New Zealand Acoustics

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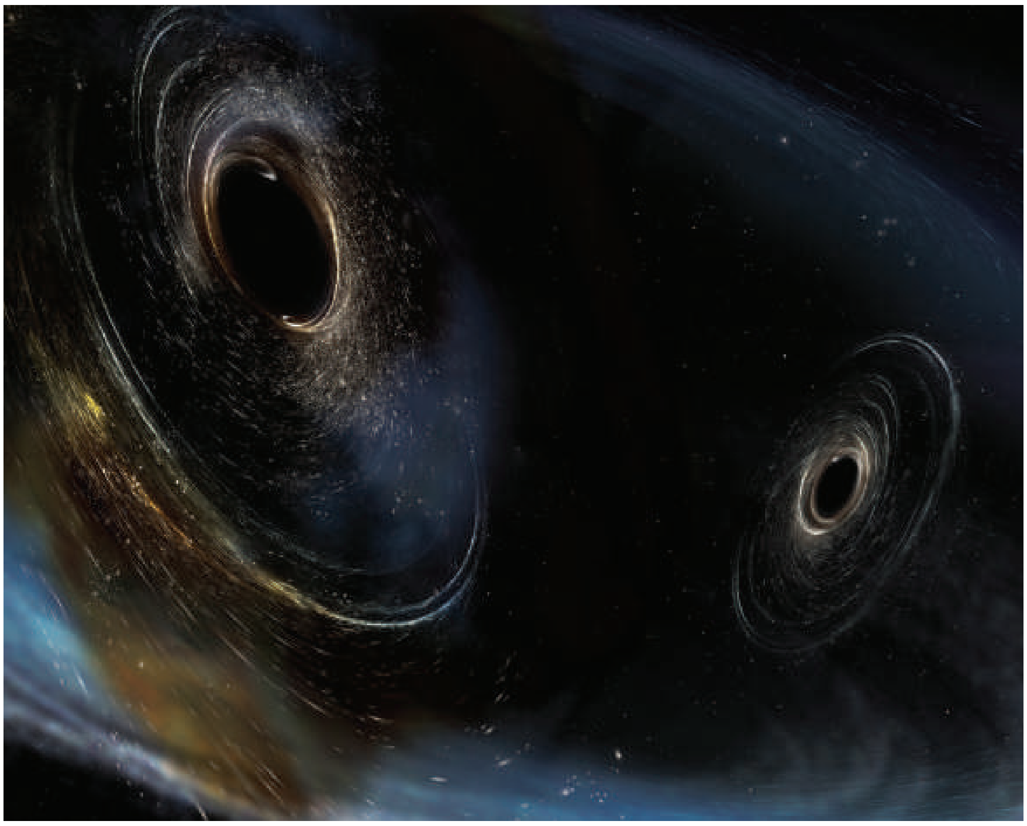

dBWav: A software tool for analysing and viewing long-duration hydrophone measurements

Reverse sensitivity issues between noise sensitive activities & commercial activities in inner city Wellington

Aeroacoustic assessment of facades

2019

#1

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Features

Regulars

Cover Image: Artist's conception shows two merging black holes similar to those detected by LIGO (Laser Interferometer Gravitational-Wave Observatory)

Source: Caltech LIGO - the sound of two Black Holes colliding ~ https://youtu.be/QyDcTbR-kEA

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Contributions to the Journal are encouraged, and may be sent directly to the Editors by email (journal@acoustics.org.nz) or by post c/o, The Acoustical Society of New Zealand Incorporated, PO Box 1181, Shortland Street, Auckland 1140.

From the President and the Editors

President's Column

Dear ASNZ Members, Associates and Fellows,

I hope 2019 has got off to a good start for our membership – it certainly seems to have been a busy start for many! I read many conflicting headlines in the papers these days about property sales slumps, record property sales, business confidence at its lowest, Auckland has the most cranes on its skyline ever etc. But as far as I can see, and despite some small fluctuations, there appears to be a great deal of momentum in our economy. It would seem that if our economy is slowing, that slow shouldn't last for too long. Something to hope for anyway.

2018 was a big year for our society, with many events, developments, agreements and awards and a great year generally.

The highlights include:

- The 2018 biennial conference held in Auckland. The conference was excellent with very high quality papers and presentations, at a great venue. Although I wasn't able to attend all of the conference, the parts I did attend were fantastic. It is superb to be part of a Society made up of such great people. A huge thanks to the presenters, the helpers, the venue operators, our sponsors, and of course, the amazing organising committee, headed by the most-capable Mr Beresford.
- The 2018 AGM for which we had a huge turnout and good discussion. Welcome to the new Council members and thank you to those who have retired from their roles, for the efforts they have put in. If it wasn't for the efforts of past and future Committees there wouldn't be a Society - it is great to have a group of such enthusiastic people running the show.
- Our two Fellowships; Vern Goodwin, awarded in Christchurch in August 2018, and Graham Warren, awarded at the Conference in November 2018. Many thanks to these two fine gentlemen for their sustained and valued contribution to the Society and the practise of acoustics in New Zealand over many years.
- The Society's involvement with the development of the new National Planning Standards. It's great for the Society to have a role in developing these and many thanks to those who have contributed with their time, experience and expertise. The standards have been gazetted now and are starting to be incorporated into District Plans as this edition of the journal goes to print.
- The agreement with the Australian Acoustical Society to hold a joint conference with them in New Zealand, every six years. This is a fantastic chance for our Society to gain good exposure to the international acoustics communities, to improve ties and share knowledge with our colleagues across the ditch, and to provide highly informative and valuable conference programmes to our members. Our first joint conference is in 2020 in Wellington – it's going to be a big one, so stay tuned.

In 2019 the ASNZ partnered with the Ministry of Transport and the New Zealand Transport Agency to bring together the inaugural Transport Acoustics Forum to be held in Auckland in May this year. The forum has been organised under the Transport Environment Knowledge Hub (TEKH) – one of the many knowledge hub topics that have been created in the Ministry's Transport Knowledge Hub programme. This forum brings together both New Zealand and international experts to discuss the assessment and management of transport noise. It's going to be a great opportunity to get involved, share knowledge and to maximise the rigour and accuracy of the wide variety of transport noise assessments and research undertaken. A great initiative from the Ministry of Transport that is only possible with the support of a wide variety of people from a range of organisations.

Cheers,
Jon

Editor's Column

We must first apologize for the lateness of this first issue for 2019. It takes a lot of effort to put together the journal and finding time this year while working full time, changing jobs (Lindsay) and moving house (Wyatt) has proved very difficult. We are looking to address this issue by contracting someone to do the layout while we focus on the content and do what editors are meant to do ☺

There are three papers this Issue: one continuing the marine acoustics theme from last year; an original on reverse sensitivity issues in inner city Wellington; and a technical paper on building façade wind induced noise (*aeroacoustics*).

Lindsay & Wyatt journal@acoustics.org.nz

Letter to the Editor

The acoustics of a typical concert hall

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As far as the present author is aware, there is no poem in the literature with regard to architectural acoustics. This letter is a poem which addresses the acoustical condition in a typical concert hall.

It's a concert hall
Its volume is not large
Its shape is irregular
Its stage is not small
Its ceiling is not tall
Its windows are rectangular
Its ceiling is hard
Its doors are tall
Its walls are partially hard
Its floor consists of a hard material
Its curtains have absorption coefficient of 0.5
Its doors are made of metal
Its pews are occupied
Its sound reinforcement systems are off
Its average absorption coefficient is not high
Its Schroeder frequency is particularly high
Its critical distance is not long
Its early decay time is long
Its reverberation time is higher than usual
It's therefore a poor concert hall.

Listening to ocean bubbles

Earthsky has reported that a research team recorded the sound of methane bubbles seeping from the seafloor off the Oregon coast, with the aim of using acoustics to identify – and perhaps measure – this important greenhouse gas in the ocean. The research team used a hydrophone, a microphone designed to listen underwater, to record the sound of methane bubbles from the seafloor off the Oregon coast. Their aim was to use acoustics to identify this important greenhouse gas in the ocean. Results of the study have now been released to the public. Robert Dziak, an acoustics scientist at NOAA, is lead author of the study, published in the journal Deep-Sea Research II in April 2018. Dziak said "*The bubbles in the streams make sound, and*

the frequency of the sound is related to the size of the bubble. The smaller the bubble, the higher the pitch. And the larger the bubble, the lower the sound pitch, but the more methane it contains. Our ultimate goal is to use sound to estimate the volume and rate of methane gas exiting these seafloor fields". A statement from Oregon State University described the study "*The research team used a remotely operated vehicle (ROV) to deploy a hydrophone about 10 kilometres (six miles) off Heceta Bank on the Oregon continental margin in 1,228 metres of water [about three-fourths of a mile deep]. The acoustic signatures of the bubbles from the seep site are depicted in the hydrophone record as a series of short, high-frequency bursts, lasting 2-3 seconds. The researchers then compared the sound record with still images from the ROV and found their estimates of bubble size from the hydrophone record matched the visual evidence*".

Journal Feedback and Comments

If you have any feedback on what you would like to see in future issues or even things you don't like to see, please share with us via email to journal@acoustics.org.nz, we would like to hear from you! All comments and feedback is treated as confidential by the Editors.

The Acoustical Society of New Zealand

www.acoustics.org.nz

The ASNZ webpage contains a host of information including information on Membership, Journal

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dBWav: A software tool for analysing and viewing long-duration hydrophone measurements

Benjamin Lawrence

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Abstract

Underwater noise surveys using passive acoustic monitoring (PAM) typically involve deploying one or more hydrophones to measure underwater noise levels over periods ranging from several days to multiple weeks. The audio data obtained can often be several terabytes in size, particularly if the measurements contain high-frequency content. A common challenge is analysing and viewing this data quickly and efficiently. To address this issue, a software tool (dBWav) has been developed that pre-processes the raw audio and stores the key information in a much smaller data file, which can then be displayed and analysed in a simple interface. This software is intended to be a screening tool, allowing the user to locate periods/events of interest and export the necessary information in full resolution for reporting or further processing with other software.

Originally presented at the XXIV^th^ Biennial Conference of the Acoustical Society of New Zealand, 12-14 November 2018, Auckland, New Zealand.

1. Introduction

Passive acoustic monitoring (PAM) is commonly used to understand the existing underwater noise environment in a given area. The information captured is often used as baseline data for environmental effects assessments as well as for research purposes.

There is currently no standard or widely available software for the production of calibrated PAM measurements [1]. Analysis using existing tools can be highly time consuming due to the large amounts of data obtained, and generally requires expensive software suites such as Matlab and expertise in coding.

This paper presents the software tool dBWav, which was developed by Marshall Day Acoustics as an efficient and user-friendly tool for analysis of long-duration measurements using the SoundTraps hydrophones produced by Ocean Instruments.

2. Background

Many marine species use sound for ecologically important functions including communication, navigation, finding prey, avoiding predators and locating mates and offspring. High levels of underwater noise can adversely impact these species, with effects ranging from reduced communication distances and avoidance of areas to disorientation and temporary/permanent hearing loss [2].

Ambient underwater noise surveys are an important part of understanding the impact of noise on marine species in a given area. Noise levels underwater can vary spatially, temporarily and in frequency content. To understand the environment therefore requires multiple measurement positions, sufficiently long-duration measurement periods, and for levels to be measured over a wide frequency range [3].

Once this data has been obtained, it must be analysed. The primary method of analysis is using visual tools such as time and frequency plots, statistical values, or a combination format such as a spectrogram (change in frequency spectrum over time).

3. The problem

PAM measurements capture significant amounts of data. For example, a survey involving three hydrophones with sample rates of up to 576 ksp (necessary to capture data in the hearing range some marine mammals), produces over 2 gigabytes per hour of audio data. It is not uncommon to deploy many more hydrophones in a survey, particularly for research purposes.

It can be very time consuming to process and view this data using available methods. Many software tools do not provide the level of detail, accuracy or speed necessary for consulting or research purposes. The most common approach is to use Matlab to run modifications of publicly available routines to produce the outputs. This requires a license of Matlab as well as programming expertise.

For many consultants and researchers in the field of underwater noise, these are significant time and cost hurdles to overcome with data analysis for ambient underwater surveys. A need was therefore identified for a simple software tool that can quickly process large amounts of raw audio data with an intuitive interface to view the results.

4. dBWav software tool

Marshall Day Acoustics has developed the software tool 'dBWav' as a solution to this problem. It is intended to be used for high-level analysis of hydrophone measurement data, suitable for most consulting and research applications. For more detailed and specialised applications (e.g. click detection or analysis of impulsive sources), dBWav is intended to be used as a screening tool to identify periods of interest and export the relevant data for further processing in other software tools.

The key element of dBWav is the pre-processing of the raw audio files and storing the relevant information in a much smaller data files called an LVX, which allow the data to be quickly displayed in dBWav's interface for real- time analysis.

5. Features of dBWav

dBWav is divided into two main components: pre-processing of the raw data, then viewing and analysing the results. The flow chart in Figure 1 below illustrates this process.

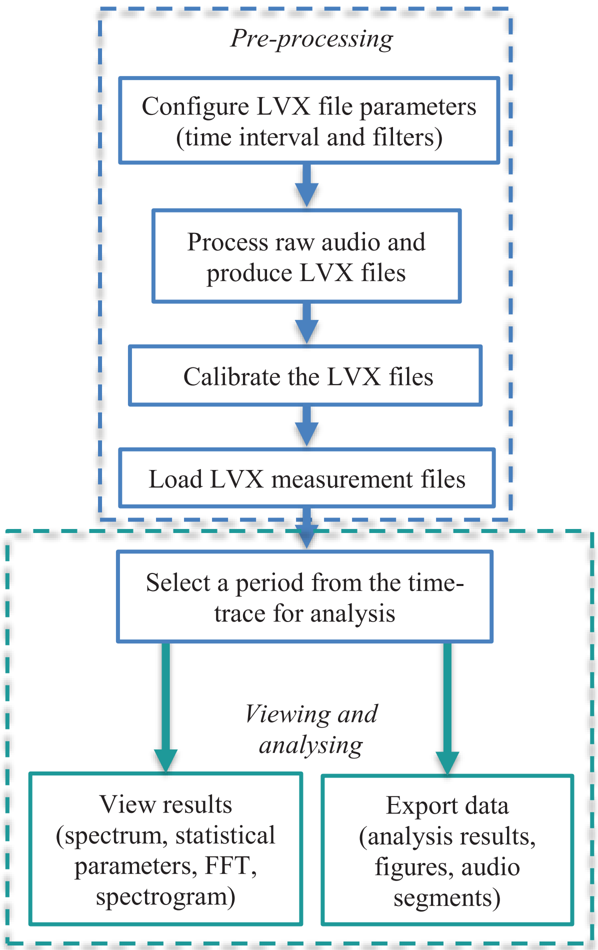

Figure 1: Figure 1. dBWav analysis process

To allow real-time analysis of data obtained from long duration surveys, dBWav pre-processes the raw audio data and stores the key results in much smaller LVX files. This means that the time consuming and computationally intensive processing of raw audio data is carried out in bulk prior to analysis, which significantly increases the speed at which the data can be accessed.

An LVX file is comprised of a table, with each row containing the levels at one-third octave bands averaged over the chosen time interval, and the relevant time stamp for that entry.

