of Auckland and is supported by a scholarship from the Acoustics and Vibration Research Centre.

Jin’s doctoral research integrates acoustic signal processing with aeroacoustics to enable high-quality audio acquisition from unmanned aerial vehicles. He is supervised by Associate Professors Yusuke Hioka and Michael Kingan.

Wenpeng Sun: Wenpeng is a PhD candidate in Mechanical Engineering at the University of Auckland, specializing in active control of thermoacoustic coupling in energy technologies. He holds a Master’s degree in Chemical Process Machinery and a Bachelor’s degree in Process Equipment and Control Engineering. He has authored 5 SCI journal papers as first author (including 3 JCR Q1 top-tier publications), along with 3 EI-indexed

and international conference papers. Previously, he served as a Quality Engineer at Xiaomi Communications Co., Ltd., where he led quality development initiatives for thermal management technologies in flagship smartphone models.

Wenpeng was awarded a prize for his research investigating mode switching capabilities in an electric-driven thermoacoustic refrigerator/heat pump system. He developed a computational model and conducted experimental validation to analyse how driving frequency modulation enables real-time switching between cooling and heating modes. The results of his work demonstrate that frequency adjustment alters the acoustic field and heat transport directions within the thermoacoustic core of the refrigerator/heat pump. The switching frequency depends on the relationship between the acoustic driver’s natural frequency and the resonator system’s fundamental frequency, with optimal performance requiring the resonator frequency moderately higher than the driver frequency. Through parametric analysis, Wenpeng was able to identify key design parameters affecting system performance.

Xinyu Zhao: Xinyu is a PhD candidate in Mechanical Engineering at the University of Canterbury, supervised by Professor Dan Zhao. He obtained his Master’s degree from Tongji University in 2020.

Xinyu’s research focuses on theoretical modelling of thermoacoustic combustion instability and its control. This work addresses critical challenges in the development of clean and efficient gas turbines, and integrates theoretical modelling, nonlinear dynamics, and artificial intelligence techniques to predict, analyse, and control self-excited thermoacoustic combustion oscillations.



Lindsay Hannah and Wyatt Page

Principal Editors

Tēnā koutou katoa, talofa lava, and welcome to the first 2026 edition of New Zealand Acoustics.

With both the summer break and Easter now firmly behind us, we turn our attention to the year ahead as the cooler months set in.

This issue returns to our 'bread and butter', a superb collection of technical papers spanning key areas of acoustics. Highlights include New Zealand round robin sound absorption measurements between Canterbury Acoustic Testing Services and Acoustic Testing Services and Tapping machine vs rubber ball for impact sound – a case study. These contributions, alongside the rest of the issue's technical papers, offer valuable insights and are well worth your time to read.

As always, the issue is rounded out with our regular quiz, upcoming events, and industry news.

The President's column provides a timely update on current activities, as well as a reminder of the upcoming Acoustical Society of New Zealand (ASNZ) Conference, to be held in the beautiful Tauranga.

The Society's new website is now live. If you haven't already, we encourage you to visit and explore its content: <https://acoustics.org.nz/>

We look forward to connecting with many of you throughout 2026.

Tofa soifua, ka kite anō and see you again soon.

Lindsay Hannah & Wyatt Page
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www.acoustics.org.nz

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Editor-in-Chief

Lindsay Hannah
Wyatt Page
journal@acoustics.org.nz

Advertising Manager

Paul Hazard
advertising@acoustics.org.nz
Design & Production
Holly Saunders-Wright
production@acoustics.org.nz

Submission All Articles
News, Products, Enquiries
journal@acoustics.org.nz

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New Zealand round robin sound absorption measurements between Canterbury Acoustic Testing Services and Acoustic Testing Services, University of Auckland

Mike Latimer ⁽¹⁾, Gian Schmid ⁽²⁾, Andrew Hall ⁽²⁾, and Michael J. Kingan ⁽²⁾

⁽¹⁾ Canterbury Acoustic Testing Services, Christchurch; mike@acoustic-testing.co.nz

⁽²⁾ Acoustics Testing Service and Acoustics and Vibration Research Centre, Department of Mechanical & Mechatronics Engineering, The University of Auckland.

Introduction

Interlaboratory variability in sound absorption measurements is a well-recognised challenge in acoustic testing. Differences observed between results from Canterbury Acoustic Testing Services (CATS) and Auckland Acoustic Testing Services (ATS) have motivated the present investigation. To quantify this variability, both laboratories collaborated to develop a test sample capable of being shipped between facilities, durable enough for repeated annual testing over several years. Results from each annual round of testing will be published in the ASNZ journal.

Over the last few decades several international Round Robin Tests (RRT) have been undertaken to quantify the variations between laboratories globally. For example, Whittstock [1] presents an analysis of interlaboratory sound absorption measurement test data from several different RRTs conducted between 1974 and 2011. Whittstock's analysis showed that there was significant variation in the sound absorption coefficients measured in different laboratories – particularly at low frequencies.

In 2020 CATS (Christchurch), ATS (Auckland), CSIRO (Melbourne), and UTS Tech Lab (Sydney) participated in the DENORMS international RRT [2] which included other laboratories from Europe and North America. It was hoped that the results from this RRT would be published in the 2021, unfortunately, the findings of this RRT are not yet available. Due to the time passed, both CATS and ATS decided to conduct their own New Zealand based RRT.

Test Sample design and construction

The New Zealand RRT used two different sound absorption test samples which were based on those used in the DENORMS RRT [2]. Each test sample comprised nine (9) MDF (Medium Density Fibre board) boxes filled with polyester sound absorption material with or without a facing placed on the top of the sound absorption material. The total sound absorption area of the top surface of each sample was 10.8 m² (11.45 m² including the sample box/frames). Six of the MDF boxes measured 1200 × 1200 × 200 mm, with the remaining three MDF boxes measuring 1200 × 600 × 200 mm (note that these dimensions are measured as shown in Figure 1). The walls of the MDF boxes were constructed with 18 mm thick MDF, with 12 mm MDF being used for the bases. The boxes were filled with two layers of 100 mm Quietspace (4100 gsm) polyester board. One sample comprised just the boxes filled with the sound absorption material, whilst the other included a 4.8 mm thick hardboard facing to simulate a panel-absorber. A sectional view of a test sample box is illustrated in Figure 1, and photographs of the test samples laid out ready for testing in both labs are shown in Figures Figure 2-5.

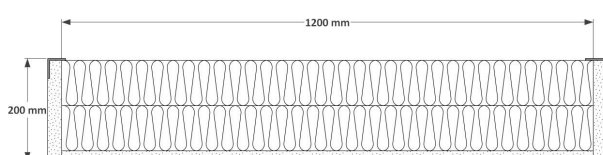


Figure 1. Section view of test sample box



Figure 2. RRT sample at CATS with no facing



Figure 3. RRT sample at CATS with hardboard facing



Figure 4. RRT sample at ATS with no facing

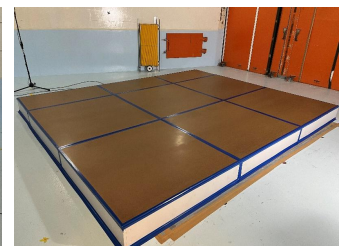


Figure 5. RRT sample at ATS with hardboard facing

Room construction

Both reverberation chambers comply with AS ISO 354 – 2006 Acoustics — Measurement of sound absorption in a reverberation room, although are quite different in design.

Auckland Acoustic Testing Services

The ATS lab is located at the City Campus of the University of Auckland. Reverberation Chamber A was used for testing and is described as follows. It is constructed from steel reinforced concrete and is part of three large, interconnected reverberation chambers.

Chamber A as shown in Figure 6 has the shape of a hexagonal prism; with six vertical walls which are perpendicular to the horizontal floor. The roof is plane but inclined at 12° from horizontal. Chamber A has a rotating vane diffuser in a central position with a surface area (both sides) of about 53 m². It has the shape of two cones with their bases joined, with the two opposite quadrants of one cone open and the complementary quadrants in the other cone open.

Chamber A has an internal volume of 203 ± 3 m³ and an internal surface area of 203.6 ± 0.9 m².

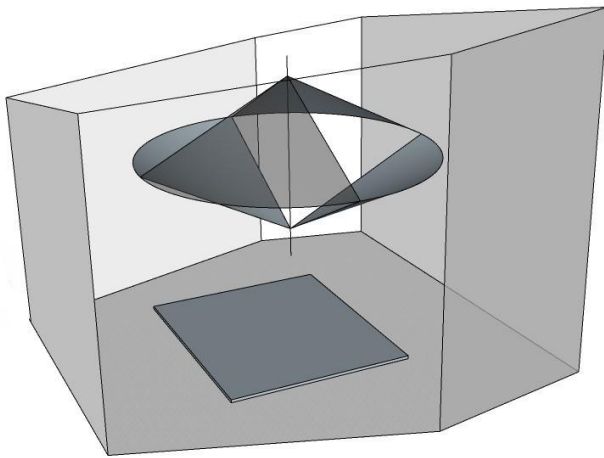


Figure 6. ATS Reverberation Chamber "A"

Canterbury Acoustic Testing Services

The CATS lab is based in Addington, Christchurch. The CATS reverberation chamber is constructed from steel framing, covered with multiple layers of plasterboard, plywood and internally lined with 2 mm aluminium sheet, as shown in Figure 7. It has a separated inner and outer structure and is a cuboid shape chamber with dimensions 7.7 m × 6.1 m × 4.7 m high.

The chamber has eight stationary hanging diffusers, made from 12 mm painted plywood and MDF, in the following sizes: 3 at 1.2 × 1.4 m, 3 at 1.2 × 1 m, and 2 at 1.2 × 1.2 m. The diffusers are suspended in a random orientation to create a diffuse sound field in accordance with AS ISO 354 – 2006.

Two adjacent corners of the chamber have melamine covered MDF volume diffusers, in the form of an acute isosceles triangle, 0.75 m at the base and 1.1 m high.

The chamber has a volume of 220 m³ and internal surface area of 223.66 m².

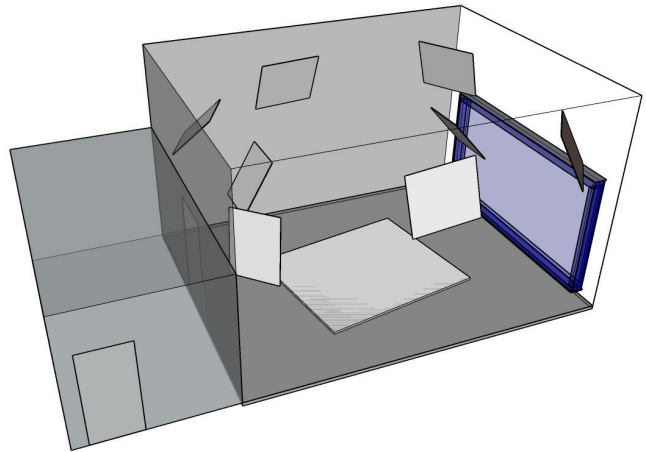


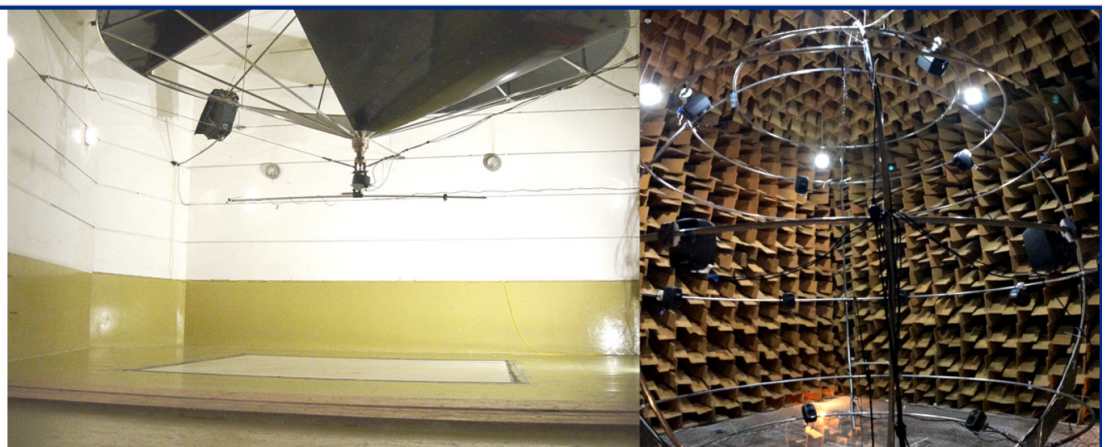
Figure 7. CATS reverberation chamber



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Measurement method

The tests were carried out following the interrupted noise technique outlined in AS ISO 354 – 2006.

The tests undertaken at CATS used six microphone positions with six decays per microphone position and the noise was generated using two sources. The tests undertaken at ATS used 12 microphone positions with three decays per microphone position and the noise was generated using two sources.

Samples tested at the CATS facility were held in the reverberation chamber, to reach environmental equilibrium.

The temperature, relative humidity and atmospheric pressure were measured in both chambers.

Measurement data was exported from the two labs' measurement equipment to a calculation template, where the sound absorption and single number ratings were calculated, in accordance with AS ISO 354 – 2006 and ASTM C423 – 23.

A summary of the characteristics of the ATS and CATS reverberation chambers and measurement methods are given in Table 1.

Feature	ATS (Auckland)	CATS (Christchurch)
Shape	Hexagonal Prism	Cuboid
Volume	~203 m ³	~220 m ³
Diffusers	Rotating Vane (53 m ²)	6 Hanging + 2 Volume Diffusers + 1
Mics/Decays	12 Mics / 3 Decays	6 Mics / 6 Decays

Table 1. Summary of the ATS and CATS reverberation chambers and measurement methods

Results

The results for the two different samples tested in both labs are presented in Table 2 and Figure 8. Reverberation room sound absorption coefficients derived in accordance with AS ISO 354 – 2006 (sub-section 3.9) and ASTM C423 may exceed 1.00 for highly absorptive thick, porous samples. This effect is attributed to edge diffraction, perimeter absorption, and lateral sound energy entering the sample, which are inherent to the test method. Absorption coefficients and derived single-number ratings are therefore reported as measured and calculated, without truncation, in accordance with standard practice.

