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PAPERS

TECHNICAL NOTES

LETTERS

REGULAR ITEMS

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MESSAGE FROM THE VICE PRESIDENT

Hello there everyone

Welcome to the first edition of Acoustics Australia for 2014 and our first edition under the current editorial team of Marion Burgess and Truda King with the continued support by Leigh Wallbank on the business management. Thank you to all for your excellent effort in putting this issue together.

I trust that everyone had an enjoyable break over the holiday season and are back fresh-faced to start the New Year. As part of Acoustics Australia's fresh face, the editorial committee decided to change the traditional way the President's Message is written, by giving the Vice President (and incoming 2015 President) an opportunity to be introduced. So, here I am writing my first message in Acoustics Australia as VP.

For those who don't know me, my name is Tracy Gowen. I am a Senior Engineer with Renzo Tonin & Associates in Sydney, specializing in environmental noise. I have been on the NSW Divisional committee since 2005 and have represented NSW on Federal Council since 2008. This year I am learning the ropes from Norm Broner and Peter Heinze, and I am looking forward to the opportunity of being AAS President in 2015.

This year is getting going and there are many things planned for 2014. Inter.noise2014 is little more than 6 months away and promises to be a very exciting conference. The organising committee has gone to incredible effort to showcase our country at the same time as putting together what looks to be an excellent technical program. I also understand that all divisions are offering travel awards to allow students (and others) to attend Inter.noise2014. This is a great opportunity for students to present at an international conference. Be sure to pass on the details of the various divisional travel awards to those you know who may be eligible to apply.

A website developer was appointed at the Federal Council Meeting in November last year and the development of the new AAS website is progressing well. Implementation of the website will essentially be in 2 phases:

- Phase 1 dealing with Subscription payments through an online payment gateway and a better, more streamlined system for membership applications/upgrades and transfers; and
- Phase 2 will have more bells and whistles for content and archived material, journals, conference proceedings, forums, video and audio, Divisional Technical evenings and so on.

The new website will be easier to navigate and provide a user-friendly interface for you (the member) to engage with your Society. If all goes to plan, Phase 1 should go live by the end of April.

Some other news on the International conference front, albeit some time down the track, the next International Workshop on Rail Noise (IWRN) will be hosted by Australia in 2016. The workshop will be held from 12 to 16 September 2016 in Terrigal, on the NSW Central Coast. Although the event will be organised by a dedicated group of rail noise specialists, AAS will act as the hosting organisation and provide seed funding to assist with the upfront conference costs. IWRN attracts a high calibre of technical papers and is attended by many of the world experts in the field. It is very exciting to be a part of this event as it signifies that Australia is now well and truly "on the map" in the field of rail noise and vibration. More details are now available at: http://www.acoustics.asn.au/IWRN12/.

AAS is extremely pleased to announce the 2014 AAS Research Grants. The aim of the AAS Research Grants is to facilitate timely research to help achieve the objectives of the Society. The AAS Research Grant provides research grant matching – that is, individual grants of up to $100,000 will be made available on the basis that this funding is matched by funding from other sources. A Research Grant Plan has been authorized by Federal Council, thanks largely to the work of Matthew Stead and Luke Zoontjens, using input from AAS members to identify strategic research needs. A call for submissions is included in this issue of Acoustics Australia or see our website (http://www.acoustics.asn.au/joomla/notices.html).

Finally, it is not without some sadness that we say goodbye to the distribution to all members of a print edition of Acoustics Australia. The journal has evolved over the years into a very smart and visually pleasing publication. With the increases in the cost of printing and postage it has become unviable to continue the print version for all members without substantial increases in membership fees. So the time has come for AAS to embrace technology and enjoy the many benefits that will come with a digital version of the journal. Commencing with the August issue the journal will maintain the same appearance and members will receive a low resolution version by email with the high resolution version available as a download from the web page - so a prompt to log on and make sure your records are up to date. A small print run will be made for those who still require, and are prepared to pay, the cost recovery charge for a hard copy.

In signing off, I would like to take this opportunity to remind members that your actions and inputs are what make this Journal, and the AAS in general, interesting. Without input from you, there would be no Journal, no workshops, no conferences. Remember this as you file this edition of Acoustics Australia away. While you're at it, set a reminder to yourself to write a tech note, write a Journal article, be part of a workshop or prepare a paper for Inter.noise and share your knowledge and experience with us. I do hope you enjoy this edition of Acoustics Australia.

Tracy Gowen
Vice President AAS

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with wifi and 3G connectivity

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SAVTEK FEATURE PRODUCTS APR 2014

- SMS and email alerts with waveform summary
- Data pushed to FTP – only new background files and events are uploaded
- Remote access to unit via 3G connection
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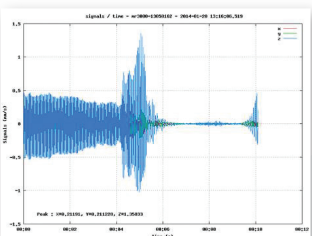
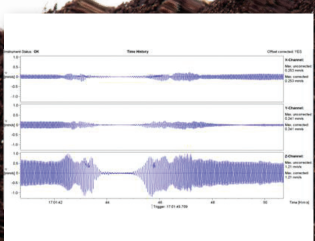
- Events and background files stored on SD card
- 12 Volt battery, mains or solar power
- Analysis software included. Background reporting software available from SAVTek.
- Weighs 4kg with internal sensor and mounting plate.

Flashing alarm and siren triggered by SMS from MR3000C





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FROM THE EDITOR

As the incoming editor, I would like to acknowledge the sterling work of the past editor Nicole Kessissoglou. Over the four years of her editorship the Journal grew in size and status; the latter reflected by the increase in the number of submissions of papers and technical notes from around the world.

I have been involved with the Journal to varying extents for a number of decades and worked with past Chief Editors: Howard Pollard, Neville Fletcher, Joe Wolfe and Nicole. When asked to take on the responsibility for producing the Journal in 2014, I understood the extent of the work involved and requested an Editorial Assistant. Truda King has a background in environmental noise and has been a valuable asset keeping all the various elements on track as we worked towards completion of our first issue. It has been a sharp learning curve for us both but rewarding when we see the final version.

Not only is there a new editorial team, but 2014 is a time of transformation for the journal. This is the last issue that will be distributed as hard copy to all members of the AAS and subscribers. Future issues will continue to look much the same as this issue and will be sent to all members as a low resolution pdf email attachment. A high resolution version will be available for downloading from the website. Those still seeking a hard copy will be required to pay at cost recovery. We are also investigating options for the publication process including online submission of articles and other benefits that arise once the focus is no longer on a hard copy print version.

This April issue comprises a mix of papers from Australian and overseas workers over a range of topic areas in acoustics. These include the paper by Robertson, which was awarded the Presidents Prise at the AAS 2013 conference. The current editorial team intends to maintain and increase the relevance of the Journal to the membership of the AAS, as well as presenting a showcase to the world of the status of acoustics in Australia. Currently the impact factor, the increasingly important measure for researchers to investigate before deciding where to publish, is between 0.3 and 0.4. While Acoustics Australia does not strive to be a primary research journal, this factor reflects the excellent work of the contributors and past editors. Our goal over the coming years is to increase this factor by a few points. However the content relies on the contributions so please keep them coming in.

In conclusion, we are very pleased to advise that we intend to have a special issue this year on Auditory Perception. Professor Catherine (Kate) Stevens from the MARCS Institute at UWS has agreed to be the special issue editor. In addition to the invited papers, we welcome papers and technical notes on this topic.

Marion Burgess

Australian Acoustical Society Awards

Prizes and Grants, 2014

The Australian Acoustical Society has a number of awards, prizes and grants each year as listed on the web page. The information on each item is updated when the application details, including deadlines, are available and an email is sent to the members. A summary of those available during 2014 is as follows:

AAS Research Grant Assistance – this grant is a new initiative of the AAS with the first award to be made in 2014. The aim of this grant is to provide support for timely research to help achieve the objectives of the Society. The project priority areas include: Wind farm noise assessment; Underwater noise monitoring & detection; Environmental noise modelling and assessment; Sleep disturbance assessment and Road traffic noise assessment.

Excellence in Acoustics Award - this is an annual award which is aimed at fostering and rewarding excellence in acoustics and is sponsored by CSR. The entries are judged on demonstrated innovation from within any field of acoustics.

Education Grant - this is an annual grant which has been established by the AAS to encourage and enhance the study of acoustics in Australia and in particular to encourage research in acoustics. The main criterion is the likely benefit that the successful completion of the proposed project will provide for acoustics, for the AAS and for its members.

Gerald Riley Award for Best Paper – for Inter.noise2014 this award replaces the annual Presidents Prize and is awarded for the best paper by an AAS member at the annual conference. This special award is in honour of Gerald Riley who was a founding member of the Society and who served the Victorian Division for many years. Gerald passed away in January 2014.

Conference Attendance Grants – A number of Divisions offer competitive grants for participation at the annual AAS conference for members within their Division. For 2014 these are applicable to the Inter.noise 2014 conference.

Secondary and Tertiary Education Grants – some divisions offer annual awards to encourage and support education and research in acoustics within their Division at both secondary and tertiary level.

HORIZONTAL STABILITY OF A QUASI–ZERO STIFFNESS MECHANISM USING INCLINED LINEAR SPRINGS

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Negative stiffness mechanisms have seen renewed attention in recent years for their ability to reduce the resonance frequency of a structure without impeding their load-bearing ability. Such systems are often described as having quasi-zero stiffness when the negative stiffness is tuned to reduce the overall stiffness of the system as close to zero as possible without creating an instability. The system analysed in this work consists of a vertical spring for load bearing, and two symmetric inclined springs which behave with a snap-through effect to achieve negative stiffness. While this structure has been analysed extensively in the literature, generally only the stiffness in the vertical direction has been considered in the past. Here, the horizontal stiffness is assessed as well, and it is shown that it is possible to achieve quasi-zero stiffness in both directions simultaneously if the spring stiffnesses and pre-loads are chosen appropriately. Attention is paid to the tuning required in order to set the equilibrium point at a position which is arbitrarily close to having quasi-zero stiffness while avoiding issues arising from mechanical instability.

INTRODUCTION

In recent years a number of nonlinear systems have been proposed for vibration isolation to overcome the trade-off between low stiffness and high load bearing. These systems in general use a combination of positive and negative stiffness elements to achieve a localised region of 'quasi–zero stiffness' at or near the equilibrium position of the system [13].

One system that exemplifies this idea involves using a repelling magnet pair to provide load bearing and an attracting magnet pair to provide negative stiffness which has been investigated previously by the present authors [10, 16, 11]. The noncontact forces of the magnetic system make them well-suited for online tuning [15, 14], but the inherent instability of magnetic systems can add complexity to the control required.

While flexible structures have been shown to operate similarly [12, 4, 7], the most common system for achieving quasi–zero stiffness involves arrangements of inclined mechanical springs which generally operate in 'snap-through' regimes such as the spring arrangement shown in Figure 1 [8, 3, 2]. This system consists of a load bearing vertical spring in parallel with a pair of inclined springs that behave in a buckling regime. Generally, analyses of this system have only considered its stiffness properties in a single degree of freedom, in the direction of the primary load bearing.

This paper consists of an analysis of the quasi-static behaviour of this inclined spring system and re-formulates the force and stiffness characteristics in both vertical and horizontal directions, describing in some detail the approach by which low stiffness in both directions can be achieved. Low stiffness in the vertical direction has been previously documented due to the negative vertical stiffness of a pair of horizontal springs in compression. Low stiffness in the horizontal direction is newly analysed here, which is achieved due to the negative stiffness in the horizontal direction of the load-bearing vertical spring.

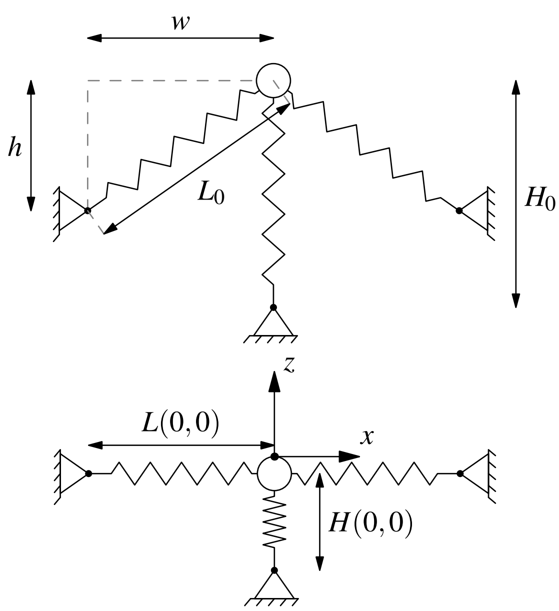

Figure 1. Negative stiffness inclined springs in parallel with a positive stiffness spring. Top: the system with the inclined springs in their uncompressed state corresponding to a vertical displacement of $z = h$. Bottom: inclined springs at a position of maximum negative stiffness, corresponding to a vertical displacement of $z = 0$

GEOMETRY

Figure 1 shows the planar inclined spring system both without load (that is, with undeflected springs) and after deflection to

This publication is based on the paper that was awarded the President's Prise at the 2013 Australian Acoustical Society Conference.

the position which has the potential of achieving 'quasi–zero stiffness', which is the position of maximum compression of the inclined springs. The overall stiffness of the system must be tuned to support the mass of the load at this position.

At the unloaded state shown in Figure 1, all springs are considered to be in their uncompressed state; with inclined spring lengths $L_0 = \sqrt{h^2+w^2}$ and vertical spring length $H_0 = \eta L_0$, where η is denoted the 'length ratio' between the vertical and inclined springs. The inclined springs each have stiffness k_i and the vertical spring has stiffness $k_v = \alpha k_i$, with α denoted the 'stiffness ratio' between the vertical and inclined springs. The stiffness and deflection properties of the springs are summarised in Table 1.

The position at which the inclined springs are horizontal defines the displacement origin of the system, where z is the displacement in the load bearing direction, and x is the displacement in the non–load bearing direction (this is used later for the derivation of the horizontal stiffness of the system).

The deflected lengths of the springs from vertical displacement z and horizontal displacement x are $L(x,z)$ for the inclined spring and $H(x,z)$ for the vertical spring. The compressed length of the inclined spring on the left is

$$L(x,z) = \sqrt{[w+x]^2+z^2}, \tag{1}$$

and the vertical spring length is

$$H(x,z) = \sqrt{x^2+[H_0-h+z]^2}; \tag{2}$$

note that $L(0,h) = L_0$ and $H(0,h) = H_0$.

The geometry that has been chosen uses linear springs that are all arranged to be undeflected in the unloaded state of the system. Kovacic, Brennan, and Waters [6] have explored the effects of including pretension and the use of nonlinear softening springs for vertical vibration isolation.

VERTICAL FORCES

The forces on the mass are calculated by analysing the components due to each spring individually. The force due to the inclined spring (on the left of Figure 1), in the direction of the spring, is given by

$$F_i(x,z) = [L_0 - L(x,z)]\,k_i = \left[\sqrt{w^2+h^2} - \sqrt{[w+x]^2+z^2}\right] k_i. \tag{3}$$

Assuming only vertical displacement ($x = 0$), the vertical component of this inclined spring force is

$$F_{i_v}(0,z) = F_i(0,z)\frac{z}{L(0,z)} = z k_i \left[\frac{\sqrt{w^2+h^2}}{\sqrt{w^2+z^2}} - 1\right]. \tag{4}$$

It is convenient to normalise this result by representing the lengths and displacements as ratios of the uncompressed height of the inclined springs. With the coordinate substitutions $\xi = z/h$ and $\gamma = w/h$, the inclined spring force in the vertical direction can be written in non-dimensional form as

Table 1. Properties of the springs in the quasi–zero stiffness inclined spring system defining stiffness ratio α and length ratio η.

Spring	Stiffness	Undeflected length
Inclined	k_i	$L_0 = \sqrt{h^2+w^2} = \sqrt{h^2[1+\gamma^2]}$
Vertical	$k_v = \alpha k_i$	$H_0 = \eta L_0$

$$\frac{F_{i_v}(\xi)}{hk_i} = \xi\left[\sqrt{\frac{\gamma^2+1}{\gamma^2+\xi^2}} - 1\right], \tag{5}$$

where γ is denoted the 'geometric ratio' of the device and ξ the normalised displacement. Note that here $\gamma = 0$ corresponds to unloaded inclined springs at 90° (that is, vertical) before compression, and $\gamma = \infty$ corresponds to unloaded inclined springs at 0° (that is, horizontal). In the coordinate system used here, the displacement origin $z = 0$ corresponds to the position of maximum compression of the inclined springs; that is, when they are horizontal.

Figure 2 illustrates the force characteristic of Eq. (5) versus normalised displacement for a range of geometric ratios γ. In Figure 2 and later figures, the geometric ratio γ is expressed as a ratio of γ^*, the value of γ that produces quasi–zero stiffness for this system; γ^* will be derived later in Eq. (12). The 'snap-through' forces that cause the negative stiffness are especially strong for smaller values of geometric ratio γ (that is, the more vertical the spring angles before deflection).