At the highest resolution (using a time interval of 1 second), the LVX files are approximately 400 times smaller than the corresponding raw audio file. Using larger time intervals further reduces the LVX file size and increases the corresponding speed at which the data can be displayed.

Not all data necessary for analysis is stored in the LVX files. To minimise the LVX file size and therefore maximise the speed of dBWav's real-time analysis, actions such as Fast Fourier Transforms (FFTs) and audio playback are carried out by selecting the period of interest in dBWav's interface and calling the relevant section of the audio file for processing. These periods can be tagged and saved with comments to the LVX file for subsequent reference and recall.

5.1 Calibration

Two methods of calibration are available in dBWav:

1. Using a recorded calibration signal at a known level
2. Using factory calibration data from the manufacturer

Method 1: pistonphone calibration
The first and primary method involves recording a tone (usually with a pistonphone at 250 Hz) at a known level on the hydrophone. The level can be determined using a sound level meter connected to the pistonphone to any hydrophone using a coupler, as illustrated in Figure 2.

Figure 2. Calibration using a pistonphone

Figure 3 shows the recorded calibration tone in dBWav. The user selects the period with the calibration tone and enters in the level recorded on the sound level meter, correcting for the difference in reference pressure between air and water. The calibration value is automatically stored in a file which is referenced when the LVX files are loaded.

This method is typically used for applications where precision is necessary for the absolute level, which requires calibration to be carried out before and after measurements, such as for effects assessments.

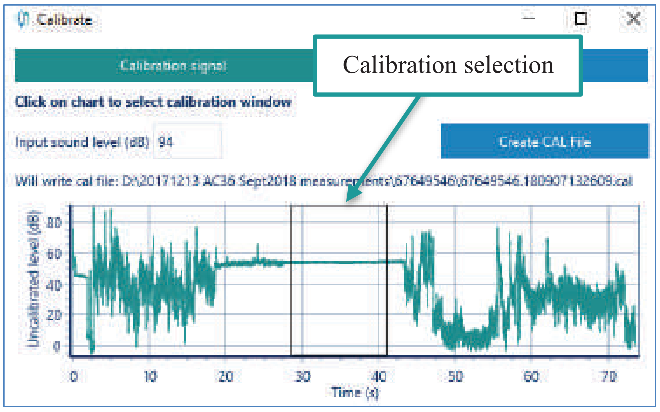

Figure 3: Viewing the calibration audio in dBWav

Method 2: factory calibration

The second method involves using the manufactures factory calibration data. This method is slightly less precise than method 1 as the sensitivity of the hydrophones can change over time. However, it is suitable for applications where absolute level precision is not necessary, such as comparing the change in noise level over the survey period.

6. Description of interface

It was the intention that dBWav's interface was dynamic and intuitive. A dynamic interface would allow almost all of the functions and results to be contained within the same window while not appearing overly busy. This was achieved by allowing the various elements in the interface to be resizable and able to be turned on/off. The interface also needed to be intuitive so that dBWav was easy to learn and use.

Figure 4 shows the interface with the LVX files from two hydrophones loaded. The top left section of the interface contains the pre- processing functions.

These are as follows:

- Set Up: Set up the properties of the LVX files (filtering and time interval).
- Process: Select the hydrophone audio files for processing.
- Calibrate: Select calibration method and produce the calibration file that the LVX files will reference.
- Open LVXs: Load the relevant LVX files. Measurements from multiple hydrophone can be loaded.
- Clear LVXs: Remove the selected LVX files

The middle of the interface shows the variation in level over time for the survey period. The time trace is used for navigation to identify periods of interest. dBWav allows for multiple hydrophone time-traces to be displayed simultaneously.

When a period of interest has been identified, the user clicks-and-drags to select that period for calculation. dBWav then calls the relevant data from the LVX files to calculate overall levels, spectral content and statistical parameters for the selected period.

The calculated results can be viewed as overall levels, as a spectrum, or as a table using the analysis tabs in the lower portion of the interface. These features are described further overleaf. The calculated results can be displayed as linear levels or with marine weightings in accordance with the NOAA technical guidance [4].

Specific functions can be carried out for the time selection using buttons in the top right section of the interface. These functions are as follows:

- Play: Plays the audio for the time selection
- FFT: Calculate the Fast Fourier Transform

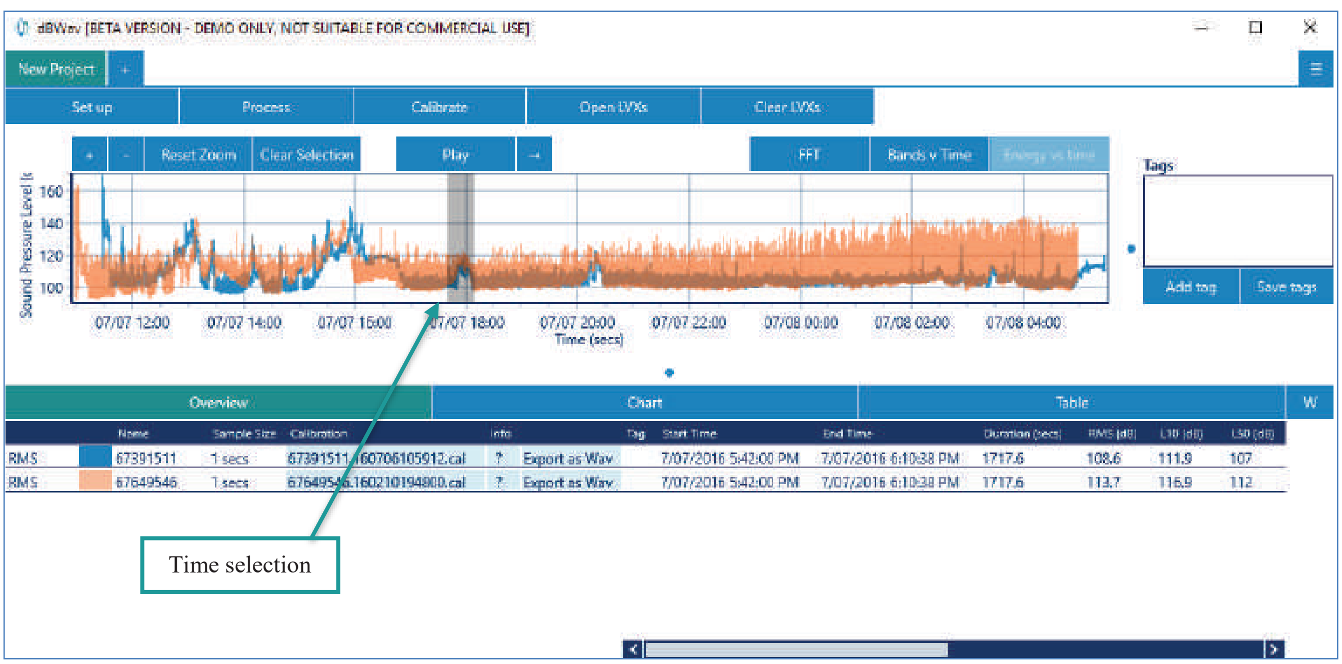

Figure 4: dBWav interface

(FFT) and corresponding spectrogram using the full resolution audio data (discussed further overleaf).

Add Tags: The user has the option to add tags to the selected period to name and describe the event. Clicking on the tag in the list will reselect that time window, and recalculate the results.

Bands vs. Time: Produce a spectrogram using the data in the LVX files. (discussed further overleaf). This is significantly faster than the FFT method.

Energy vs. Time This function will produce power spectral density plots. It is still under development.

7.1 Overall levels, spectral data and exporting

The overall levels and spectral data is updated when the user selects a period of interest. This data can be accessed by clicking on the following tab headings:

Overview: This tab shows the key overall information such as overall level, duration of selection, data and time, and statistical parameters.

Chart: The chart tab displays the average and statistical levels for each frequency band over the selected period.

Table: This tab shows the spectral data in a table. This data can be exported to the clipboard, or into a text file. It is also possible to export the raw table data from the LVX file.

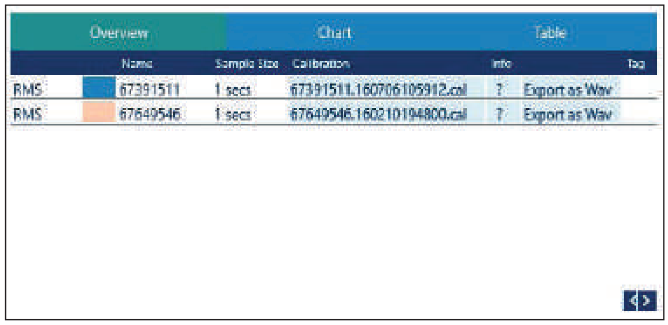

Figure 5a: Overview tab

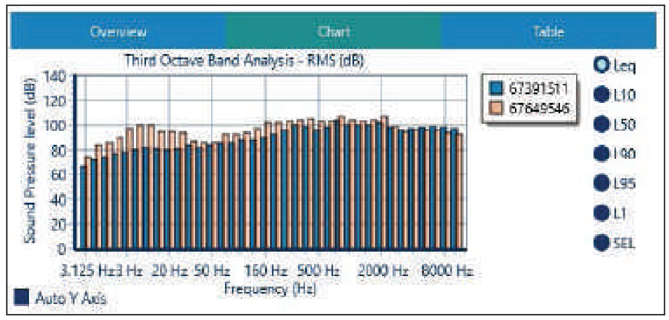

Figure 5b: Chart tab

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Information and Journal Articles, Continuing Professional Development, Cafe and Restaurant Acoustic Index, Standards Committees and Standards, the Latest News and Discussion and Contact details of the Society.

Why not visit for yourself?

Changes to Brüel & Kjær's representation in New Zealand

Following a review of Brüel & Kjær representation in New Zealand, as of February 2019, Wellington based Nichecom will no longer be representing Brüel & Kjær.

Brüel & Kjær has served New Zealand customers for over 30 years by providing leading Sound & Vibration solutions and services and we value continuing this tradition for many more years to come.

To ensure we strengthen our sales and technical support to New Zealand customers we are in the process of identifying a new local partner. While we work through a new arrangement, Brüel & Kjær Australia will take care of all sales and technical enquiries directly during this period. You can reach us by phone or email:

Brüel & Kjær Australia (Sydney): +61 2 9889 8888

Brüel & Kjær Email: nzinfo@bksv.com

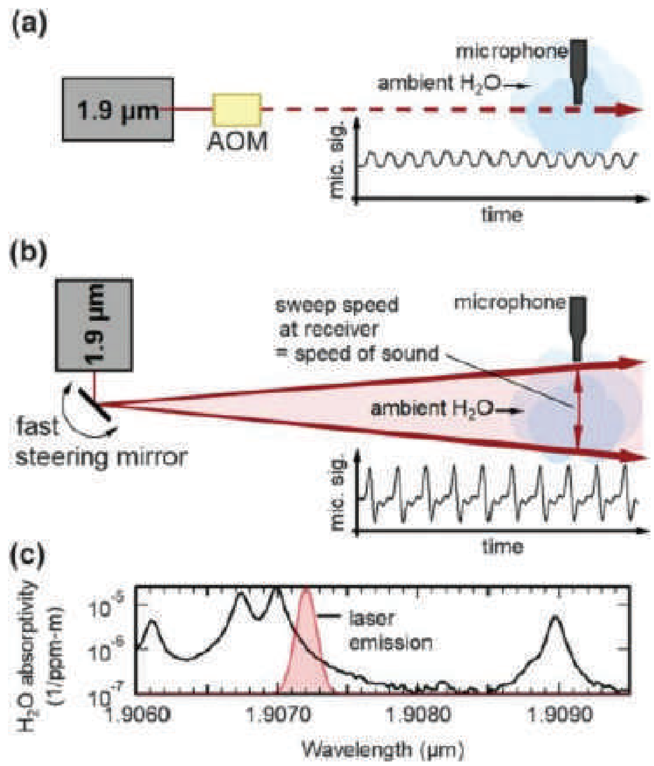
Kind regards, Maurizio Demontis
General Manager - Brüel & Kjær Australia

Now hear this: Photoacoustic communications via lasers

Modern choices of conveying information range from smartphones to computers to texts and emails. These data transmission modalities require both the sender and the recipient to be similarly equipped, but what if the intended receiver lacks the appropriate electronic devices?

Photoacoustics might be able to support communications needs in this case. MIT researchers have demonstrated two laser-based techniques that can transmit an audible message to a person without any type of receiver equipment.

Experiments demonstrated the use of a 1.9 µm thulium laser to produce photoacoustic signals from ambient atmospheric water vapour at 50% relative humidity with sound pressure levels well into the audible realm. The method generates continuous wave audible signals near the receiver via the absorption of light by water vapour.



Delivery of audible messages via photoacoustics. (a) Traditional photoacoustic configuration: 1907.2 nm laser light is absorbed by ambient water vapour. (b) Dynamic photoacoustic communication amplifies the audible signal. (c) Water absorptivity near 1.9 µm, with an overlay of the laser emission from the thulium fibre laser. Source: MIT

A fast-steering mirror was also used to sweep the laser beam, spurring the laser spot at the speed of sound over some arch adjacent to the receiver. The process amplifies the acoustic signal and produces pulsed acoustic emission without the need for a resonant chamber. Commercially available equipment applied to this technique can transmit sound to a person more than 2.5 m away at 60 decibels.

These methods for sending highly targeted audio signals over the air could be used to communicate across noisy rooms or warn individuals of dangerous or emergency situations. The researchers next plan to demonstrate the technology outdoors at longer ranges.

The study results are published in Optics Letters (https://doi.org/10.1364/OL.44.000622)

Scientists gave alligators Ketamine and headphones to understand dinosaur hearing

An experiment involving 40 drugged alligators reveals how dinosaurs might have located sounds in their environment. Scientists dosed alligators with Ketamine and had them listen to sounds through earbuds to better understand the auditory abilities of dinosaurs.

The experiment, described in a paper published Monday in The Journal of Neuroscience [Vol. 39, Issue 20, 15 May 2019), was designed to study the "*neural maps*"—brain passageways that carry information about soundwaves—that alligators generate to locate noises in their habitats. These maps are vital for many vertebrates, and are especially developed in nocturnal predators such as barn owls because they rely heavily on sound to locate prey.

See www.vice.com/en_us/article/a3b9kj/scientists-gave-alligators-ketamine-and-headphones-to-understand-dinosaur-hearing for more information.

Can we design a structure that can block noise but preserve air passage?

"*Today's sound barriers are literally thick heavy walls*," says Reza Ghaffarivardavagh, a mechanical engineer at Boston University. Although noise-mitigating barricades, called sound baffles, can help drown out the whoosh of rush hour traffic or contain the symphony of music within concert hall walls, they remain a clunky approach not well suited to situations where airflow is also critical.

Imagine barricading a jet engine's exhaust vent—the plane would never leave the ground. Instead, workers on the tarmac wear earplugs to protect their hearing from the deafening roar.

An alluring question enticed the researchers: "*Can we design a structure that can block noise but preserve air passage?*"

Leaning on their mathematical prowess and the technology of 3D printing, it turns out they can. The research appears in Physical Review (Vol 99, Issue 2, January 2019). The mathematically designed, 3D-printed acoustic metamaterial is shaped in such a way that it sends incoming sounds back to where they came from, Ghaffarivardavagh and Zhang say. Inside the outer ring, a helical pattern interferes with sounds, blocking them from transmitting through the open centre while preserving air's ability to flow through. (Credit: Cydney Scott/Boston U.)