No Facing			Hardboard facing		
Frequency f [Hz]	CATS	ATS	Frequency f [Hz]	CATS	ATS
	α_s One-third octave	α_s One-third octave		α_s One-third octave	α_s One-third octave
100	0.97	0.95	100	0.37	0.26
125	0.88	1.10	125	0.15	0.18
160	0.81	1.12	160	0.12	0.12
200	1.01	1.06	200	0.12	0.11
250	0.99	1.04	250	0.12	0.09
315	0.91	1.00	315	0.07	0.10
400	0.98	0.97	400	0.07	0.07
500	0.98	0.97	500	0.06	0.06
630	0.97	0.96	630	0.05	0.04
800	0.98	0.95	800	0.04	0.04
1000	1.00	0.97	1000	0.04	0.04
1250	1.02	0.97	1250	0.03	0.04
1600	1.04	0.96	1600	0.03	0.04
2000	1.07	0.97	2000	0.03	0.03
2500	1.01	0.99	2500	0.02	0.04
3150	0.97	0.97	3150	0.04	0.04
4000	0.98	0.98	4000	0.05	0.05
5000	0.97	0.99	5000	0.03	0.06
α_w	1.00	0.95	α_w	0.25	0.15
SAA	1.0	0.96	SAA	0.05	0.05
NRC	1.00	0.95	NRC	0.04	0.05
CATS results are an average of 4 measurements and ATS results are an average of 2 measurements					

Table 2. Sound absorption measurements. CATS & ATS results. No facing (left) and with hardboard facing (right)

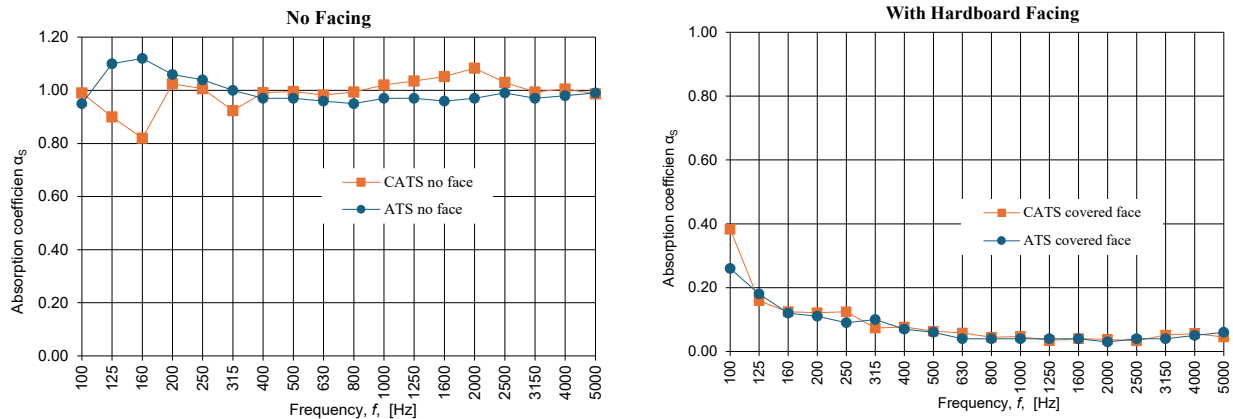


Figure 8. Absorption coefficient spectra. No facing (left) and with hardboard facing (right)

Discussion and conclusions

Some differences between the sound absorption coefficients for the test sample with no facing measured in both laboratories are apparent at low frequencies, from 100 to 315 Hz, and in the mid-frequency range from 800 to 3150 Hz. These variations are typical between labs and have been observed in previous RRTs. The measurements of the test sample with the hardboard facing shows close agreement, with the only notable difference occurring at 100 Hz.

As noted in the introduction, previous RRTs have shown that sound absorption measurements carried out in different laboratories closely following the same standard test and calculation procedures are expected to produce somewhat different values – particularly at low frequencies below 250 Hz. These factors include:

- 1. Room Geometry and Size:** Reverberation time depends on the size and shape of the test chamber. Variations in room dimensions and proportions between labs can lead to different low frequency reverberation times.
- 2. Boundary Conditions:** The way sound reflects off surfaces (walls, ceilings, floors) affects reverberation times. Differences in the materials used for these surfaces and the room's construction can result in differences between labs.
- 3. Room Modes:** Standing waves vary depending on room dimensions and can affect low frequency reverberation times. Different labs will have different room modes, creating variation in low-frequency results.
- 4. Measurement Microphone and Speaker Positioning:** The placement of microphones and sound sources within the test chamber can lead to differences, particularly at low frequencies. If microphones are placed near room modes or in positions where certain frequencies are amplified or attenuated, this can influence the measured reverberation time.

- 5. Environmental Factors:** Temperature, humidity, and air pressure can affect sound propagation, particularly at low frequencies, although these factors tend to be more controlled in lab settings.
- 6. Sample Mounting:** Is critical in reducing measurement differences between labs, this was investigated in 2011. A working group in Europe was formed to investigate "Test Codes for Suspended Ceilings". This group commissioned a European Round Robin Test (RRT). From the working group's findings, a new standard was produced, EN 16487: 2014 Acoustics Test code for suspended ceilings sound absorption.
- 7. Integration time:** The integration time used to calculate the reverberation time can affect the calculated absorption coefficient – particularly at low frequencies.

Acknowledgements

Special thanks to T&R Interior Systems and AUTEX Acoustics, for donating time and materials, enabling this project to proceed.

References

- [1] Wittstock W. Determination of Measurement Uncertainties in Building Acoustics by Interlaboratory Tests. Part 2: Sound Absorption Measured in Reverberation Rooms. Acta Acust united Ac, 2018; 104: 999 – 1008.
- [2] Chiara Scrosati, N.B Roozen, Edoardo Alessio Piana, 26th International Congress on Sound and Vibration, Principles at the basis of the DENORMS round robin test on the low frequency sound absorption measurements in reverberation rooms and impedance tube.

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Tissue mimicking phantom of the acoustical and geometrical properties of the human eye

Hussain Al-Sadiq⁽¹⁾⁽²⁾, James Walters⁽²⁾, Ali Alshayeb⁽¹⁾, Harendra Parekh⁽³⁾
and Martin Veidt⁽²⁾

⁽¹⁾ Department of Mechanical Engineering, Alasala Colleges, Dammam, Saudi Arabia
Hussain.Alsadiq@alasala.edu.sa

⁽²⁾ School of Mechanical and Mining Engineering, University of Queensland, Brisbane, Australia

⁽³⁾ School of Pharmacy, University of Queensland, Brisbane, Australia

Abstract

The use of acoustofluidic delivery agents to transport medication to the back of the posterior eye has shown a promising potential in several studies. Testing this drug delivery system in human eyes phantoms is an essential pre-clinical step in advancing those systems. In this study, tissue mimicking materials that have the acoustical properties of the sclera and the vitreous humor have been manufactured. Phantoms that have the geometrical properties of the human eyes were then made of these materials. Two types of sclera mimicking phantom were manufactured. The first was made of Polydimethylsiloxane (PDMS) and the second type of phantoms were manufacture of agar. Both materials were manufactured with different concentrations of Barium Titanate BaTiO_3 that works as a scattering agent to control their acoustic impedance. The vitreous body mimicking material was made of acrylamide and Sodium persulfate. At 1.7% of acrylamide the material almost matched the properties of the vitreous liquid where it had a speed of sound of 1511 m s^{-1} and attenuation factor of $1.039 \text{ dB cm}^{-1} \cdot \text{MHz}^{-1}$. The PDMS samples closely mimicked the attenuation factor of the sclera but not the speed of sound. The agar samples were found to mimic the speed of sound and acoustic impedance of the retina and sclera with greater accuracy at speed of sound values between 1500 m s^{-1} and 1540 m s^{-1} .

Introduction

Tissue mimicking materials are essential elements in image-guided intervention training [1], and testing of drug delivery systems [2, 3]. Recent studies suggested acoustofluidic manipulation of microbubbles (MBs) and echogenic liposomes (ELIPs) as a targeted drug delivery system for age related macular degeneration disease [4, 5]. Acoustofluidic behaviour and translation of MBs and ELIPs have been studied *in vitro* in cylindrical and rectangular cross-sectional tubes [6-8]. This study aims to develop a tissue mimicking phantom of the human eye's sclera and vitreous humour to be utilized in the *in vitro* investigations for the latter mentioned drug delivery system.

Phantoms can be categorised into two types: synthetic polymers, and biological polymers. Synthetic polymer tissue-mimicking materials react chemically to take their structure and are generally constructed from a base material and a catalyst material that causes the polymerisation. Bio polymers are primarily made of water and they degrade with time [9].

One family of the synthetic phantom materials is polymerised siloxanes, and polydimethylsiloxane (PDMS) is one of its common materials. Polydimethylsiloxane has been shown to mimic acoustic properties of human tissue. Polydimethylsiloxane phantoms were used as an alternative to many water-based phantoms, for their ability to form small, complex castings and their ability to sustain damage. Polydimethylsiloxane has a speed of sound around 1300 m s^{-1} which is about 12% lower than typical soft tissue speed of sound. The speed of sound in PDMS can be increased by adding titanium dioxide and black ink to manipulate the acoustic properties. One advantage of PDMS is that it can be moulded by lithography, and create stable structures [10].

Agar is another common material from the biological polymers family which is utilized in tissue-mimicking phantoms. Agar is defined as a carbohydrate biopolymer, which when hydrated with water and processed, forms a solid [10].

The vitreous humour is the medium in which the ELIPs are to be manipulated in the suggested drug delivery system. The vitreous humour is a colourless, transparent gel that fills the space between the lens and the retina. It is composed of mostly water with small percentage of collagen, glycosaminoglycans (sugars), electrolytes (salts), and proteins [11]. Acrylamide-based phantoms have been shown in a previous study to mimic both acoustical and mechanical characteristics of the vitreous body of the eye [12].

The acoustic properties of the major tissues of the eye along with those of water are listed in Table 1. This study aims to mimic those properties in the manufactured human eye phantom.

Table 1: Acoustic properties of the major tissue components of the human eye.

Component	Acoustic Impedance, $\times 10^6$ ($\text{kg m}^{-2} \text{s}^{-1}$)	Attenuation ($\text{dB cm}^{-1} \text{MHz}^{-1}$)	Speed of sound (m s^{-1})	Ref.
Vitreous Humour	1.54	0.1	1510 ± 10	[13, 14]
Retina	1.57	3.56 ± 1.21	1618 ± 58	[15]
Sclera	1.67	11.70 ± 2.99	1618 ± 46	[15]
Lens	1.73		1641	[13]
Water	1.5	0.0025	1500	[13]

This study manufactured and tested the acoustic properties of polydimethylsiloxane phantoms and agar phantoms to the shape of the human eye's sclera and an acrylamide-based phantom to mimic the vitreous humour. The composition and manufacturing process of the tissue mimicking materials along with the setup to test the acoustic properties of the materials are shown in the methodology section. The materials final shape and their acoustic properties are shown in the results section and discussed in the discussion section. Concluding remarks and recommendation for future work are presented in the conclusion section.

Methodology

Two types of tissue mimicking materials of the sclera were formulated: PDMS and agar. The attenuation factors of both materials were manipulated by adding barium titanate as a scattering agent. The vitreous humor tissue mimicking material was made of acrylamide solution as detailed in the next section. The materials' acoustic properties were measured in rectangular cuboid after formulation, and then moulded to the geometry of the human eye.

Vitreous humour tissue mimicking material

The gel that mimics the vitreous humour properties was formulated by diluting a 4 g of 19:1 ratio of acrylamide to bis-acrylamide (Sigma Aldrich, MO, US) in 16 mL of deionised water, 0.2 mL of N,N,N',N'- Tetramethylethylenediamine TEMED was diluted in 19.8 mL of de-ionised water, and 0.2 g of Sodium persulfate was diluted in 10 mL of de-ionised water. The solutions were degassed for 30 minutes and placed in a gloves box that was vacuumed and filled with argon gas three times to eliminate the oxygen from the box. Different containers were then filled with 1.6 mL, 1.625 mL, 1.65 mL, 1.675 mL, and 1.7 mL of the acrylamide solution. Each container was then filled with 2 mL of TEMED, 1 mL of sodium persulfate solution, 15.4 mL of de-ionised water and 0.045 g of sephadex. The mixture is then poured in the desired casting container. In this case, the desired containers are the testing rectangular cuboid chamber showed in Figure 2, and the casted sclera (Figure 11,12). The containers are then rotated for 12 hours to ensure that the sephadex did not settle to the bottom of the casting containers during polymerisation.

Rectangular cuboid sclera's tissue mimicking phantoms

The tissue mimicking material of the sclera were manufactured in rectangular cuboids to test the acoustic properties of the materials without the effect of the geometry on the acoustic wave behaviour.

Polydimethylsiloxane

Polydimethylsiloxane Sylgard™ 148 (Dow®, MI, US) mixtures of 1:5, 1:10, 1:20 and 1:30 curing agents to elastomer and 1:5 curing agent to elastomer with 0.1%, 1%, 2.5% and 5% of barium titanate were vigorously mixed for 10 minutes. A vacuum was then applied to the mixtures for 10 minutes to extract any gas within them.

The mixtures were then moulded in rectangular cuboids that are 1 cm in thickness and left to cure at room temperature for 48 hours. The PDMS with BaTiO₃ samples were rotated during the 48 hours to prevent the barium titanate particles from settling down due to gravity.

Agar

De-ionised de-gassed water was mixed with agar (SigmaAldrich®, MO, US) at 0.1%, 1%, 2% 5%, 7.5% and 10% agar to water ratio, and 7.5% agar to water ratio with 0.1%, 1%, 5%, and 10% of barium titanate. The mixtures were then heated to 90 °C for an hour with magnetic stirrer until the mixture turns translucent. The samples were then cast into moulds and left to cool until completely set. The agar samples containing BaTiO₃ were rotated for several hours until the sample set to prevent the barium titanate particles from settling down due to gravity.

In shape sclera's tissue mimicking phantom

The outer phantom mimicking the sclera's properties was manufactured from: polydimethylsiloxane and agar with the composition illustrated in the previous sections. Sacrificial moulds to the size of human eye's sclera were 3 D printed of acrylonitrile

butadiene styrene (ABS). The dimensions of the human eye are found in [16]. The prints were then smoothed with acetone bath to eliminate the surface imperfections resulting from the layer resolution of the 3D printer. The acetone bath resulted in smoother surfaces of the moulds as shown in Figure 1. The PDMS mixtures and PDMS with BaTiO₃ were then poured in the moulds and left to cure for 48 hours. The samples with barium titanate were rotated during the 48 hours to avoid particles sinking to the bottom due to gravity and to ensure equal distribution of BaTiO₃ in the samples.

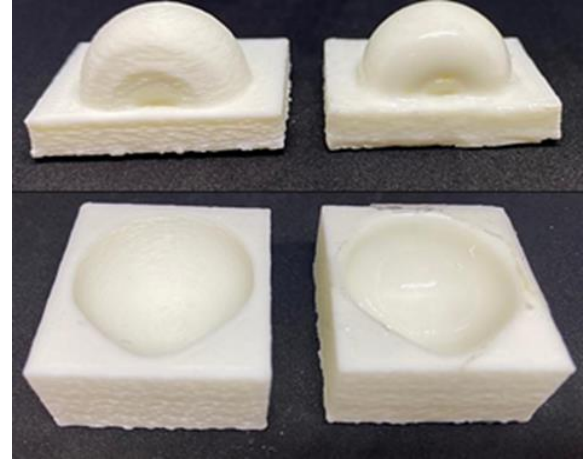


Figure 1: 3D acrylonitrile butadiene styrene printed moulds for human eye's sclera. The figure shows the moulds as printed (left) and after acetone bath smoothing (Right).