The total vertical force produced by the system, $F_{t_v}(x,z)$, is calculated by combining Eq. (4) for each inclined spring with the force due to the vertical spring:

$$F_{t_v}(x,z) = 2F_{i_v}(x,z) + F_{v_v}(x,z). \tag{6}$$

For vertical displacements, the force due to the vertical spring is given by

$$F_{v_v}(x,z) = [h-z]\,k_v, \tag{7}$$

and the total force in the vertical direction can be nondimensionally represented by

$$\frac{F_{t_v}(x,z)}{hk_i} = -\xi\alpha + \alpha + 2\xi\left[\sqrt{\frac{\gamma^2+1}{\gamma^2+\xi^2}} - 1\right], \tag{8}$$

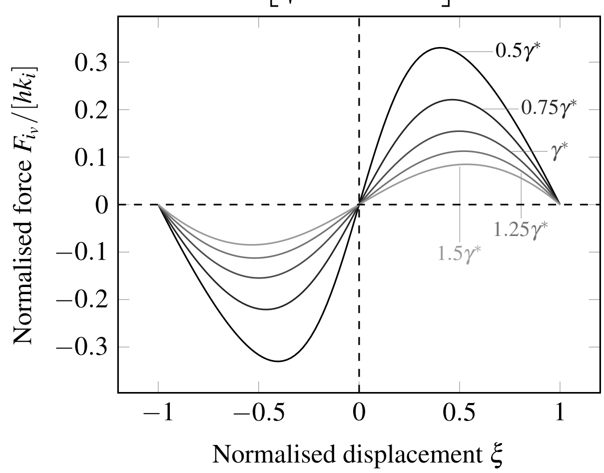

Figure 2. Vertical force due to inclined springs only for a range of geometric ratios γ.

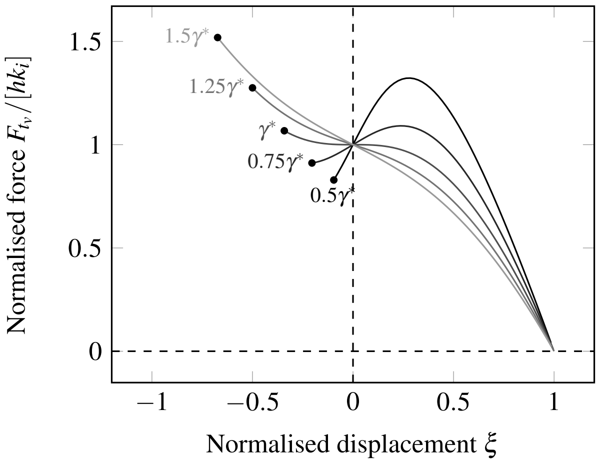

Figure 3. Normalised vertical force characteristic of the system calculated with Eq. (8).

recalling that $\alpha = k_v/k_i$ is the stiffness ratio between the vertical and inclined springs. This equation is depicted in Figure 3 for a unity stiffness ratio ($\alpha = 1$), where it can be seen that by selecting the geometric ratio γ appropriately it is possible to generate a local region of low stiffness at displacement $\xi = 0$, approaching the quasi–zero stiffness condition under ideal circumstances. The calculation for γ^*, the value of the geometric ratio γ for which quasi–zero stiffness is achieved, will be shown later in Eq. (12).

The force curves in Figure 3 terminate at a certain point in the negative displacement region, which corresponds to the maximum possible compression of the vertical spring, given by the condition $H(0, z_{\min}) = 0$. In other words, the spring has been compressed to zero length. This condition can be solved for $z_{\min}$ and subsequently normalised for the equivalent $\xi_{\min}$, which are given by

$$z_{\min} = h - H_0, \qquad \xi_{\min} = 1 - \eta\sqrt{\gamma^2 + 1}. \tag{9}$$

VERTICAL STIFFNESSES

The vertical stiffness characteristic, K_v, of the system is calculated by differentiating the vertical force, Eq. (8), with respect to vertical displacement z, yielding

$$K_v = -\frac{\mathrm{d}}{\mathrm{d}z} F_{t_v}(x, z), \tag{10}$$

which can be written in non-dimensional form as

$$\frac{K_v}{k_i} = -2\gamma^2 \sqrt{\frac{\gamma^2 + 1}{[\gamma^2 + \xi^2]^3}} + \alpha + 2. \tag{11}$$

Graphs of the normalised vertical stiffness K_v/k_i versus normalised displacement ξ are shown in Figure 4 for a range of geometric ratios γ, which show that the stiffness at $\xi = 0$ varies from negative to positive as γ increases. The parameter selection required to achieve a quasi–zero stiffness condition in the vertical direction can be found by solving Eq. (11) for $K_v = 0$ at $\xi = 0$. This results in the relation

$$\gamma^* = \frac{2}{\sqrt{\alpha^2 + 4\alpha}} \tag{12}$$

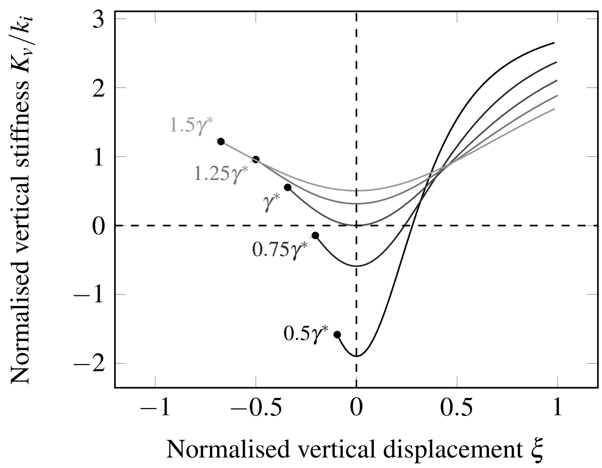

Figure 4. Vertical stiffness characteristic for a range of geometric ratios γ at $\alpha = 1$, calculated with Eq. (11).

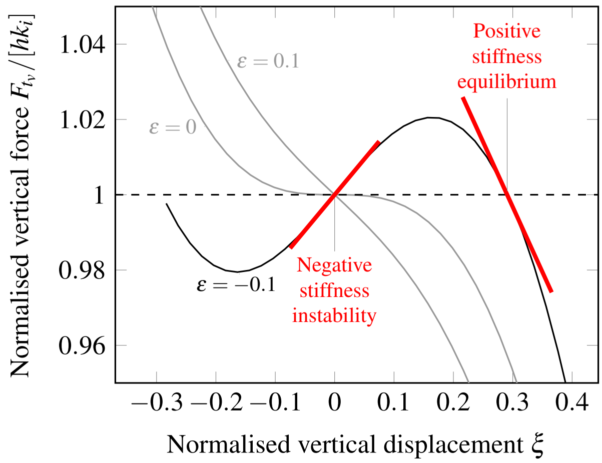

Figure 5. The stable and unstable equilibrium points of the inclined spring system near quasi–zero stiffness for $\varepsilon \in \{-0.1, 0, 0.1\}$. The rest position will move from the unstable point to the stable point of equilibrium.

which is used as the reference value of the geometric ratio γ for the results shown in Figures 2, 3, 4 and 7.

Achieving exactly quasi–zero stiffness with this spring is not feasible in practice as the stiffness characteristic becomes negative for $\gamma < \gamma^*$, as shown in Figure 4. This is important as the geometric ratio γ will have some uncertainty in its value due to environmental conditions such as temperature and physical imperfections such as creep. The deviation of γ from γ^*, ε, can be defined by

$$\gamma = [1 + \varepsilon]\gamma^*. \tag{13}$$

Figure 5 shows the total vertical force, F_{t_v}, of the system for $\varepsilon \in \{-0.1, 0, 0.1\}$. It can be seen that negative values of ε (that is, a geometric ratio less than that for quasi–zero stiffness) correspond to negative stiffness at normalised displacement $\xi = 0$. A system in this condition is in a position of unstable equilibrium, and will move towards and remain at the position of stable equilibrium indicated in the figure rather than the design point at $\xi = 0$.

Figure 6 plots the stiffness at this deviated equilibrium point as ε varies; in the unstable zone, the system will move to the equilibrium point shown in Figure 5 away from $\xi = 0$. (With

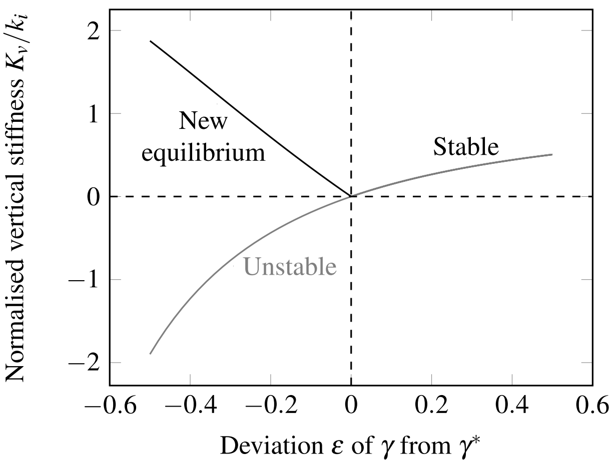

Figure 6. The stiffness at equilibrium as ε varies; as the stiffness becomes negative, the stiffness shown corresponds to the stable point of equilibrium shown in Figure 5.

sufficient excitation the system will 'snap though' from one equilibrium position to another with a resulting displacement profile that is comparatively large given the excitation amplitude; this mechanism has been proposed as a useful phenomenon for energy harvesting purposes [9].) It can be seen that the stiffnesses in the stable region for $\varepsilon > 0$ are smaller than the stiffnesses in the equilibrium region for $\varepsilon < 0$. This highlights the importance of never breaching the $\varepsilon < 0$ instability condition. Therefore, a chosen value for the geometric ratio γ will approach γ^* but always be slightly greater in order to retain stability of the equilibrium position.

HORIZONTAL STIFFNESS CHARACTERISTIC DUE TO VERTICAL DISPLACEMENT

Now that the vertical stiffness characteristics of the system have been analysed and a condition derived to achieve quasi–zero stiffness in that direction, the same approach will be taken for the horizontal behaviour. Only vertical displacements will be considered in assessing the horizontal stability. This can be justified by considering how instability in the horizontal direction arises: as the vertical spring is compressed it generates lateral forces as the load becomes off-centre. These lateral forces correspond to a negative stiffness that has greatest magnitude for zero horizontal displacement, and therefore for a position of stable equilibrium a small deviation will not result in sudden instability.

In order to calculate the horizontal stiffness of the system, the force from the vertical spring needs to be represented in terms of both vertical and horizontal displacements. This force, aligned in the direction of the nominally-vertical spring, is

$$F_v(x,z) = \left[\eta L_0 - \sqrt{x^2 + [-h + z + \eta L_0]^2}\right] k_v, \tag{14}$$

recalling that x is the displacement of the mass in the horizontal direction. Substituting $x = 0$ into Eq. (14) yields the previous Eq. (7). The horizontal component of this force is

$$F_{v_h}(x,z) = F_v(x,z)\frac{x}{H(x,z)}\,. \tag{15}$$

Similarly, the horizontal component of the force from the inclined spring on the left (referring to Figure 1) is given by

$$F_{i_h}(x,z) = F_i(x,z)\frac{w+x}{L(x,z)}\,, \tag{16}$$

and the horizontal component of the force from the inclined spring on the right is

$$F_{i_h}(x,z)\bigg|_{\text{right}} = -F_{i_h}(-x,z)\,. \tag{17}$$

The stiffness characteristic in the horizontal direction, K_h, is derived in a similar fashion to the vertical stiffness. The total force in the horizontal direction is

$$F_{t_h}(x,z) = F_{i_h}(x,z) - F_{i_h}(-x,z) + F_{v_h}(x,z)\,. \tag{18}$$

Differentiating with respect to horizontal displacement x and evaluating at $x = 0$ gives the horizontal stiffness characteristic as the vertical displacement varies,

$$\frac{K_h}{k_i} = -2\xi^2\sqrt{\frac{\gamma^2+1}{[\gamma^2+\xi^2]^3}} + \frac{\alpha\,[\xi-1]}{\eta\sqrt{\gamma^2+1}+\xi-1} + 2. \tag{19}$$

This horizontal stiffness is shown in Figure 7 as a function of vertical displacement. Comparing this to the vertical stiffness results (Figure 4), it can be seen that while the vertical stiffness is zero at normalised displacement $\xi = 0$ and geometric ratio $\gamma = \gamma^*$ (which is as derived), the horizontal stiffness exhibits separate behaviour, and can even be negative (that is, unstable) for values of γ lower than around $1.25\gamma^*$.

Since the vertical stiffness and horizontal stiffness are independent, further analysis into the behaviour of the horizontal stiffness at the vertical quasi–zero stiffness condition is warranted. Substituting the quasi–zero stiffness condition of Eq. (12) into Eq. (19) at displacement $\xi = 0$ gives the normalised horizontal stiffness as a function of stiffness ratio α:

$$\frac{K_h}{k_i}\bigg|_{\text{V. QZS}} = 2 - \alpha\left[\frac{[\alpha+2]\,\eta}{\sqrt{\alpha\,[\alpha+4]}} - 1\right]^{-1}. \tag{20}$$

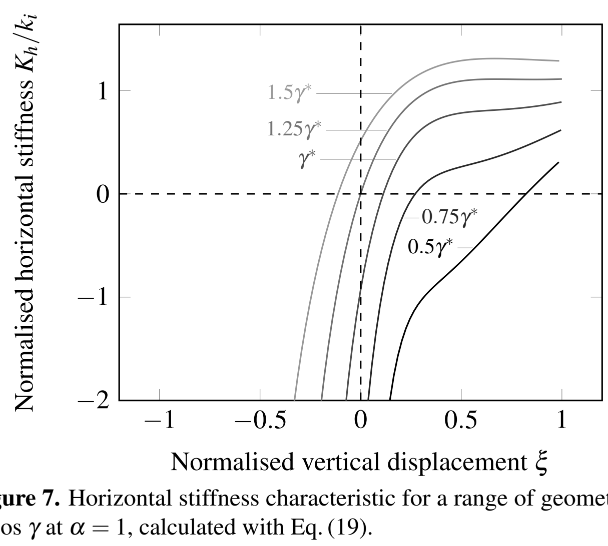

Figure 7. Horizontal stiffness characteristic for a range of geometric ratios γ at $\alpha = 1$, calculated with Eq. (19).

This equation is depicted in Figure 8; it can be seen that the horizontal stiffness of the spring may be chosen by varying both the spring stiffness ratio α and the spring length ratio η. Since the length ratio η is not found in Eq. (11), the horizontal and vertical stiffnesses may be tuned independently in order to achieve quasi–zero stiffness in both simultaneously.

To obtain zero stiffness in the horizontal direction at the nominal position, Eq. (20) is solved for $K_h = 0$, showing a relationship between α and η when the quasi–zero stiffness condition is achieved in both the vertical and the horizontal directions.

$$\alpha^*(\eta) = 2\left[\sqrt{\eta^2+1}-1\right], \text{ or} \\ \eta^*(\alpha) = \frac{1}{2}\sqrt{\alpha\,[\alpha+4]}. \tag{21}$$

As a consequence, increasing η (say, in order to reduce the compression of the vertical spring) results in an increasing value of the vertical spring stiffness in order to remain at quasi–zero stiffness.

Using α^* from Eq. (21) in the stiffness equations (11) and (19) allows the stiffness characteristics of the system in the two directions to be compared when both have quasi–zero stiffness simultaneously. Considering the vertical stiffness first in Figure 9, it can be seen that increasing the length ratio η increases the vertical stiffness gradient, which is an important parameter to be kept small in order to mitigate possible nonlinear dynamic effects that may arise due to a large rate of change of stiffness over displacement.

The graph of horizontal stiffness versus vertical displacement is shown in Figure 10. Note that contrary to the vertical case, the horizontal stiffness curves are not symmetric around zero vertical displacement. This is caused by the effect of the vertical spring; with negative vertical displacement (compression of the vertical spring) a horizontal perturbation results in an unstable horizontal force, whereas with positive vertical displacement (extension of the vertical spring) any horizontal forces act in a restoring sense.

Figure 10 illustrates that the quasi–zero stiffness condition is always marginally unstable in the horizontal direction since negative vertical displacement will result in negative horizontal stiffness. In practice this requires that the system be tuned slightly away from the quasi–zero stiffness condition in the horizontal direction after accommodating for the maximum disturbance displacement of the isolator. It is possible to do this without compromising the quasi–zero stiffness condition in the vertical direction because the spring length ratio η does not affect the vertical stiffness.

As an example, Figure 11 shows the horizontal stiffness for a stiffness ratio detuned by five percent below that required for quasi–zero stiffness (that is, $\alpha = 0.95\alpha^*$). In comparison with Figure 10, the spring has a stable displacement range of approximately $\xi = \pm 0.025$. Provided that the spring length ratio η is large enough, the horizontal stiffness at $\xi = 0$ is still significantly reduced.

Therefore, there is a direct compromise between the nonlinearity of the stiffness in the vertical direction (which

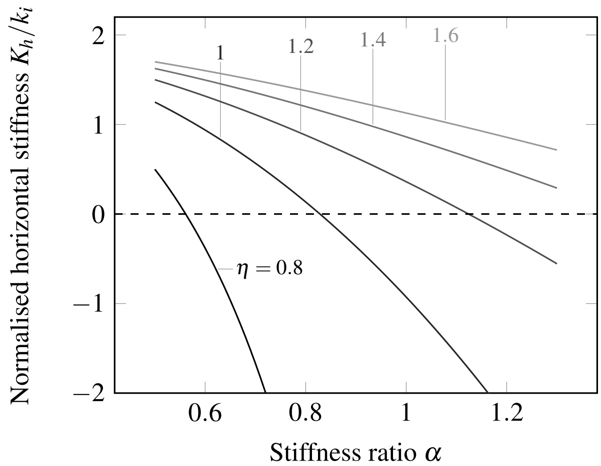

Figure 8. Horizontal stiffness characteristic versus stiffness ratio α at the vertical quasi–zero stiffness condition for varying length ratio η, calculated with Eq. (20).