Ghaffarivardavagh and Zhang let mathematics—a shared passion that has buoyed both of their engineering careers and made them well-suited research partners—guide them toward a workable design for what the acoustic metamaterial would look like.

"*Sound is made by very tiny disturbances in the air. So, our goal is to silence those tiny vibrations,*" Ghaffarivardavagh and Zhang say. "*If we want the inside of a structure to be open air, then we have to keep in mind that this will be the pathway through which sound travels.*"

They calculated the dimensions and specifications that the metamaterial would need to have in order to interfere with the transmitted sound waves, preventing sound—but not air—from being radiated through the open structure. The basic premise is that the metamaterial needs to be shaped in such a way that it sends incoming sounds back to where they came from, they say.

As a test case, they decided to create a structure that could silence sound from a loudspeaker. Based on their calculations, they modelled the physical dimensions that would most effectively silence noises. Bringing those models to life, they used 3D printing to materialize an open, noise-cancelling structure made of plastic

Sounding the alarm on aquatic noise

A collaborative team led by University of Victoria (Canada) doctoral student and Hakai Scholar Kieran Cox and fish ecologist Francis Juanes has found that human-caused noise is changing the ability of fish to forage, reproduce and avoid predation. The team analysed

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Figure 5 (a-c) shows a series of screen shots from each of the tabs.

Source	Parameter	3.125 Hz	4 Hz	5 Hz	6.25 Hz	8 Hz	10 Hz	12.5 Hz
[illegible]	Leq (dB)	66.5	72.1	74.3	77.2	77.7	80	82
[illegible]	L10 (dB)	70	74.9	75.5	78.8	79.9	82.7	84.2
[illegible]	L50 (dB)	61.6	67.4	67.2	71.5	73.7	75.5	78.5
[illegible]	L90 (dB)	52.1	59.5	57.5	63.9	67.4	69.6	72.9
[illegible]	L95 (dB)	48.7	57.3	54.5	61.9	65.8	67.9	71
[illegible]	L1 (dB)	77	83.3	86.8	88.6	86.2	89.3	91.7
[illegible]	Max Leq (dB)	81.7	87.5	96	98.1	98	98.8	102.2

Figure 5c: Table tab

7.2 FFT

The user can choose to calculate the FFT over the time selection. The FFT function utilises the full resolution of the raw data by calling the relevant section from the audio file and processing it. The results can be displayed quickly for short time selections; however, longer selections can be time consuming to process.

Once that FFT has been calculated, a spectrum will be displayed as shown in Figure 6. A range of standard window lengths and types can be chosen from the drop-down menus. The levels shown for the FFT are relative levels, not absolute calibrated levels.

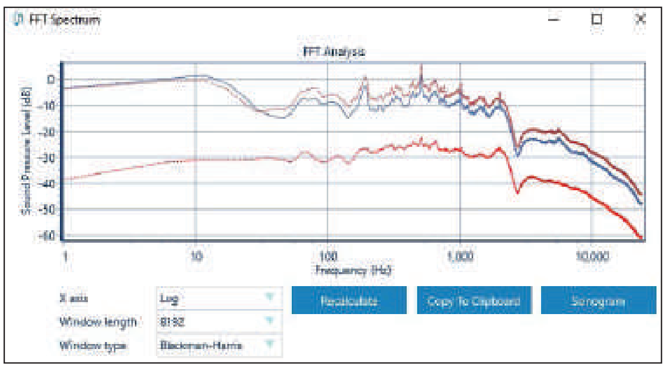

Figure 6: FFT example

A spectrogram can also be produced from the FFT by clicking on the 'Sonogram' button. An example is shown below in Figure 7. These levels are also relative.

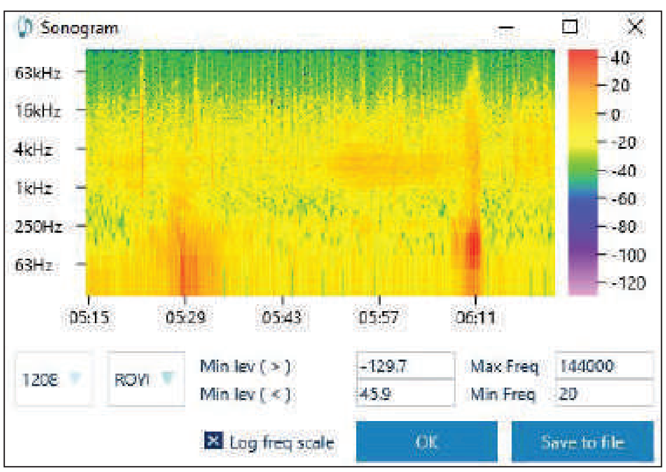

Figure 7: Sonogram example

7.2 Bands versus Time

The Bands versus Time function can also produce a spectrogram. This method is significantly faster than the FFT as it uses the data in the LVX file instead of calculating from the raw audio. The Bands versus Time levels are calibrated.

An example of the Bands versus Time output is shown in Figure 8 below.

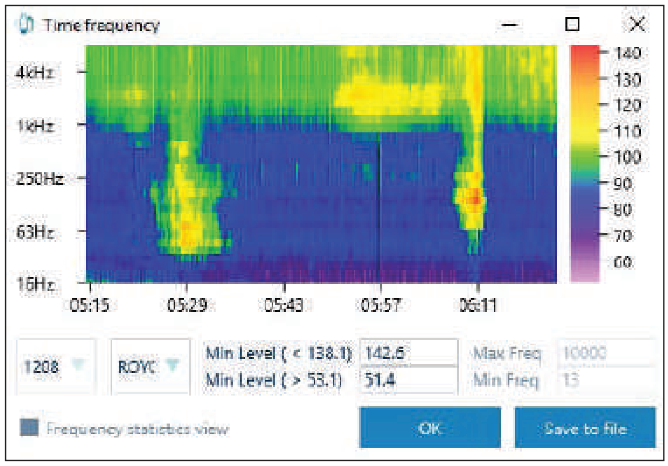

Figure 8: Bands versus Time example (1/3 octave spectrogram)

8. Conclusions

A need for an efficient and easy to use software tool for analysing long-duration hydrophone measurements has been identified.

Marshall Day Acoustics has developed the software tool dBWav to meet this need. This tool allows for real-time analysis of the measurement data by pre-processing the raw audio data and storing the relevant information in a much smaller data file, which can be quickly accessed to display information in dBWav's interface.

dBWav is able to produce many of the results necessary for use as a high-level analysis tool for both consulting and research purposes. It contains exporting features for further analysis using other software tools as required.

9. Future work

This paper has described version 1.0 of dBWav. Features that are in progress for the next version are:

- Produce power spectral density and empirical probability density plots
- Underlay the spectrogram in the main time-trace navigation window. Periods of interest can be identified more easily using a spectrogram as it contains frequency information as well as level.
- Allow calibration with electrical values as well as pistonphone and factory calibration
- Increase upper frequency limit

- Add tags to the spectrogram

Features which are being considered for following releases are as follows:

- Ability to produce results for specific time periods such as day/night, or tidal cycles
- Include audiogram weightings to supplement linear and NOAA marine weightings
- Include option for one-twelfth octave spectral data
- Include a click detector

Acknowledgments

I would like to thank Marshall Day Acoustics for the opportunity to have a role in the development of this software tool. In particular, I would like to thank Craig Fitzgerald for the opportunity to be involved in the exciting field of underwater acoustics.

The credit for development of dBWav goes to the T3 group of MDA, namely Martin Keane, Dan Griffin, Daniel Protheroe, Keith Ballagh and Michael Morrow.

I would also like to thank John Atkins of Ocean Instruments for his input and for developing the Soundtrap hydrophones for which dBWav was initially designed.

The feedback from researches in the field of underwater acoustics has been valuable in developing and refining dBWav. Thank you to Matthew Pine, Craig Radford and Jenni Stanley for this input.

10. References

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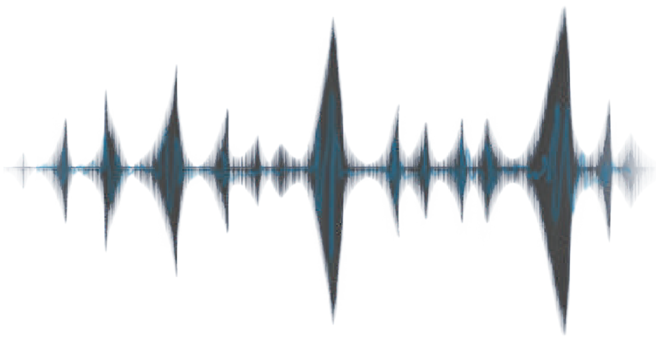

Reverse sensitivity issues between noise sensitive activities & commercial activities in inner city Wellington

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Original peer-reviewed paper

1. Introduction

Wellington's Inner City is zoned the 'Central Area' in the Operative Wellington City District Plan (The Plan). It is the most densely populated mixed-use area in Wellington and stretches from the Basin Reserve towards Thorndon.

The number of apartments in the Central Area is continually increasing and further construction is being encouraged by Wellington City Council (the Council) as an organisational strategy to increase affordable housing in Wellington. Therefore, it is essential that The Plan noise rules requiring external sound insulation for noise sensitive use buildings[1] are proven to be effective in providing adequate internal residential amenity to residents and to prevent potential reverse sensitivity issues affecting commercial activities[2].

This paper focuses on the effectiveness of the current sound insulation rules in reducing potential reverse sensitivity issues that may constrain commercial activities. Reverse sensitivity is a planning term. Judge Sheppard, an Environment Court Judge, described reverse sensitivity as sensitive activities causing restraints on other non-sensitive activities in their vicinity[3]. In this paper an assumption is made that complaints from residents are a precursor to any potential action aimed at restraining commercial activities. Namely, prior to any action being mobilised it is likely a large number of complaints are first generated from adversely affected people.

The number of annual noise complaints attributed to the Central Area was calculated as a percentage with the results showing that these noise complaints are disproportionately high when considering the number of people living in this area compared to Wellington overall. An analysis of annual complaint numbers by type over time is made to better understand the potential reverse sensitivity associated with the introduction of noise sensitive uses into what was originally a commercial area with little residential use.

Sound insulation of noise sensitive uses was not initially required under the original first-generation Wellington City District Plan when the Central Area was rezoned mixed use in 1998. The period prior to the introduction of the insulation rules in 2003 is compared to the period after the introduction of the insulation rules to ascertain the effectiveness of sound insulation in reducing the potential for reverse sensitivity issues to arise due to an increased number of residents living in a mixed use area. As the population increases in the Central Area an increasing proportion of residents will be living in newly constructed sound insulated apartments. If the sound insulation is effective, the Council should receive few if any complaints from residents living in insulated apartments about noise emanating from external sources such as entertainment venues. Therefore, complaints attributed to entertainment venues should not increase with the increase in population.

Based on the above parameters and results, a conclusion has been made as to whether or not the introduction of sound insulation requirements into the Plan has been effective in reducing potential reverse sensitivity issues due population growth in the Central Area as a whole.

Photo 1: Recently constructed sound insulated apartments on the left and uninsulated apartments on the right bordering entertainment venues facing Courtney Place

1 Any residential activity, any hotel, motel or other premises where residential accommodation for five or more travellers is offered at a daily tariff or other specified time, early childhood centres
2 Noisy activities of a commercial nature such as entertainment venues
3 Auckland Regional Council v Auckland City Council (RMA 10/97)

2. District plan noise limits in the central area

The Wellington District Plan was introduced in the mid- 1990s and rezoned the Central Area as a mixed-use area. Both noise sensitive uses and commercial uses became permitted activities. Monitoring of background or ambient sound pressure levels show that they are high in the Central Area[4] when compared to ambient sound pressure levels in the residentially zoned areas. This is anticipated due to the commercial nature of many activities within this area.

The permitted noise limit specified in the Operative Wellington City District Plan[5] is a compromise between noise sensitive uses and non-sensitive commercial uses. In setting the permitted noise limit it was recognised that the high ambient sound levels in the area dictated a higher permitted base line limit. By setting a more stringent noise limit (comparable to the residential areas) this could constrain commercial activities. However, the permitted activity noise limits (and existing high ambient sound pressure levels) do not in the authors' opinion afford an adequate level of residential amenity to residents living in these areas[6] and does not in all cases prevent sleep disturbance when only modern standard construction[7] is used at building facades.

For mechanical plant The Plan currently sets the following permitted noise limits:

- Noise emission levels from fixed plant shall not exceed the following at or within the boundary of any land parcel, or at the outside wall of any building on any site, other than the building or site from which the noise emitted[8]

At all times	55 dB $L_{Aeq\ (15min)}$
10.00pm to 7.00am	70 dB $_{LAFmax}$

For all other general day to day activities, The Plan currently sets the following permitted noise limits:

- Noise emission levels when measured at or within the boundary of any fee simple site or at the outside wall of any building on any site, other than the building or site from which the noise emitted shall not exceed the following:[9]

At all times	60 dB $L_{Aeq\ (15min)}$
10.00pm to 7.00am	70 dB L_{AFmax}

4 E.g. Allen Street (Coutrtenay Place) ambient L_{Aeq} range from 53 -70 dB Weekend nights, Lambtom Quay ambient L_{Aeq} range from 57 -63 dB Weekday night.

5 60 dB $L_{Aeq\ (15\ min)}$ and 85 dB L_{AFmax} for activities and 55 dB $L_{Aeq\ (15\ min)}$ for mechanical plant

6 As recommended by NZS6802:2008 and by the World Health Organisation for residential living

7 In accordance with the building code only. The Building Code dies not seek to control noise from external sources.

8 Wellington District Plan Standard 13.6.1.1.1

9 Wellington District Plan Standard 13.6.2.1.1

3. Current external noise insulation requirement in the central area

After re-zoning the Central Area and permitted mixed use, by 2001 the Central Area accounted for around 25% of the total noise complaints the Council received for the entire Wellington District. It is noted that at that time, this was from an area that accounted for only 3.7% of Wellington's total population.

Pressure was placed on the Council by both inner city residents, and by commercial operators, such as entertainment venues. Residents complained of high levels of internal noise in their apartments, and commercial premises were concerned about the level of complaint aimed at their legitimate businesses. The Council was looked to for a solution to this issue. Consultation was undertaken and a public meeting was held, with the entertainment sector naturally demanding higher (more permissible) noise limits and higher sound insulation requirements for apartments. The residents naturally demanded more stringent noise limits imposed on the commercial operators.

Following the consultation process, new rules requiring sound insulation of all newly created apartments[10] in the Central Area were introduced in 2003. A minimum performance standard was set which sought to provide an acceptable internal residential noise limit for the protection of health and amenity and thus prevent sleep disturbance. This was to be achieved by designing a minimum noise insulation performance standard for the façade structure of the building. The acceptable internal level would only be achieved when all external windows and doors were closed, and consequently an additional requirement for mechanical ventilation provided to habitable rooms to allow for fresh air was required. The aim was to provide a minimum adequate level of residential amenity within apartments, (and other noise sensitive use buildings) as well as to reduce the number of noise complaints emanating from the Central Area, in particular, complaints against noisier commercial activities such as entertainment venues.