Measuring the acoustic properties

The rectangular cuboid samples shown in Figure 5 were placed in a test chamber as shown in Figure 2. The vitreous humour gel was poured in another type of chamber that has mylar film on the sides facing the transducer and the hydrophone. The test chamber was positioned in a water bath between an immersion transducer and a 0.2 mm diameter needle hydrophone (Precision acoustic®, Dorset, UK). A set of immersion transducers V381 (3.5 MHz), V308 (5 MHz), V321 (7.5 MHz), A327 (Olympus®, Tokyo, JP) were used to cover a range of frequencies from 1-10 MHz, at 1 MHz intervals. The transducers were excited in burst mode at 40 cycles by 10 ms inter pulse period, using an arbitrary function generator DG4062 (Rigol®, Beijing, CN). The signal was amplified with 2100L amplifier (Electronic navigation industries, NY, US). The signal of the acoustic wave after passing the chamber was acquired by the hydrophone powered by a DC coupler, using an oscilloscope MSO-5074 (Rigol®, Beijing, CN).

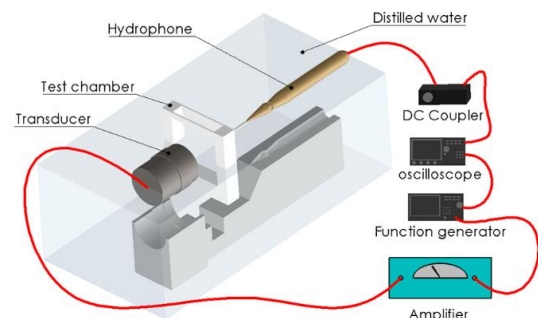


Figure 2: Schematic of transmission attenuation and speed of sound measurement experiments

Acoustic attenuation

The acoustic attenuation coefficient of the sample was calculated from measuring the received signal with and without the sample using Equation 1:

$$\alpha = \frac{20}{h} \log_{10} \left(\frac{A_m}{A_w} \right) \quad (1)$$

where a is the acoustic attenuation factor, h is the sample thickness, A_m and A_w are the root mean square of the received signal amplitudes with and without the material respectively.

Figure 3 shows an example of the received signal's amplitude drop due to the presence of the sample in the path of the wave propagation, where the blue waveform represents the excitation amplitude and the grey waveform show the attenuated waveform due to the presence of the sample in the acoustic path.

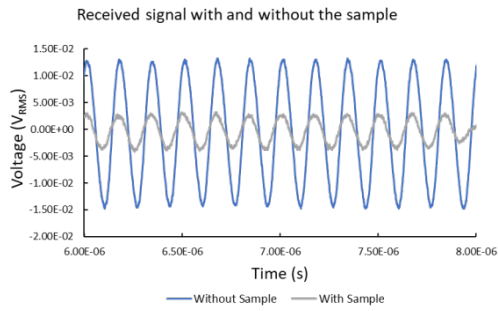


Figure 3: Amplitude drop of the received signal voltage due to the presence of the sample in the acoustic wave path.

Speed of sound

The speed of sound of the samples was calculated through measuring the time delay caused by the presence of the sample in the acoustic path. A pulser/receiver 5077PR (Olympus®, Tokyo, JP) was used instead of the function generator and the amplifier in the experimental setup (Figure 2). Knowing the thickness of the sample is 1 cm, the speed of sound was calculated using Equation 2:

$$c_{phantom} = \frac{h}{\Delta t + \frac{h}{c_{water}}} \quad (2)$$

where $c_{phantom}$ is the speed of sound of the sample, h is the sample thickness, Δt is the time delay due to the presence of the sample in the acoustic path, and c_{water} is the speed of sound in the water.

Figure 4 illustrates the time delay in the received signal caused by the presence of the sample in the acoustic path. The blue waveform is the excitation pressure wave in the water path without the sample, and the grey waveform shows the delay in the acoustic wave due to the presence of the sample in the acoustic path.

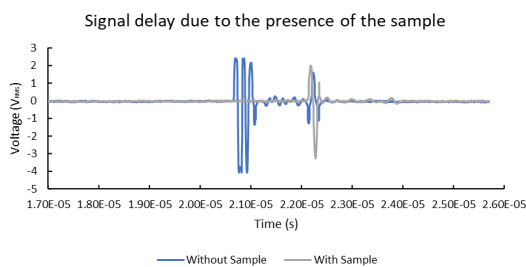


Figure 4: Time delay of the received signal due to the presence of the sample in the acoustic path

Acoustic impedance

The magnitude of the specific acoustic impedance Z of the

samples was calculated using Equation 3:

$$Z = \rho c \quad (3)$$

where ρ is the volumetric density and c is the speed of sound of the sample.

The volumetric density of the samples was measured through measuring the volume and mass of the samples and also derived from the rule of mixture.

Results and Discussion

The moulded rectangular cuboids of PDMS are shown in Figure 5. Increased curing agent to the elastomer percent slightly reduces the transparency. The presence of barium titanate resulted in significant decrease of transparency with percentage as low as 0.1%. Samples with barium titanate of 1% and more became opaque.

The agar samples are a biological compound derived from algae and therefore did degrade. They developed mould after a period of two months of refrigeration, unlike the PDMS samples which maintained their structure dignity for more than a year in room temperature.

The acrylamide-based phantom mimicking the vitreous humours solution showed as a clear solution with no effect of the sephadex powder suspended within them on their transparency.

Acoustic attenuation

Table 2 shows the attenuation coefficient of the tissue mimicking gel of the vitreous humour at frequencies between 3 MHz and 9 MHz. The results are expected to show that the attenuation factor increase in higher frequency. However, some of the results in the table shows otherwise. This could be due to uneven distribution of the scattering agent sephadex in the sample or that it moves through the gel due to poor polymerisation. The sample of 1.7% acrylamide had an average attenuation factor of 0.104 which is close to the vitreous humour attenuation factor of 0.1 dB cm⁻¹ .MHz⁻¹ (Table 1).

The attenuation coefficient of different PDMS and PDMS with BaTiO₃ at frequencies between 3 MHz and 9 MHz are reported in Table 3. Increasing the barium titanate scattering agent percentage in the sample significantly increased the attenuation factor. The average attenuation factor increased from 3.9 dB cm⁻¹ .MHz⁻¹ for PDMS 1:5, to 7.5 dB cm⁻¹ .MHz⁻¹ for PDMS 1:5 with 10% of BaTiO₃. Despite that increase, the attenuation factor is still significantly below the attenuation coefficient of the sclera which is 11.7 dB cm⁻¹ .MHz⁻¹ (Table 1).

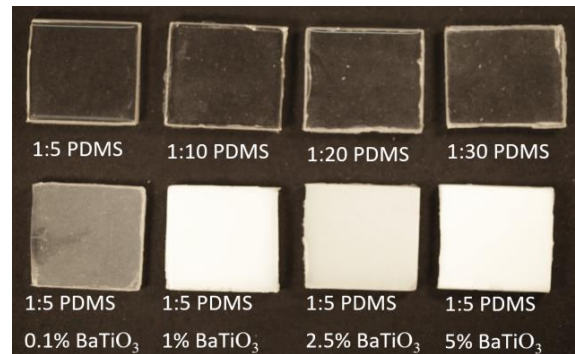


Figure 5: Polydimethylsiloxane (PDMS) samples of different elastomer to curing agent ratios. The second row of samples include barium titanate (BaTiO₃) of different percentages in their composition. The figure shows that barium titanate

Table 2: Acoustic attenuation factor as function of frequency of the tissue mimicking gel of the vitreous humour with different acrylamide concentrations

Acrylamide %	1.6%	1.625%	1.65%	1.675%	1.70%
Frequency (MHz)	Attenuation (dB cm ⁻¹)				
3	0.09±0.06	0.32±0.01	0.09±0.05	0.18±0.13	0.25±0.05
4	0.33±0.11	0.24±0.12	0.29±0.11	0.39±0.11	0.17±0.11
5	0.44±0.12	0.3±0.01	0.27±0.12	0.26±0.14	0.79±0.22
6	0.5±0.15	0.44±0.08	0.48±0.23	0.31±0.07	0.66±0.28
7	0.54±0.17	0.3±0.1	0.58±0.13	0.49±0.2	0.87±0.13
8	0.79±0.13	0.68±0.09	0.45±0.21	0.79±0.08	0.79±0.2
9	0.82±0.3	0.77±0.52	0.77±0.13	1.01±0.15	1.09±0.57

Table 3: Acoustic attenuation factor as function of frequency of the tissue mimicking phantom of the sclera made of different Polydimethylsiloxane combinations

	PDMS 1:30	PDMS 1:20	PDMS 1:10	PDMS 1:5	PDMS 1:5, 0.1% BaTiO ₃	PDMS 1:5, 1% BaTiO ₃	PDMS 1:5, 2.5% BaTiO ₃	PDMS 1:5, 5% BaTiO ₃	PDMS 1:5, 10% BaTiO ₃
Frequency (MHz)	Attenuation (dB cm ⁻¹)								
3	8.09±0.12	7.18±0.02	8.66±0.07	8.35±0.05	8.72±0.09	8.97±0.22	10.82±0.21	15.14±1.3	21.76±0.06
4	12.42±0.01	11.6±0.1	13.6±0.07	13.1±0.19	12.19±0.13	15.51±0.11	15.74±0.04	21.4±0.03	27.38±0.46
5	20.02±0.1	19.47±0.09	21.34±0.1	20.16±0.05	19.8±0.15	22.77±0.51	23.96±0.06	31.1±0.07	41.58±1.32
6	22.59±0.17	21.99±0.16	23.24±0.08	23.12±0.43	21.21±0.35	25.2±0.24	29.82±0.18	39.4±0.16	45.18±0.33
7	32.67±0.18	30.62±0.1	31.78±0.12	30.28±0.23	32.83±0.46	35.59±0.16	38.39±0.2	47.11±0.88	N/A
8	37.01±0.12	36.05±0.08	36.29±0.5	32.97±0.3	36.98±0.73	39.33±0.76	44.61±0.61	N/A	N/A
9	41.89±0.69	40.59±0.17	40.98±0.14	42.77±0.33	40.56±0.21	43.27±0.78	N/A	N/A	N/A

Table 4 shows the acoustic attenuation of the agar and agar with barium titanate samples. The 7.5% agar sample with 10% barium titanate had an acoustic impedance of 1.78 dB cm⁻¹ .MHz⁻¹. In comparison with all the

samples formulation in this study, this is the closest acoustic impedance to the human sclera which is 1.67×10⁶ kg m⁻² s⁻¹ (Table 1).

Table 4: Acoustic attenuation factor as function of frequency of the tissue mimicking phantom of the sclera made of different Agar combinations

	2% Agar	5% Agar	7.5% Agar	10% Agar	7.5% Agar, 0.1% BaTiO ₃	PDMS 1:5, 1% BaTiO ₃	7.5% Agar, 5% BaTiO ₃	7.5% Agar, 10% BaTiO ₃
Frequency (MHz)	Attenuation (dB cm ⁻¹)							
3	0.08±0.1	0.38±0.32	0.15±0.22	0.25±0.08	0.22±0.17	0.73±0.02	2.7±0.14	7.19±0.07
4	0.23±0.17	1.29±0.18	1.01±0.25	1.35±0.13	0.4±0.11	0.8±0.04	2.37±0.12	7.25±0.13
5	0.31±0.21	0.84±0.21	0.96±0.04	1.34±0.12	0.67±0.04	0.97±0.07	2.48±0	8.48±0.01
6	0.24±0.11	0.3±0.14	0.82±0.07	1.21±0.09	0.47±0.11	1.44±0.06	3.52±0.3	9.78±0.13
7	0.42±0.11	1.25±0.35	2.49±0.13	2.65±0.14	0.67±0.04	1.21±0.13	3.76±0.15	11.3±0.01
8	0.26±0.06	0.93±0.07	1.06±0.25	1.2±0.06	1.01±0.12	2.05±0.03	3.81±0.04	14.62±0.11
9	0.57±0.01	1.37±0.14	2.01±0.17	2.68±0.13	1.34±0.09	2.3±0.07	5.42±0.34	16.81±0.05

Speed of sound

The speed of sound of the vitreous humour tissue mimicking materials as a function of acrylamide percentage in the mixture are shown in Figure 6. Increasing acrylamide percentage increases the speed of sound of the material. At 1.625 % Acrylamide the sample speed of sound showed as an out layer of the pattern, which is most likely due to human error in sample preparation. Results shows that at 107% acrylamide, the sample's speed of sound equals the speed of sound of the vitreous humour. The presented results except for the out layer at 1.625% acrylamide are in agreement with previously reported results in [12].

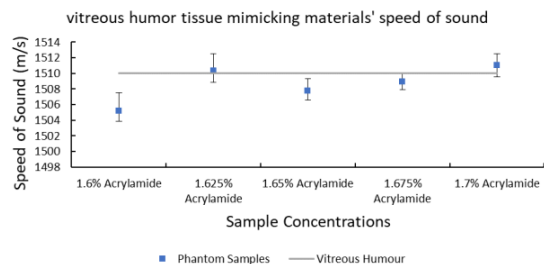


Figure 6: Speed of sound of the tissue mimicking material of the vitreous humour with different concentration of acrylamide.

Figure 7 shows the speed of sound of the PDMS and PDMS with BaTiO₃ samples. The sclera's speed of sound is 1618±46 m s⁻¹ (Table 1), which means that all the PDMS samples have a speed of sound approximately 36% lower than that of the sclera. The figure shows that increasing the curing agent to the elastomer ratio increases the speed of sound and increasing the BaTiO₃ concentration in the samples decreases the speed of sound.

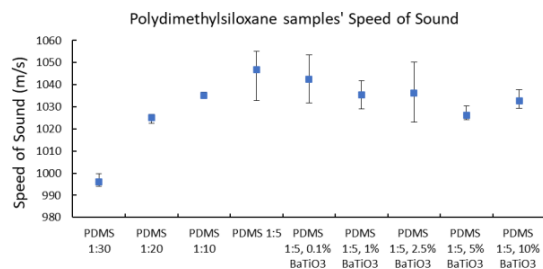


Figure 7: Speed of sound of the tissue mimicking material of the sclera. The figure shows the speed of sound of samples of polydimethylsiloxane (PDMS) of different curing agent to elastomer ratio, and samples of PDMS with barium titanate (BaTiO₃) as scattering agent.

The speed of sound of the pure agar samples increased as the agar percentage in the sample increased (Figure 8). However, as the percentage of barium titanate increased in the 7.5% agar samples, the speed of sound decreased.

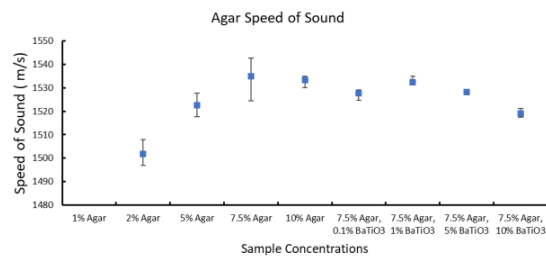


Figure 8: Speed of sound of the tissue mimicking material of the sclera made of Agar with different concentrations and Agar with Barium titanate (BaTiO₃) as scattering agent.

Figures 9 and 10 show the acoustic impedance of the PDMS and Agar samples respectively. The minimum and maximum impedance value correspond to the acoustic impedances calculated from the maximum and minimum densities calculated using the rule of mixture and the variation appears to increase as the ratio of the Barium titanate increases in the samples. The impedance represented by the blue rectangles is calculated from the densities calculated through measuring the volume and the mass of the samples.

The agar samples had acoustic impedances close to those of the sclera. The human's sclera has an acoustic impedance of $1.67 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$ (Table 1), and the closest value to that was the impedance of the 7.5 % agar with 5% BaTiO₃.