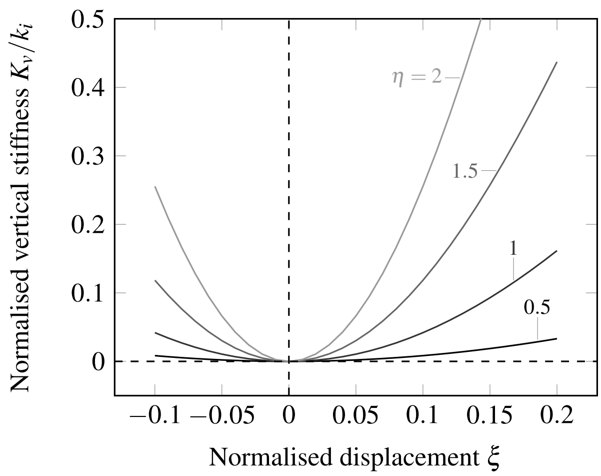

Figure 9. Vertical stiffness characteristics at quasi–zero stiffness in both directions, for a range of spring length ratios η.

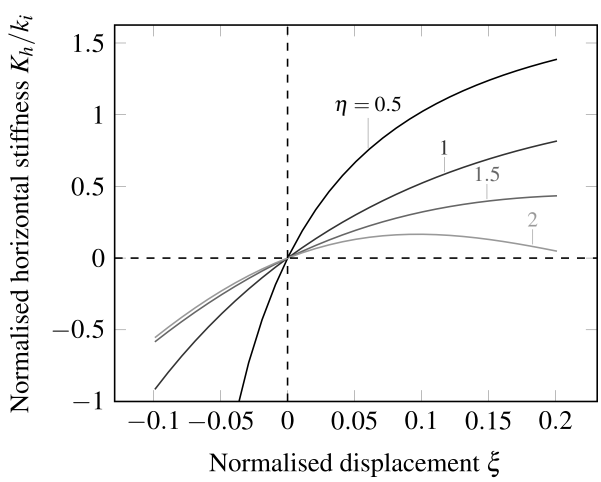

Figure 10. Horizontal stiffness characteristics at quasi–zero stiffness in both directions, for a range of spring length ratios, η. Note that negative displacement will result in negative stiffness.

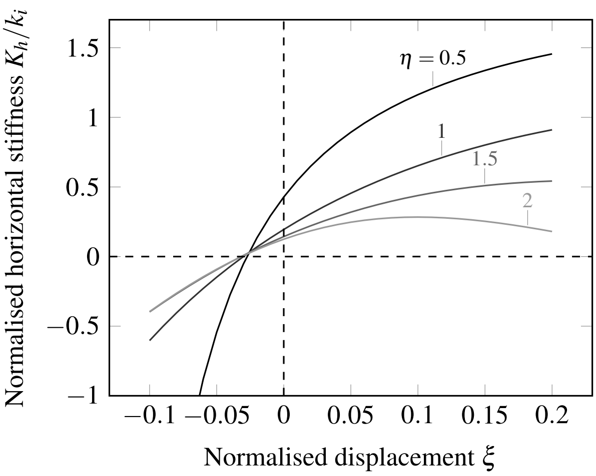

Figure 11. Normalised horizontal stiffness of the system at $\alpha = 0.95\alpha^*$ in order to obtain a small range of displacement around $\xi = 0$ with positive stiffness. The vertical quasi–zero stiffness condition is unaffected.

increases with η) and the amount of stiffness reduction in the horizontal direction (which decreases with η).

CONCLUSION

This paper has analysed the horizontal stiffness characteristics of a common quasi–zero stiffness arrangement that uses linear mechanical springs. This system has been analysed extensively in the literature with respect to its vertical stiffness properties and its suitability for vibration isolation; this work has shown that with correctly tuned spring stiffnesses, low horizontal stiffness can be achieved simultaneously with low vertical stiffness.

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CHARACTERISING NOISE AND ANNOYANCE IN HOMES NEAR A WIND FARM

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This study examines the relationship between indoor sound pressure level, local weather conditions, wind farm output power and resident rated annoyance in homes near a wind farm. A new methodology is presented that simultaneously records resident rated annoyance and corresponding time-series noise data while continuously monitoring one-third octave band noise levels and local weather conditions. Results of indoor noise and annoyance monitoring are presented for two homes near a wind farm whose residents claim to be annoyed by wind farm noise. Annoyance was found to be related to the overall noise level; however, noise levels were more strongly controlled by local wind speed.

INTRODUCTION

Annoyance due to wind farm noise has been shown to occur at lower sound pressure levels than annoyance due to other environmental noise sources such as road, rail and aircraft and the reason for this is unclear [1]. It is worth mentioning here that noise exposure is often calculated as an outdoor exposure and the level difference between outdoor and indoor exposure is frequency dependent, which may in part explain differences in indoor annoyance from various noise sources. Only a few field studies have investigated the relationship between wind turbine noise and annoyance in the past [1 − 7] and almost all of these studies use A-weighted sound pressure level as the sound emission metric to correlate with annoyance. Standard techniques of measuring noise in residents' homes that rely upon 10-minute averages and A-weighting may not have the required fidelity to capture important features of the noise character such as amplitude modulation and low frequency noise [8, 9]. However, it is difficult to record noise in sufficient detail in the field to resolve these effects due to large data storage and postprocessing requirements. Additionally, annoyance events may be hard to predict and only occur once per day, or occur when certain conditions are present.

To overcome these issues, a system that records time series noise data in a home at the precise time that the resident claims to be annoyed was recently developed by Doolan and Moreau [7]. This system was able to successfully relate the noise level in a home to personal annoyance level; however, the system was preliminary and a number of improvements were needed to increase its usefulness. Specifically, it is desirable to understand the role of local wind speed and direction on noise level and annoyance. Also, it is important to understand how the noise level varies over long periods of time (when the resident is annoyed and not annoyed) to determine if certain weather or other conditions are related to noise level and annoyance.

In this paper, an improved resident controlled noise and annoyance recording system is presented. The system records resident rated annoyance and two minutes of corresponding time-series noise data while performing continuous one-third octave band noise monitoring. This detailed dataset has been taken at two homes near a wind farm in conjunction with continuous local weather measurements. The aim of this study is to determine whether annoyance is more closely linked to overall sound pressure level, low frequency noise, infrasound, local wind speed or wind farm output power. It is worth noting that in their previous study, the authors [7] examined whether amplitude modulation is related to personal annoyance. The results of [7] showed significant level variation was present in the home however; the degree of modulation was relatively uniform with annoyance. For the current study, analysis showed amplitude modulation was not present in the signals recorded in the homes so this can not be a factor controlling annoyance.

METHODOLOGY

The noise and annoyance recording system

The noise and annoyance recording system consisted of 4 low frequency ½" microphones (GRAS type 40AZ) connected to preamplifiers (GRAS type 26CG) and 4 mA constant current power modules (GRAS type 12AL) with a flat frequency response down to 0.5 Hz. Acoustic data were recorded using a 24 bit National Instruments data acquisition device (NI USB-9234) at a rate of 51.2 kHz onto the hard drive of a laptop computer (Dell Vostro 3550). The microphones were calibrated in the frequency range from 0.1 to 100 Hz prior to testing using a low frequency calibrator (GRAS type 42AE). Additionally, calibration was checked just prior to the measurements at 1 kHz and 94 dB with a pistonphone. Microphone sensitivity values from both calibrations were in agreement.

Personal annoyance level was reported via a graphical user interface (GUI) that was programmed using Matlab and ran on the laptop computer. In all tests, the laptop was placed outside of the room containing the microphones. The system was designed so that the resident rates the annoyance of the noise they hear as either 'Not annoyed', 'Slightly annoyed', 'Moderately annoyed' or 'Very annoyed'. Additionally, they could leave a comment about the weather conditions, noise characteristics etc.

With the recording system, continuous unweighted one-third-octave band noise levels were recorded every two minutes and saved to the hard drive of the computer. The one-third-octave band measurements were calculated using the entire two minute time-series noise sample, ensuring low levels of uncertainty. When a resident reported their personal annoyance level using the computer program, the two minute time-series noise sample during which the button was pressed was saved directly to the hard drive of the computer for further analysis. Narrow-band spectra associated with an annoyance rating are presented and have been calculated from the entire two minute time-series noise sample. It should be noted that the time-series noise samples associated with an annoyance rating were carefully analysed and there was no indication that amplitude modulation was present or related to annoyance.

Test sites

Noise and annoyance measurements have been taken in two homes near a wind farm with capacity of 111 MW in South Australia. The first home, referred to as Residence A, is located approximately 2.5 km east of the wind farm. The second home, referred to as Residence B, is located approximately 8 km west of the wind farm. The wind farm is visible from Residence A but not from Residence B. In both homes, the residents claimed to be annoyed by noise that they attributed to the wind farm in all rooms of their homes.

Local wind speed and direction were also recorded in 5 min intervals at the homes using a weather station to determine if noise level and annoyance are related to wind induced noise at the home. At Residence A, weather conditions were monitored 5 m from the house façade at a height of 1.5 m above the ground. At Residence B, weather conditions were monitored 40 m from the house façade at two heights of 1.5 m and 10 m.

Noise and annoyance testing was conducted at Residence A over the period of 2/5/2013 – 7/5/2013 and during this time, 20 self reported annoyance measurements were taken. Testing was conducted at Residence B over the period of 22/4/2013 – 28/4/2013 and during this time, 8 self reported annoyance measurements were recorded. It should be noted that the total number of samples measured in the two homes is small and any conclusions are limited to this dataset and cannot be made general to a resident's perception of wind farm noise.

Microphone placement

To determine the effect of room geometry and standing waves on the results, measurements were first recorded with all four microphones placed in an unoccupied room of Residence A as shown in Figure 1. The room has dimensions of 3.9 m × 3.5 m × 3 m and is located on the side of the house that faces the wind farm. In particular, one microphone (M4) was positioned close to the window and another (M3) was located 10 cm from the ground in the corner of the room. Microphones M1, M2 and M4 were all located at a height of 1.5 m from the floor. During all tests in this study, the microphones were covered with 90 mm spherical foam wind caps.

Figure 2 shows narrowband acoustic spectra measured with the four microphones in Residence A calculated from one two minute time-series noise sample. Apart from microphone M3 which was located in the corner of the room and showed an increase in amplitude compared with the others, the signals of the remaining three microphones located in the centre of the room were essentially equivalent. As microphone placement was found to have little influence on the recorded noise signals, all remaining results presented in this paper have been taken with a single microphone located in the centre of an unoccupied room that faced the wind farm. Only indoor noise levels are presented in this paper as the focus of this study is noise and annoyance inside homes, however, a previous study by the authors has employed both indoor and outdoor microphones to examine the relationship between noise and personal annoyance [10].

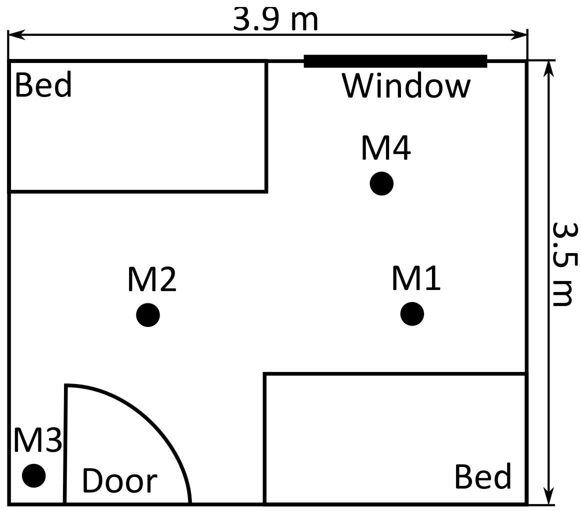


Figure 1: Microphone positions (M1 − M4) in an unoccupied room of Residence A.

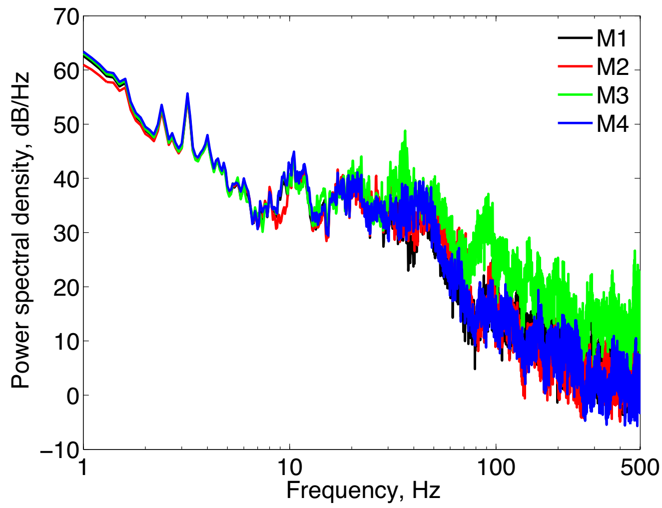


Figure 2: Acoustic spectra measured in Residence A at the 4 microphone positions.

RESULTS

Residence A

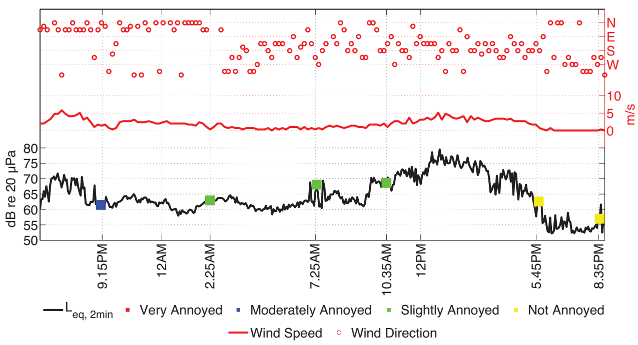
During the complete measurement period at Residence A, 20 self-reported annoyance measurements were taken with 3 rated as 'Very Annoyed', 6 as 'Moderately Annoyed', 7 as 'Slightly Annoyed' and 4 as 'Not Annoyed'. The comments accompanying each annoyance rating are presented in Table 1. These comments show that the resident perceives unwanted noise and can describe it. Additionally, the comments suggest that the noise is perceived as thumping, rumbling or roaring.

Table 1: Annoyance ratings and corresponding resident comments. Repeated comments are only listed once.

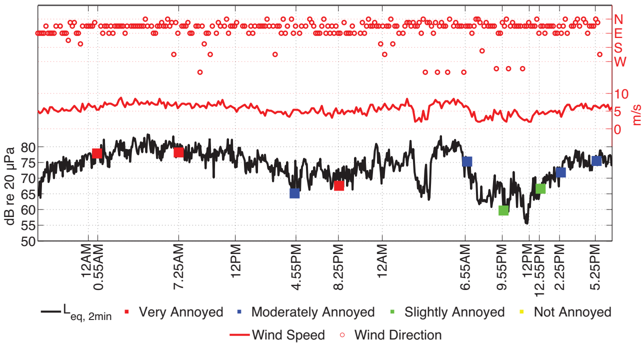
Annoyance rating	Comments
'Very Annoyed'	• Loud rumbling noise
'Moderately Annoyed'	• Thumping, roaring noise • Rumbling noise • Weird dreams and slight headache
'Slightly Annoyed'	• Bad nights sleep, not much noise • Weird dreams, hardly any noise • Rumbling • Felt pressure in ears • Mild whirring noise

Figure 3 shows the un-weighted $L_{eq,2min}$ level, local wind direction and wind speed with annoyance ratings at Residence A. The data from 2/5/2013 to 7/5/2013 are divided into three figures for clarity.

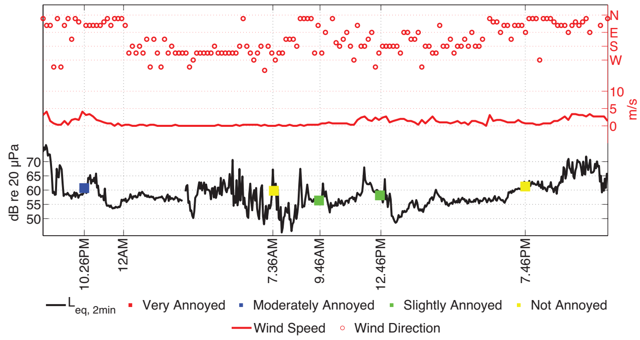
In general, the data in Fig. 3 reveal a strong relationship between local wind speed and noise level. In dataset 1 (Fig. 3 (a)), the wind speed ranges from 0 to 5 m/s. The dominant wind direction from the evening of 2/5 until the early morning of 3/5 is N/NE. For the rest of the measurement period of dataset 1, the wind direction is scattered. During this period, the resident rated themselves as 'Not Annoyed' to 'Moderately Annoyed'.



(Figure 3a) Dataset 1 from 6.25PM 2/5 to 8.25PM 3/5.



(Figure 3b) Dataset 2 from 7.55PM 5/5 to 7.06PM 6/5.