The sound insulation and ventilation requirements introduced into the Central Area Rules of the Plan which remain current as of today are as follows:

- Any habitable room in a building used by a noise sensitive activity within the Central Area shall be protected from noise arising from outside the building by ensuring the external sound insulation level achieves the following minimum performance standard;

  $D_{nT,w}+C_{tr}$ >35 dB for the Courtenay Place Area

10 The defining criteria being whether there was creation of any new 'Habitable room used for a noise sensitive activity'. Habitable room is separately defined.

and $D_{nT,w}+C_{tr}$ >30 dB[11] for all other areas[12]

- Where bedrooms with openable windows are proposed, a positive supplementary source of fresh air ducted from outside is required at the time of fit out. For the purposes of this requirement, a bedroom is any room intended to be used for sleeping. The supplementary source of fresh air is to achieve a minimum of 7.5 litres per second per person[13]

4. Results

We assessed statistics held by the Council with regards to population growth for the region, and excessive noise complaints. Noise complaints were separated by type and location, namely 'Entertainment Venue', or 'Residential/Stereo Music', and 'Central Area' compared with the overall Wellington Region. Complaints of the type 'Entertainment Venue' are directly attributed to complaints from residents regarding noise from entertainment venues. Complaints of type 'Residential/ Stereo Music' are considered to reflect inter-tenancy type noise complaints, for example where one apartment dweller complains about their residential neighbour.

4.1 Population

Rezoning the Central Area to a mixed-use area led to a proliferation of Inner City residents. The population increased by 237 % from 6,414 in 2001 to 15,209 in 2016.

Table 1: Population numbers for the Central Area, Wellington District (total) and the percentage of the Central Area relative to total Wellington population – 2001 to 2017[14]

Population: Percentage of total attributed to Central Area			
Year	Central area	Wellington district	Percentage
2001	6,414	171,100	3.7
2006	8.964	187,700	4.8
2013	12,612	197,500	6.4
2016	15,209	207,900	7.3

The results in Table 1 show:

- Wellington's[15] population increased by approximately 22% from 171,100 in the year 2001 to 207,900 in 2016.
- The population increased by 237% from 6,414 in 2001 to 15,209 in 2016.
- The Central Area accounted for 3.7 % of Wellington's population in 2001 and this increased to 7.3% of Wellington's population in 2016.

4.2 Noise complaints

Table 2 below illustrates the total number of noise complaints in the Central Area relative to the entire Wellington District between year 2000 and 2017 (17-year period) Annual Total Noise Complaints in Wellington and the Central Area.

Table 2: Summary of noise complaint totals for Wellington 2000-2017

Year	Total noise complaints Wellington District	Total noise complaints Central Area	% Cental area
2000	3513	987	28.1%
2001	4059	993	24.5%
2002	4316	1024	23.7 %
2003	4173	1284	30.8 %
2004	4100	1150	28 %
2005	4150	1000	24.1 %
2006	4277	802	18.8 %
2007	4634	972	21 %
2008	4636	980	21.1 %
2009	5680	1308	23 %
2010	5980	1296	21.7 %
2011	5997	1444	24.1 %
2012	5463	1325	24.3 %
2013	5416	1255	23.2 %
2014	5117	1169	22.8 %
2015	5963	1430	24 %
2016	6223	1501	24.1 %
2017	6154	1212	19.7%

The results show:

- A significant trend of increasing total annual numbers of noise complaints in Wellington for the period 2000 to 2017.
- The percentage of annual complaints attributed to the Central Area varies (peaking in 2003) but is consistently disproportionate to the population of the Central Area (cf. the region).

4.2 Noise complaints by type in the Central Area

Table 3 provides a breakdown of Central Area noise complaints by type; noise complaints resulting from noise emanating from entertainment venues, noise complaints associated with noise emanating from residential noise and stereos and other types of noise (predominately inner city construction noise).

11 $D_{nT,w}$ (weighted standardized level difference) + C_{tr} (is used to take into account different source spectra such as a low frequency correction from amplified sounds from an entertainment venue found in the central city area).
12 Wellington District Plan Standard 13.6.1.2.1
13 Wellington District Plan Standard 13.6.1.2.2
14 The latest censuses results provide up to 2016, only
15 Area of Wellington within Wellington City Council's jurisdiction

Table 3: Types of Central Area noise (percentage breakdown)

Year	Noise complaints related to entertainment venues	Noise complaints related to apartment amplified music - stereos	Noise Complaints Related to other sources
2000	41.8 %	34.3 %	23.9 %
2001	22.3 %	45.1 %	32.6 %
2002	26.9 %	49.7 %	23.4 %
2003	26.9 %	56.6 %	16.5 %
2004	30 %	55 %	15 %
2005	35 %	50 %	15 %
2006	36.4 %	43.1 %	20.5 %
2007	29.3 %	42.2 %	28.5 %
2008	15.8 %	53.7 %	30.5 %
2009	14 %	66 %	20 %
2010	16 %	64 %	20 %
2011	18.4 %	54.6 %	27 %
2012	25.1 %	54.7 %	20.2 %
2013	19.7 %	54 %	26.3 %
2014	25.4 %	47 %	27.6 %
2015	17.3 %	56.7 %	26 %
2016	11.9 %	59.7 %	28.4 %
2017	14.7 %	59.1 %	26.2 %

The results show:

- A decreasing trend over time regarding noise complaints attributed to entertainment venues
- An increasing trend over time regarding noise complaints attributed to residential noise.
- No pattern of noise complaints attributed to other sources such as for example temporary construction noise.
- The average percentage of noise complaints attributed to entertainment venues between 2000 and 2006 is approximately 31 % and the average between 2007 and 2017 is 19 %.

The above trends for entertainment venues and apartment stereos are depicted in Graph 1.

Graph 2 compares these trends further with the increase in population in the Central Area during the same period. It shows that the decreasing trend in the percentage of noise complaints attributed to bars and increasing trend attributed to residential complaints occurred in a period of significant population growth in the Central Area.

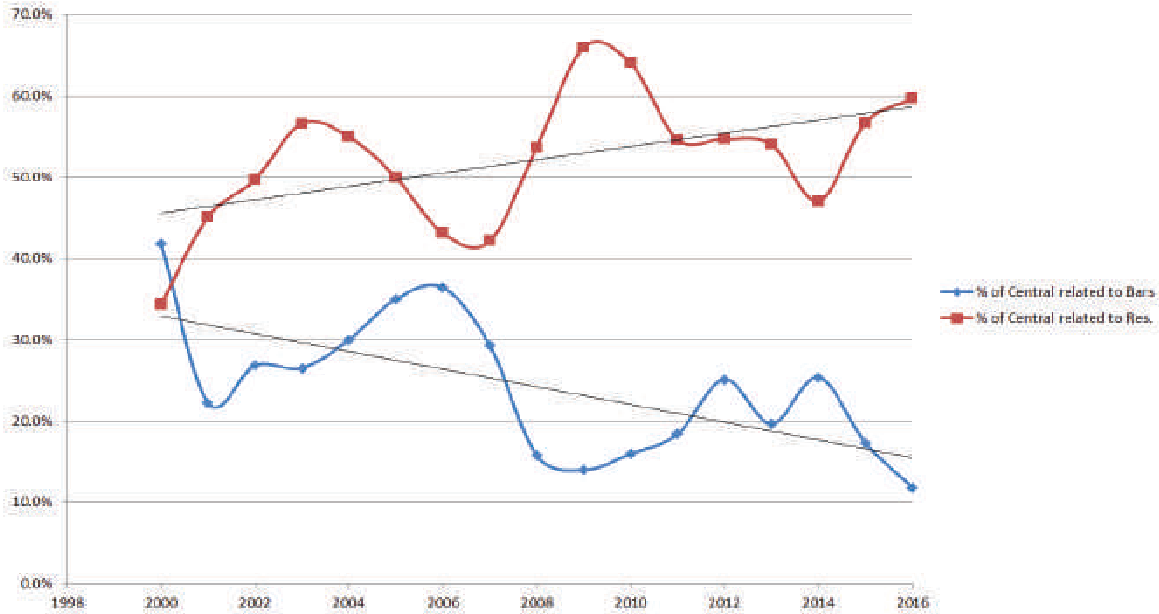
We then compared, the percentage of complaints against bars received from uninsulated apartments against insulated apartments. This is shown in Graph 3[16].

Photo 2: Measurements showed "internal noise levels" in these uninsulated apartments (glass wall façade) in the Courtenay Place area exceeded recommended levels for residential living when external levels met District Plan requirements

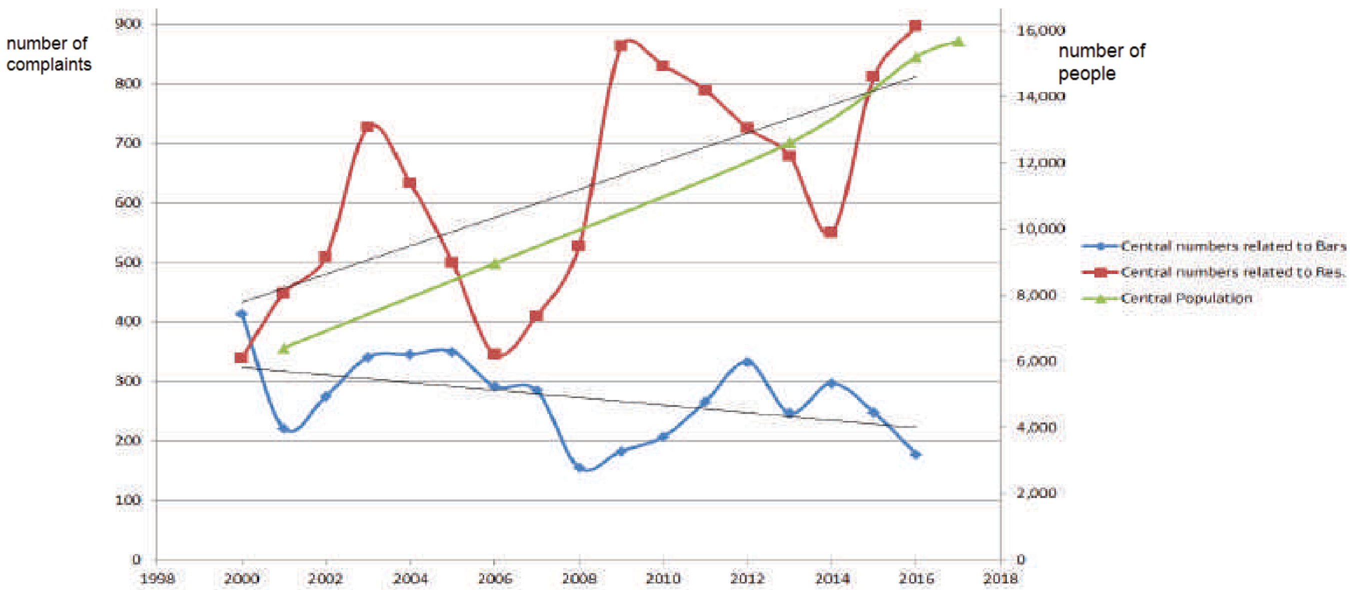
The results show:

- In 2016, 78 % of complaints relating to noise emanating from entertainment venues were received from residents living in uninsulated apartments, compared to 22 % from insulated apartments.

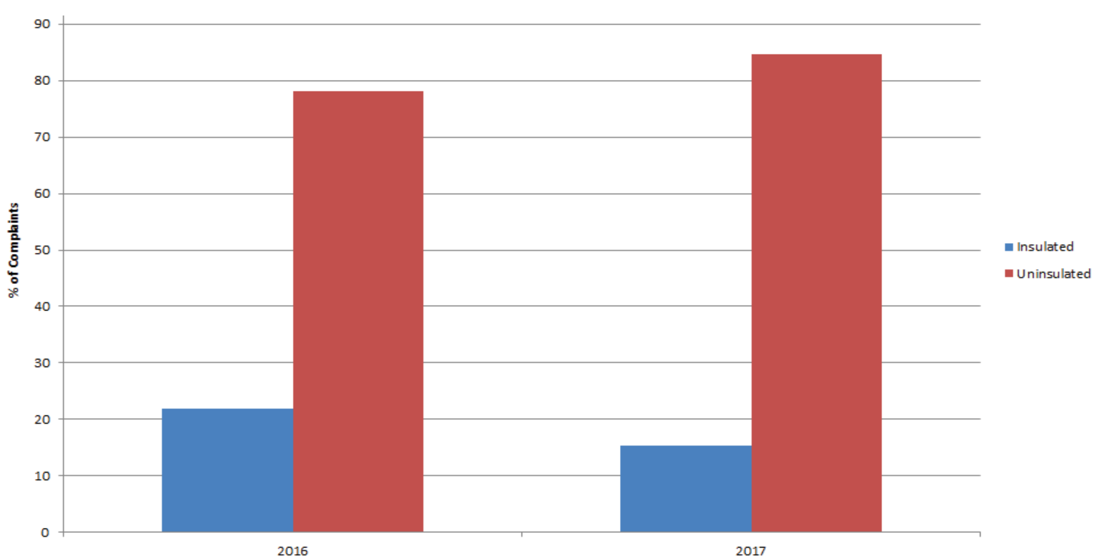
16 'Insulated' is reference with respect to meeting or exceeding the minimum noise insulation performance standard from the Wellington City District Plan.



Graph 1: Annual percentage of Central Area complaints by type (Entertainment venues and residential stereos)



Graph 2: Annual numbers of Central Area complaints by type and annual population



Graph 3: Noise complaint related to entertainment venues – Insulated versus uninsulated buildings in the Central Area


QUIETSPACE®
PANEL
When there is no room for compromise, Quietspace® Panel is the best solution for superior broadband absorption. Intentionally designed in the most common interior colours – black, white and our latest edition, grey, Quietspace® Panel can be left "nude" or covered in one of our 40 Vertiface® colours.
Acoustic testing to ISO 354. University of Auckland Testing Service Report
25mm Test: T0712-18. 50mm Test: T0712-13. 75mm Test: T1905-4. 100mm Test: T1905-5.
Sound Absorption Coefficient (αs)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
125
250
500
1000
2000
4000
Frequency f (Hz)
25mm (αs)
50mm (αs)
75mm (αs)
100mm (αs)
Want to learn more? Visit our website
www.autexindustries.com/acoustics/quietspace-panel
AUTEX

- In 2017, 85 % of complaints relating to noise emanating from entertainment venues were received from residents living in uninsulated apartments compared to 15% from insulated apartments.

Liquor licensing data shows the number of bars in the Central Area has remained very constant over the last 6 years with 90 bars in 2010 and 89 bars in 2016.

5. Discussion

Wellington's population increased between the year 2000 and 2016 with a disproportionate rate of increase attributed to the Central Area compared to the overall wider Wellington District (27 % percentage change compared to 22 %, respectively). Wellington City Council's proposal is to encourage further residential development in the Central Area so as to provide for affordable housing which is predicted to lead to a continued disproportionate increase in the number of people living in the Central Area.