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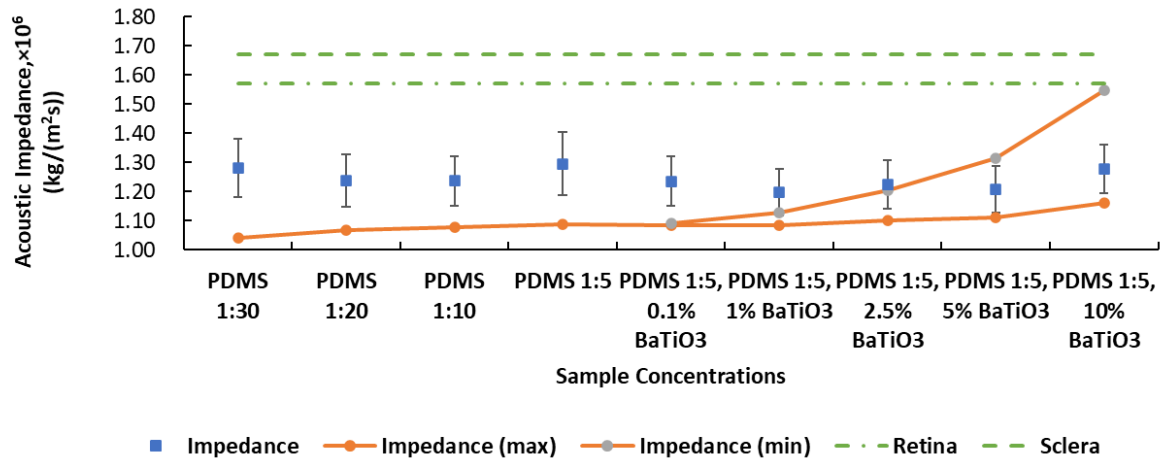


Figure 9: Acoustic impedance of the tissue mimicking material of the sclera. The figure shows the speed of sound of samples of polydimethylsiloxane (PDMS) of different curing agent to elastomer ratio, and samples of PDMS with barium titanate (BaTiO₃) as scattering agent.

Agar Acoustic Impedance

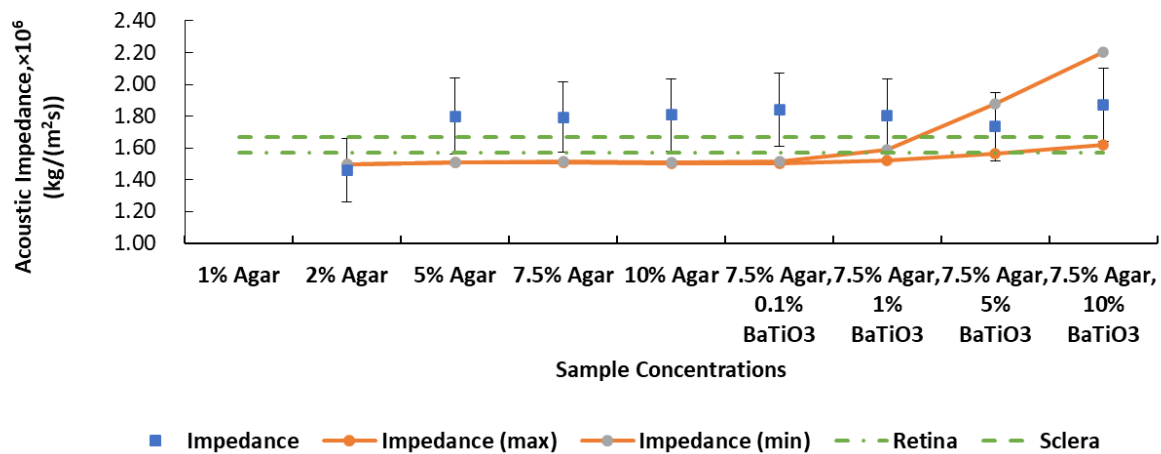


Figure 10: Acoustic impedance of the tissue mimicking material of the sclera made of Agar with different concentrations and Agar with Barium titanate (BaTiO₃) as scattering agent

In shape sclera's tissue mimicking phantom

Figure 11 shows the tissue mimicking phantoms of the human eye's sclera. The figure shows that the PDMS with 5% BaTiO₃ significantly affected the transparency of the sclera's phantom. The molded phantoms replicated the sclera's shape and dimensions with good accuracy.

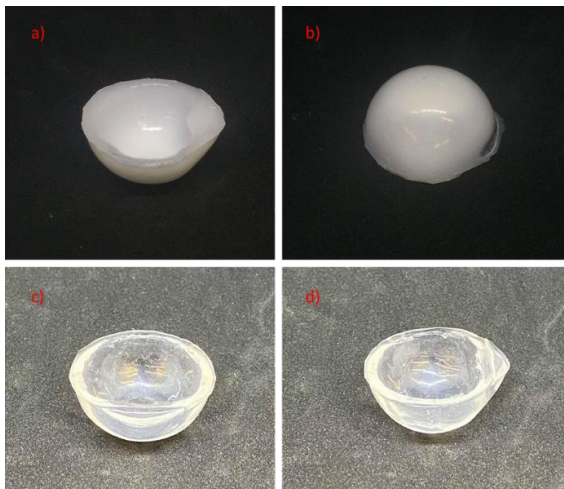


Figure 11: Polydimethylsiloxane (PDMS) tissue mimicking phantom of the human eye's sclera. a and b show phantoms made of 1:5 PDMS with 5% of barium titanate, and c and d show phantoms made of 1:5 pure PDMS.

The in-sclera shape moulded agar samples are shown in Figure 12. The agar samples took the shape of the mould effectively. The presence of the barium titanate made the sample oblique (Figure 12 a and b) where pure agar samples were translucent (Figure 12 c and d).

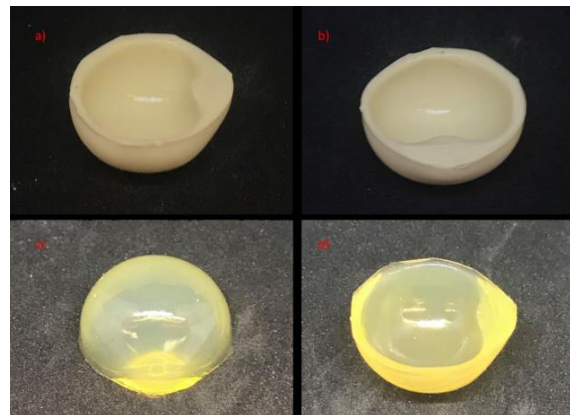


Figure 12: Agar tissue mimicking phantom of the human eye's sclera. Images a and b show phantoms made of 7.5% agar and 10% barium titanate, and c and d show phantoms made of 10% pure agar.

Conclusion

The tissue mimicking phantom of the eye showed acoustic properties close to those of the human eye's sclera and vitreous humour. Polydimethylsiloxane showed the ability to be moulded in the shape and size of human's eye sclera, replicate the acoustic properties of the sclera while providing good transparency at 1:5 curing agent to elastomer ratio. These PDMS phantom eye is of good use for research that requires optical access inside the eye.

The 7.5% Agar sample was shown to have the closest speed of sound to the that of the human sclera with only 5% difference, However the PDMS with 10% Barium titanate sample had the closest attenuation factor to that of the human sclera. The 1.7% acrylamide had matching speed of sound and attenuation factor to that of the human's vitreous humours.

The eye phantom can be used in future work to observe the translation of acoustofluidicly manipulated drug carriers.

References

- [1] P. Li, Z. Yang, and S. Jiang, "Tissue mimicking materials in image-guided needle-based interventions: A review," *Materials Science and Engineering: C*, vol. 93, pp. 1116-1131, 2018, doi: <https://doi.org/10.1016/j.msec.2018.09.028>.
- [2] H. Alsadiq, "Acoustofluidic manipulation of microbubbles for targeted drug delivery applications," PhD thesis, School of Mechanical and Mining Engineering, The University of Queensland, Australia, 2022.
- [3] C. D. Arvanitis, M. Bazan-Peregrino, B. Rifai, L. W. Seymour, and C. C. Coussios, "Cavitation-enhanced extravasation for drug delivery," *Ultrasound in medicine & biology*, vol. 37, no. 11, pp. 1838-1852, 2011, doi: <https://doi.org/10.1016/j.ultrasmedbio.2011.08.004>.
- [4] S. S. Thakur, N. L. Barnett, M. J. Donaldson, and H. S. Parekh, "Intravitreal drug delivery in retinal disease: are we out of our depth?," *Expert opinion on drug delivery*, vol. 11, no. 10, pp. 1575-1590, 2014, doi: <https://doi.org/10.1517/17425247.2014.927864>.
- [5] S. S. Thakur et al., "Ultrasound-responsive nanobubbles for enhanced intravitreal drug migration: An ex vivo evaluation," *European Journal of Pharmaceutics Biopharmaceutics*, vol. 136, pp. 102-107, 2019, doi: <https://doi.org/10.1016/j.ejpb.2019.01.014>.
- [6] H. AlSadiq, K. Tupally, R. Vogel, H. S. Parekh, and M. Veidt, "Multi-physics study of acoustofluidic delivery agents' clustering behavior," *Physics in Medicine & Biology*, vol. 67, no. 1, p. 015002, 2022, doi: <https://doi.org/10.1088/1361-6560/ac4666>.
- [7] H. Alsadiq, K. Reddy, H. Parekh, and M. Veidt, "Influence of acoustofluidic parameters on velocity streaming of sonicated medical microbubbles," in *Australian Acoustical Society Annual Conference, AAS 2018*, 2018: Australian Acoustical Society, pp. 22-29.
- [8] C. N. Acconcia, A. Wright, and D. E. Goertz, "Translational dynamics of individual microbubbles with millisecond scale ultrasound pulses," *The Journal of the Acoustical Society of America*, vol. 144, no. 5, pp. 2859-2870, 2018, doi: <https://doi.org/10.1121/1.5063353>.
- [9] G. Rajeshkumar, R. Vishnupriyan, and S. Selvadeepak, "Tissue Mimicking Material an Idealized Tissue Model for Clinical Applications: A Review," *Materials Today: Proceedings*, vol. 22, pp. 2696-2703, 2020/01/01/ 2020, doi: <https://doi.org/10.1016/j.matpr.2020.03.400>.
- [10] A. Cafarelli, A. Verbeni, A. Poliziani, P. Dario, A. Menciassi, and L. Ricotti, "Tuning acoustic and mechanical properties of materials for ultrasound phantoms and smart substrates for cell cultures," *Acta Biomaterialia*, vol. 49, pp. 368-378, 2017/02/01/ 2017, doi: <https://doi.org/10.1016/j.actbio.2016.11.049>.
- [11] T. V. Chirila and Y. Hong, "Chapter C2 The Vitreous Humor," in *Handbook of biomaterial properties*: Springer, 2016, pp. 125-134.
- [12] L. A. Negron, F. Viola, E. P. Black, C. A. Toth, and W. F. Walker, "Development and characterization of a vitreous mimicking material for radiation force imaging," *IEEE Trans Ultrason Ferroelectr Freq Control*, vol. 49, no. 11, pp. 1543-51, Nov 2002, doi: <https://doi.org/10.1109/TUFFC.2002.1049736>.
- [13] D. Rohrbach et al., "Material Properties of Human Ocular Tissue at 7-microm Resolution," *Ultrason Imaging*, vol. 39, no. 5, pp. 313-325, Sep 2017, doi: <https://doi.org/10.1177%2F0161734617713498>.
- [14] J. M. Thijssen, H. J. M. Mol, and M. R. Timmer, "Acoustic parameters of ocular tissues," *Ultrasound in Medicine & Biology*, vol. 11, no. 1, pp. 157-161, 1985/01/01/ 1985, doi: [https://doi.org/10.1016/0301-5629\(85\)90018-3](https://doi.org/10.1016/0301-5629(85)90018-3).
- [15] D. Rohrbach, H. O. Lloyd, R. H. Silverman, and J. Mamou, "Fine-resolution maps of acoustic properties at 250 MHz of unstained fixed murine retinal layers," *J Acoust Soc Am*, vol. 137, no. 5, pp. EL381-7, May 2015, doi: <https://doi.org/10.1121/1.4916790>.
- [16] R. C. Augusteyn, D. Nankivil, A. Mohamed, B. Maceo, F. Pierre, and J.-M. Parel, "Human ocular biometry," *Experimental eye research*, vol. 102, pp. 70-75, 2012, doi: <https://doi.org/10.1016/j.exer.2012.06.009>.



The next Acoustical Society of New Zealand biennial conference is locked and loaded... and is going to be in Tauranga Moana!

The theme is "... And now for something completely different!", which admittedly isn't a very typical theme for a conference. It has been chosen for two excellent reasons:

- 1) Tauranga – a beautiful harbour city in the Bay of Plenty – will be the first city outside of Auckland, Wellington and Christchurch to host our conference. It is 2.5hrs drive (or a quick 45min flight) from Auckland on the Aotearoa east coast. Famed for its white sand surf beaches at Mount Maunganui and Papamoa, and for 'The Mount' itself... an iconic volcanic standing tall above the waves (named Mauao in Te Reo Māori)
- 2) The world is a very serious place right now. Geopolitical tensions are high around the globe, and some once reliable government institutions appear to be fixated

on fighting fire with petrol. Parody and irreverence have long been used as coping mechanisms for the masses, so our 2026 Conference is going to provide us with something to chuckle about by being just a little bit... silly

We will still have a delectable array of high-quality papers and presentations. Our keynotes (to be announced) will still be expertly selected for their knowledge on the current hot topics from at home and abroad. We will promote the same friendly, collegial atmosphere in which to meet, reacquaint and share a laugh with like-minded individuals. We will provide a splendid array of trade stands thanks to the unwavering support of our sponsors. All the key ASNZ conference ingredients will still be present, but in an entirely new city... and possibly involving silly hats.

Hope to welcome you to Tauranga in November 2026!

James Whitlock – Conference Chair

Investigating the directional accuracy of ambisonics microphone arrays

Jessica Robinson

Marshall Day Acoustics Ltd, 84 Symonds St, Grafton, Auckland 1010 jessica.robinson@marshallday.co.nz

Abstract

Ambisonics microphones offer many advantages over omnidirectional microphones for room acoustic measurements. In particular, these can be used to generate 3D room impulse responses to better understand the directions of various reflections in a room. However, the large variety of ambisonics microphone systems now on the market have different numbers of capsules, different configurations, and different ambisonics encoding methods, which can lead to discrepancies between results. Six ambisonics microphone systems were tested using a loudspeaker array and the 3D impulse response software IRIS, to assess their directional accuracy in the horizontal plane.

Introduction

Ambisonics microphone arrays, first produced in the 1970s by Calrec Audio [1] from designs by Gerzon and Craven [2], have become increasingly popular for applications in studio recording and virtual reality. By arranging four microphones in a tetrahedral array, the sounds in the X, Y and Z directions can be separated. The process of converting the raw microphone signals (A-format) to the X, Y, Z and omnidirectional components (B-format) is known as encoding. Once the signal has been encoded, the direction of a sound source can be identified from its strength in each axis. More microphone capsules can be used for higher spatial resolution. Many ambisonics microphone arrays are now commercially available, with various numbers of capsules in different configurations.