(Figure 3c) Dataset 3 from 8.26PM 6/5 to 10.46PM 7/5.

Figure 3: Wind direction, wind speed and $L_{eq,2min}$ with annoyance ratings at Residence A.

Dataset 2 in Figure 3(b) shows the largest portion of the measurement period during which the resident was most annoyed. During this time, the local wind speed was high at up to 8 m/s and the dominant wind direction was NE. Of the three times that the resident was 'Very Annoyed', two occurrences correspond to relatively high noise levels between 75 and 80 dB (0.55AM 5/5 and 7.25AM 5/5). However, the third 'Very Annoyed' measurement does not follow this trend and occurs when the noise level is between 65 and 70 dB (8.25PM 5/5).

In dataset 3 (Fig. 3(c)), the local wind direction was mostly scattered and the wind speed was low, measuring 0 m/s half of the time. During this measurement period, the resident rated themselves as 'Not Annoyed' to 'Moderately Annoyed'.

Figure 4 shows all measured noise spectra associated with the annoyance ratings in one-third octave bands compared to the curve representing the median hearing threshold as listed in ISO:226 [11]. This figure shows that as annoyance increases from 'Not Annoyed' to 'Very Annoyed', there is a general increase in the noise levels at low frequencies below 100 Hz as well as a slight increase in the levels of broadband energy to 1 kHz. At the highest annoyance rating, the highest noise levels are recorded across the entire frequency range of interest. The levels of noise in Fig. 4 are low and are at the limits of detectability. The recorded noise is observed to only just exceed the median hearing threshold at low frequencies between 50 and 100 Hz at the highest annoyance rating.

In Figure 5 the acoustic narrow-band power spectral density of two annoyance cases are compared. The noise floor of the recording system measured in the anechoic chamber at the University of Adelaide is also included for comparison. The spectra in Fig. 5 have been calculated using Welch's averaged modified periodogram method of spectral estimation with a Hanning window of length 512000 points, 50% overlap and 512000 FFT points. The power spectral density has also been corrected by dividing by the bandwidth in order to compensate for the use of a Hanning window [12]. In both annoyance cases, the wind farm was operational and the power output was high at 60% and 90% for the 'Not Annoyed' and 'Very Annoyed' cases, respectively. When the resident rated themselves as 'Very Annoyed', higher noise levels were recorded and the local wind speed was high at 8 m/s. Conversely, when the resident was not annoyed, the noise levels were lower and the local wind speed was 0 m/s. High amplitude peaks are visible in the 'Not Annoyed' noise spectrum at frequencies of 1.6 Hz, 2.4 Hz and 3.2 Hz which corresponds to harmonics of the blade pass frequency at 0.8 Hz. These peaks are likely visible in the noise spectrum due a reduction in the background noise at very low wind speed.

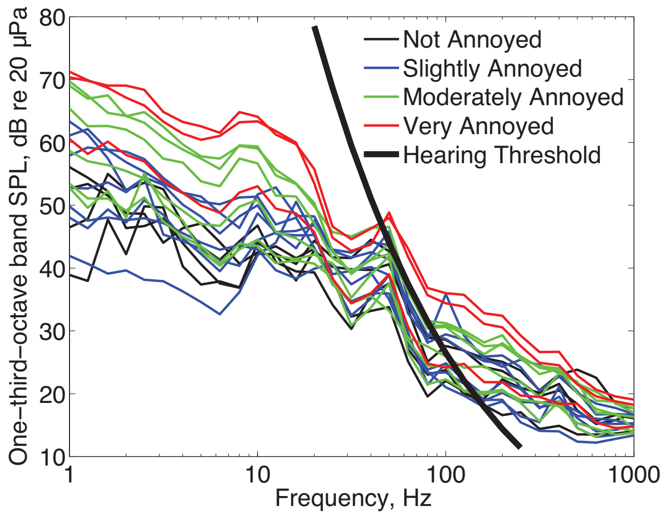


Figure 4: One-third-octave band spectra (un-weighted) for all annoyance ratings at Residence A compared to the median hearing threshold.

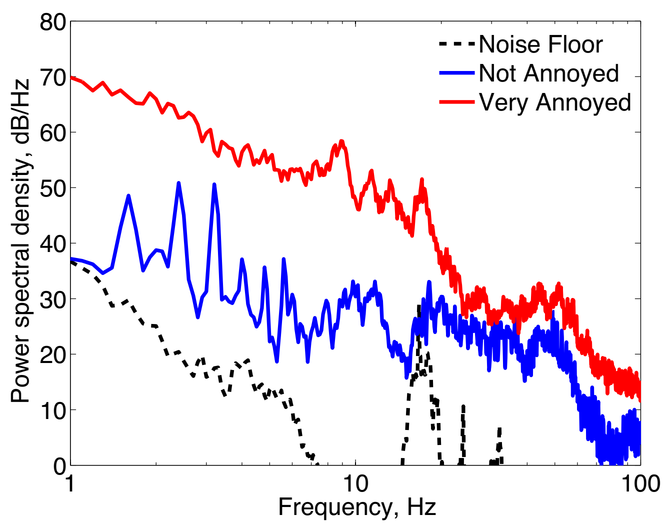
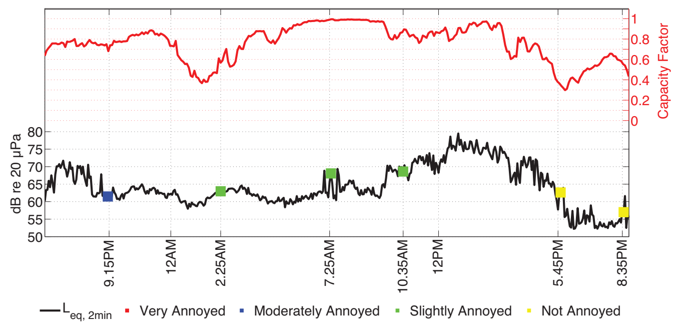
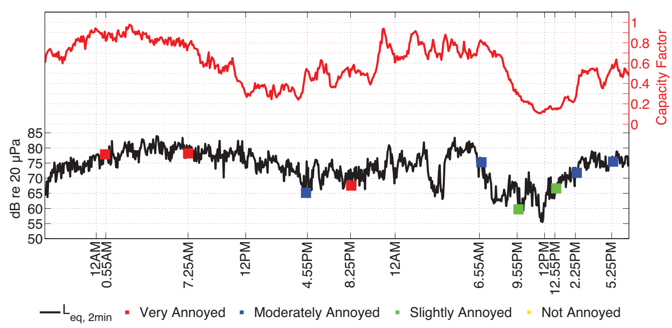


Figure 5: Power spectral density (un-weighted) of acoustic data for two annoyance ratings.

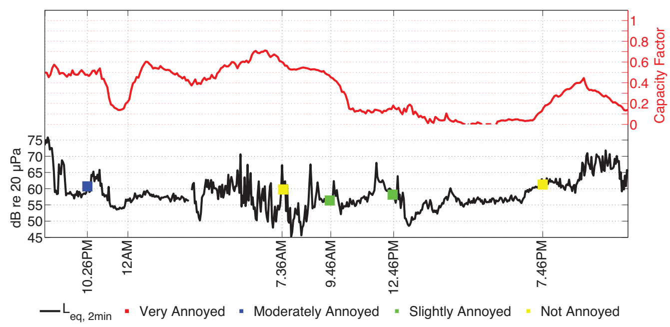
Figure 6 shows the wind farm capacity factor over the measurement period compared with the un-weighted $L_{eq,2min}$ level and annoyance ratings. Again the data from 2/5/2013 to 7/5/2013 are divided into three figures for clarity. Figure 6 shows that when the wind farm output power was close to maximum, the resident was either 'Slightly Annoyed' (Fig. 6(a)) or 'Very Annoyed' (Fig. 6(b)). The wind speed at the residence at these times was 0 − 2 m/s and 5 − 8 m/s, respectively and the corresponding noise level was measured to be 65 − 70 dB and 75 − 80 dB, respectively. If the wind farm was the source of annoying noise, it would be expected that the highest annoyance level would be to be reported when the local wind speed was low (minimising masking noise) and when the wind farm output was high. However, from the results, it appears that annoyance is most likely related to sound level and local wind speed at Residence A.



(Figure 6a) Dataset 1 from 6.25PM 2/5 to 8.25PM 3/5.



(Figure 6b) Dataset 2 from 7.55PM 5/5 to 7.06PM 6/5.



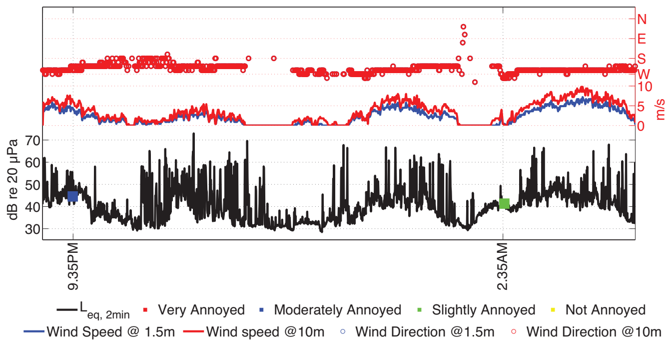
(Figure 6c) Dataset 3 from 8.26PM 6/5 to 10.46PM 7/5.

Figure 6: Wind farm capacity factor and $L_{eq,2min}$ level with annoyance ratings at Residence A.

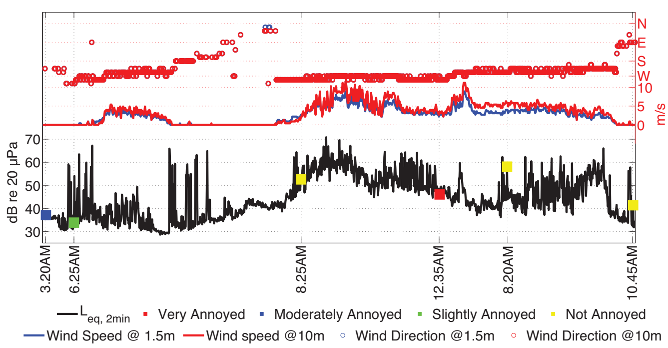
Residence B

During the complete measurement period at Residence B, 8 self-reported annoyance measurements were taken with 1 rated as 'Very Annoyed', 2 as 'Moderately Annoyed', 2 as 'Slightly Annoyed' and 3 as 'Not Annoyed'. No comments were left by the resident. Figure 7 shows the un-weighted $L_{eq,2min}$ level, local wind direction and wind speed with annoyance ratings at Residence B. The data from 22/4/2013 to 28/4/2013 are divided into two figures for clarity.

As seen for Residence A, the data taken at Residence B in Fig. 7 reveal a strong relationship between local wind speed and noise level. During times of high local wind speed and noise level, the dominant wind direction was SW. Interestingly, the times that the resident was either ‘Very Annoyed’ (12.35AM 28/4) or ‘Moderately Annoyed’ (9.35PM 25/4, 3.20AM 26/4) do not necessarily coincide with the highest noise levels or times of highest local wind speed.



(Figure 7a) Dataset 1 from 5.00PM 22/4 to 4.00PM 25/4.



(Figure 7b) Dataset 2 from 3.00AM 26/4 to 11.05PM 28/4.

Figure 7: Wind direction, wind speed and $L_{eq,2min}$ with annoyance ratings at Residence B.

Figure 8 shows all measured noise spectra associated with the annoyance ratings at Residence B in one-third octave bands compared to the curve representing the median hearing threshold. The highest noise levels are evident in the low frequency and infrasonic region. Again the levels of noise are low and only exceed the median hearing threshold at frequencies above 100 Hz.

One of the ‘Slightly Annoyed’ measurements (2.35AM 25/4) contains tonal components that may correspond to harmonics of the blade pass frequency at 1.6, 2.4, 3.2 and 4 Hz and these tones are also visible in the ‘Slightly Annoyed’ one-third-octave band spectrum in Fig. 8. This measurement was taken when the local wind speed was 0 m/s and therefore when very low background noise levels were present. Conversely, when the resident rated themselves as ‘Very Annoyed’ (12.35AM 28/4), broadband noise levels were recorded and the local wind speed was higher at 3 m/s.

The sound levels at Residence B (in Fig. 7) contain a lot of peaks during the day time and additionally peaks are visible in the spectra of Fig. 8. It is worth noting that the authors did listen to the audio obtained at Residence B but the source of these peaks could not be determined as they did not occur during times of reported annoyance.

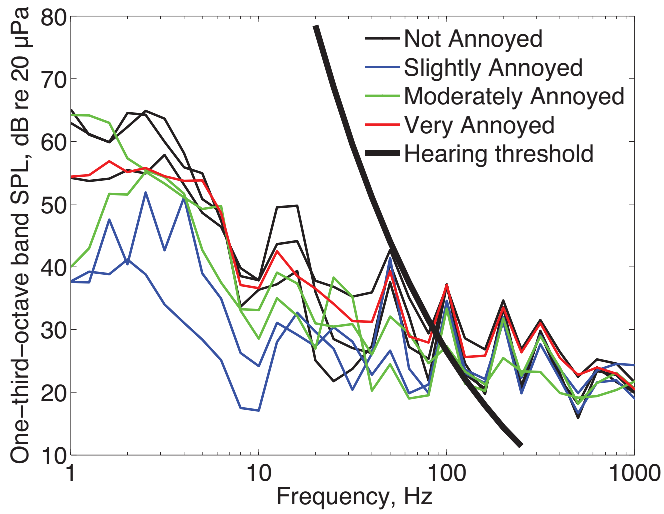


Figure 8: One-third-octave band spectra (un-weighted) for all annoyance ratings at Residence B compared to the median hearing threshold.

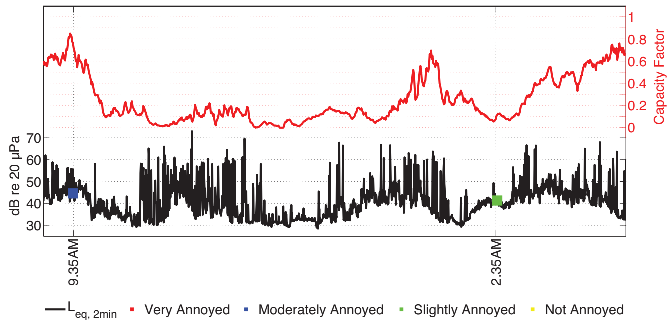
Figure 9 shows the wind farm capacity factor over the measurement period compared with the un-weighted $L_{eq,2min}$ level and annoyance ratings at Residence B. Again the data from 22/4/2013 to 28/4/2013 are divided into two figures for clarity. Figure 9(b) shows that when the wind farm output power was close to maximum, the resident was either ‘Not Annoyed’ (8.25AM 27/4) or ‘Very Annoyed’ (12.35AM 28/4). The local wind speed at both of these times was 2 − 3 m/s and the noise measured in the home was broadband at a level of 50 – 55 dB and 45 − 50 dB, respectively.

CONCLUSION

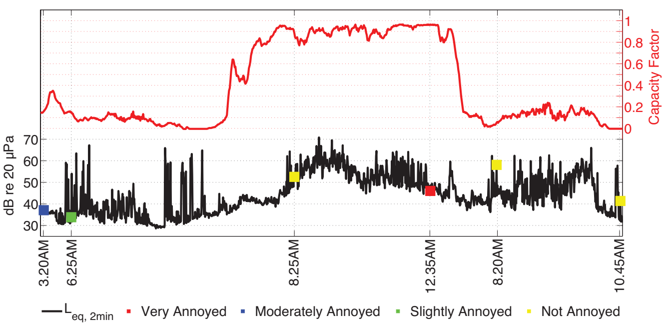
This paper has presented measurements of noise level, local wind speed and direction and personal annoyance in two homes near a wind farm. The noise level measured in both homes was found to be controlled by local wind speed more than any other factor. The highest noise levels were measured in the low frequency and infrasonic range however the levels at these frequencies were below the median hearing threshold making them unlikely to be audible by a person with normal hearing.

Annoyance was found to be related to noise level and local wind speed in the home located 2.5 km from the wind farm. However, at the home located 8 km from the wind farm, annoyance was not controlled by noise level. In this case, time of day seemed to be a more important factor.

When the local wind speed was at a very low level, with correspondingly low background noise levels, tones at harmonics of the blade pass frequency were measured inside both homes. These tones were however below the threshold of hearing.



(Figure 9a) Dataset 1 from 5.00PM 22/4 to 4.00PM 25/4.



(Figure 9b) Dataset 2 from 3.00AM 26/4 to 11.05PM 28/4.

Figure 9: Wind farm capacity factor and $L_{eq,2min}$ level with annoyance ratings at Residence B.

ACKNOWLEDGEMENTS

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FREE VIBRATIONS OF INTERSPERSED RAILWAY TRACK SYSTEMS IN THREE-DIMENSIONAL SPACE

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Statistically, the actual loading conditions for railway tracks are rather dynamic and transient. The dynamic loadings due to train and track interactions redistribute from the rails to the rail pad, from the rail pad to the railway sleeper, and from the railway sleeper to the underlying ground. Commonly, railway sleeper in track systems is modeled as a beam on elastic foundation. This study makes use of a calibrated finite element model of railway sleepers in a track system, in order to investigate the resonant frequencies and associated mode shapes of railway components in interspersed track systems. The numerical model takes into account the tensionless characteristic of the elastic support as well as the more realistic partial support condition. Using a finite element package STRAND7, the dynamic finite element model of the railway concrete sleeper was precisely established. The dynamic model has then been extended to demonstrate free vibration behaviours of the railway tracks. The effect of interspersed patterns (1 in 2; 1 in 3; and 1 in 4) on railway track dynamics has been firstly investigated and presented herein.