As expected the total number of noise complaints in the Central Area have increased as the population of the Central Area increased. The number of noise complaints in the Central Area in the year 2000 was disproportionate to its population size, being 28 % of noise complaints received from 3.7 % of Wellington's wider population. This anomaly remains in 2016 with 24 % of complaints emanating from the Central Area, which now accounts for 7.3 % of Wellington's total population. This suggests that Central Area residents may have more cause to complain about noise than say their suburban counterparts. This can in part be explained due to the known higher ambient noise levels within the Central Area, however, an assessment of the type of noise complaint made offers more insight into this.

Wellington noise complaint data breaks down the type of complaint into categories of 'entertainment venues', 'residential noise', and 'other' (predominantly construction activity). When assessing noise complaint numbers by type, the percentage of Central Area noise complaints associated with entertainment venues has significantly decreased over time, The percentage attributed to residential-type noise has significantly increased over time and the percentage associated with other sources remaining relatively consistent.

Complaints attributed to entertainment venues have decreased from 41.8 % in the year 2000 to 14.7 % in 2017. This suggests that although there are far more people living within the Central Area now (cf. 2000), the instance of those people complaining about entertainment venues is decreasing. The percentage of complaints attributed to entertainment venues in the Central Area for the period 2001 – 2007 is 31 % and the average between 2007 and 2017 is 19 %.

The reduction in complaints against entertainment venues is more prominent after 2006; three years after the external sound insulation rules were introduced into the Wellington City District Plan. When allowing for a lag period for the effects of the introduction of the sound insulation rules to be realised, the decrease in complaints may be attributed to the external sound insulation performance. It is reasonable to make the assumption that the increasing numbers of people residing in newly constructed apartments with a minimum level of sound insulation introduced by the Plan would take time to produce a representative population. Graph 3 shows there are a disproportionate percentage of complaints received against entertainment venues from residents in uninsulated buildings compared to residents in insulated buildings. This supports the hypothesis that the decreasing numbers of complaints received against noise emanating from bars can be attributed to the requirement of sound insulation introduced into the Plan.

There is another hypothesis that could be attributed to the reduction in complaints against entertainment venues, which is that people living in the Central Area may become 'conditioned' to the noise over time, that is, they are potentially more accepting of noise within the Central Area being located with the CBD. However, with increasing population and new residents being continually introduced to the Central Area, arguably the expectation would be for increased complaints, even when accounting for some residents becoming conditioned. It is noted noise complaints relating to inter-tenancy noise is shown to have risen with increased population. These two noise sources (residential noise and entertainment venues) commonly produce noise of a similar character, i.e. bass beats, and generally attention grabbing. Therefore, Central Area residents are still sensitized to noise, since inter-tenancy type noise is being complained about.

In summary the hypothesis that some residents becoming conditioned to living in the city with lower expectations regarding noise may contribute but cannot account for the significant reduction in complaints against entertainment venues.

Graph 2 shows a trend of the annual number of complaints attributed to entertainment venues is slightly decreasing over time while the annual numbers of complaints attributed to residential noise is significantly increasing. Residential stereo noise complaints are instances of one resident complaining against another, normally in the same building. The annual number of complaints attributed to residential stereos in apartment blocks has increased by 264 % from the year 2000 to 2016. There were 339 complaints received in the year 2000 (34 % of total Central Area noise complaints at that time) which increased to 896 (59 % of total Central Area noise complaints) in 2016. This is believed to be the predominant reason for the continued rise in Central Area noise complaints, despite the introduction of noise insulation requirements.

The introduction of a minimum noise insulation standard to the façade of a building results in a reduction in internal noise, due to noise emanating from outside the building. This may result in an increase in the perceived audibility of noise between apartments. The external noise insulation of the building façade does not protect residents from noise emanating between internal spaces[17] within the building. The Building Code (G6 'Airborne and Impact Sound) sets a minimum performance standard for internal noise. However, the sound insulation requirements for inter-tenancy noise set within G6 of the Building Code would not necessarily protect residents from excessive noise emanating (for example) from a modern stereo system within the building.

6. Conclusion

The 2003 Wellington City District Plan noise rules (and performance Standards) introduced a new minimum requirement for sound insulation to be introduced into the façade of new or altered buildings used for noise sensitive activities within the Central Area. These performance standards remain in place in the Plan.

The noise insulation performance standards can be demonstrated to be effective at reducing the potential for reverse sensitivity effects, when assessing the nature/type of noise complaints emanating from the Central Area since the introduction of the noise insulation requirements. This is with regards to issues arising between noise sensitive activities and noisy commercial activities, and in conjunction with the population living in the mixed-use area increasing. This is supported by data that shows that there are a disproportionate percentage of complaints received against entertainment venues from residents in insulated buildings, compared to residents in uninsulated buildings.

While the number of noise complaints in the Central Area have been increasing and remain disproportionate to population when compared to the number of complaints received in the Wellington District overall, the number of complaints attributed to the entertainment sector have not increased with the increased population. In fact, they have decreased (as a percentage).

There has been a significant increase in the percentage of complaints attributed to residential stereos over the same period. This is also in conjunction with a significant increase in numbers of residents living in close proximity to each other.

17 Between apartments or rooms

...Continued on Page 33

...Continued from Page 8

42 studies from across the globe on the effects of aquatic noise on fish behaviour and physiology and found anthropogenic noise to be the most compromising factor affecting the ability of fish to feed, avoid predators and reproduce. "*Fish understand their environment through sound*," says Cox. "*Mining activities and sea vessels interfere with what they need to hear in order to thrive. The results indicate that fish are stressed and have difficulty hearing over the noise*." The paper, "*Sound the alarm: A meta-analysis on the effect of aquatic noise on fish behaviour and physiology*", can be read in the peer-reviewed journal Global Change Biology (Vol 24, Issue 7, July 2018). Juanes is involved in another UVic research project announced last week that will study the impact of underwater noise on British Columbia's Southern Resident Killer Whale population and the whales' primary food fish, chinook salmon.

RMLA's 2018 outstanding person award goes to Chris Day

At New Zealand's Resource Management Law Association (RMLA) conference dinner on Saturday 22nd September 2018, Chris Day , co-founder of Marshall Day Acoustics, was awarded the Outstanding Person Award for his significant contribution to the understanding and management of building acoustics and environmental noise, and so facilitating complex developments and furthering resource management practice in New Zealand.

The nomination and award was kept secret from Chris, and since he was sailing around the Mediterranean at the time, its presentation over Skype was completely unexpected - he had to very quickly think on his feet and readjust from sailing to award dinner!

The RMLA also published a news article on their website, www.rmla.org.nz

Aaaaahh! Researchers probe the acoustics of screams

Work is under way to precisely define the most primal of human vocalisations. When people hear a scream, English fantasy writer and humorist Terry Pratchett once wrote, "*they don't necessarily come running... ...that's not how humans work*," he said. "*Humans look at other humans and say, 'Did you hear a scream?' because the first scream might have been you screaming inside your head, or a horse backfiring.*"

Hollywood's most famous scream: Janet Leigh in the shower scene from Psycho. BETTMAN/GETTYIMAGES

But in this case, scientists say, he might not be fully correct. It turns out that humans are pretty good at recognising screams for what they are — even though there are plenty of opportunities for confusion.

When animals scream, says bioacoustics researcher Jay Schwartz, a graduate student in neuroscience and animal behaviour at Emory University in Atlanta, Georgia, US, it's probably for a fairly specific reason, such as trying to startle an attacking predator in order to escape, or to recruit help when in trouble. But humans scream for a great many other reasons: terror, anger, pain, excitement, surprise, psychological distress, or even the delicious fear of roaring downhill on a roller-coaster.

"*Animal screams have been studied in depth, (but) human screams have received little attention*," Schwartz recently told a meeting of the Acoustical Society of America in Louisville, Kentucky. To remedy this, his team asked 181 volunteers, mostly undergraduate students, to listen to 75 non-verbal human vocal sounds — sounds that represented

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Aeroacoustic assessment of facades

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Abstract

Façade designs are becoming increasingly complex, resulting in an increased occurrence of a façade generating wind- induced noise which can be a nuisance for sensitive receivers. Despite this, wind-induced noise is often overlooked in the design of a façade. This paper highlights typical wind-induced noise mechanisms and typical methods used to assess and quantify the potential for a façade to generate noise. A novel technique is presented which was developed to assess the potential of a façade to generate noise. Application of this technique to a case study is discussed for the Adelaide Medical and Nursing Schools (AMNS) project, a new campus facility at the western end of North Terrace in Adelaide's CBD.

Originally published in the Proceedings of ACOUSTICS 2016, Brisbane, Australia

1. Introduction

Wind-induced noise is often overlooked for building design. Wind noise can be generated by wind flowing over façade elements or through gaps within buildings. Noise generated from wind impacting façade elements, especially at higher wind speeds has received increased attention in recent years. The most notable example is Europe's tallest residential building in Manchester, England, known as "*Beetham Tower*", which received widespread publicity when completed, refer to Figure 1, as reported by Leeming (2006). Baker (2015) has recently reported that work to reduce or eradicate the noise took place in 2007 with foam pads installed, aluminium nosing in 2007 and further undisclosed work completed in February 2010. Attempts to eradicate the noise permanently have been unsuccessful.

Tallest tower whistles in the wind

Figure 1: Article from The Enquirer – North West, from Leeming (2006)

Ploemen et al. (2011) provides evidence of two tall buildings, part of the Hague in the Netherlands, which became notorious for noise generated at wind speeds of around 12-15 m/s, with steel grids being claimed to be the noise source. Other recent and local examples include Aeolian noise generated by the finned balustrade of freeway pedestrian overpasses installed at 6 locations along the 40 km Eastlink project in Melbourne, Australia (Mitchell et al., 2010). Noise levels at nearby residential properties were reported to be 40 dB greater than the background (or ambient) noise level.

There is a strong overlap between acoustic and wind engineering, with recent developments in the assessment of noise from wind farms instigating improved understanding of aerodynamic sound concepts (as well as an understanding of meteorological conditions and models usually associated with air quality and dispersion analysis). The study of aerodynamic sound began with noise from jets (Lighthill, 1952 & 1954), and was developed within the domain of aerospace (high mach numbers) and mechanical (low mach numbers) engineering. Lighthill rearranged the Navier-Stokes equations governing fluid flow (conservation of mass, momentum and energy) into a wave equation describing the acoustic field generated by turbulence.

2. Facade aeroacoustics - Previous work

Rofail and Tonin (2000) first introduced the issue of "*wind-noise*" in buildings. Full-scale wind tunnel measurements were carried out with flow through an open window/door with recesses in aluminium extrusions as per Figure 2. Results indicated that the wind speed coinciding with the onset of Aeolian tone generation is dependent on gap width, and frequency of the tone is dependent on incident wind speed. The sound pressure level was found to increase with wind speed and, for constant wind speed,

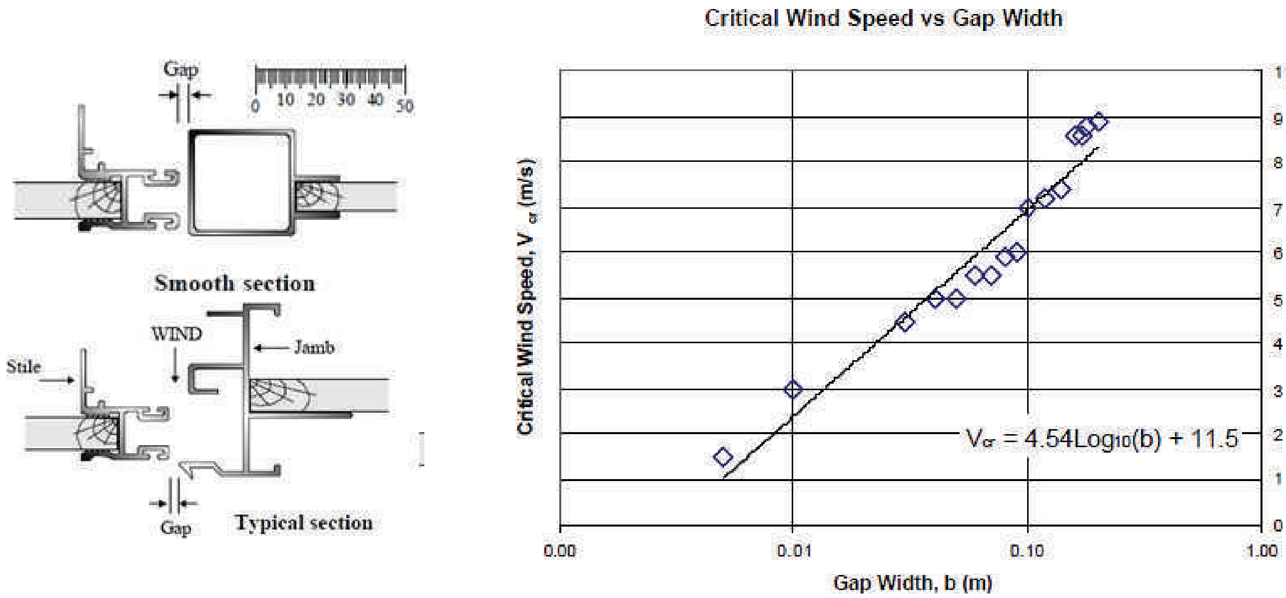

Figure 2: Wind generated noise from accelerated flow across a cavity (Rofail and Tonin, 2000)

decrease with gap width.

Moloney et al. (2010) provided a general discussion of testing and assessment of wind noise around buildings which briefly discussed aerodynamic noise sources (eg. vortex shedding, cavity resonance, structural resonance) and potential issues with building elements (eg. cables, slots, etc.). Various test methods rather than analytical or computational methods were introduced to identify problems with building elements.

Coppa and Paduano (2015) describe a design process to evaluate the potential of wind noise for façade elements using computational fluid dynamics (CFD). CFD modelling demonstrated vortex shedding from sunshade elements by calculating the power spectral density of the time trace of the pressure coefficient. There is some discussion on "*lock- in*" phenomena or coincidence of vortex shedding with acoustic resonance, but no definition of the radiated sound power level. Coppa and Paduano also outline the Arup Acoustics guidance notes (Figure 3a) that have "never been fully tested or studied extensively" and have been "too often deemed impractical and unreasonable from an aesthetic and façade engineering standpoint". Coppa and Paduano's work also highlighted the importance of flow parallel to the façade.