Ambisonics microphone arrays offer a useful tool for acoustic measurements, including 3D room impulse responses [3]. By emitting a swept sine signal and recording it with the microphone array, both the timing and direction of acoustic reflections can be determined. These 3D room impulse responses can then be used to understand the spatial acoustic characteristics of a room.

IRIS is a program for performing these measurements [4, 5]. It records the swept sine signals through the microphone, processes these into ambisonics impulse responses, and generates 3D plots of the impulse responses. Some microphones can perform the A-format to B-format encoding onboard and send a four channel ambisonics signal directly to IRIS. Other manufacturers have provided encoding software which has been integrated into IRIS to convert to B-format within the software.

However, the different numbers of capsules, different configurations, and different ambisonics encoding methods between microphone systems can lead to different levels of

accuracy in direction [6]. Six microphones were tested with IRIS - the Zoom H3-VR [7], Core Sound TetraMic [8], Rode NT-SF1 [9], Sennheiser Ambeo [10], Voyage Spatial Mic [11], and Zylia ZM-1 [12] - to compare their directional accuracy.

Method

The microphones were set up in the centre of a 12-channel spherical loudspeaker array. The six loudspeakers in the horizontal plane, each 60° apart, were used to test the directional accuracy of the microphone in the horizontal plane. The microphones and speakers were aligned using a laser measuring tape to ensure each microphone was mounted in the same position. The array was in a highly absorptive space, with no significant room reflections.



Figure 1: Loudspeaker array testing setup

Table 1. Ambisonics microphone arrays

	Model	Microphone capsules	Ambisonics order	Price (USD)*	Encoding method
	Zoom H3-VR	4	1 st	\$250	Onboard FuMa encoding
	Core Sound TetraMic	4	1 st	\$800	Encoder provided
	Rode NT-SF1	4	1 st	\$1000	Encoder provided
	Sennheiser Ambeo	4	1 st	\$1500	Encoder provided
	Voyage Spatial Mic	8	2 nd	\$3000	Onboard AmbiX encoding
	Zylia ZM-1	19	3 rd	\$1700	Encoder provided

*Prices from online retailers at time of publishing [13, 14, 15, 16, 17, 18]

Microphones were positioned facing forward in the room. A swept sine signal was sent to each of the six horizontal loudspeakers, delayed sequentially in an anticlockwise direction starting from the front left loudspeaker. This is located at 30° on the direction plots. The resulting signal was then recorded by the ambisonics microphone into *IRIS*. *IRIS* could then use the intensity in each direction to plot the direction of the sound from the six loudspeakers.

The plots represent the direction as determined by *IRIS*, via the intensity method [3], using a 4 ms window of energy from the impulse response corresponding to each simulated reflection. The directions calculated by *IRIS* were then rotated slightly to minimise error, compensating for any slight rotational misalignments of the physical microphone setup.

The microphones tested included four first-order four-channel tetrahedral arrays, one second-order eight-channel array, and one third-order 19-channel array. All were open arrays except for the enclosed Zylia ZM-1. Two were capable of onboard ambisonics encoding, and four provided software encoding to be used with *IRIS*.

Results & Discussion

All microphone arrays reported the direction of sounds to within $\pm 9^\circ$. The most accurate were the Core Sound TetraMic, Sennheiser Ambeo and the Zylia ZM-1 microphones.

Table 2. Microphone array directional accuracy in horizontal plane

Microphone array	Error
Core Sound TetraMic	$\pm 3.1^\circ$
Sennheiser Ambeo	$\pm 3.2^\circ$
Zylia ZM-1	$\pm 3.5^\circ$
Rode NT-SF1	$\pm 6.2^\circ$
Zoom H3-VR	$\pm 7.4^\circ$
Voyage Spatial Mic	$\pm 8.7^\circ$

The Zylia, Rode and Zoom microphones all had lower directional accuracy in the horizontal plane. For the tetrahedral arrays, it is worth noting that the loudspeakers in these positions (at 90° and 270°) would both give equal energy to the two nearest microphone capsules. This may be the cause of the lower directional accuracy in these directions, especially if the individual capsules were not properly matched due to inconsistencies with the construction.

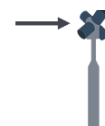


Figure 2. Horizontal sound source to tetrahedral array

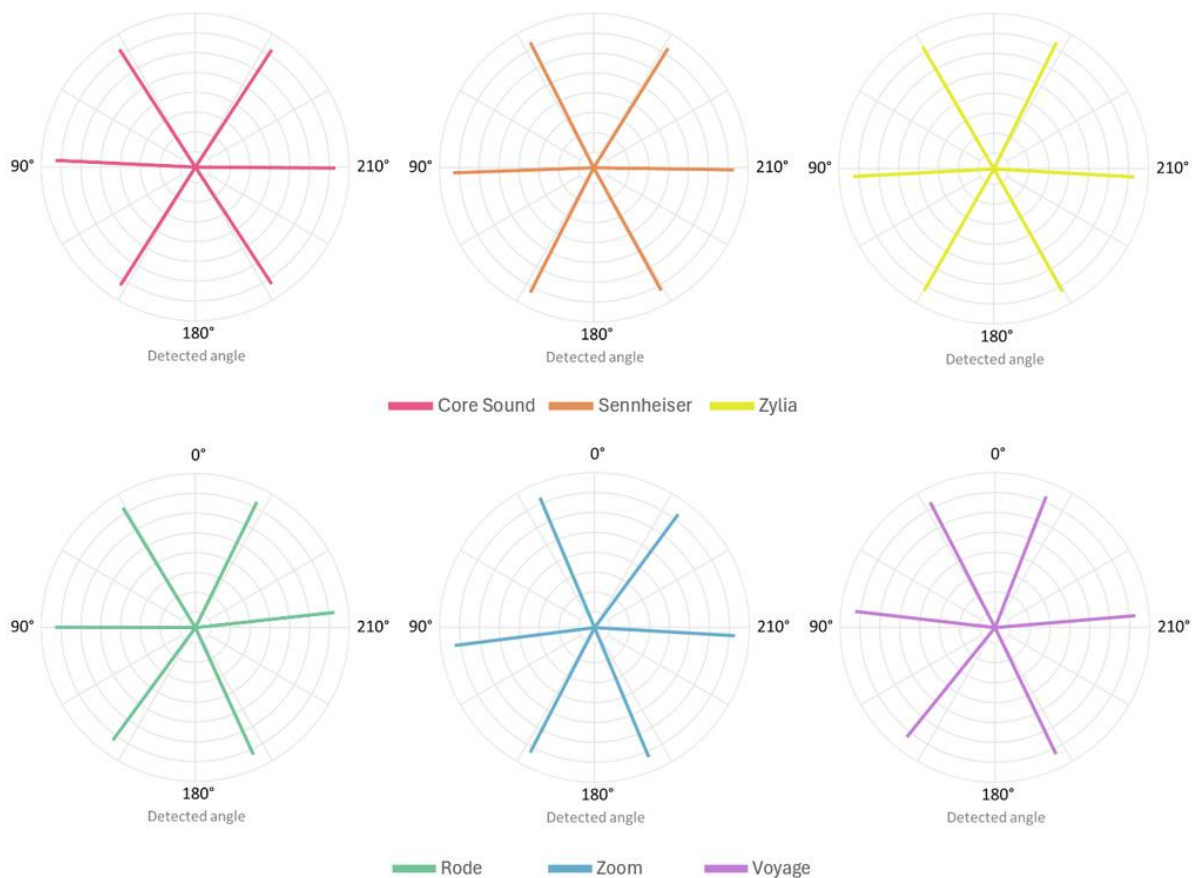


Figure 3. Direction detected by each microphone array

The $\pm 3.1^\circ$ error associated with the Core Sound TetraMic measurements was lower than the error of $\pm 7.5^\circ$ previously reported by Protheroe et al. [3]. This may be due to differences in experimental setup, especially as their experiment captured significantly more directional information (72 impulse response measurements in 5° increments).

The $\pm 7.4^\circ$ error associated with the Zoom H3-VR is slightly higher than the error of $\pm 5^\circ$ reported by Dunn [19]. Again, differences in experimental setup may have led to this discrepancy, as well as variation between units and over time.

Conclusion

All microphones tested were able to locate the loudspeakers with a directional accuracy of $\pm 9^\circ$ or better in the horizontal plane, which would seem to be suitable for most ambisonics recordings and measurements. Where a higher degree of precision is desired for 3D room impulse response measurements, or the microphone array needs to be used for acoustic tracking, the Core Sound TetraMic, Sennheiser Ambeo and Zylia ZM-1 performed the best with horizontal errors of $\pm 3.1^\circ$, $\pm 3.2^\circ$ and $\pm 3.5^\circ$ respectively. Further testing would be needed to report accuracy with more certainty, by testing with intervals smaller than 60° and with different elevations. This could be performed with a larger loudspeaker array, or by rotating the microphone in a controlled environment. With small enough intervals, the polar responses for the omnidirectional and dipole modes for each microphone could be generated.

Although the microphone with the most capsules, the Zylia ZM-1, performed well, it is hard to determine the effect of number of capsules on directional accuracy without testing more ambisonics microphones, and without a more controlled testing environment. Additionally, *IRIS* only uses the first-order ambisonics modes to calculate direction, so more microphone capsules would only contribute to more accurate first-order

polar responses, rather than higher-order ambisonics. Bertet et al. have shown that higher-order microphones are more capable of accurately reproducing a sound field than first-order arrays [6], but differences between microphone capsules, array configurations and encoding methods among the arrays will also affect their localisation accuracy.

The tests performed relied on the manufacturer-provided encoders - either built-in or added to the *IRIS* software. It may be of interest to compare these encoders to other encoder plugins, such as SPARTA Array2sh [20], which analytically determines encoding filters based on the geometry and properties of the microphone array.

Acknowledgments

The author would like to thank Daniel Protheroe and Malcolm Dunn for their assistance.

References

- [1] K. Farrar, "Soundfield microphone," *Wireless World*, vol. 85, no. 1526, pp. 48-50, 1979.
- [2] P. Craven and M.A. Gerzon. "Coincident microphone simulation covering three dimensional space and yielding various directional Outputs". U.S. Patent 4,042,779, 16 August 1977.
- [3] D. Protheroe and B. Guillemain. "3D impulse response measurements of spaces using an inexpensive microphone array," *Building Acoustics*, vol. 20.2, pp. 141-155, 2013.
- [4] M. Dunn and D. Protheroe. "Visualization of early reflections in control rooms," *Audio Engineering Society Convention 137*. Audio Engineering Society, 2014.

- [5] "IRIS." <https://www.iris.co.nz/> (accessed May. 30, 2024).
- [6] S. Bertet, J. Daniel, E. Parizet and O. Warusfel. "Investigation on localisation accuracy for first and higher order ambisonics reproduced sound sources." *Acta Acustica united with Acustica*, vol. 99, no. 4, pp. 642-657, Jul. 2013.
- [7] "The Zoom H3-VR." <https://zoomcorp.com/en/us/handheld-recorders/handheld-recorders/h3-vr-360-audio-recorder/> (accessed May. 30, 2024).
- [8] "Core Sound TetraMic™ 1st-order Ambisonic Microphone." <https://www.core-sound.com/products/tetramic> (accessed May. 30, 2024).
- [9] "NT-SF1." <https://rode.com/en/microphones/360-ambisonic/nt-sf1> (accessed May. 30, 2024).
- [10] "3D audio microphone Ambeo VR Mic." <https://www.sennheiser.com/en-nz/catalog/products/microphones/ambeo-vr-mic/ambeo-vr-mic-507195> (accessed May. 30, 2024).
- [11] "Spatial Mic – Voyage Audio." <https://voyage.audio/spatialmic/>
- [12] "ZYLIA – 3D Audio Recording & Post-processing Solutions." <https://www.zylia.co/zylia-zm-1-microphone.html> (accessed May. 30, 2024).
- [13] "H3-VR 360° Audio Recorder." <https://zoomcorp.com/en/us/handheld-recorders/handheld-recorders/h3-vr-360-audio-recorder/> (accessed May. 30, 2024).
- [14] "Core Sound TetraMic™ 1st-order Ambisonic Microphone." <https://www.core-sound.com/shop/tetramic> (accessed May. 30, 2024).
- [15] "RODE NT-SF1 True Condenser Ambisonic Microphone Kit." <https://avlgear.com/products/rode-nt-sf1-true-condenser-ambisonic-microphone-kit> (accessed May. 30, 2024).
- [16] "Sennheiser Ambeo VR 3D Microphone." <https://www.trewaudio.com/product/sennheiser-ambeo-vr-mic/> (accessed May. 30, 2024).
- [17] "Shop Spatial Mic Dante 2nd-Order Ambisonic Microphone." <https://voyage.audio/shop/spatial-mic-dante/> (accessed May. 30, 2024).
- [18] "ZYLIA PRO Have it all!" <https://www.zylia.co/shop/zylia-pro-have-it-all-zylia-pro-have-it-all-216#attr=> (accessed May. 30, 2024).
- [19] M. Dunn. "3D room acoustic measurements with low cost equipment." *Proceedings of the Acoustical Society of New Zealand Conference 2021*, Acoustical Society of New Zealand, 2021.
- [20] L. McCormack and A. Politis. "SPARTA & COMPASS: Real-time implementations of linear and parametric spatial audio reproduction and processing methods." *AES International Conference on Immersive and Interactive Audio*. Audio Engineering Society, pp. 1-12, 2019.



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Tapping machine vs rubber ball for impact sound - Case study in result variability

Jeffery Chen ⁽¹⁾, Tim Beresford ⁽¹⁾, Thomas Warren ⁽¹⁾

⁽¹⁾ NDY, Level 1, 29 Customs Street West, Auckland, New Zealand Jeffery.Chen@ndy.com

Abstract

Residential inter-tenancy floors are required to achieve the Building Code G6 requirements for airborne and impact sound, where compliance is often determined through verification testing. For impact sound, a tapping machine is the industry standard in New Zealand for verification of the Field Impact Insulation Class (FIIC) rating. Although uncommon and not adopted in the Building Code, a standardised rubber ball can be used to assess impact sound especially at lower frequencies. This paper explores the variability in test results for a floor sample that could be achieved using both methods of impact sound assessment by selectively choosing source positions used in the calculation to influence the result in either favour. Data for the study has been gathered through routine testing of floor samples, where an excess number of source positions were tested so that the best and worst position combinations could be selectively chosen to assess potential variability of results. Through applying the lens of bias on the tests, we found that the range in achievable for both tapping machine (1dB) and rubber ball (3dB) are relatively minor; with tapping machine having lower variability. This indicated that the rubber ball had utility for a relatively consistent in-situ test method of low frequency impact noise.

Introduction

In the building industry, acoustic engineers/consultants typically find themselves carrying out FIIC testing to verify on-site performance of floor constructions' impact sound insulation. This could be for compliance against Building Code G6 requirements [1] or, project-specific requirements. This paper presents case studies exploring the variability in results that can occur during routine testing. This has been tested by taking an excess number of source positions (tapping machine positions) on several floor systems and finding the variability in results that could be achieved using the minimum number of standard-compliant positions per test.