INTRODUCTION

A traditional railway track consists of steel rails, sleepers, fasteners, ballast, and formation (capping layer over compacted soil). A review on the loading conditions acting on railway tracks for either passenger or freight trains shows that dynamic behaviour of railway track is vital to understand the track dynamic responses to diverse loading conditions [1]. The critical loading condition, which often causes structural cracks in brittle sleepers, is the large impact loads due to wheel/rail irregularities. A common transient waveform pattern of wheel impacts due to short-pitch rail corrugations can be seen in Figure 1. Clearly, the magnitude of the impact forces varies from 200kN to 400kN while the duration is ranging from 2 to 10 msec. Using a transient pulse concept, these impact pulses are associated with the vibration excitation frequency range from 100 Hz to 500 Hz ($f = 1/T$: f is a frequency and T is a period). In reality, wheel/rail interaction generates impact forces acting on a rail seat. The pulse load patterns are dependent on train speed, track geometry, axle load, vehicle type, and wheel/rail defects. Rail engineers must take into account the frequency ranges of static and dynamic loadings in design and construction of railway tracks with respect to critical train speeds and operational parameters [1-3].

The effect of ballast conditions on the flexural response of the railway concrete sleepers was established using a finite element model of the railway concrete sleeper [4]. It was found that the static wheel load generally imparts the positive bending moment at the railseat whilst provides the negative bending moment at mid span of the sleepers. The variation of ballast stiffness has a low sensitivity on the flexural responses of the railway concrete sleeper but such variation plays a role in rail responses and track modulus [5-6]. From a quasi-static point of view, the standard design of a railway track is fairly conservative [7]. In contrast, the actual transient loadings excite the track components dynamically and it is up to the capability of such components to filter and redistribute the dynamic force onto adjacent components supporting one another. The dynamic amplification factor is substantially dependent on the ratios between the period of the transient loading and each modal period of the railway track components [8-12]. It is noteworthy that wheel force excitation also applies laterally to track components by virtue of rail cant (to enable conical wheels) and track superelevation (to balance centrifugal effect from the body of trains). In fact, a wheel excitation could excite track natural frequencies in any particular dynamic mode, which can either induce the corresponding structural damage or emit noises. There are many types of railway noises of which the root causes are contradicting. For example, increasing rail pad stiffness might reduce 'rolling noise', but also has potential to increase 'ground-borne noise' and reduce service lives of adjacent track components [11-12]. Some of the common railway noises due to wheel-rail interactions, community may experience, are [13]:

- rolling noise from wheel-rail roughness interaction
- ground-borne noise from track vibrations
- structural-borne noise from railway bridge vibrations
- wheel flanging noise from the rubbing of wheel flange onto rail in curved tracks
- wheel squeal noise from wheel-rail interactions at resonance.

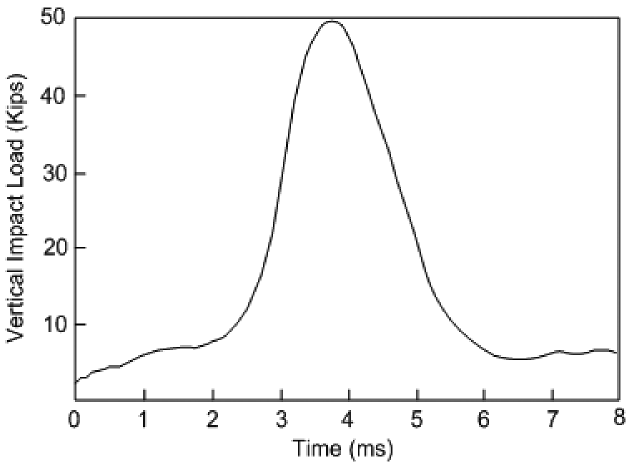


Figure 1 A typical impact due to a wheel/rail out-of-round defect, 1 Kip = 4.448 kN [1]

The frequency range of rolling, ground-borne and structural-borne noises is from 0 to 500 Hz, while the impact noise could vary from a hundred up to 1,000 Hz and often the wheel flanging and squeal noises are found to exceed 4,000 Hz [13].

It is clear that track components play significant role in railway dynamics. In the past (since 1850s), timber was commonly used as railway sleepers in Australia due to the then economy and availability. Timber sleepers tend to have service life about 15-20 years, depending on maintenance and operational situations. Over a period of time, the timber sleepered tracks age and require a major maintenance. In addition, to enhance railway operations, timber sleepered tracks need strengthening. A method, which is a temporary measure, is to partially re-sleeper the track with concrete sleepers. This method is commonly called 'intersperse' [14]. Depending on track stiffness, deterioration process, and operational parameters, there are a variety of interspersing patterns, i.e. 1 in 2; 1 in 3; or 1 in 4 (Note: 1 in 2 means imposing a concrete sleeper every two sleepers). The concrete sleepers used are generally medium-duty type so the rail levels can be retained. This method has some disadvantages because one only replaces a stiffer concrete sleeper on the aged and soft existing formation, often resulting in a soil foundation failure. Due to track stiffness inconsistency and different decay rates of time-dependent material properties, such a method is normally suitable for a short-term maintenance strategy where track strengthening cannot wait until a major trackwork could be programmed.

This paper presents free vibration behaviours of the interspersed railway tracks in three-dimensional space. To explore the dynamic effects, a variety of interspersing patterns have been established. The finite element model in this study has taken into account more realistic boundary conditions and load cases. The results provide better insight into the dynamic behaviour of railway track and its components under different interspersing patterns. This paper is aimed at raising the dynamic consideration in the design of ballasted railway tracks. The use of commercial finite element program would enable the industry outreach to researchers and engineering practitioners in order to construct a numerical model to better predict and control the track responses and to develop solutions to vibro-acoustic problems in interspersed railway tracks.

FINITE ELEMENT ANALYSIS

A two-dimensional Timoshenko beam model was previously developed and found to be one of the most suitable options for modeling concrete sleepers [8-13]. In this study, the finite element models of railway tracks have been developed and calibrated against the numerical and experimental modal parameters [8, 9]. Figure 2 shows the finite element models

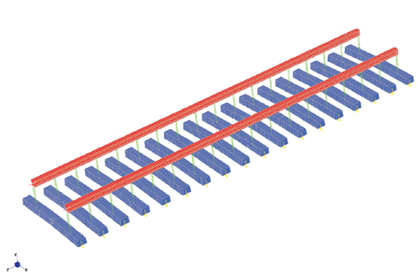


Figure 2 a) concrete sleepered track

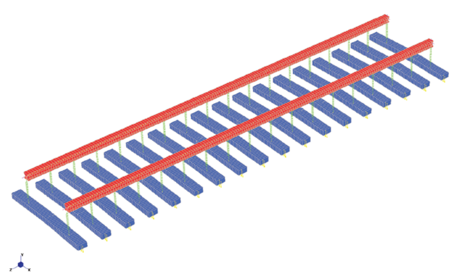


Figure 2 b) timber sleepered track

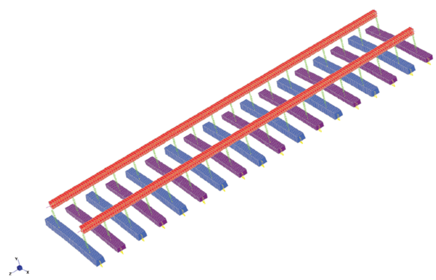


Figure 2 c) 1:2 interspersed track

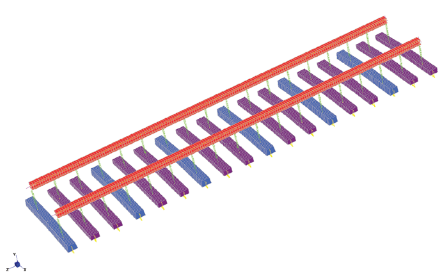


Figure 2 d) 1:3 interspersed track

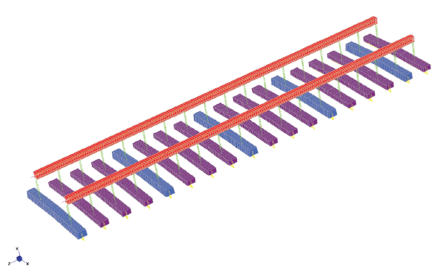


Figure 2 e) 1:4 interspersed track

Figure 2 STRAND7 finite element models of railway tracks in three-dimensional space for an in-situ railway track with different types of sleepers. Using a general-purpose finite element package STRAND7 [15], the numerical model included the beam elements, which take into account shear and flexural deformations, for modeling the sleeper and rails. The 60kg rail cross section and sectional parameters were used in accordance with Australian Standard AS1085.1 [16]. The trapezoidal cross-section was assigned to the concrete sleeper elements in accordance with the standard medium duty sleepers [17-20]. The rectangular cross-section was assigned to the timber sleeper elements in accordance with the standard timber sleepers used in NSW [21]. The rail pads at railseats were simulated using a series of spring-dashpot elements. The distance offset between rails and sleepers was set to 100mm to more clearly illustrate the track behaviours. This setup does not affect the numerical results [17]. In this study, the stiffness and damping values of HDPE pads were assigned to these springs [22, 23]. The support condition was simulated using the nonlinear tensionless beam support feature in Strand7 [15]. This attribute allows the beam to lift over the support while the tensile supporting stiffness is omitted. The tensionless support option can correctly represent the ballast characteristics in real tracks [15, 17]. It is important to note that the experimental modal testing was first performed to identify structural parameters of the sleepers. Then, the finite element model was developed using available data from the manufacturer. The model was then updated through the comparison of modal parameters. Table 1 shows the geometrical and material properties of the finite element model. Based on previous studies [7-8], effects of length and boundary of track in this study (18 bays or 10.8 m) on the computation and the frequencies of interest are negligible. These data have been validated and the verification results were presented elsewhere [8-10].

Table 1 Engineering properties of the standard concrete sleeper used in the modeling

Parameter lists		
Flexural rigidity	$EI_c = 4.60$, $EI_r = 6.41$	MN/m^2
Shear rigidity	$\kappa GA_c = 502$, $\kappa GA_r = 628$	MN
Ballast stiffness	$k_b = 13$	MN/m^2
Rail pad stiffness: vertical	$k_p = 800$	MN/m
: lateral	$k_p = 400$	MN/m
Sleeper density	ρ_s - 2,750	kg/m^3
Sleeper length	$L = 2.5$	m
Rail gauge	$g = 1.5$	M
Sleeper spacing	$s = 0.6$	m

According to a literature review, free vibration analyses of interspersed railway track systems have not thoroughly been evaluated. Therefore, numerical simulations were conducted using the nonlinear solver in STRAND7 [15], in order to investigate the effect of interspersing patterns on the natural frequencies and associated dynamic mode shapes of such railway track systems. Note that STRAND7 can take care of both viscous and hysteric damping parameters for dynamic analysis. The study will provide the better understanding into the vibro-acoustic behaviours of interspersed railway tracks before carrying out any design or maintenance process. The understanding will enable rail engineers to make a better decision on asset management and maintenance strategies.

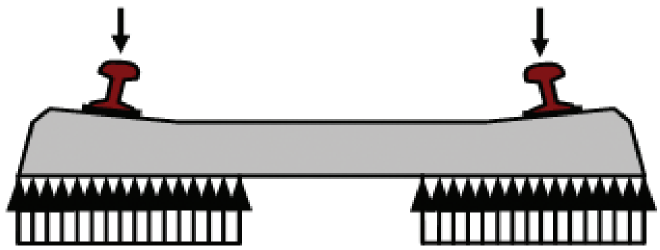


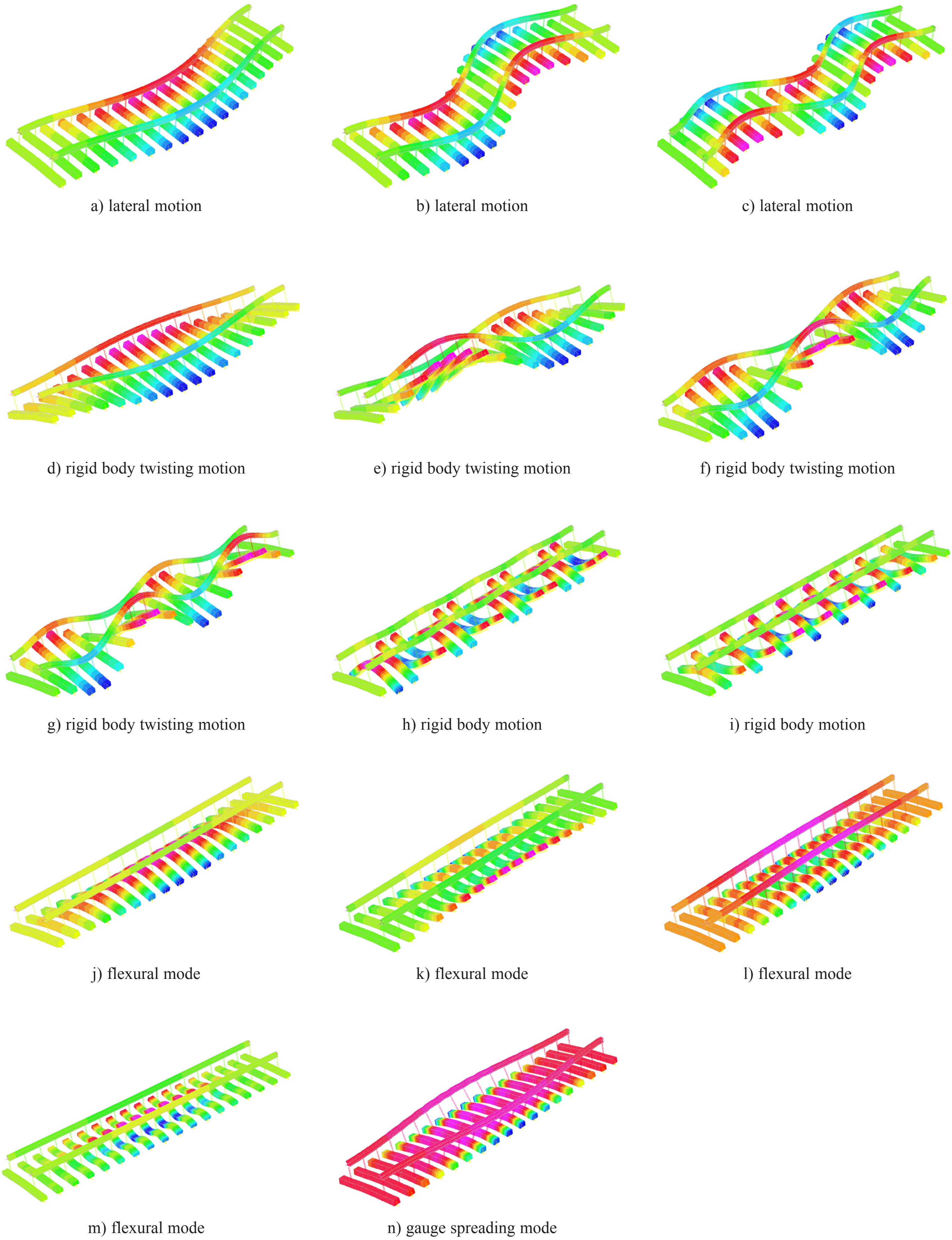
Figure 3 Standard partial ballast support condition [2, 9-11]

FREE VIBRATION ANALYSES

Based on the previous analyses [8], the standard design sleepers have been employed to investigate and benchmark the free vibration behaviours between timber and concrete sleepered tracks [20, 21]. It should be noted that the Australian Standard AS1085.14 [2] suggests the use of partial ballast support for a standard gauge sleeper, as shown in Figure 3. The ballast support underneath the sleeper spans about 1.0 times of the difference between the total length of sleeper and the rail gauge length [24]. For a new rail track construction, the ballast underneath sleeper' central part will not be tamped and sometimes about 50mm void (or more in some practices) between sleeper soffit and ballast will be left in order to minimise the negative bending moment at sleepers' mid-span [25]. This practice allows the realistic ballast pressure distribution to be controlled as per the design process, especially for concrete sleepered tracks [2, 24].

Table 2 and Figure 4 show the dominant natural frequencies and associated dynamic mode shapes of the timber and concrete sleepered tracks, respectively. It is found from Figures 4a-c that the lateral dynamic rail bending modes are among the lowest natural frequencies. Body twisting modes can be seen in Figures 4d-g, whereas these modes may affect dynamic hunting-coupler behaviour of rolling stocks.