Fricke (2010) initiated some work on local façade velocity estimates, as shown in Figure 3(b), with local peak (3 second gust) velocities at the roof edge up to 1.7 times the incident peak velocity. Mean and peak wind speeds and multipliers to account for directionality, topography, terrain and the like are well established in building codes such as AS/NZS1170 but are not ordinarily recognised nor understood by acoustic consultants.

a)

Elements-aperture	Dimension	Comments
Unsealed slots, apertures and exposed elements within façade cladding	>100mm	For exposed elements introduction of vibration damping treatments needed. For cavities and apertures it is recommended to close all openings and apertures to avoid the creation of resonant cavities.
Wires, circular cables, tubular elements or hollow sections	>50mm	If a bigger dimension than 50mm is not possible to be included then provide special damping treatment.
Array elements	>100mm	In case of regular array of elements, smaller dimension of apertures should be avoided or provide special damping.
Constructions	>100mm	Irregular constructions should be used to break-up vortex street formations.

b)

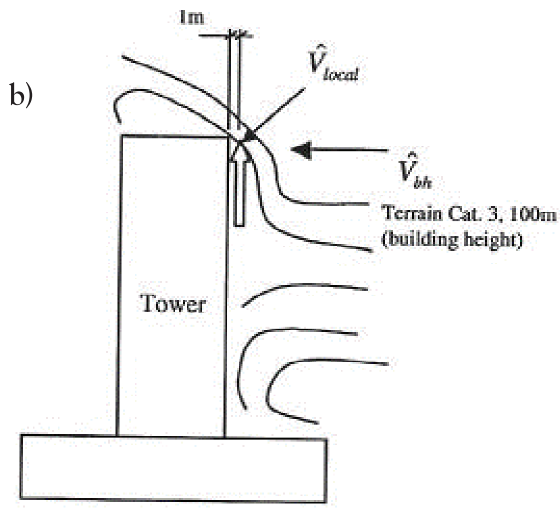

Figure 3: a) Arup Acoustics guidance notes (Coppa and Paduano, 2015); b) Wind velocity across a façade relative to the incident velocity at building height Fricke (2010)

3. Aerodynamic noise sources and aeroacoustics

Noise generated from fluid flow is called aerodynamic sound and is considered within the field of aeroacoustics. Subsonic flow can be classified into three source types: monopole, dipole and quadrupole. A monopole source is produced by pulsating flow or flow which causes pulsations such as flow over a small aperture in a wall, with the flow inducing pulsating motion of air in the aperture. A dipole is produced when flow interacts with surfaces or bodies, such as vortex shedding from airfoils, cables or similar. A quadrupole is formed by Reynolds stresses in a turbulent flow, such as that of a jet or the turbulent boundary layer over a flat plate. The radiation efficiency of dipoles and quadrupoles is less than that of monopoles due to phase cancellation of pressure pulsations (depicted in Figure 4).

As an example, sound pressure levels measured by Rofail and Tonin (2000) for flow exciting a cavity resonance (refer to Figure 2) is shown in Figure 5 b). Change in sound pressure is consistent with the 4th power of the velocity ratio suggesting the aerodynamic noise source is of monopole type.

Similarly sound pressure levels measured by Akagi et al (1998) for Aeolian tones generated from vortex shedding of power lines are given in Figure 5a), with the change in sound pressure level with doubling of the wind speed consistent with the 6th power of velocity suggesting the aerodynamic source is of dipole type.

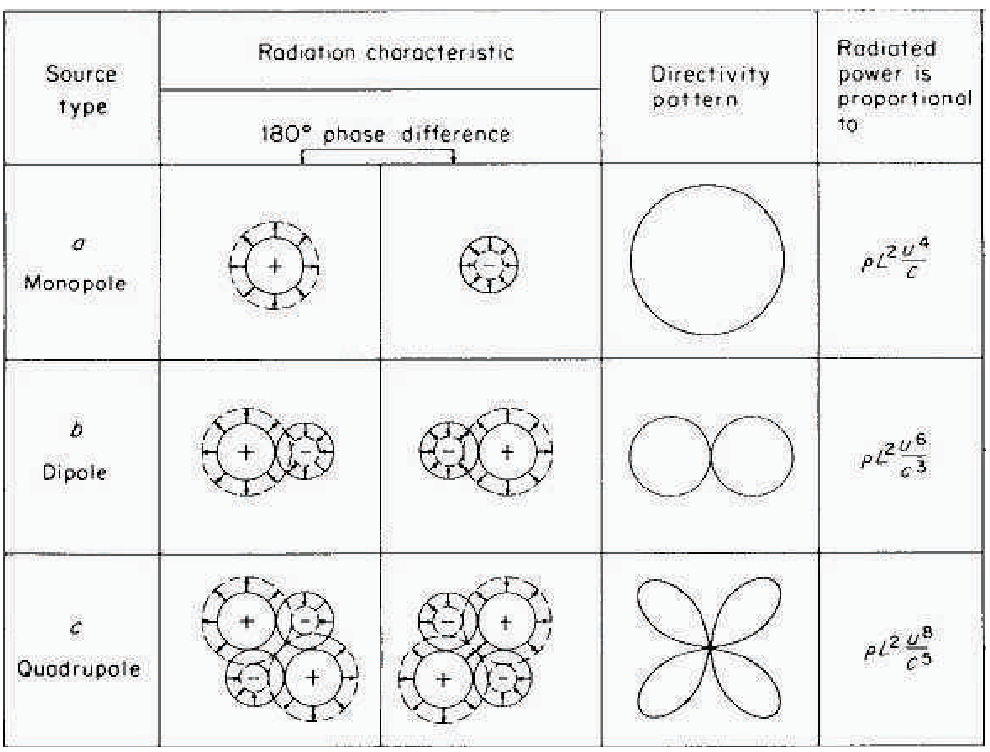

Figure 4: Aerodynamic noise source types (Ver and Beranek, 2006)

4. Analytical methods

Analytical methods can be used to estimate wind speeds required to generate noise for typical flow interactions. Semi-empirical approaches can be used to estimate the frequency and intensity of the resulting acoustic field. Some common flow interactions, and mechanisms of wind-induced noise utilising these methods are discussed in the following.

Aerodynamic noise at low wind speeds is usually caused

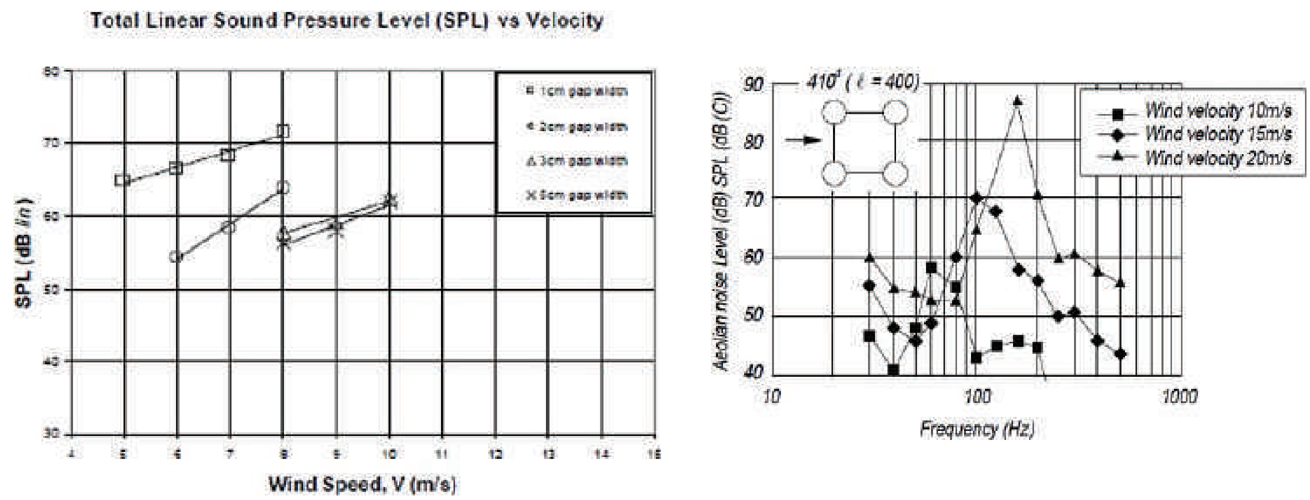

Figure 5: Aeolian noise generated from: a) a 4-bundle conductor (Akagi et al 1998); and, b) excitation of a cavity resonance (Rofail and Tonin, 2000).

by tonal noise (or "*aerodynamic whistle*") or modulation thereof. Chanaud (1970) provides a summary of tonal noise generation mechanisms which, as shown in Figure 6, can be classified into 3 types:

Class I: Hydrodynamic feedback generated by vortex shedding from bluff bodies such as cylinders. Generally well understood method of noise generation, with the frequency of the tone determined from the Strouhal Number, and the intensity based on the Scruton Number. This is similar to the example provided for Akagi et al. (1998), with the theory generally well understood.

Class II: Acoustic feedback from sound generated by flow onto a bluff body (eg. Jet impinging an edge, or jet impinging an orifice). Acoustic feedback from vortices induced by the jet impacting on the nearby edge generates a dipole acoustic source which radiates acoustic energy back into the impinging jet, further enhancing the periodic generation of vortices.

Class III: Require a resonating or reflecting structure to perpetuate the acoustic feedback, with the frequency of the tone dependent primarily on the resonant modes of the reflecting/resonating geometry. This is characteristic of flow over a cavity with methods presented in Ver and Beranek (2006) of Rossiter's formula and the like.

5. Numerical methods or computational aeroacoustics

The rearrangement of the compressible Navier-Stokes equations into the non-homogeneous wave equation is known as Lighthill's acoustic analogy (Lighthill 1952). The left hand side of this equation represents acoustic propagation while the right hand side contains noise sources produced by all remaining fluid motion. Problem classification depends on the coupling between noise sources and propagation.

One-way coupled aeroacoustic problems occur when fluid dynamic motions induce acoustic waves and there is no significant feedback. This tends to occur in incompressible flows, such as wind around buildings where resonances do not occur. Here the acoustic analogy can be solved in two parts; first the time varying incompressible flow is solved by standard CFD techniques to obtain the aerodynamically generated acoustic source terms, and then a dedicated acoustic solver is used to calculate the acoustic propagation of those sources. Alternatively, two way coupled problems occur when there is significant feedback from the acoustic waves to the fluid dynamics. In these situations the complete aerodynamic and acoustic

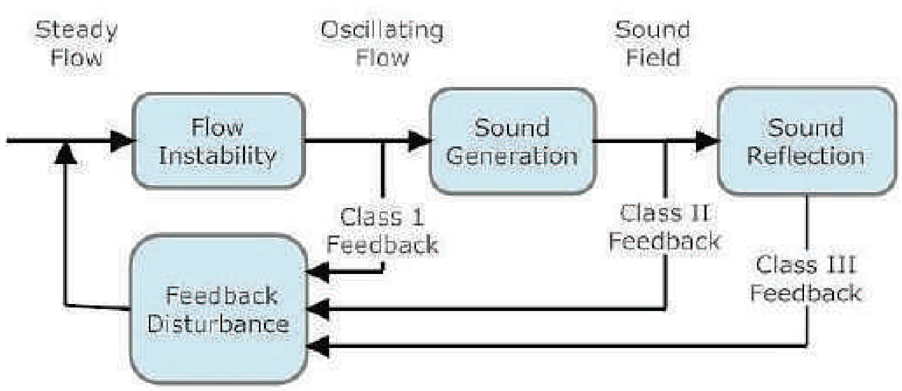

Figure 6: Tonal noise generation methods (Chanaud, 1970)

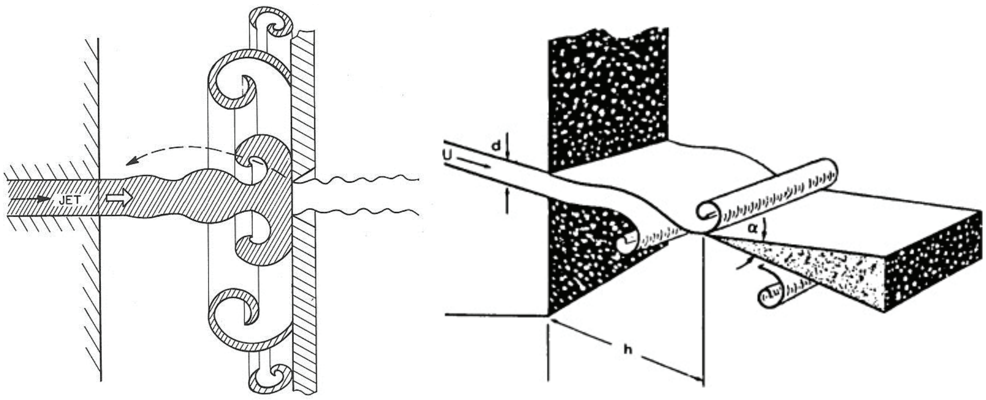

Figure 7: Acoustic feedback resulting from vortex shedding affecting flow within the jet

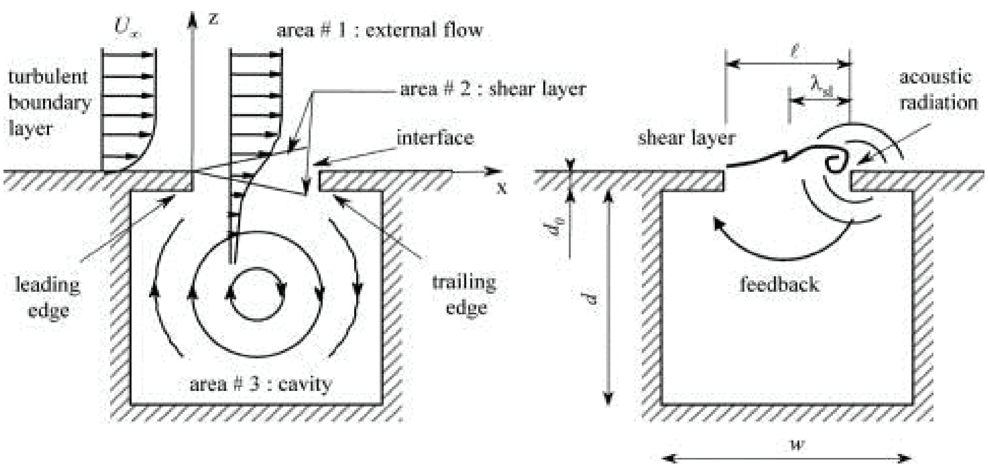

Figure 8: Acoustic feedback due to flow over a cavity perpetuated by acoustic resonance within the cavity

system needs to be solved simultaneously.

For one way coupled problems the time dependent fluid motion must be solved. In general the finite volume method is the primary method for CFD of engineering scale problems. Within this framework the two main categories of analysis are Large Eddy Simulations (LES) and Reynolds Averaged Simulations (RAS). LES is generally an attractive method of calculating aerodynamic noise sources since a majority of energy will be accurately resolved in the larger, resolved eddies. However, the computational resources required for industrial scale applications are still prohibitively expensive for most practitioners. Reynolds Averaged Simulations dramatically lower the required computational resources compared to LES, often at the expense of accuracy. If a steady RAS solution is calculated, then the time or frequency record of noise sources must be artificially synthesised by other means (e.g. stochastic noise generation). With aerodynamically generated source terms obtained by one of the CFD methods listed above, a one-way coupled problem requires calculation of acoustic propagation by either integral or differential methods. Integral methods include general solutions to Lighthill's acoustic analogy such as the Kirchoff integral or Ffowcs-Williams and Hawkings equation. These methods only include limited effects of the fluid shear layer on the propagating acoustic waves, if at all. Differential acoustic methods such as Linearised Euler Equations (LEE) or Acoustic Perturbation Equations (APE) are, however, capable of including such effects.

An alternative to traditional finite volume CFD is a simplified method known as the Lattice Boltzman Method (LBM). It uses a microscopic approach applying conservation of mass, momentum and energy to particles moving in a lattice structure. As demonstrated by de Jong (2008), LBM is able to accurately predict the frequency and intensity of sound generated by hydrodynamic and acoustic feedback mechanisms, as well as acoustic resonance. This is a promising approach for building aeroacoustics where resonance is significant.