The rubber ball drop method [2] is an alternative to assessing impact sound insulation. It has benefits for assessing low frequency noise compared to a tapping machine, and is increasingly researched for use in lightweight buildings where a tapping machine may not fully characterise the human perception of impact noise. The rubber ball drop test allows different combinations of source/receiver positions per test. Similarly to the tapping machine methodology, we have conducted an excess number of source and receiver room positions to determine the variability of results for any given test in the case studies.

The tapping machine test is widely used and trusted by consultants and councils as a measure of floor impact noise performance. By comparing the variability between test positions for tapping machine tests with the variability between positions with a ball drop test, we hope to provide some confidence (or doubt, if variability was found to be high) for rubber ball drop testing.

The data presented in this paper is gathered from four sites, where the floor construction differs between each site. In assessing results from routine testing, we found the variability in results for each floor sample that could be measured depending on the testing engineer's chosen source positions across the sample.

Test approach

Tapping Machine

As the intent of this study was to identify the variability of results during routine on-site testing, tapping machine positions were selected with a grid-like structure (indicatively as shown below) to emulate positions that could likely be used during testing. Spacings were at least 0.5m apart, in accordance with the test standard [2].

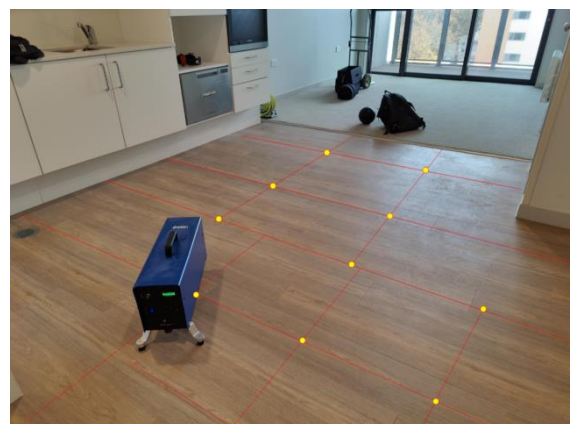


Figure 1. Indicative tapping machine positions

Orientation of the tapping machine for the sample floors was set at a 45-degree angle from beams and primary structural elements to minimise variables that may influence the results.

The number of tapping machine positions varied from 8 – 18 positions subject to available floor-space of the hard-floor finishes. Sample floors where hard-floor finishes were limited to kitchen counter areas inherently have fewer positions than those where the entire living-room spaces consisted of hard-floor finishes.

The microphone measurement technique was kept consistent for each floor sample: a sweeping motion at identical locations throughout the receiver room to obtain a room average over 30 seconds. The intent was to minimise the test methodology variability between tests, such that the only variable was the tapping machine position.

For results processing for Building Code sign-off testing, typically this involves a minimum of four tapping machine positions for a single FIIC result. For the purposes of this study, the best four and worst four positions for each sample were used to determine the range in result for each floor sample that could be achieved, depending on the four test positions chosen by a notional testing engineer.

Rubber Ball Drop

Rubber ball testing involves dropping a standardised ball from a standardised height and measuring the maximum noise levels below, often reported as a L'_{iA}, F_{max}, V, T . Further test details can be found in the ISO test standard [3].

For the rubber ball method, five source positions were used for each floor sample. Each source position had five receiver positions, for a total of 25 measurements per floor sample.

To determine the variability of L'_{iA}, F_{max}, V, T , all five source positions were used with only two measuring positions for each source position, making a total of 10 measurements per result. To determine the worst L'_{iA}, F_{max}, V, T result, the worst two sets were used for each of the five source positions. To determine the best result, the best two sets were used for each of the five source positions. As with the tapping machine testing, we can then see the potential variability in results achieved by a notional testing engineer.

TAPPING MACHINE FLOOR SAMPLES

Floor Sample A

Floor sample A consisted of vinyl on acoustic underlay, with floor-finish extent 3.3m x 1.5m. The floor substrate consisted of 200mm suspended reinforced concrete slab (80mm profiled metal tray). Below slab comprised 100mm air gap, insulated with 75mm polyester insulation and finished with plasterboard ceiling.

The following figure depicts the tapping machine positions in red and blue. For this sample, 8 tapping machine locations were used, where each tapping machine consisted of two tapping machine orientations orientated 90 degrees apart. This results in a total of 16 test positions of the tapping machine.

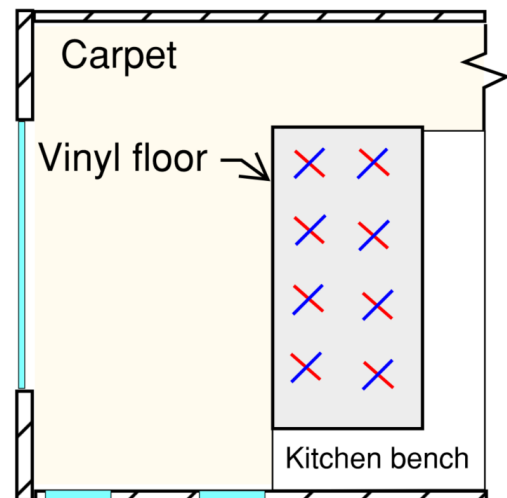


Figure 2. Sample A tapping machine positions (indicated red and blue)

Floor Sample B

Floor sample B is identical to floor sample A, located in another apartment within the same building. This test however only consisted of a single tapping machine orientation for the eight positions.

Floor Sample C

Floor sample C consists of vinyl floor covering over acoustic underlay, spanning the kitchen for an approximate area of 3.0m x 3.0m as shown below. The floor substrate is 80mm profiled metal tray with 100mm concrete topping. Below slab comprises 100mm air gap, insulated with 25mm insulation and finished with plasterboard ceiling. 13 tapping machine positions were assessed for this floor sample.

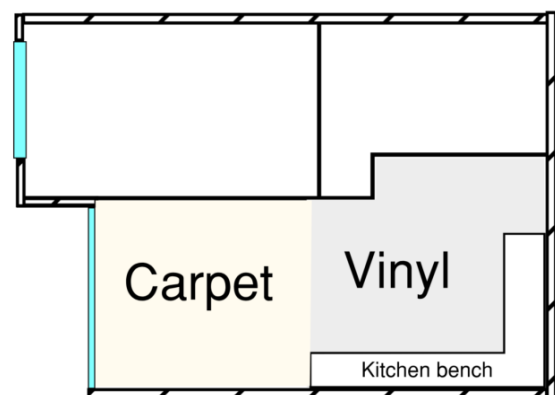


Figure 3. Sample C floor layout

Floor Sample D

Floor sample D consists of timber plank on acoustic underlay, spanning the entirety of the kitchen/dining/living area. The floor substrate is of concrete construction (full details not available). 18 tapping machine positions were used for this floor sample.

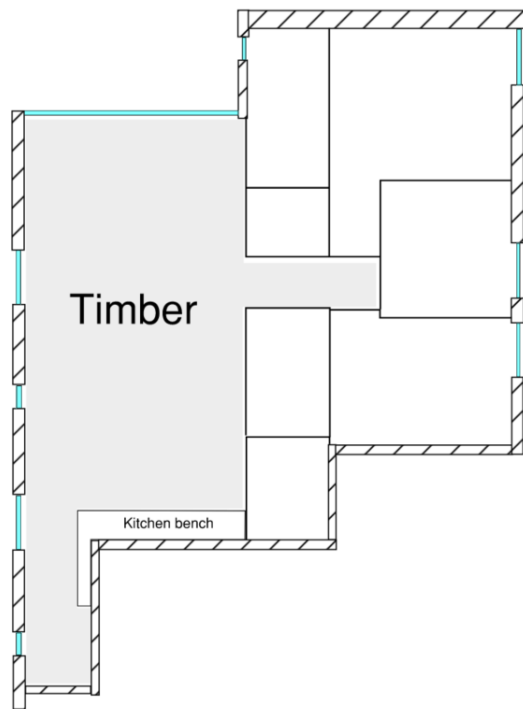


Figure 4. Sample D floor layout

Floor Samples E through L

These samples were all taken from the same project. The floor substrate is of concrete construction (full details not available). We do not have tapping machine data with multiple positions available for this building.

Tapping Machine Range in Results

After selecting the four best/worst positions for each floor sample with tapping machine data, the following table outlines the potential results and range.

Table 1. Tapping Machine Range of FIIC Results

	Min.	Max	Range
Sample A	FIIC 59	FIIC 60	1 dB
Sample B	FIIC 57	FIIC 58	1 dB
Sample C	FIIC 59	FIIC 60	1 dB
Sample D	FIIC 60	FIIC 61	1 dB

As can be seen, for all floors tested there is very little variability (1dB) in the results that could be achieved by selectively (or randomly) choosing 4 test positions. This is reassuring given the widespread use of tapping machine testing for Building Code certification in New Zealand and other countries.

Rubber Ball Range in Results

After selecting the best and worst source/receiver positions for the rubber ball testing, the following table outlines the potential results and range.

Table 2. Rubber Ball Range in $L'_{IA,Fmax,V,T}$ Result

	Min.	Max	Range
Sample C	49 dB	52 dB	3 dB
Sample E	48 dB	50 dB	2 dB
Sample F	47 dB	49 dB	2 dB
Sample G	47 dB	50 dB	3 dB
Sample H	48 dB	50 dB	2 dB
Sample I	47 dB	48 dB	1 dB
Sample J	46 dB	48 dB	2 dB
Sample K	42 dB	43 dB	1 dB
Sample L	39 dB	40 dB	1 dB

Of the rubber ball case study samples, the maximum observed range between the best and worst achievable results on one floor is 3dB, with the smallest range being 1dB.

Discussion and Comparison of Tapping Machine vs Rubber Ball

For the sample where we have both tapping machine and rubber ball data (sample C), the rubber ball drop data has slightly more variability at 3dB compared to 1dB for the tapping machine. There were no rubber ball samples exhibiting variability of greater than 3dB, and several with 1 or 2dB variability.

Despite the rubber ball having slightly higher variability than the tapping machine, the variability of up to 3dB is still relatively low when considering that the rubber ball measurements were selected to bias a maximally favourable/unfavourable result. During routine testing where source and receiver positions should be chosen without bias, most results would be statistically clustered within a smaller range.

The range observed from the rubber ball method is surprisingly small considering the frequency range used in analysis extends one octave lower than the tapping machine method. Testing into lower frequency ranges is known to make repeatable results more difficult due to the wavelengths involved. The relatively low variability suggests that the rubber ball may be a suitable method to obtain consistent results for assessing low-frequency impact noise that correlates more with footfall noise in situ, not just in a laboratory setting.

From the case studies, both the tapping machine and rubber ball methods of assessing impact sound insulation are shown to have a small range of variability when considering the selective-measurement methodology of determining the minimum and maximum possible results from one floor. This suggests that both methods are unlikely to yield a large variation in results when carried out on-site, and are therefore useful methods of characterising a floor system performance for comparison with a performance criterion.

Limitations

Limitations to this study are the variation of floor samples that have been used for this paper; all assessed samples are concrete building constructions. For future study, floor constructions would ideally include both lightweight timber-framed, mass timber, and concrete floor constructions to observe differences across common construction methods. The outcome of the study may differ with more samples for both the tapping machine and rubber ball.

Conclusions

This paper is a case study using routine impact sound insulation testing data to determine the range of results that could be observed when carrying out on-site testing. Findings from this study are that the range of results from both the tapping machine (1dB) and rubber ball (3dB) is small, especially as the source/receiver positions were selectively processed to obtain the best and worst results for each test sample. This suggests that both methods are suitable to obtain consistent results when carrying out impact sound insulation testing. Encouragingly; with the rubber ball method of assessing down an octave band lower than the tapping machine method, the relatively low variability of the results suggest that this method may be appropriate and practical for assessing on-site low frequency sound insulation performance of floors.

Acknowledgments

The author would like to thank members of the NDY Acoustics team for their assistance in carrying out the laborious activity of impact insulation testing, and for their input into piecing together this paper.

References

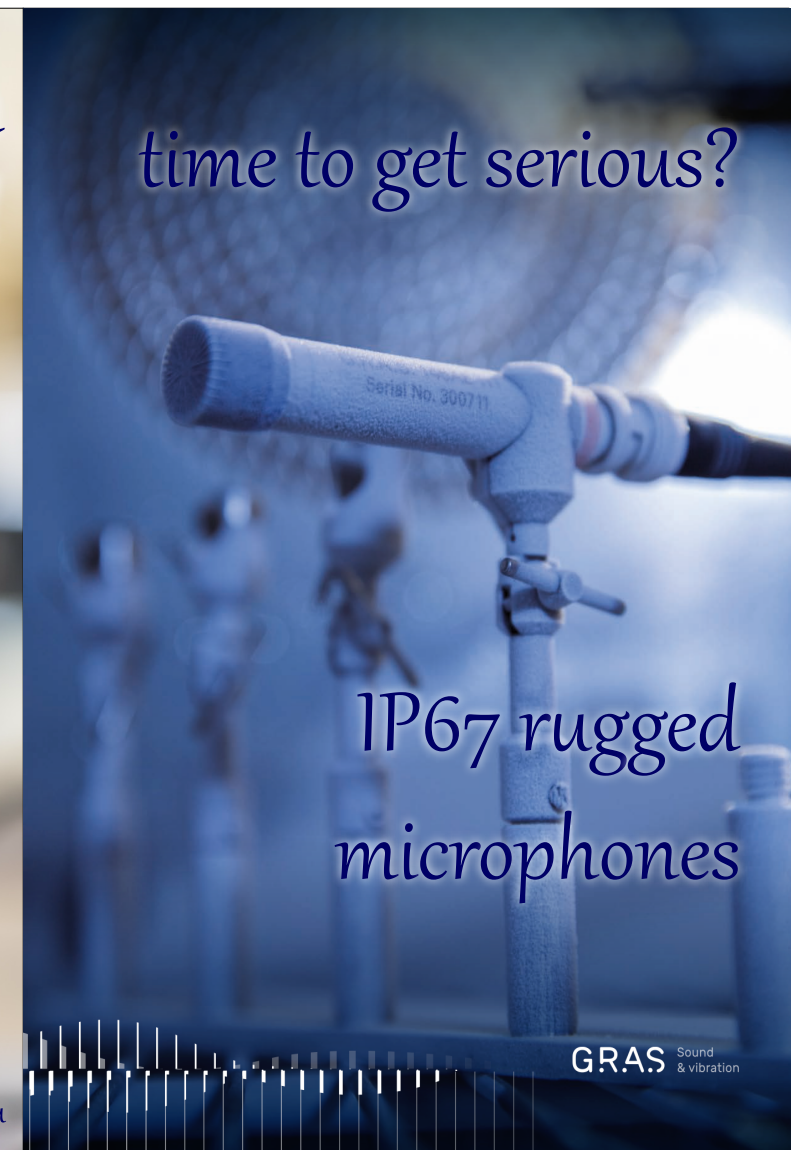
- [1] New Zealand Building Code clause G6, "Airborne and impact sound", amendment 2, Department of Building and Housing, 2006. [Online document]. Available: <https://www.building.govt.nz/building-code-compliance/g-services-and-facilities/g6-airborne-and-impact-sound> [Accessed Aug. 8, 2024].
- [2] ISO 16283-2: Part 2:2020, "Impact sound insulation", 3rd ed.
- [3] ISO 10140-3: Part 3:2021, "Measurement of impact sound insulation", 2nd ed.