Figures 4h and 4i display the rigid body motions of railway tracks. In these modes, the rail pads (modelled by using a spring-dashpot) enable large-amplitude dynamic axial motions. The sleepers then behave as consistent masses either in-phase or out-of-phase with the rail motions. The results show that a modal phase difference also occurs in the dynamic bending responses of structural elements. These out-of-phase dynamic mode shapes suppress the acoustic radiation from rail vibrations at such resonant frequencies. It is important to note that the rail pad stiffness plays a key role on the dynamic modes and phase differences. Softer rail pads (e.g. < 100 MN/m) tend to further diminish such effects.



a) lateral motion b) lateral motion c) lateral motion

d) rigid body twisting motion e) rigid body twisting motion f) rigid body twisting motion

g) rigid body twisting motion h) rigid body motion i) rigid body motion

j) flexural mode k) flexural mode l) flexural mode

m) flexural mode n) gauge spreading mode

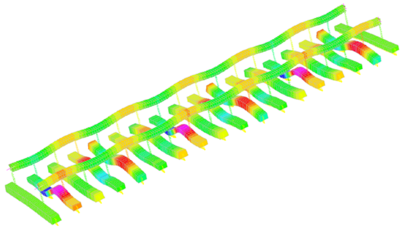
Figure 4 Free vibrations of railway tracks (0 to 500 Hz)

Table 2 Natural frequencies and associated mode shapes of interspersed railway tracks

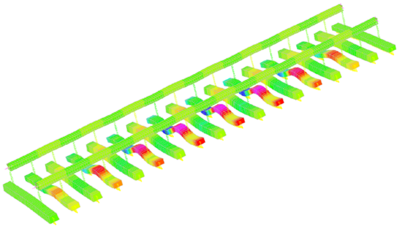
Dynamic mode shapes	Natural frequencies of different types of railway tracks (Hz)				
	Concrete	1 in 2	1 in 3	1 in 4	Timber
Lateral bending (Fig. 4a)	3.87	4.34	4.58	4.70	5.05
Lateral bending (Fig. 4b)	10.48	11.77	12.42	12.72	13.72
Lateral bending (Fig. 4c)	20.44	22.97	24.23	24.52	26.79
Body twisting (Fig. 4d)	44.69	48.98	51.17	52.25	55.80
Body twisting (Fig. 4e)	46.77	51.38	53.71	54.73	58.69
Body twisting (Fig. 4f)	52.94	58.46	61.16	61.62	62.28
Body twisting (Fig. 4g)	64.85	72.02	75.08	82.46	67.18
Rigid body (Fig. 4h)	112.36			93.28	99.83
Rigid body (Fig. 4i)	114.97	99.73			101.22
Flexural (Fig. 4j)	117.34	101.14; 116.64	101.92; 116.10	104.25; 115.23	101.49
Flexural (Fig. 4k)	267.79	176.22; 248.81	182.81; 224.48		181.47
Flexural (Fig. 4l)	404.32	230.75; 341.59	233.58; 263.24	277.18	260.89
Flexural (Fig. 4m)					440.68
Guage spreading (Fig. 4n)	307.60				
Out-of-phase (Fig. 5a)		352.20			
Out-of-phase (Fig. 5b)		404.25			
Out-of-phase			193.45 (Fig. 6a)	182.89 (Fig. 7a)	
Out-of-phase			257.16 (Fig. 6b)	235.77 (Fig. 7b)	
Out-of-phase			329.06 (Fig. 6c)	360.62 (Fig. 7c)	
Out-of-phase + Rigid body			398.85 (Fig. 6d)	418.40 (Fig. 7d)	
Out-of-phase + Rigid body				482.14 (Fig. 7e)	

Figures 4j-k illustrates the dynamic bending modes of the railway sleepers. Clearly, the maximum positive dynamic bending at rail seats is associated with the second and third bending modes. The negative or hogging bending moment is maximal at the first flexural mode. In reality, it has been commonly found that railway sleepers are often damaged when the load excitations approach these flexural resonant frequencies.

Figure 5 shows the effect of interspersed pattern 1:2 on the dynamic mode shapes at a higher frequency range. It is clear in Figures 5 to 7 that the interspersed patterns play a key role in altering dynamic mode shapes of the railway tracks. Crossing-over of natural frequencies at higher frequency range (over 200 Hz) can be observed in the interspersed tracks as tabulated in Table 2. In addition, interspersing a railway timber sleepered track with concrete sleepers is very likely to induce the out of phase vibrations. However, the crossover between mixed dynamic modes between in-phase and out-of-phase flexural modes together with rigid body motions can also be observed, especially with an inclusion of a different element (i.e. an interspersed concrete sleeper) in track systems. This effect is more pronounced for the 1:4 interspersing pattern.

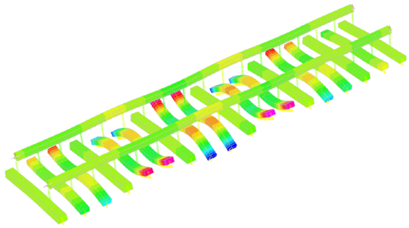


a) out-of-phase bending

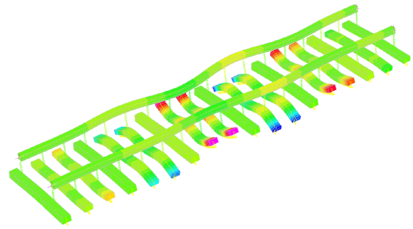


b) out-of-phase bending

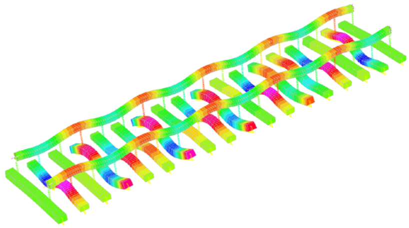
Figure 5 Free vibrations of 1:2 interspersed railway tracks (300 to 500 Hz



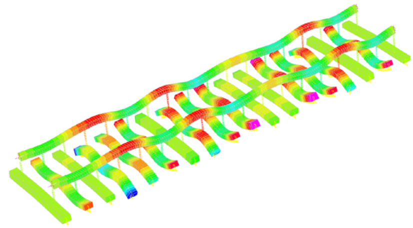
a) out of phase



b) out of phase

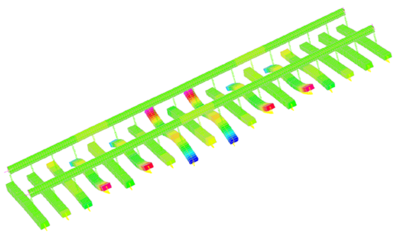


c) out of phase

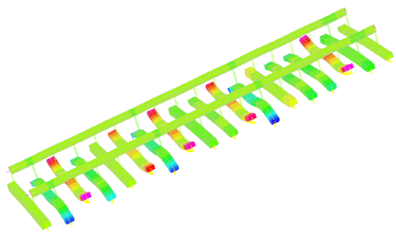


d) out of phase

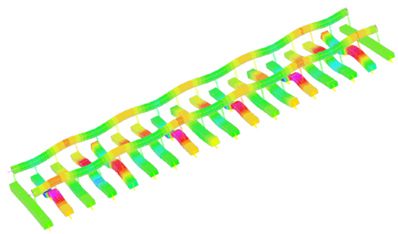
Figure 6 Free vibrations of 1:3 interspersed railway tracks (300 to 500 Hz)



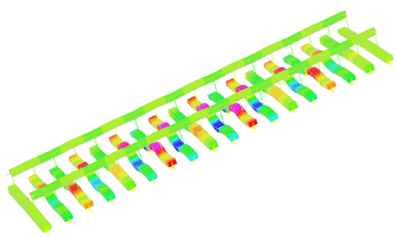
a) out of phase



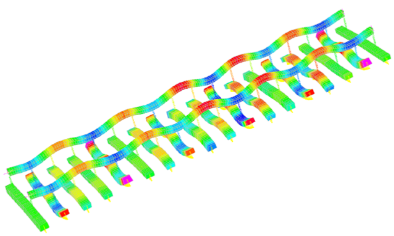
b) out of phase



c) out of phase



d) out of phase + rigid body motion



e) out of phase + rigid body motion

Figure 7 Free vibrations of 1:4 interspersed railway tracks (300 to 500 Hz)

CONCLUSIONS

Using finite element modeling, this paper investigates the effect of different types of interspersed patterns on the dynamic mode shapes and resonant frequencies of the railway track systems in three-dimensional space. An established dynamic finite element model of railway track was utilized in this study. The free vibration and nonlinear analysis solver in STRAND7 was employed to cope with the tensionless support and the more realistic partial support condition.

From a systems perspective, the free vibration analyses found that the dynamic bending modes are affected significantly by the interspersing practice. The flexural track dynamics can be crossed over in order to magnify alternate interspersed sleepers' vibration amplitudes. It is noticeable that the dynamic flexural amplitudes at mid span of sleepers act out of phase between the first and the second rigid-body resonances. In reality, lowering rigid body resonances can cause more breakage and pulverisation of ballast and formation. Importantly, the interspersed patterns tend to self-initiate the out of phase vibrations that potentially damage the fastening systems of railway tracks. The mixed modes of rigid body motion and out-of-phase vibration can also be observed at a higher frequency range. Note that the partial support condition (see Figure 3) hardly shows the influence over the dynamic flexural responses at rail seats, but it occasionally alters the dynamic bending moments of sleepers at mid span, by reducing the negative dynamic bending amplitudes at mid span.

Understanding in the free vibration behaviour of railway track systems is vital for structural health monitoring and vibration control strategies as well as rail asset management. This paper demonstrates the application of finite element modeling for railway tracks to extend the appropriate methodology to investigate resonant frequencies and associated dynamic mode shapes of interspersed railway track systems. Future work involves the parametric studies into time-dependent characteristics of interspersed railway tracks.

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COMPARISON OF MEASURED AND SIMULATED ROOM ACOUSTIC PARAMETER VALUES USING HIGH RESOLUTION GRIDS

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When the acoustic properties of enclosures are evaluated, it is normal to use measured and simulated data. So when an auditorium is already built, the usual strategy to analyse the parameter values spatially consists of obtaining experimental results from a few receivers and using this data to validate a simulated model. Working on the basis of acoustic parameter measurements made seat by seat in a medium-sized auditorium, this document analyses a simulation program's capacity and limitations in terms of predicting values for these parameters.

INTRODUCTION

The acoustic parameters described in the ISO 3382 standard [1] are used as a reference for acoustic characterisation of enclosed areas intended both for speech and musical transmission. They can be derived from measured or simulated impulse responses and each strategy has its advantages and disadvantages. When a room has already been built, it seems to be essential to know the measured acoustic parameter values with a view to making an objective assessment of the enclosure under existing conditions. On the other hand, it is clear that for highly detailed spatial analysis - such as in each seat of the audience zones - simulation is an invaluable, if not essential, tool allowing us to assess results in a reasonable time. Apart from making the job easier or faster, it is undeniable that choosing one procedure over the other to assess premises should really come down to the reliability of the data obtained. And it seems that in this aspect, the results of direct measurement have an advantage over results from a simulation. However, it should not be forgotten that each strategy has its limitations and that operator knowledge and experience play a fundamental role in both cases.

Measurements tend to be considered as more accurate given that the geometric model, the absorption of air or the absorption and diffusion coefficients for the materials, main sources of uncertainty in simulation, are inherent to the actual room and are, by definition, entirely included. In addition, wave phenomena such as diffraction or diffusion are also inseparable from the real sound field measured. On the other hand, simulation programs, at least any based on geometric acoustics, generally exclude information relating to the wave phase from their calculations. Consequently, their results should only be considered valid for frequencies over the Schroeder frequency, where room modes are superimposed and wave effects due to the phase can be discarded without significant loss of information over the acoustic field.

In comparison, simulations present a series of advantages relating to the accuracy of the data obtained that should not be ignored. On the one hand, the sound signal issued by a source is directly the Dirac function and not an approximation. There is no background noise so the dynamic range is unlimited at all frequencies. This eliminates possible uncertainties related to truncation processes and background noise compensation. These procedures cannot be avoided when dealing with measured impulse responses. Also errors relating to calculating the start of the impulse responses, perfectly defined geometrically in a simulated model, or possible delays in the filters required for band analysis can be discarded in a simulation. Finally, the sound source, in addition to not needing to be calibrated to measure the Sound Strength parameter (G), does not generate distortion at high levels and, more relevantly, it is also perfectly omnidirectional at high frequencies.

Despite all this, the main factor to take into account when assessing the reliability of a simulated model is the concordance of the results obtained with 'in situ' measurements. It is usual to find technical papers in the literature comparing acoustic parameter values, both measured and simulated, in a few receivers. This strategy has been used in newly built auditoriums, predicting the values of the main acoustic parameters at the planning stage when only the plans are available and putting them up against parameters obtained once the enclosure has been built [2]; when auditoriums are remodelled as part of heritage protection programmes where any action undertaken can cause irreversible damage to the cultural value of the preserved buildings [3]; or to analyse the renowned acoustic capacity of famous old theatres using new techniques such as 3D FDTD methods to simulate wave phenomena such as diffraction or interference [4].

This work aims to go into greater depth on the usual comparison between measured and simulated values for acoustic parameters by means of high resolution spatial analysis, comparing the measured and simulated values of the acoustic parameters seat by seat in a medium sized auditorium. In this scenario, some questions arise about uncertainties involved in both, measurement and simulation results. In particular, a lower spatial homogeneity in measured values is highlighted. Also the lack of omnidirectionality of the real sound source appears to have a noticeable influence on some acoustic parameters derived from the impulse response, especially at high frequencies.

EXPERIMENTAL PROCEDURE AND VALIDATION OF THE MODEL USING T_{30}

The results presented in this research come from an exhaustive characterisation carried out in the new Navarre Senior Music Conservatory Auditorium (Pamplona - Spain), where the monaural acoustic parameters were measured and simulated in an empty room for each and every one of the 375 seats intended for the audience. The enclosed area (Figure 1), panelled in two types of wood, has a volume of around 4000 m^3 with the audience area divided into two sections. The experimental device used to take the measurements meets ISO 3382 requirements. As an excitation signal, logarithmic sweeps lasting 20 s were emitted by a dodecahedral loudspeaker. With a diameter of 450 mm and twelve 5 inches drivers, the source was positioned halfway across the front of the stage at a height of 1.50 m. The microphones were placed in the middle of each seat at a height of 1.20 meters.

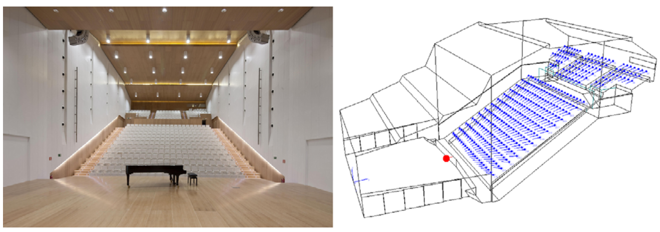

Figure 1. Photo of the auditorium (left) and arrangement of the source and the receiver grid (right)

On the other hand, the simulations were carried out using the ODEON v.12 room acoustic simulation program, using a simplified geometric model of 105 surface areas (Figure 1) recreating the measurement conditions regarding source and receiver positions. The materials' absorption coefficients were initially selected in accordance with the technical sheets provided by the manufacturers of materials used for the panelling and a visual inspection of the room. These coefficients were later refined in order to equal out the average values of T_{30}, both measured and simulated. Through an iterative process of gradual calibration for the absorption and diffusion coefficients, the reverberation time in octave bands is progressively adjusted so that the difference between the simulated and experimentally measured data is maintained within a 5% interval, meaning the just noticeable difference (jnd) in the value of a parameter that can be perceived by the average listener.

This criterion could be met (Figure 2) in all bands except for 8 kHz where the actual air absorption in the simulated model meant that the measured values were unattainable, even when minimising absorption of all materials. It should also be highlighted that there was little spatial variation in the values simulated in all the frequency bands. For the measured values, it increases as the frequency decreases, reaching 0.23 s (3 jnd of a 1.55 s reverberation time) at lowest frequency. The cause of this phenomenon can be attributed to not including the phase in the simulated model, taking into account that repeatability of the measurement usually rounds one tenth of the jnd value for acoustic parameters [5]. However, we should not forget the impact of uncertainty on the measurements as well, usually greater at low frequencies. The measured fluctuation can reach up to one second between adjacent seats and can also be caused by a poor signal to noise ratio during the measurement or due to over-sensitive truncation procedures. Nevertheless, this variability is not justified, at least from the point of view of the average listener's sensitivity.

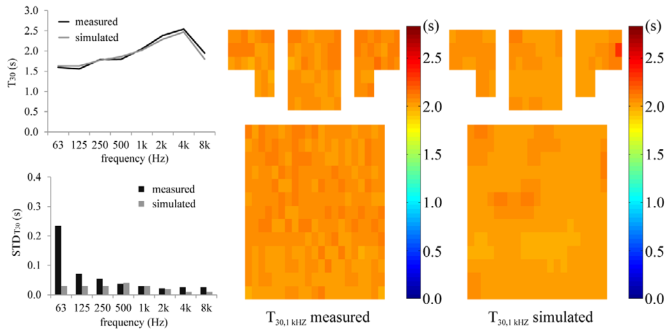

Figure 2. T_{30}. Average values and standard deviations (STD) for the 375 receivers (left). Measured (centre) and simulated (right) values in the 1 kHz band.

The validation process followed or other similar processes are frequently applied when the rooms to be modelled are physically available and it is normally done on the basis of a few receivers. If we analyse the process using the available high resolution grid, the adjustment between the measured and simulated values for the T_{30} is also practically perfect in the 1 kHz band (Figure 2), where barely 2% of receivers differs more than 1 jnd. It is clear that the variability of the analysed parameter, usually used for calibration, is low except in the case of enclosures with strong coupling. This would be a good time to wonder if the same values can be achieved with different refinements in each material, causing inequalities in the different simulated sound fields that might be reflected in the rest of the parameters. For this reason, some authors do not consider this process to be appropriate [6] and they choose to base their simulation just on physical data and databases containing the typical entry data. In this case, it should include an analysis of the uncertainty sources that would established its impact on the accuracy of the results obtained both experimentally and when simulated [7].