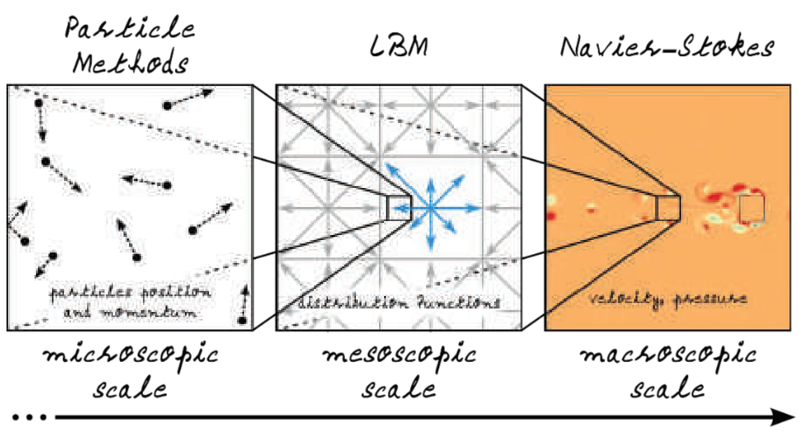

Figure 9: Comparison of computational methods

6. Wind tunnel test methods

It has become customary to test full-scale façades or elements as shown below in Figure 10 (Ploemen et al., 2011) to assess their potential for wind generated noise (or assess the cause of the noise post construction). Ploemen noted that two types of tones were measured, type I which increased in frequency with increasing wind speed, and type II which

had a constant frequency but increased intensity with wind speed. Wind tunnel testing could not define the mechanism behind these types of tones. The acoustic response of the façade element for a range of wind speeds is shown in Figure 10.

By exposing a scale model of a façade, or an element of the façade, to scaled atmospheric wind conditions wind tunnel testing can be used to predict wind effects on the full-scale façade. Similarity laws allow results measured for a scale prototype to be applied to the full-scale model, reducing number of tests required and cost involved. Similarity utilises non-dimensional analysis which reduces the number of variables investigated. Similarity can be described as geometric, kinematic and dynamic similarity whereby the ratio of model to prototype dimensions, velocities and accelerations, and applied forces, respectively, are equal.

Kinematic and dynamic similarity is commonly achieved by Reynold's number equivalence, although other non-dimensional parameters may be suitable. Reynolds number equivalence (for example) requires a prototype 1/10th of the actual size (tested in the same fluid as that to which the model will be exposed) to be exposed to a flow speed ten times faster to produce similar flow characteristics. Achieving this similarity requirement can be an issue depending on the wind tunnel's upper-limit wind speed.

Although small-scale testing can have time and cost benefits, full-scale testing may be preferred if small-scale measurements cannot be applied at full-scale appropriately, an appropriate wind tunnel is not available, or the cost and time benefits of small-scale are not seen to be worthwhile pursuing. When considering full-scale testing it is important to consider blockage effects in the wind tunnel test section. The real-life structure is essentially exposed to wind in an infinite space, whereas the test model is tested in a confined space. Distortion of the boundary layer flow occurs if the area of the test model projected onto a plane normal to the flow direction (blockage area) is significant compared to this area of the test section (Choi and Kwon, 1998).

7. Case studies

This section describes a case study for aeroacoustic assessment of a façade. The building of interest is the University of Adelaide's new Medical and Nursing School building located on North Terrace, along-side the main rail corridor into Adelaide. This building is shown in Figure 11, with a relatively complex façade. A meteorological assessment was completed to establish the frequency of occurrence of wind speeds in each wind direction. CFD was used to assess wind flow across the façade as shown in Figure 12. Semi-analytical methods were used to assess the potential for wind generated noise, which were later tested inexpensively in a factory rig with a quiet fan and spun nozzle, shown in Figure 12. The general methodology utilised in this assessment is described below.

To understand whether aeroacoustics is likely to be an issue for a particular façade or element it is important to understand the local climate, and more importantly, local wind conditions. Although it may be anticipated that a building element will be an aeroacoustic source, there is potential that the frequency of occurrence is so small such that the noise is of little concern. Thus it is important to understand the site's prevailing wind directions and distribution of wind speeds in these directions. At least one year of hourly observations from the nearest Bureau of Meteorology (BoM) site is typically analysed, and a wind rose generated (see Figure 13), graphically depicting local wind speeds and wind directions relevant to the site.

Upon establishing typical on-site wind conditions CFD modelling can be completed to simulate these conditions, including local effects such as surrounding structures and complex terrain. Wind speeds at locations on or near the building's façade can be estimated from such an assessment (see Figure 12). CFD modelling requires creation of a

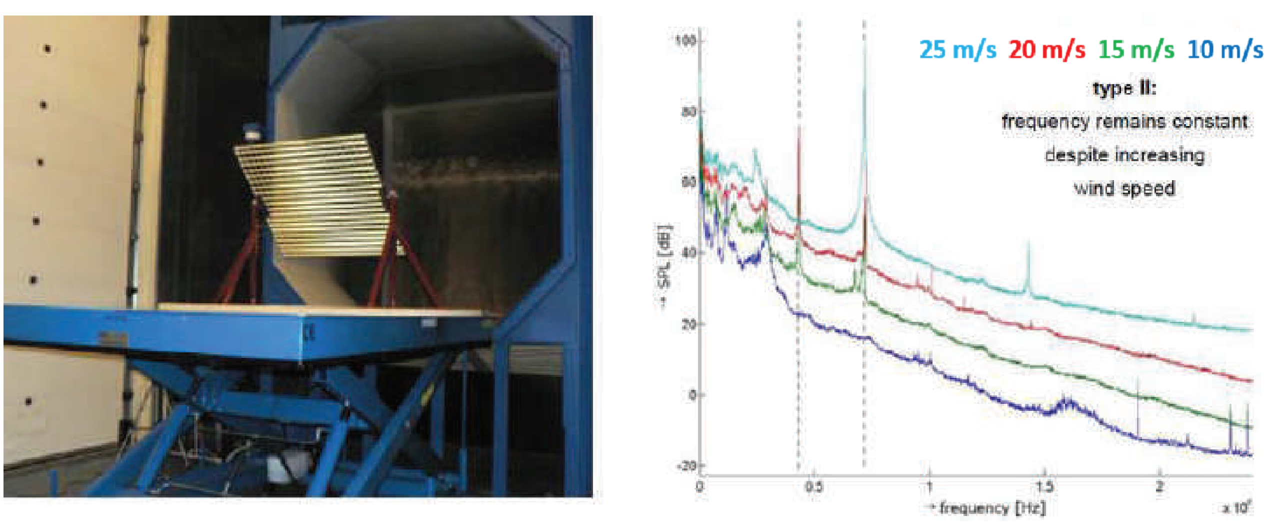

Figure 10: Wind tunnel test setup of façade element (left) and noise levels measured from test (right)

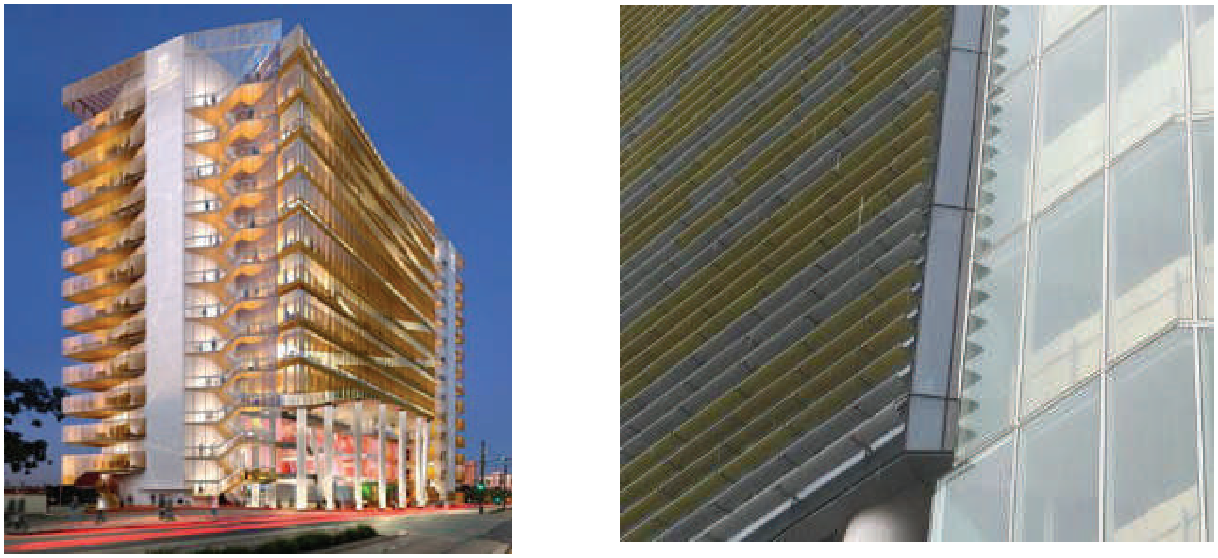

Figure 11: University of Adelaide's new Medical & Nursing School – LEFT: Artistic Impression; RIGHT: As Built

three-dimensional massing model of the building of interest, and of nearby surrounds. Surrounding buildings, especially those removed from the building of interest, can be modelled to a lower level of detail.

Another input into the model is correct representation of turbulent and shear effects in the approach flow arising from positioning and heights of upstream structures. Turbulence and shear effects are replicated by creating and using a boundary layer profile which compensates for inclusion of only limited surrounds. The boundary layer profile specifies flow properties of speed and turbulence at various heights above ground level to ensure flow properties change appropriately with increased height above-ground. This profile is specified at the inlet faces of the model's domain.

Façade shading elements, particularly at the junction between glass panels, were identified as potentially causing wind-induced noise issues. Smaller structural elements (< 50 mm) can generate noise at low-to-medium wind speeds, whereas larger elements (dimensions of up to or greater than 200 mm) require much higher wind speeds (in excess of 20 m/s) to generate noise. Thus, it is often the smaller façade elements which have the potential to create the most frequent noise annoyance.

To study the potential of the façade shading element to generate wind-induced noise, the design (spacing and width) of the elements was carefully reviewed and compared to existing studies detailing wind-induced noise for similar element geometry. Semi-analytical methods published by Ver and Beranek (2006) and others were used to estimate the likely frequency and intensity of tonal noise. Modifications to the design were recommended based on this analysis.

To confirm the results from the analytical assessment, prototype testing was required. Rather than test in a large wind tunnel, a quiet jet fan was used for prototype testing of a sunshade element, shown in Figure 12. The fan type, nozzle size and silencer were carefully selected such that the required air velocity was achieved, whilst maintaining a relatively low background noise. A variable speed drive was connected to the fan motor to vary the airflow velocity, and a hot-wire anemometer and array of microphones (positioned outside the flow) were used to record the results. Before conducting measurements, all constant noise sources in the room (e.g. air conditioner) were turned off. During measurements, the speed of the jet fan was set to simulate the expected wind conditions across the façade. Sound pressure levels and airflow velocity were recorded concurrently. The test was repeated for various angles of flow incident on the test element, to detect dependence of tone on wind direction.

8. Conclusions

This paper has highlighted the increasingly common, and typically overlooked, issue of wind-induced noise impacts for façade design. Work which has been completed previously to understand wind-induced noise mechanisms, and methods commonly used to quantify this noise for a particular façade design, have been described. Finally, a case study was discussed to demonstrate a novel technique of façade aeroacoustic assessment. Unlike previous assessments, this technique combines outputs from multiple assessment types to assess the potential of a façade to generate wind-induced noise, as well as the occurrence, frequency and intensity of this noise. An issue for further consideration is the subjective response of occupants to wind noise on a daily, weekly, monthly basis to establish appropriate criteria.

9. Acknowledgements

We would like to acknowledge the support from the University of Adelaide's Property Division and Lend

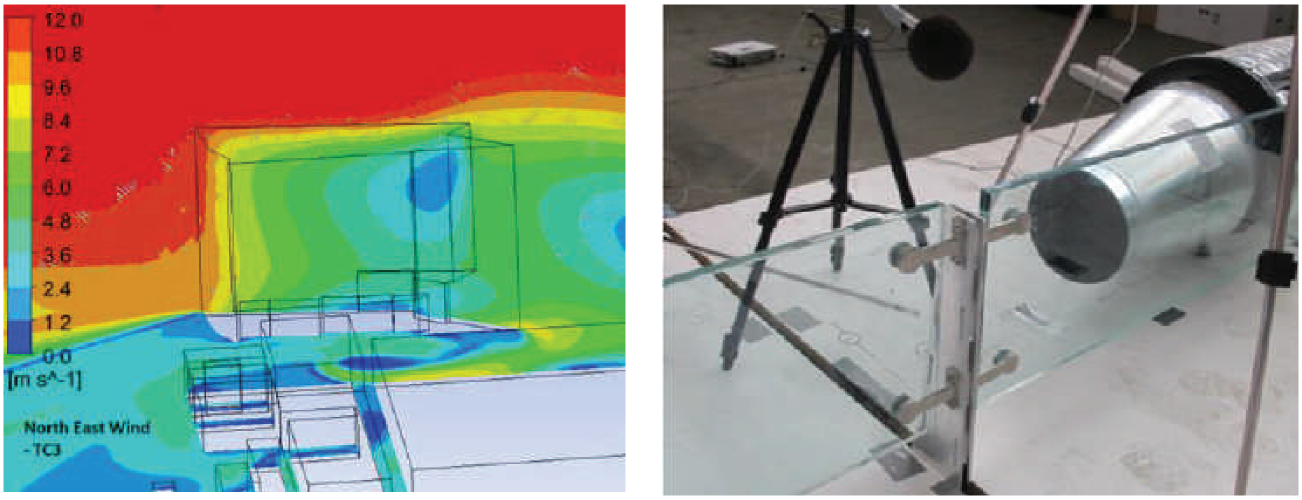

Figure 12: CFD model of AMNS to establish façade wind speeds (left) and test rig set up (right)

What	Meaning
Sector direction	Direction from which wind is blowing from
Length of sector	Frequency of occurrence for each wind direction
Length and width of sub-sector	Wind speed in that direction

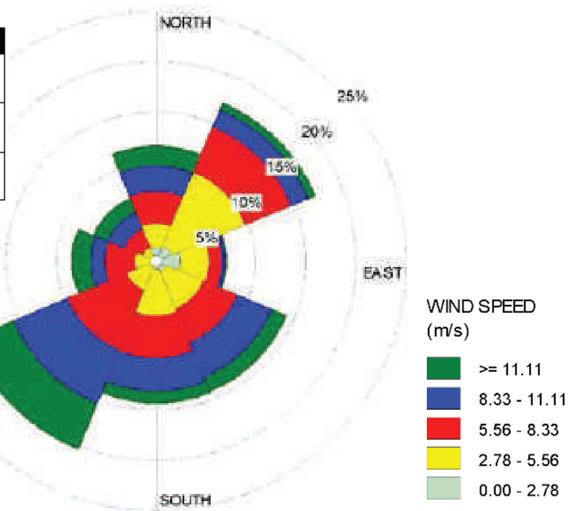

Figure 13: Wind rose of hourly observations recorded at the Adelaide Airport BoM station in 2014

Lease for funding the case study work, and Kingswood Aluminium for constructing the façade mock-up.