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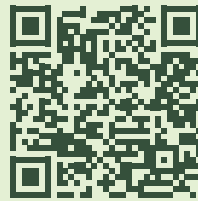
I knew John and succeeded him as Regional Noise Control Officer (South Island) Department of Health after he retired in 1989. John had been appointed to the position in February 1977 after earlier work in the engineering section of National Audiology Centre, Department of Health after migrating from the UK in 1967. Born in 1931, John lived in Kent during the war as air battles raged overhead. He did his National Service around 1950 in the RAF as a radio technician. He later worked for Submarine Cables making repeater stations. John had assisted the committee responsible for the seminal NZ Board of Health report no 21 "Noise," published in 1974. From 1977 he was based at National Radiation Laboratory in Christchurch and his duties took him all over the South Island and sometimes to the North Island. Alongside Charles Salmon, George Bellhouse, Nevil Hegley and later Philip Dickinson and Michael Hart, he provided advice in noise assessment and measurement, and training to Department of Health Inspectors of Health (post 1993

renamed Health Protection Officers), and Local Authority Health Inspectors (post 1984 renamed Environmental Health officers). In that era John also ran occupational noise courses for Mines Safety Officers and Health Nurses, did occupational noise surveys of industrial premises, calibrated audiological equipment for hospitals, advised on audiological booth isolation, and room acoustics as well as the routine advice on noise provisions in City, Borough and County district schemes and investigation of noise problems. He gave expert evidence on environmental noise in Town and Country Planning Appeals and a few District Court noise nuisance cases. John was recognised for over 50 years of long service with Kiwanis in Canterbury. He wrote and produced and performed in amateur plays and films. John was 94 when he died in February and is survived by his wife Carol. Those who remember him will always recall his great sense of humour and wit. He always stayed in the Leviathan Hotel when in Dunedin. His explanation - he was guaranteed a whale of a time. Farewell Johnno.



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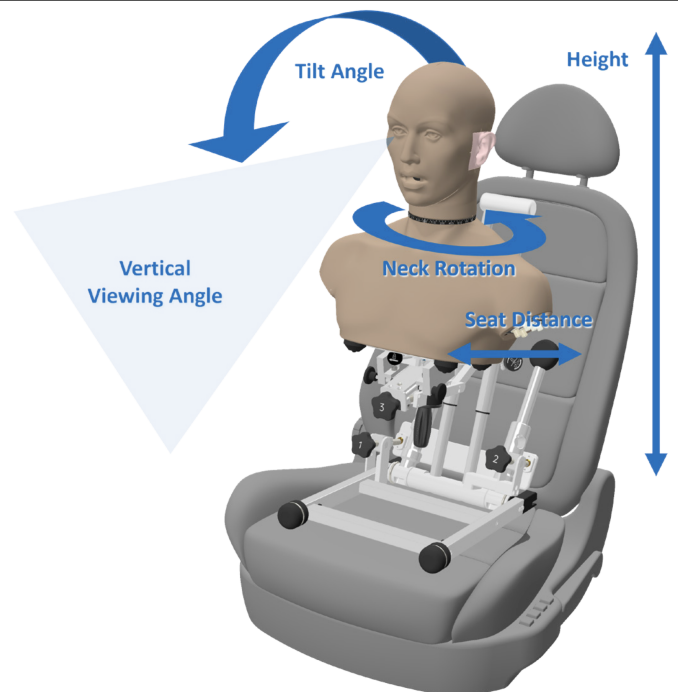
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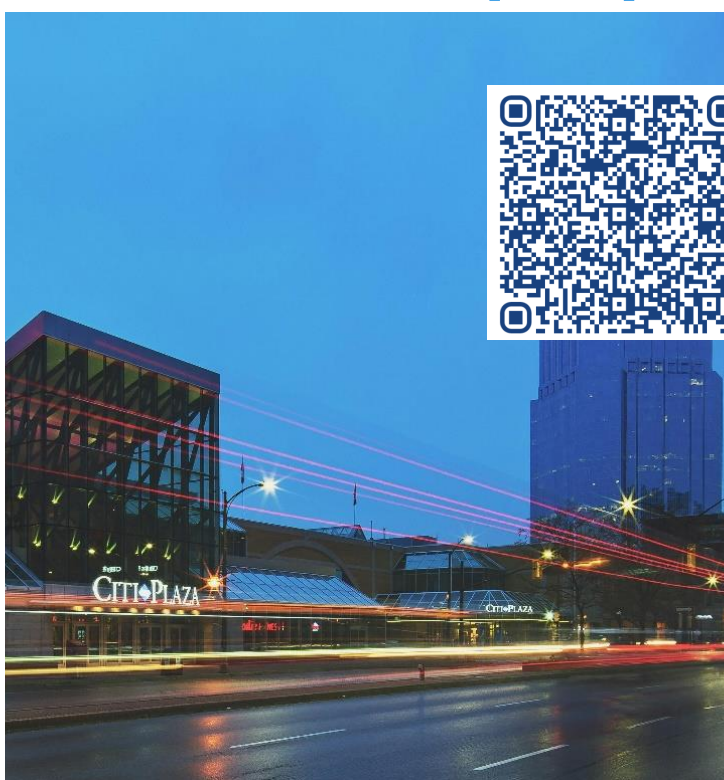
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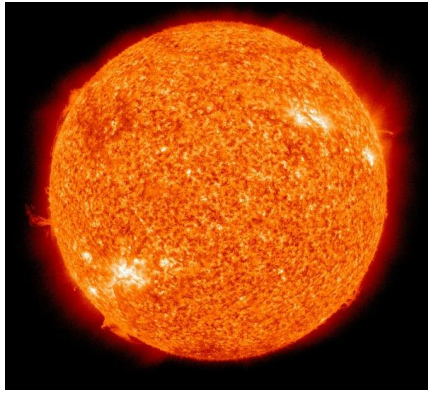
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Swaying building makes noise like a Ship ⁶



The largest Anechoic Chamber in the World ⁷



The real reason Analog recording is better ⁸



1. <https://theweek.com/tech/the-noise-of-bitcoin-mining-is-driving-americans-crazy>
2. https://www.kten.com/news/owls-inspire-new-revolutionary-noise-reduction-technology/article_de3a5074-e514-5923-9f56-44f31e52acde.html
3. <https://www.theguardian.com/environment/2025/jun/24/noise-pollution-harms-health-of-millions-across-europe-report-finds>
4. <https://www.youtube.com/watch?v=2aCOyOvOw->

5c&list=WL&index=37

5. <https://www.youtube.com/watch?v=XYXAdXf5g-WU&list=WL&index=30>
6. <https://www.youtube.com/watch?v=KwdrjTX4t-vc&list=WL&index=29>
7. <https://www.youtube.com/watch?v=3dxdyweAE-BA&list=WL&index=7>
8. <https://www.youtube.com/watch?v=Zq4BOSaKiY-o&list=WL&index=14>

QUIZ

1. Sound is a type of:
 - A. Electromagnetic wave
 - B. Transverse wave
 - C. Longitudinal wave
 - D. Light wave
2. The unit used to measure sound intensity is:
 - A. Watt
 - B. Hertz
 - C. Pascal
 - D. Decibel
3. The frequency range of human hearing is approximately:
 - A. 1 Hz to 1 kHz
 - B. 20 Hz to 20,000 Hz
 - C. 10 Hz to 1,000 Hz
 - D. 1 kHz to 100 kHz
4. Which of the following materials best absorbs sound?
 - A. Metal
 - B. Glass
 - C. Fibreglass insulation
 - D. Concrete
5. An echo is caused by?
 - A. Absorption
 - B. Diffusion
 - C. Interference
 - D. Reflection
6. Which instrument measures sound level in decibels?
 - A. Barometer
 - B. Oscilloscope
 - C. Sound level meter
 - D. Thermometer
7. Which state of matter does sound travel fastest in?
 - A. Gas
 - B. Liquid
 - C. Solid
 - D. Plasma
8. What is the wavelength of a 1 kHz sound wave in air? (Speed = 343 m/s)
 - A. 0.0343 m
 - B. 3.43 m
 - C. 343 m
 - D. 0.00343 m
9. The decibel scale is:
 - A. Linear
 - B. Logarithmic
 - C. Inverse
 - D. Exponential
10. The threshold of hearing is:
 - A. 100 dB
 - B. 10 dB
 - C. 0 dB
 - D. -10 dB
11. Which of the following best describes a standing wave?
 - A. A wave moving away from the source
 - B. A wave with no vibration
 - C. A wave that appears stationary
 - D. A broken wave
12. The fundamental frequency of a vibrating string depends on:
 - A. Length, tension, and mass per unit length
 - B. Amplitude only
 - C. The loudness
 - D. The material alone
13. Which phenomenon causes a change in frequency due to motion?
 - A. Diffraction
 - B. Refraction
 - C. Doppler effect
 - D. Echo
14. A room with short RT60 sounds could be described as:
 - A. Echoey
 - B. Muffled
 - C. Reverberant
 - D. Resonant
15. Beats in sound result from:
 - A. Different amplitudes
 - B. Two identical frequencies
 - C. Two close but different frequencies
 - D. Phase alignment
16. An increase of 10 dB represents a (perceived) increase of:
 - A. $\frac{1}{2}$ as loud
 - B. 10× louder
 - C. 2× louder
 - D. 10× power
17. Ultrasound operates at frequencies:
 - A. Below 20 Hz
 - B. Between 20–200 Hz
 - C. Above 20 kHz
 - D. 100–1,000 Hz
18. The inverse square law states that sound intensity:
 - A. Increases with distance
 - B. Remains constant
 - C. Drops by half each meter
 - D. Decreases by 6 dB for each doubling of distance
19. What's a 'typical' RT60 for a concert hall?
 - A. 0.1s
 - B. 0.5s
 - C. 1.5–2.5s
 - D. 5s or above

QUIZ

20. In a Helmholtz resonator, what affects the resonant frequency?
 - A. Temperature
 - B. Volume of the cavity and size of the neck
 - C. Room shape
 - D. All of the above
21. The critical distance in a room is where:
 - A. Echoes dominate
 - B. Direct and reverberant sound are equal
 - C. Microphone critical placement
 - D. Sound is cancelled out
22. Which principle explains room modes?
 - A. Newton's law
 - B. Rayleigh's law
 - C. Standing wave theory
 - D. Inverse mode law
23. What is the Sabine formula used for?
 - A. Calculating wavelength
 - B. Measuring pressure
 - C. Estimating reverberation time
 - D. Determining frequency response
24. Diffusers in room acoustics do what?
 - A. Absorb sound
 - B. Reflect sound evenly
 - C. Block noise
 - D. Create echoes
25. Which component has the greatest influence on microphone frequency response?
 - A. Where the operator stands
 - B. Capsule design
 - C. Windshield size
 - D. Height of mic above ground
26. In audio engineering, comb filtering occurs due to:
 - A. Reverb
 - B. Parallel signal delay
 - C. Microphone coloration
 - D. Over-compression

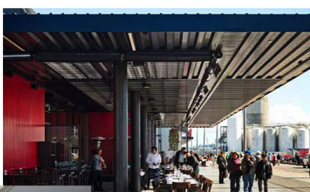
ANSWERS
 2. D 2. D 3. B 4. C 5. D 6. C 7. C 8. A 9. B 10. C
 11. C 12. A 13. C 14. B 15. C 16. C 17. C 18.
 D 19. C 20. B 21. B 22. C 23. C 24. B 25. B 26. B



Architectural Acoustics

Noise & Vibration Control

Environmental Acoustics



The ASNZ has teamed up with **SoundPrint** to provide this curated list of acoustic ratings for food and beverage venues across Aotearoa (replacing the previous **CRAI** ratings). This data is collated from submissions made by users of the SoundPrint app, which rates venues based on the ambient noise levels present at the time of review and a subjective impression of how easy it was to hold a conversation. SoundPrint ratings follow a decibel scale, and these correspond with our awarded star ratings as follows:

QUIET		MODERATE	LOUD	VERY LOUD
70 dBA or below + subjectively "great" for conversations	70 dBA or below	70 - 75 dBA	75 - 80 dBA	80 dBA or above
★★★★★	★★★★	★★★	★★	★

The list below contains submissions from the past 3 years only. The numbers in parentheses are the total reviews over this period.

AUCKLAND

&Sushi Smales Farm, Auckland	★★★★★	(1)
Ah Ssak, Auckland	★★	(1)
Ahi, Auckland	★	(1)
Albert's Post, Auckland	★★★	(1)
Ambler, Point Chevalier	★★★	(2)
Atelier, Auckland	★★★★★	(1)
Botswana Butchery, Auckland	★★★★★	(2)
BurgerFuel, Auckland	★★★	(1)
Casablanca Cafe, Auckland	★	(1)
Casita Miro, Onetangi	★★★	(1)
Cassia, Auckland	★★★	(1)
Chamate, Auckland	★★	(1)
Charlie Farley's, Onetangi	★★	(1)
Cotto, Auckland	★★	(1)
Daphnes, Grey Lynn	★★★	(2)
Dear Jervois, Herne Bay	★★★★★	(1)
Deco Eatery, Auckland	★★★	(4)
Dizengoff, Ponsonby	★★	(1)
Ebisu, Auckland	★★	(2)
Farina, Ponsonby	★	(1)
Fat Puku's Smashed Burgers, Auckland	★	(1)
Gemmayze St شارع الجميزة, Auckland	★★	(3)
Goat From India, Auckland	★★★	(1)
Harbour Society, Auckland	★★★	(1)
Hugo's Bistro, Auckland	★★★★★	(1)
Kingi, Auckland	★★★	(1)
Kol, Auckland	★★★	(1)
Little Creatures Hobsonville, Hobsonville	★★★	(1)
Lokanta Eating House & Bar, Grey Lynn	★★★★★	(1)
Manuka, Auckland	★★★★★	(1)
Masu, Auckland	★	(1)
McDonald's, Albany	★★★	(1)
Mr Charcoal BBQ 炭烧时代, Auckland	★★	(1)
Nanny's Eatery, Kingsland	★★	(1)
Onslow, Auckland	★★★	(1)
Pocha, Auckland	★★	(2)
Prego, Ponsonby	★★	(1)
Provecho, Auckland	★★★	(1)
Ragtag, Auckland	★★★	(3)
Roses Dining Room, Auckland	★★	(1)
Saint Alice, Auckland	★★	(1)
Shake Out Smales Farm, Auckland	★★★★★	(1)
Sidart, Ponsonby	★★★★★	(1)
Ssam Jang, Auckland	★	(1)

Tempero, Auckland	★	(1)
The Conservatory Bar, Auckland	★★★	(1)
Tomi Ro Sushi & Robata Grill, Auckland	★★★★★	(1)
Vondel, Devonport	★★★	(2)
Wynyard Pavilion, Auckland	★★★★★	(1)

BAY OF PLENTY

Capers Epicurean, Rotorua	★★★	(1)
Coco's Trattoria, Mount Maunganui	★★★	(1)
Drift Coffee, Matata	★★★	(1)
Izakai, Mount Maunganui	★★★★★	(1)
Lloyds Deli & Pizzeria, Tauranga	★★★	(3)
Macau, Tauranga	★★★	(1)
Pearl Kichen, Papamoa Beach	★	(1)
Salinity, Tauranga	★★★★★	(1)
Somerset Cottage, Tauranga	★★★★★	(1)
The Freeport, Mount Maunganui	★★★	(1)