AVERAGE VALUES AND SPATIAL VARIABILITY FOR THE REMAINING PARAMETERS

While the reverberation time, at least T_{30} is a global parameter that is related to the room and not to a determined position, the remaining parameters show greater deviations. Figure 3 shows the average values, both measured and simulated, for the EDT parameter in the 375 receivers. In addition, its spatial variability in the enclosure is analysed again using the standard deviation (STD). Except for the lower frequency bands where the difference reaches 3.3 jnd, a value that warns us of appreciable inequality in the decay curves obtained using both methods, it can be seen that the values do not differ by more than 1 jnd. However, the same does not happen if we analyse the EDT values using a high resolution grid for the same frequency band as used for analysing the T_{30}. Despite the fact that the average values and the deviations would indicate a good match, the values from 52% of the receivers differ by more than 1 jnd, also showing great deviations depending on the area of the audience being analysed.

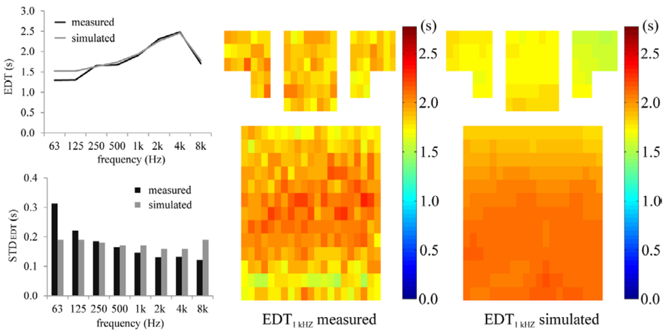

Figure 3. EDT. Average values and standard deviations (STD) for the 375 receivers (left). Measured (centre) and simulated (right) values in the 1 kHz band.

This greater homogeneity in the simulated values is repeated for other parameters and frequencies, generally more noticeable at low frequencies. This is what happens, for example, for musical clarity C_{80} (Figure 4), where the spatial variability of the values measured is clearly greater than what is simulated at low frequencies. However, the average values are within the recommended margin (except at 8 kHz, where the difference is 1.2 jnd), which would indicate good agreement between the values obtained and would validate the simulated model in a usual procedure. However, the availability of the measured values in each of the enclosure's seats allows us to make a more accurate comparison and analyse the causes of both the similarities and the differences encountered. So for example, if we represent the C_{80} values for the 500 Hz band depending on the distance of each receiver (Figure 4), both strategies follow the same trend, above all in the area of the audience closest to the source (up to 18 m approximately), although the dispersion is clearly greater in the measured values. It should be highlighted that if this dispersion were represented using just the standard deviation, these inequalities would not be detected, because they are similar in both cases.

The high spatial resolution of the measurements taken over the audience zone also allow us to analyse the possible lack of omnidirectionality of the real sound source and its influence on the acoustic parameters derived from the impulse response. In addition, the peculiarities of this phenomenon, appearing at high frequencies, leads us to consider that a simulation program - whose main limitation is found at low frequencies - might be an appropriate tool for comparison, considering the constant omnidirectional radiation.

Figure 4 represents the difference between the value of the C_{80} parameter measured and simulated in units of jnd for the 2 kHz band, where the dodecahedral source starts to behave in a noticeably directive way. Despite the fact that the measured values and the STD are practically the same for this parameter and frequency band, it can be seen how a noticeable directivity lobe appears on the middle zone, causing differences that are even greater than 3 jnd in some receivers. In fact, in more than 50% of the receivers, the measured and simulated values are more than 1 jnd apart (20% are more than 2 jnd apart) due to the directivity of the sound source in this frequency band. In a parameter such as D_{50} that is more sensitive to this variable [7], at a higher frequency, 4 kHz, these percentages reach 60 and 30% respectively, confirming previous results based entirely on simulations [8]. Recent research [9] shows that the influence of the dodecahedral sources' directivity is clear even in the later part of the impulse response in highly reverberating environments, and a correct interpretation of the ISO recommendation is required to rotate the source when providing reliable measurements [10].

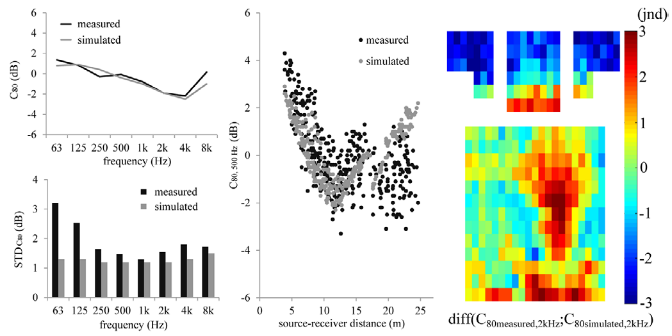

Figure 4. C_{80}. Average values and standard deviations (STD) for the 375 receivers (left). Values depending on the source-receiver distance for the 375 measured and simulated receivers in the 500 Hz band (centre). Difference between the measured and simulated values (ref: 1 jnd) in the 2 kHz band (right).

CONCLUSIONS

Despite the fact that the acoustic parameters from measured impulse responses are generally taken as 'true' and are used as a reference, other factors should be taken into account when validating a simulated model. The directivity of the dodecahedral sources, the algorithms for processing the impulse responses or the poor signal to noise ratio can cause noticeable differences between measured and simulated values that cannot merely be attributed to the limitations of the simulation programs based on geometric acoustics.

A high resolution comparison, as has been carried out here, has revealed differences in the spatial analysis of the parameters that could be masked in a usual validation procedure, based on a few receivers. It is clear that the procedure followed in this work is not feasible to be performed regularly and so more research is required based on analysing the validity of the usually used adjustment processes.

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Inter-Noise 2014

MELBOURNE AUSTRALIA 16-19 NOVEMBER 2014

The Australian Acoustical Society will be hosting Inter-Noise 2014 in Melbourne, from 16-19 November 2014. The congress venue is the Melbourne Convention and Exhibition Centre which is superbly located on the banks of the Yarra River, just a short stroll from the central business district. Papers will cover all aspects of noise control, with additional workshops and an extensive equipment exhibition to support the technical program. The congress theme is *Improving the world through noise control*.

Key Dates

The dates for Inter-Noise 2014 are:
Abstract submission deadline: 10 May 2014
Paper submission deadline: 25 July 2014
Early Bird Registration by: 25 July 2014

Registration Fees

The registration fees have been set as:

Delegate	$840	$720 (early bird)
Student	$320	$255 (early bird)
Accompanying person	$140	
Congress Banquet	$130pp	

The registration fee will cover entrance to the opening and closing ceremonies, distinguished lectures, all technical sessions and the exhibition, a USB containing the full papers and light lunch plus morning and afternoon teas. The Congress Banquet will have a strong Australian theme and feature the opportunity for delegates to take photographs of themselves with native Australian animals, so should prove to be a major attraction.

The social program commences with the welcome reception on the Sunday evening after the opening and first plenary lecture. On each of the following days, the morning and afternoon refreshments and light lunch (all included in the registration fee) will be provided in the exhibition area. The optional banquet (additional charge applies) will be held at the venue and provide, along with great food and wine, an Australiana theme. After the final sessions the closing reception will bring the congress to an end. Additional features are included in the program for accompanying persons.

An exhibition of the latest developments in equipment and acoustic related materials will take place in the foyer of the Conference centre from Monday morning until Wednesday lunch-time. Over 50 out of 60 booths are already booked by international and Australian companies. More details on booking space in the exposition available from www.internoise2014.org.

Technical Program

The opening plenary lecture will be: "Sound Sketch: its Theory and Application using Loudspeaker Arrays" by Prof. Jung-Woo Choi of South Korea.

The closing plenary lecture will be: "Soundscape Planning as a Complement to Environmental Noise Management" by Prof. Lex Brown of Australia.

The four keynote topics, by world authorities on their subject, will complement major areas within the Congress. They cover Aircraft Noise, Active Noise Control, Wind Turbine and LFN as well as the Impact of Building Acoustics on Speech Comprehension and Student Achievement.

ABSTRACT SUBMISSION IS NOW OPEN and submissions are sought in relation to the broad theme of the Congress - "Improving the World through Noise Control" . The online abstract submission allows you to select the most appopriate session from the list of over 100 sessions. The Congress will feature 12 parallel sessions as well as an area for poster presentation.

Abstract deadline is 10 May 2014 and this date is firm and will NOT BE EXTENDED

During the year the details of technical study group meetings plus workshops and courses will be provided on the website.

More details on all aspects of the conference at www.internoise2014.org

IN SITU CALLS OF THE MARINE PERCIFORM *GLAUCOSOMA HEBRAICUM*

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West Australian dhufish (*Glaucosoma hebraicum*), a marine perciform, possess a swim bladder which has associated muscles that are used in sound production. Individuals have been recorded producing sounds during capture that may be associated with disturbance from their normal behaviour. To determine whether individuals produce sound during natural behaviour, a passive sea-noise logger was deployed on the seafloor for one month in close proximity to low-relief artificial substrates occupied by *G. hebraicum*. During this time, both juvenile and sub-adult *G. hebraicum* were observed within metres of the logger on numerous occasions. At approximately the same time, sounds with characteristics similar to the disturbance calls of *G. hebraicum* were detected by the logger. Two types of swimbladder generated calls were recorded, one of widely-spaced pulses and the other of pulses in quick succession The maximum received levels and sound exposure levels of the recorded calls were 132 dB re 1 μPa and 121 dB re 1 μPa^2.s, respectively. Based on previously determined *G. hebraicum* source levels and time of arrival techniques (direct and surface-reflected ray paths), the vocalising fish were estimated at between 1 and 19.5 m from the hydrophone and thus within the area where they had been observed. This study has provided evidence that juvenile *G. hebraicum* produce sounds at similar source levels to those generated during human-induced disturbance. This indicates that sound is produced by individuals of this species during normal behaviour, but may or may not be associated with natural sources of disturbance.

INTRODUCTION

Sources of biological sounds in Western Australian waters are numerous, from snapping shrimp, through multiple fish species to marine megafauna, such as humpback (*Megaptera novaeangliae*) and pygmy blue whales (*Balaenoptera musculus brevicauda*) [1-8]. Recording these signals is often conducted to help monitor the temporal and spatial distribution of the source species [9-12]. Some of the greatest contributions to ambient noise come from the vocalisations of fish, particularly at frequencies of 100-1000 Hz. Previously undetected fish choruses, either from a known source at a new location or a new chorus type, are being discovered all the time [13-15] and, under certain conditions, the characteristics of these types of choruses can provide a complementary source of data for monitoring and management [e.g. 16, 17].

The West Australian dhufish (*Glaucosoma hebraicum*) is an important marine perciform in Western Australian fisheries [18] and has been the subject of numerous studies to understand its biology [e.g. 19, 20, 21]. The species has been shown to produce disturbance calls comprising a mean of all maximum root mean square (rms) source levels (SL) within calls and sound exposure level (SEL) of 126 dB re 1 μPa at 1 m and 117 dB re 1 μPa^{2}s at 1 m, respectively [22]. Determining the behaviours associated with sounds produced by *G. hebraicum* would increase our understanding of their biology (e.g. are sounds associated with reproduction) and the possibility of employing passive acoustic techniques for detection of their presence in an area. If the species only produces disturbance calls, the application to monitoring presence and the number of callers is significantly reduced.

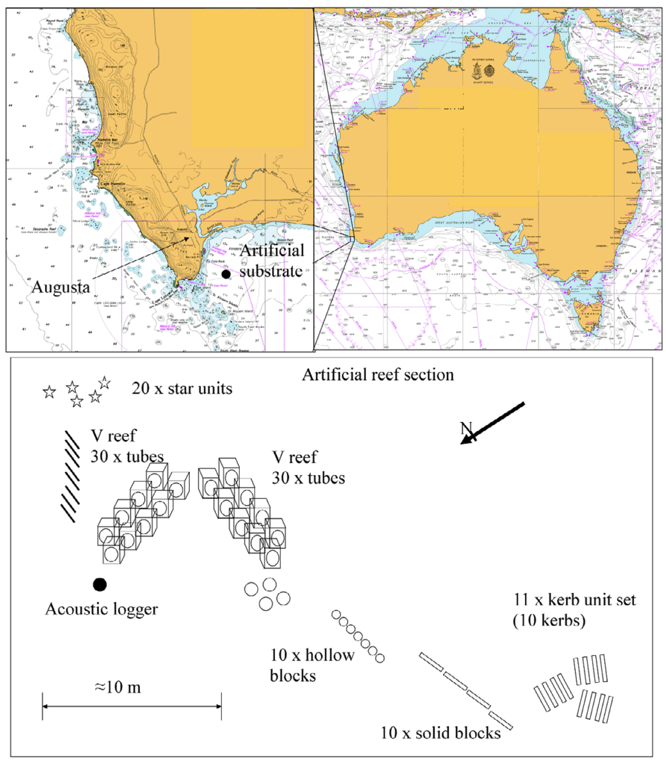

Figure 1. Map of southwest Australia indicating location of lease and line drawing of the spatial organisation of artificial substrates located in the area. Location of logger marked by the black circle.

Other than the confirmation of sound production by *G. hebraicum* during capture, vocalisation of this species under natural circumstances, *i.e.* in the wild, has not been recorded. The aim of this study was to determine whether individuals of this species produce sound in the natural environment and thus without behavioural bias. This was conducted via the collection of long-term recordings from a location where *G. hebraicum* have been regularly observed at close range (< 20 m) [22]. As the logger was deployed 17 days before recordings commenced, this gave fish the opportunity to become habituated to its presence, thus any recorded vocalisations would be less likely to be associated with disturbance.

METHODS

In 18 m deep waters off Augusta, Western Australia, Ocean Grown Abalone Pty Ltd deployed numerous types of low-relief artificial substrates in 2011 to investigate which type provides preferred habitat for marine ranching greenlip abalone *Haliotis laevigata* [23]. Subsequently, juveniles of various species of fish also recruited to the habitats, including *G. hebraicum* [24, Figure 1]. An autonomous sea-noise logger, developed by the Centre for Marine Science and Technology and the Defence Science and Technology Organisation, was deployed to the seabed next to one of the artificial substrates where *G. hebraicum* were consistently observed, between 17th November, 2012 and 12th January, 2013. This logger was connected to an omni-directional, HTI 90-U hydrophone (HighTech Inc., MS, USA) and recorded for 700 of every 900 s for the entire deployment, sampling at 6 ksps. The system was calibrated with a white noise generator at -90 dB re 1 V^2/Hz and data analysed using the Characterisation Of Recorded Underwater Sound (CHORUS) Matlab toolbox, written at the Centre for Marine Science and Technology (CMST). Spectrograms were produced with a 1024-point Hanning window at a frequency resolution of 1 Hz.

In calls where reflected paths could be identified, techniques using the difference in time of arrival between direct- and surface-reflected paths of a biological signal were used here to estimate source ranges of *G. hebraicum* [25, 26]. As *G. hebraicum* is a demersal species, often reported around the base of rocky lumps [20], an assumption of their position near the seafloor was made to simplify the range estimate calculations.

The combination of estimated range and known received levels (RLs) provides the possibility of estimating SL using methods similar to Parsons *et al*. [27]. As the fish were assumed, but not confirmed to be near the seafloor at the time of vocalisation, the calculated SL is taken as a coarse estimate to add weight of evidence to determine source species. The effective plane receive beam pattern of the bottom positioned hydrophone should also be considered. In this case, the sand substrate and likely calcarenite beneath it in the area, combined with the estimated water column position of the callers would most likely increase the RLs by between 1 and 4 dB re 1 μPa [28].

Figure 2. Still shots from video of a sea-noise logger deployed near artificial substrates off Augusta in December 2012 and January 2013, showing a single juvenile *Glaucosoma hebraicum* next to the sea-noise logger (left) and multiple juveniles next to artificial substrate approximately 7 m from the logger (right). Photos taken by S. Longbottom

Table 1. Acoustic characteristics of calls recorded in an area where multiple *G. hebraicum* occurred. Mean values are presented with standard deviation, maximum and minimum values in parentheses.