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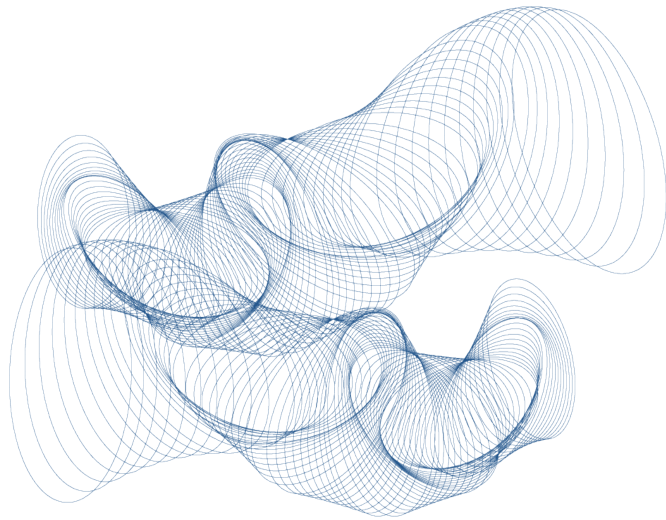
7. Recommendations

1. The existing sound insulation rules and performance standards for noise sensitive uses specified within the current Operative Wellington City District Plan for the Central Area should be maintained; and
2. An educational programme regarding reducing noise impact on neighbours in apartment style accommodation, i.e living in close proximity is recommended to be investigated.
3. A survey of inner-city residents' regarding perceived noise impacts would be beneficial.

Appendix

Limitations and uncertainties:

1. No data is available for 2004 and 2005, and the data points for these years are approximated.
2. The population data for 2016 is predicted by idcommunity / demographics resource, it is yet to be verified by census.
3. The location of bars to new apartments would add value to the assessment. That said, the results are very significant.
4. Noise data prior to 2000 is not available (1998 and 1999).
5. No sound measurements were taken inside apartments to compare internal levels with accepted criteria.



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both a broad acoustical range and an array of emotional contexts. In each case, the study participants were asked to classify them as screams or non-screams.

Despite the wide range of vocal options, the study participants were in "substantial agreement" over whether any given one was or wasn't a scream. In fact, the researchers reported, for 26 of the sounds, more than 90% of the participants agreed that they were screams, with the consensus sometimes reaching as high as 99%.

Schwartz and colleagues then turned to physics to look at the acoustical structures of scream sounds. They found screams tended to be relatively high in pitch and to have a sweeping, arcing range in pitch as they progressed. They also tended to score highly on a parameter called roughness, which, Schwartz explains, is perceived by listeners as a harsh buzzing or gravelly sound, as opposed to a more "pure" tone. "*Sounds that were more rough were classified as screams," he says. "Even though (they represented) different emotional contexts, people agreed they were screams.*"

Nor did the gender of the recorded voice appear to play a role. "*We found that a vocalisation was no more or less likely to be classified as a scream if it was female or male*," Schwartz says.

The next step, he adds, is to look into the acoustical variations among sounds recognised as screams — versions that might relate to differences between the roller-coaster yell of faux fear and a shriek of pure horror. "*It is possible that some of the acoustical variation might map onto different emotions*," he says. See https://cosmosmagazine.com/biology/aaaaahh-researchers-probe-the-acoustics-of-screams for more information.

People 'hear' flashes due to disinhibited flow of signals around the brain

A synaesthesia-like effect in which people 'hear' silent flashes or movement, such as in popular 'noisy GIFs' and memes, could be due to a reduction of inhibition of signals that travel between visual and auditory areas of the brain, according to a new study led by researchers at City, University of London.

The study is the first to provide insight into the brain mechanisms underpinning such auditory sensations also known as a 'visually-evoked auditory response' (aka vEAR or 'visual ear').

The condition has received more attention due to the recent, viral popularity of the 'skipping pylon GIF' (see: http://gph.is/1ajJToS), and other 'noisy GIFs' depicting silent motion, which in some people evoke very vivid visual ear sensations.

Whilst one theory is that areas of the brain responsible for visual and auditory processing normally compete, this research suggests that they may actually cooperate in people who report visual ear.

It was also found that musicians taking part in the study were significantly more likely to report experiencing visual ear than non-musician participants. This could be because musical training may promote joint attention to both the sound of music and the sight of the coordinated movements of the conductor or other musicians.

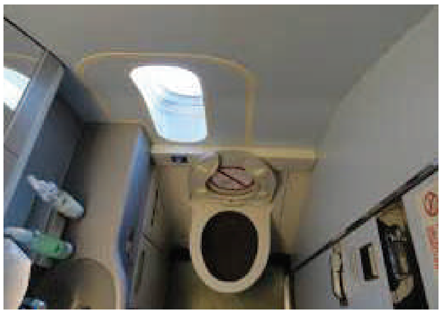
Dr Elliot Freeman, Principal Investigator on the study and a Senior Lecturer in Psychology at the University said:

"*We already knew that some people hear what they see. Car indicator lights, flashing neon shop signs, and people's movements as they walk may all trigger an auditory sensation. Our latest study reveals normally-occurring individual differences in how our senses of vision and hearing interact. We found that people with 'visual ears' can use both senses together to see and also 'hear' silent motion, while for others hearing is inhibited when watching such visual sequences.*"

Some neuroscientists believe visual-ear may be a type of synaesthesia, with other examples including music, letters or numbers that can evoke perceptions of colour. However, visual ear appears to be the most prevalent, with as many as 20% of people reporting some experiences of it compared to 4.4 percent for other types.

Researchers engineer a quieter aeroplane toilet

A group of physicists from Brigham Young University (BYU) said they have figured out how to make aeroplane toilets quieter. The researchers invented a vacuum-assisted toilet that is about half as loud as a typical aeroplane commode.



First-class lavatory, Air Canada Boeing 777-200LR. Source: kristoferb/CC BY-SA 3.0

They said the problem was a challenging one to solve in part because getting aeroplane toilets to flush with little water requires a partial vacuum. At 38,000 feet, that partial vacuum pulls air at nearly half the speed of sound. As a result, any disturbance to the flow — like the bend of a pipe or a valve — can generate significant noise.

To solve the problem, the BYU team focused on three valve conditions during the flush cycle: the initial noise level peak associated with the flush valve opening, an intermediate noise level plateau associated with the valve being fully opened and the final noise level peak associated with the flush valve closing.

The researchers added piping to increase the distance between the toilet bowl and the flush valve and made the pipe attachment at the bowl more of a gradual bend as opposed to a 90-degree angle. Tests show aeroacoustically generated noise dropped up to 16 decibels during the flush valve opening and about 5 to 10 decibels when the valve was fully opened.

The BYU invention works with existing airplane toilets, the researchers said. Only the elbow needs to be removed during a retrofit, while the valve and the bowl stay where they are. The vacuum-assisted tech could also be used for toilets on cruise ships and trains and even in some new green building projects where housing units are looking for ways to reduce water usage. See www.eurekalert.org/pub_releases/2019-04/byu-rhi040319.php for more info.

It's torture': Veterans sue 3M over faulty earplugs they say left them with constant ringing and hearing loss

US veterans are filing scores of lawsuits against 3M over defective earplugs that they claim led to their hearing loss and disorders after the company allegedly knowingly sold to the military.

3M's Combat Arms Earplugs became the new standard issue for American troops in 2009, with promises that they would protect soldiers' hearing so long as they were properly used.

But countless military personnel did suffer hearing loss and tinnitus, like Joseph Junk who described the constant ringing in his ears as 'torture'.

Later examination of the earplugs revealed they did not seal properly, leaving wearers' ears vulnerable to deafening helicopter and artillery sounds.

The military settled with 3M for $9.1 million - enough to cover the cost of purchasing the earplugs in the first place - in a lawsuit claiming the company knowingly sold defective products to the Department of Defence.

Yet the court did not rule that 3M was liable for damage suffered by people that wore the earplugs, leaving soldiers who sustained hearing loss without any compensation.

Now, military personnel are filing lawsuits to try to recover funds to help them get treatment for tinnitus and hearing loss.

The Combat Arms Earplugs made by 3M (pictured) were found to have a faulty design. Now, veterans are suing the company for causing their hearing loss and tinnitus

Joseph Junk says that as soon as a room is quiet, the ringing in his ears becomes loud. He is among the many veterans suing 3M over its earplugs. Tinnitus, a symptom of hearing loss, causes relentless ringing - or sometimes hissing, roaring, clicking, humming or buzzing sounds - that one hears even in silence.

It is also the number one cause of disability among US service men and women, affecting 2.7 million people who collect benefits from the US department of Veterans Affairs for it.

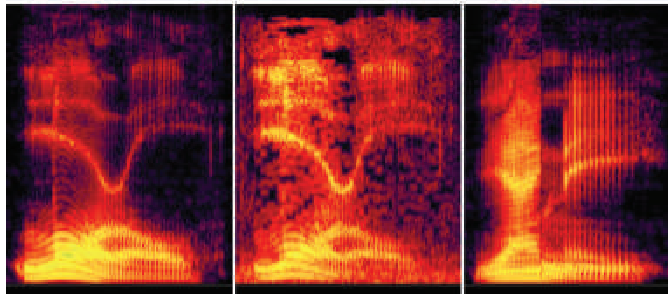
Tinnitus is still a rather mysterious symptom. We know it is related to damage in the auditory system that connects the ears to the brain's hearing system. Exposure to too much loud noise damages tiny hairs in the ears that sense sound waves and transmit them to the brain. But from there it's unclear why we hear the sounds we do.

Yanny and Laurel? You decide

Every so often a quirky photo, question, or illusion goes viral over the internet. One of the most recent viral offerings is an audio illusion. It's a simple question: What do you hear, "*Yanny*" or "*Laurel*"? This question originally appeared on Instagram, but it was then shared widely and inspired others to develop their own audio tool to investigate, one such place being the New York times. Visit the address below and you decide is it "Yanny' or "laurel" you hear?

https://www.nytimes.com/interactive/2018/05/16/upshot/audio-clip-yanny-laurel-debate.html

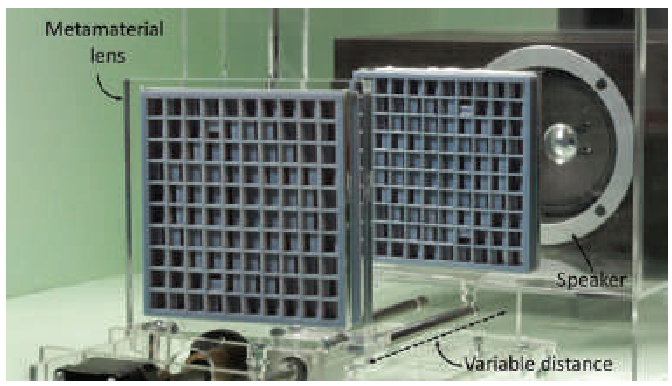
One way to understand the dynamics at work is to look at a type of chart called a spectrogram (see above) a way to visualize how the strength of different sound frequencies varies over time. The spectrograms above show that the word "*laurel*" is strongest in lower frequencies, while a simulated version of the word "*yanny*" is stronger in higher frequencies. The audio clip shows a mixture of both. By using the slider to manipulate which frequencies are emphasized, it makes one word or the other more prominent.



Metamaterial-based acoustic lenses focus on the future of super-targeted speakers and microphones

Imagine speaking to an individual a hundred feet away in a noisy crowd of thousands – and hearing their reply – without using your phone. Now imagine sitting in the cheap-seats at the back corner of a concert hall, but hearing everything just as well as someone front and centre. Researchers at the universities of Sussex and Bristol in the UK are working towards making scenarios like these – and more – possible by employing "acoustic metamaterials" to manipulate sound in the same way lenses do with light. Think, sniper-scopes and narrow-beam torches, but with sound.

The research team has demonstrated the very first dynamic metamaterial device with the zoom objective of



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2019

12-14 June, Lisbon, Portugal, International Conference on Wind Turbine Noise (WTN2019)
https://www.windturbinenoise.eu/content/conferences/8-wind-turbine-noise-2019

9-12 June 2019, Madrid, Spain. 48th International Congress and Exposition on Noise Control Engineering (INTER-NOISE 2019)
https://internoise2019.org

24-27 June, Torun, Poland (ICA Endorsement) 14th School on Acousto-Optics and Applications
www.saoa.fizyka.umk.pl

7-11 July, Montreal, Canada, 26th International Congress on Sound and Vibration (ICSV26)
www.icsv26.org

8-13 September 2019, Aachen, Germany. 23rd International Congress on Acoustics (ICA 2019)
www.ica2019.org

13-17 September, Detmold, Germany, International Symposium on Musical Acoustics (ISMA 2019)
www.isma2019.de

15-17 September, Amsterdam, Netherlands, International Symposium on Room Acoustics (ISRA 2019)
www.isra2019.eu

2-6 December, San Diego, California, 178th Meeting of the Acoustical Society of America
www.acousticalsociety.org

2020

11-15 May, Chicago, Illinois. 179th Meeting of the Acoustical Society of America
www.acousticalsociety.org

15-18 June, Karolinska Institutet, Stockholm, Sweden. 13th ICBEN Congress on Noise as a Public Health Problem
http://www.icben.org

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a varifocal lens for sound, dubbed "*Vari-sound*." The team also built a collimator (a device which produces a parallel beam of rays or radiation) capable of transmitting sound as a narrow, directional beam from a standard speaker. An acoustic collimator could be used for the individual-in-the-crowd scenario mentioned above, or perhaps to aim a signal up the aisles of a cinema, to deter people from sitting on the aisle steps.

"*Acoustic metamaterials are normal materials, like plastic, paper, wood or rubber, but engineered so that their internal geometry sculpts the sound going through*," says Dr. Gianluca Memoli, who leads this research at the University of Sussex. "*The idea of acoustic lenses has been around since the 1960s and acoustic holograms are starting to appear for ultrasound applications, but this is the first time that sound systems with lenses of practical sizes, similar to those used for light, have been explored*."

The research team sees a multitude of opportunities for this technology. From using an acoustic lens as a highly-focused, directional microphone pinpointing fatigue within vulnerable machinery parts, to distinguishing the difference between a burglar breaking your glass-door and the sound of your dog barking at the cat outside.

"*Using a single speaker, we will be able to deliver alarms to people moving in the street, like in the movie Minority Report*," says Jonathan Eccles, a Computer Sciences undergraduate at the University of Sussex. "*Using a single microphone, we will be able to listen to small parts of a machinery to decide everything is working fine. Our prototypes, while simple, lower the access threshold to designing novel sound experiences: devices based on acoustic metamaterials will lead to new ways of delivering, experiencing and even thinking of sound*."

The paper was presented at the ACM CHI Conference on Human Factors in Computing Systems (CHI 2019) in Glasgow, May 2019, and has been published in the ACM Digital Library.

Surround-sound setups – in cinemas and in the home – work best for those sitting plumb in the middle, and current acoustic lenses (e.g. in high-end home audio and ultrasonic transducers) have scale issues which restricts their use to higher frequencies.

Production is simpler too, as metamaterials are smaller, cheaper and easier to build than phased speaker arrays, and can be fabricated from simple, everyday substances – even recycled materials. Metamaterial devices also lead to less aberrations than speaker arrays.

Most of this is possible using existing speakers – which the team has shown – as the acoustic metamaterial sits in front of the sound source, between the source and the recipient (or receiver). For more information see: https://newatlas.com/metamaterial-targeted-directional-speakers-microphones/59586

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