CANTERBURY

5th Street, Christchurch	★★	(1)
BurgerFuel, Christchurch	★★★★★	(1)
C4 Coffee, Christchurch	★★★	(2)
Cafe Valentino, Christchurch	★★★	(1)
Coffee Culture, Rangiora	★★★	(1)
Doubles, Christchurch	★★★★★	(1)
Gatherings Restaurant And Living Wine Bar, Merivale	★★	(1)
Jinweide Beef Noodle, Christchurch	★★★	(1)
Khmer Satay Noodle House, Riccarton	★★★★★	(1)
Little Poms, Christchurch	★★	(4)
Lyttelton Coffee Company, Lyttelton	★★★	(1)
Mac's South Bar & Café, Christchurch	★★★★★	(1)
McDonald's, Christchurch	★★★★★	(1)
Meshino, Saint Albans	★	(1)
Misceo Cafe & Bar, Ilam	★★★	(2)
Mitchelli's, Christchurch	★★	(1)
Robert Harris Lincoln, Lincoln	★★	(1)
Sal's Authentic New York Pizza, Riccarton	★★★★★	(1)
Sherpa Kai, Lyttelton	★★★★★	(1)
Super, Lyttelton	★★★★★	(1)
The Birdwood, Beckenham	★★★	(1)
The Garden Brasserie, Riccarton	★★	(1)
The Laboratory, Christchurch	★★★★★	(1)
The Rockpool Bar, Christchurch	★	(1)
Two Thumb Brewing Co Ltd, Christchurch	★★	(1)
Vic's Cafe (& Bakehouse), Christchurch	★★★	(3)

Volstead Trading Company, Christchurch	★★★★★	(1)
You Hanoi Me, Christchurch	★★★★	(1)
Zephyr, Kaikoura Central	★★★★★	(1)

MANAWATU-WANGANUI

Café Cuba, Palmerston North	★★	(1)
Carl's Jr., Palmerston North	★★★★★	(1)
Little Savanna, Palmerston North Central	★★★★★	(1)
Spice Guru, Whanganui	★★★★	(1)
Viv's Kitchen, Sanson	★★	(1)

MARLBOROUGH

Quench Restaurant at Chateau Marlborough, Blenheim	★★	(1)
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NELSON

Sprig & Fern Tavern, Nelson	★★★	(1)
The Free House, Nelson	★★★★	(1)

NORTHLAND

The Gables, Russell	★★	(1)
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OTAGO

Bacchus, Dunedin	★★★	(1)
Big Fig, Wanaka	★★★	(1)
Blue Kanu, Queenstown	★★	(2)
Etruscos At The Savoy, Dunedin Central	★	(1)
Fogo Brazilian Barbecue Experience, Queenstown	★	(1)
Jervois Steak House, Queenstown	★★★★	(1)
Jizo Japanese Cafe & Bar, Dunedin	★★	(1)
My Thai Lounge, Queenstown	★★★★	(1)
No 7 Balmac, Dunedin	★★★★★	(1)
Slow Cuts, Arrowtown	★	(1)
Winnies Gourmet Pizza Bar, Queenstown	★★★	(1)

SOUTHLAND

Bailiez Cafe, Te Anau	★★★★★	(1)
Ranch Bar And Grill, Te Anau	★★	(1)
Speights Ale House, Invercargill	★★★	(1)

TARANAKI

Gusto Restaurant, New Plymouth	★★★★	(1)
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WAIKATO

Orca Restaurant & Bar, Raglan	★★★★★	(1)
Robert Harris, Cambridge	★★★★	(1)

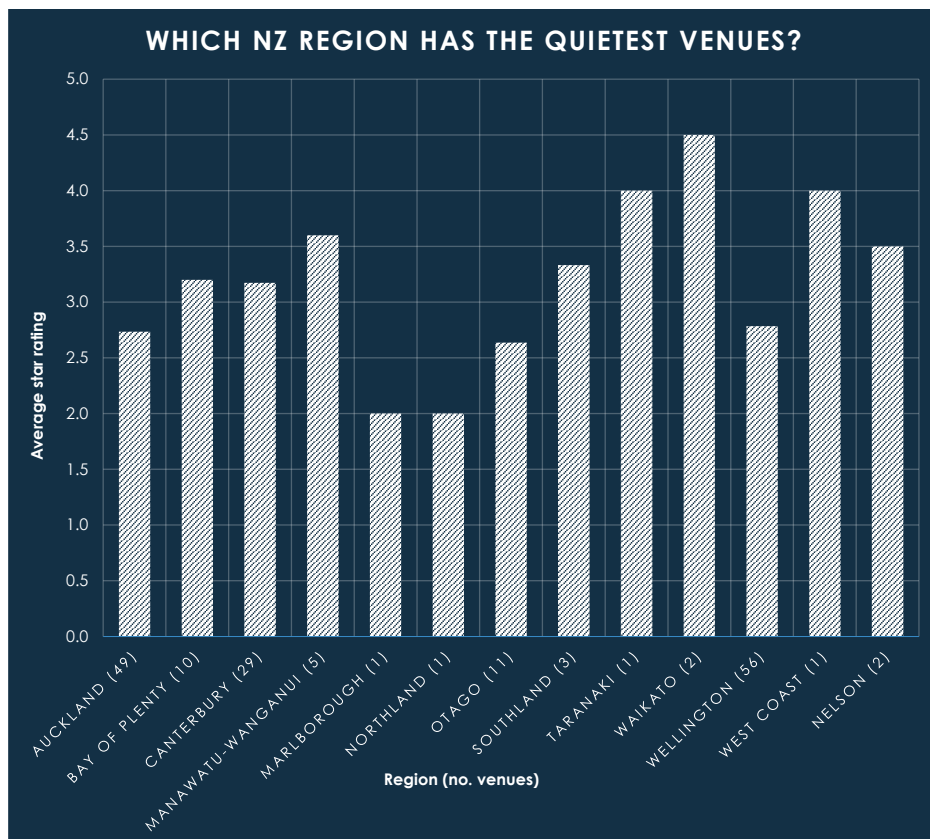
WELLINGTON

1154, Te Aro	★	(1)
Abrakebabra, Te Aro	★★★★★	(1)
Balter Bar & Kitchen, Carterton	★★★	(1)
Baylands Brewery, Lower Hutt	★★★★	(1)
Bethel Woods, Wellington	★★	(1)
Black Coffee, Wellington	★★★	(1)
Boulcott Street Bistro, Wellington Central	★	(1)
Brown Sugar Cafe, Otaki	★★★★	(1)
BurgerFuel, Wellington	★★★★	(1)
Caffe L'affare, Te Aro	★	(2)
Cool Change, Martinborough	★	(1)
Dockside, Wellington Waterfront	★	(1)
Dragon Fly, Te Aro	★	(1)
Elements Cafe, Lyall Bay	★★★	(1)
Flamingo Joe's, Pipitea	★★	(1)

Fratelli, Te Aro	★★★	(3)
Fuel Espresso, Wellington	★★★★	(1)
Glocal Bistro, Upper Hutt	★★★★★	(1)
Hashigo Zake, Wellington	★★★★★	(1)
Heaven, Wellington	★★	(1)
Hola Mexican Cantina, Paraparaumu	★★	(1)
Indian Alley, Te Aro	★★★	(2)
Karahui, Martinborough	★★	(1)
La Bella Italia, Petone	★★★★★	(1)
Le Bouillon Bel Air, Wellington	★★	(1)
Le Saigon Vietnamese Kitchen, Wellington	★★	(1)
Lola Stays, Oriental Bay	★★★	(1)
Loosies Superette, Wellington	★★★★★	(1)
Maranui Cafe, Wellington	★★	(1)
Miyabi, Wellington	★	(2)
Monsoon Poon, Wellington	★★★	(1)
Mystic Kitchen, Strathmore	★★★★★	(3)
Ombra, Te Aro	★★	(1)
Panhead Tory, Te Aro	★★★★★	(1)
Pomelo Kitchen And Bar, Oriental Bay	★	(1)
Poquito, Wellington	★★	(1)
Prefab - ACME HQ, Te Aro	★★★	(1)
Preservatorium, Wellington	★★★★	(1)
Puro Chile, Wellington	★★	(1)
Rasa, Wellington	★★	(2)
Revive Cafe, Petone	★★	(1)
Rose's Red-Hot Cantina & Taco Joint, Wellington	★	(1)
Seashore Cabaret, Petone	★★	(1)
Seoul House, Wellington	★★★★★	(1)
Siam Spoon, Petone	★★	(1)
Somtum Thai, Te Aro	★★★	(1)
Te Papa Cafe, Wellington	★★★★	(1)
The Beanery By Mojo, Wellington	★★★	(2)
The Chopstick Table, Petone	★★★★	(1)
The Ram, Te Aro	★	(1)
The Salt and Wood Collective, Waikanae	★★★★	(1)
Union Square Bistro, Martinborough	★★	(2)
Viva México, Lower Hutt	★★★	(1)
Viva Mexico, Wellington	★	(1)
Waitoa Social Club, Wellington	★★★	(1)
Whitby's Restaurant & Piano Bar, Wellington	★★★★★	(1)

WEST COAST

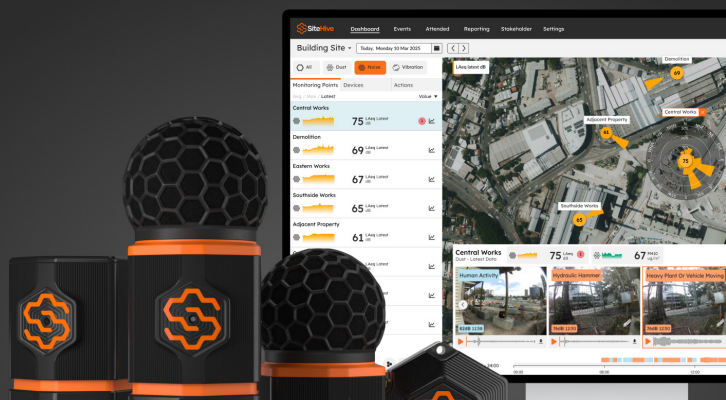
Betsey Jane, Fox Glacier	★★★★	(2)
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SoundPrint can be downloaded from the Apple App Store and Google Play Store. More information and reviews are available at the website: <https://www.soundprint.co/locations/nz>

SiteHive

Next-generation SiteHive Hexanodes



Rethinking Ground-Borne Noise Monitoring

Ground-borne noise has long been one of the trickiest challenges in construction acoustics. Generated by tunnelling, excavation and heavy works, it travels invisibly through the ground before re-emerging inside buildings as a low-frequency hum or rumble—often felt as much as heard.

Traditionally, measuring it has meant going inside people's homes. Microphones are installed in living spaces to capture internal noise levels. While effective in theory, the reality is far less straightforward: access can be difficult, monitoring can feel intrusive, and results are easily skewed by everyday household sounds. Scaling this approach across large projects quickly becomes costly and impractical.

At the same time, expectations have changed. Communities and regulators increasingly expect real-time insight, transparency and proactive management, especially in dense urban environments. This is pushing the industry to rethink how ground-borne noise is monitored.

One promising innovation - developed by environmental monitoring leader SiteHive - enables intelligent estimation from direct measurement. The core idea is not new: for decades, researchers have shown that vibration levels can be correlated with the noise heard inside buildings. What has changed is the technology.

Today's vibration sensors process data in real time, transforming raw signals into meaningful noise metrics such as LAeq. With an initial calibration, linking vibration measurements to actual indoor noise levels, these systems can continuously estimate ground-borne noise without ever entering a property.

The implications are significant. With tools like the SiteHive Hexanode Vibration, monitoring becomes remote, scalable and far less intrusive. Data is often cleaner, as it is no longer affected by household activity. And with real-time alerts, project teams can respond more quickly to emerging issues.

This doesn't mean traditional measurements disappear altogether. Instead, they play a more targeted role, supporting calibration and verification, while day-to-day monitoring shifts to smarter, more efficient methods.



Next-generation SiteHive Hexanodes

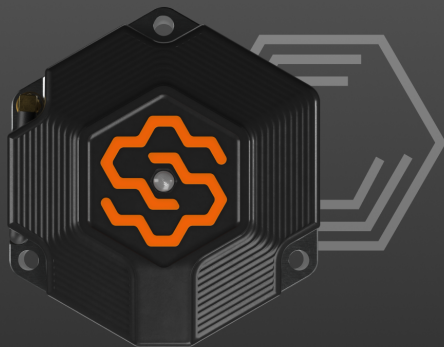


**A new benchmark in environmental monitoring.
Real-time, accurate noise and vibration measurements made easy.**



SiteHive Hexanode Noise

- Can be NATA calibrated (IEC 61672-3:2013) by accredited laboratories
- Octave band analysis (IEC 61260.1:2019)
- Directional noise monitoring
- Directional images triggered by noise
- AI classified audio identifies activities on site



SiteHive Hexanode Vibration

- Can be NATA calibrated (ISO 16063-21:2003) by accredited laboratories
- Structural (PPV) & Human Comfort (VDV) measurements in one device
- Automated structural frequency assessment (DIN 4150-3 & BS 7385-2)
- Ground-borne noise calculations
- Self-orienting in any deployment

See how SiteHive can
make your job easier

sitehive.com



Or scan the QR code
to get in touch.

UPCOMING EVENTS

MAY 2026

190th Meeting of the Acoustical Society of America (ASA).

May 11-15, 2026

Philadelphia,
Pennsylvania, USA
acousticalsociety.org

Baltic-Nordic Acoustic

May 4-6, 2026

Gothenburg, Sweden
Euracoustics.org

AUGUST 2026

55th International Congress and Exposition on Noise Control Engineering (INTER-NOISE 2026).

August 9-12, 2026
Adelaide, Australia



International Conference on Acoustics and Vibration (ICAV 2026)

August 19-20, 2026

Bangkok, Thailand
waset.org

OCTOBER 2026

International Conference on Acoustics (ICA 2026)

October 7-8, 2026

Tokyo, Japan
waset.org

NOVEMBER 2026

The Acoustical Society of New Zealand

November 2-4 2026

Tauranga, New Zealand
<https://www.acoustics.org.nz>

DECEMBER 2026

International Conference on Acoustics and Vibration (ICAV 2026)

December 6-7, 2026

Kuala Lumpur, Malaysia
waset.org

International Conference on Acoustics and Vibration (ICAV 2026)

December 16-17, 2026

Bangkok, Thailand
waset.org

AUGUST 2027

International Congress of Phonetic Sciences

August 9-13, 2027

Victoria, Canada
<https://www.internationalphoneticassociation.org>

DECEMBER 2027

International Conference on Acoustics and Vibration (ICAV 2027)

December 6-7, 2027

Kuala Lumpur, Malaysia
waset.org

International Conference on Acoustics and Vibration (ICAV 2027)

December 16-17, 2027

Bangkok, Thailand
waset.org

Note: Dates and information are subject to change. We encourage you to go directly to the source material and event website of each event to ensure you have the latest and most up to date information including dates.