Call Type (n)	Number of pulses	Pulse repetition frequency (Hz)	Duration (s)	Spectral peak frequency (Hz)	Bandwidth (Hz; 3dB down)
All multiple pulse calls (68)	13.5 (9.7, 36, 2)	9.2 (5.6, 25.9, 2.4)	1.41 (0.73, 4.1, 0.4)	231 (21, 268, 114)	89 (59, 155, 71)
Pulses in quick succession (36)	13.0 (5.9, 36, 10)	13.2 (4.7, 25.9, 4.0)	1.8 (0.71, 4.1, 1.02)	159 (66, 251, 114)	171 (57, 122, 71)
Separated pulses (32)	4.4 (1.9, 9, 2)	4.66 (1.7, 10.2, 2.4)	0.99 (0.48, 2.6, 0.42)	178 (58, 268, 145)	110 (61, 155, 101)
Single pulse calls (7)	1	n/a	0.04 (0.02, 0.6, 0.02)	149 (46, 251, 99)	107 (66, 185, 89)

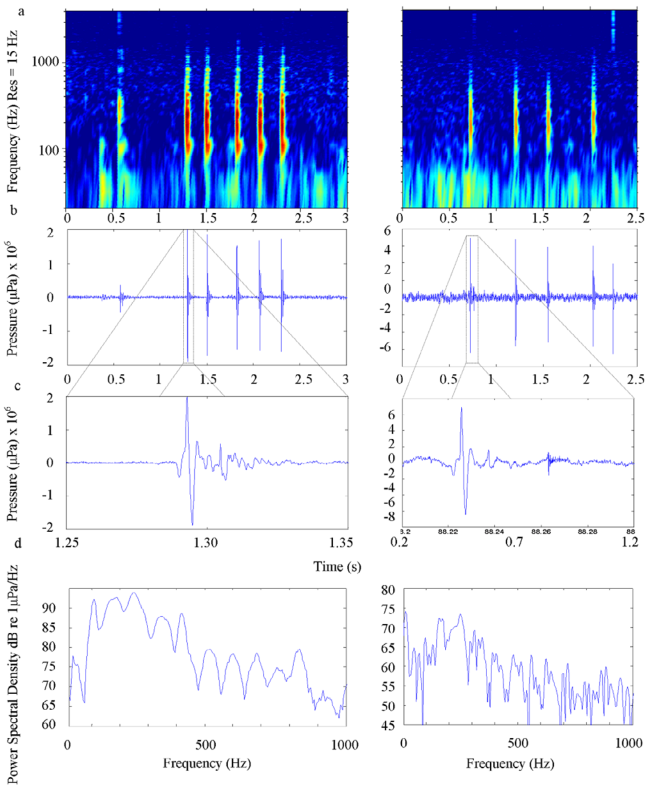

Figure 3. Spectrogram (a) and waveform (b) of two sets of likely *Glaucosoma hebraicum* calls recorded. Expanded waveforms of individual pulses (c) and power spectral density of the overall calls (d) are also shown.

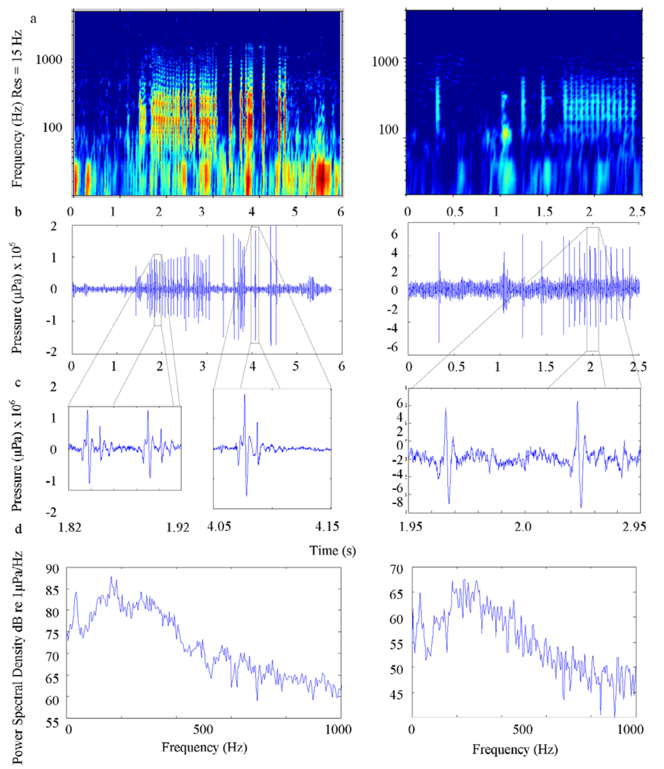

Figure 4. Spectrogram (a) and waveform (b) of two multiple pulse *Glaucosoma hebraicum* calls recorded. Expanded waveforms of individual pulses (c) and power spectral density of the overall calls (d) are also shown.

RESULTS

Ongoing monitoring of the study site by Department of Fisheries WA (DoFWA) and Curtin Aquatic Research Laboratory (CARL) researchers has noted that the study site consistently supports many juvenile and, on occasion, *G. hebraicum* greater than the species length at which 50 % of individuals reach sexual maturity (50-246 individual *G. hebraicum* across nine surveys, Lewis, unpublished data). The site was examined multiple times during the day while the logger was deployed by CARL scientists. Three length cohorts of *G. hebraicum*, estimated by eye at a mean of approximately 100, 200 and 300 mm (total length), predominantly of the former two size cohorts, were often seen within 10 m of the noise logger (Figure 2). Other species predominantly observed were snapper (*Pagrus auratus*), weeping toadfish (*Torquigener pleurogramma*), Western king wrasse (*Coris auricularis*) and a single juvenile Rankin's cod (*Epinephelus multinotatus*) that was also noted on the 15th January, 2013.

The recordings displayed significant wave and mooring noise (artefacts created by motion of the hydrophone or tapping of the cable) throughout the deployment, often masking any concurrent sounds. However, during periods of low ambient noise, a large number of fish calls were detected. A sample of those most similar to *G. hebraicum* disturbance calls (n = 91) are described here. These calls were generalised into two categories; the first comprising calls of an individual pulse or a series of multiple pulses that were each separated in time by up to 1 s, but not less than 0.2 s (Figure 3), while the second comprised multiple pulses in quick succession (Figure 4). The latter category calls often included initial pulses separated by > 0.2 s, but were then quickly followed by a series of pulses in quick succession. In each case these calls displayed spectral peak frequencies between 100 and 300 Hz (Table 1) with further spectral peaks at higher frequencies (Figure 3). The maximum rms RLs and SELs of the recorded calls were 132 dB re 1 μPa and 121 dB re 1 μPa^2.s, respectively.

Surface reflected paths were identified in the pressure waveforms of 77 sounds. Time of arrival difference between the direct and surface reflected paths estimated the closest of these sounds at 1.2 m from the hydrophone, if positioned on the seafloor, with others at up to 19.5 m range (Figure 5). The SL of these calls, estimated from least squares linear regression of the RLs with range from the hydrophone, as per the methods in Parsons *et al.* [27], was 129 dB re 1 μPa.

DISCUSSION

This study provides significant evidence to show that *G. hebraicum* produce sound in the wild, and that these calls may be associated with behaviours other than anthropogenic disturbance. Acoustic characteristics of calls recorded (frequency, duration, estimated SL) were similar to those made during capture of adult *G. hebraicum* off Rottnest Island [22]. Moreover, video evidence and observations by researchers at times close to that of the recorded calls showed that *G. hebraicum* were present and the most likely source. There is none or little evidence that other species present (e.g. labrids, *Pagrus auratus*) can produce sound [29] or are so prevalent in surrounding locations that vocalisations of this type would be recorded more commonly [29]. Furthermore, juvenile *G. hebraicum* have been recorded at this location consistently over two years in substantial numbers [24].

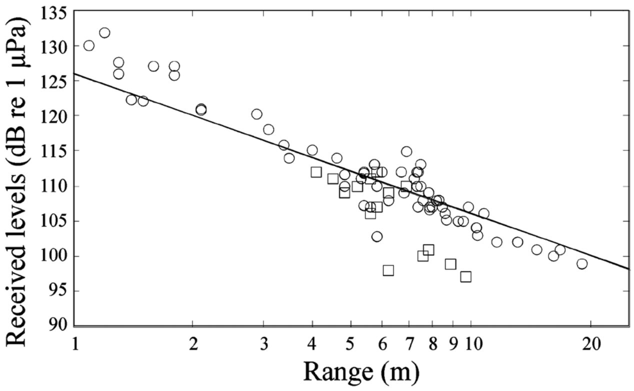

Figure 5. Relationship between mean squared (a) received levels and log estimated range for the calls of *Glaucosoma hebraicum* with closely spaced pulses (squares) and separated pulses (circles). Spherical spreading losses with range for a call of source level 126 dB re 1 μPa shown by the black line.

The estimated SLs reported here imply that the callers ranged between 1 and 19.5 m of the logger when compared to previous SL estimates [22]. Ranges determined by surface reflections techniques positioned the fish up to nearly 20 m away. However, to offer a useful and cost-effective method of gathering data on the biology/ecology of *G. hebraicum*, fish would need to be detectable at greater ranges than this. Simple models of transmission loss estimate that in low levels of ambient noise (around 80-90 dB re 1μPa) the calls could be detected at a minimum of 50-100 m from the hydrophone, but this has yet to be shown in the field [22]. If multiple *G. hebraicum* call together this detection range could be extended considerably, similar to other fish choruses [11].

The similarities between the received levels, spectral peak frequencies, waveforms and time between pulses of sounds recorded during this study suggest that both the single pulse and multiple pulse calls came from the same individual, or at least were produced using the same mechanism, and therefore, the same species. The reason for the variations in the number of pulses and time between pulses is unknown, but has been documented in other vocal species [30]. This may or may not have an associated function. The next step in understanding vocal behaviour of *G. hebraicum* is to combine the recordings with long-term visual recordings to determine what the associated functions are. These calls were produced by juvenile and sub-adult fish and therefore not related to spawning. However, as adults of this species demonstrate social hierarchies [20] and individuals produce sound in the natural environment, it is possible that *G. hebraicum* is vocal during spawning or aggregating activities. Confirmation of such behaviour would allow investigation of the presence/absence of spawning activity in particular locations using passive-acoustic techniques.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Australian Government via the Fisheries Research and Development Corporation (FRDC) for project support and funding. Logistical support from the Ocean Grown Abalone Pty Ltd was gratefully received. We are also grateful Rhiannon Jones of the Department of Fisheries for her comments on the manuscript.

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Website

The website is undergoing transition in two phases. The first phase should be occurring in April and will provide a streamlined system for membership applications, upgrades and transfers as well as for payment of membership dues. Later in the year, phase 2 will introduce improved navigation and information storage. While some of the website will be open access, the key areas you as a member will need to access will be in the member only area. Please ensure that you are able to log on and double check that your records are up to date - in particular that your email address is correct.

Acoustics Australia

This issue, Vol. 42, No. 1 is the last issue that is distributed as hard copy to all AAS members and subscribers. It is simply no longer financially viable to continue with printing and postage charges without substantial increases in subscriptions and advertising rates. The future issues will maintain the same style and content and will be available in two formats. A low resolution version will be sent as an email attachment to all members and subscribers and a high resolution version on the website. Hard copies will be available to those prepared to pay around $40 per issue, ie $120 per year, on a cost recovery basis for the printing and postage charges, and this will be an option on the annual subscription notice.

NARROWBAND SOURCE LOCALISATION IN THE DEEP OCEAN USING A NEAR-SURFACE ARRAY

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A narrowband source at moderate range can be localised in a deep ocean using a near-surface vertical linear array without knowing the bottom properties. By casting the localisation as separate estimations of the source range and source depth, the performance is much better than that of the matched-field-processing (MFP) technique with the Bartlett processor. Source range estimation is based on the weighted subspace fitting technique with modification to consider the array tilt. Source depth estimation is based on the time delay of multipath arrivals. Experimental results using explosive sources are shown. The presented method shows a significant improvement in performance.

PACS: 43.30.Cq, 43.30.Wi

INTRODUCTION

The MFP technique for narrowband source localisation has been analysed widely [1], [2]. It has been pointed out that its performance is poor when the array aperture is limited or the ocean environment is uncertain [3], especially when the bottom properties are unknown. In contrast, the arrival structures of the multiple arrivals that do not penetrate into buried layers, are much more stable. Furthermore, in the deep ocean the information of source range and source depth is included primarily in arrival angles and time delays [4], respectively. Therefore, the localisation can be casted as separate estimations of the source range and source depth.

The "weighted-subspace-fitting matched field (WSF-MF) technique" for passive narrowband source localisation developed by Duan *et al*. [5], is to minimise the distance between the signal subspace and the space spanned by the array manifold in a finite range-depth space. The information of arrival angles is contained in the signal subspace and thus this technique does not estimate the arrival angles. However, as only the arrival angles are used, the method is only effective in the estimation of source range. The array tilt [6] caused by the ocean current would reduce the performance of the WSF-MF technique. Therefore, a modified approach of the WSF-MF technique considering the array tilt is used to estimate the source range. Then, a method based on the time delays between multipath arrivals is presented to determine the source depth. By combining the above two methods, the source location can be estimated more accurately.

The data with explosive sources collected during an experiment in the deep ocean is used to verify the modified WSF-MF technique and the depth-estimation method. The detailed description of the experiment and the results are shown in Section 3 and Section 4, respectively.

LOCALISATION APPROACH

Modified WSF-MF method

An overview of the detailed WSF-MF technique [5] is as follows. In the deep ocean, it is assumed that the array aperture is rather small and the source is in the far field. Therefore, the K multipath arrivals can be modeled as K plane waves. Consider a uniform linear array (ULA) of M elements. It is assumed that K narrowband arrivals impinge on it from directions Θ_0 being $[\Theta_1, \Theta_2, \dots, \Theta_k, \dots, \Theta_K]^T$, where Θ_k is the arrival angle of the kth arrival. Then, the M-vector of hydrophone outputs are

$$\mathrm{y}(t) = \mathrm{A}(\Theta_0)\mathrm{s}(t)+\mathrm{n}(t), \tag{1}$$

where the array manifold $\mathrm{A}(\Theta_0)$ is a $M\times K$ matrix whose kth column $\mathrm{a}(\Theta_k)$ is the steering vector for the kth arrival, $\mathrm{s}(t)$ is the $K\times 1$ signal vector, and $\mathrm{n}(t)$ is the $M\times 1$ noise vector and the noise at different hydrophones is uncorrelated. It is assumed that the signals and noise are complex-valued and are statistically independent of each other. The noise is a stationary, zero-mean, Gaussian process. It is noted that the matrix $\mathrm{A}(\Theta_0)$ can be simplified for a ULA [7]. The eigen-decomposition of the array covariance is expressed as

$$\mathrm{R_y}=\mathrm{E}(\mathrm{y}(t)\mathrm{y}^H(t)) = \mathrm{U}_s\Lambda_s\mathrm{U}_s^H + \sigma^2\mathrm{U}_n\mathrm{U}_n^H, \tag{2}$$

where, Λ_s contains the K' largest eigenvalues. K' is the rank of the signal covariance. The signal subspace U_s is the set of corresponding eigenvectors, σ^2 is the variance of the noise, and the noise subspace U_n contains the M-K' eigenvectors. By minimising the distance between the signal subspace and the space spanned by the array manifold [8], the arrival angles Θ_0 are given by

$$\tilde{\Theta}_0 = \min\|\mathrm{U}_s\mathrm{V}^{1/2} - \mathrm{A}(\Theta)\mathrm{B}\|_F^2, \tag{3}$$

where $\|.\|_F$ denotes the Frobenius norm, V is a positive definite weighting matrix. To give the lowest asymptotic variance [8], V equals $\Lambda^2\Lambda_s^{-1}$, where Λ is $\Lambda_s - \sigma^2\mathrm{I}$. Solving Eq. (3) for B and substituting back into Eq. (3), one obtains

$$\tilde{\Theta}_0 = \min\, tr\{P_{\mathrm{A}}^{\perp}(\Theta)\mathrm{U}_s\mathrm{V}\mathrm{U}_s^H\}, \tag{4}$$

where A is the array manifold in Eq. (3), $P_A^{\perp}(\Theta)$= I-P_A=I-AA^+=I-$A(A^HA)^{-1}A^H$ and $tr\{.\}$ denotes the trace of a matrix.

The hypothesised source location is denoted by $L_h=[z,r]$, where z is the source depth from the ocean surface and r is the horizontal range from the array. The arrival angles of the multipath arrivals on the array are the function of the hypothesised source location. This function can be expressed as

$$\Theta_h = g(L_h), \tag{5}$$

where g (.) is determined by the acoustic environment and can be calculated using the standard ray approach. Substituting Eq. (5) into Eq. (4), one obtains

$$\widetilde{L}_o = \min tr\{P_A^{\perp}(g(L_h))U_s V U_s^H\}, \tag{6}$$

where the parameters U_s and V are calculated from the received signal, and the value of $P_A^{\perp}$ $(g(L_h))$ is only determined by the hypothesised source location L_h. Therefore, the estimated source location $\widetilde{L}_o$ can be given by searching the finite range-depth space of L_h to satisfy Eq. (6).

Considering the array tilt in the ocean environment, the real arrival angles may deviate from the ideal arrival angles by a random variable φ, which increase the distance between the signal subspace and the space spanned by the array manifold at the real source location. Therefore, for a certain hypothesised source location the corresponding array manifold should take the random variable φ into consideration. It can be accomplished by searching the interval of φ to get the minimum distance. That is

$$\widetilde{L}_o = \min_{L_h}\{\min_{\varphi\in[\varphi_{\min},\varphi_{\max}]} tr\{P^{\perp}_{A(\Theta_h+\varphi)}(g(L_h))U_s V U_s^H\}\}, \tag{7}$$

where $\varphi_{\min}$ and $\varphi_{\max}$ are the lower and upper bounds of the array tilt angle.

The ambiguity surface of the source locations corresponding to the modified WSF-MF method is defined as

$$E_W = \frac{1}{tr\{P^{\perp}_{A(\Theta_h+\varphi)}(g(L_h))U_s V U_s^H\}} . \tag{8}$$

It is noted that E_W is a cost function of three unknown parameters, r, z and φ. The normalised ambiguity surface in dB is defined as

$$E_N = 10\log_{10} (\frac{E_W}{\max(E_W)}). \tag{9}$$

It is noted that searching the interval of φ might give rise to false peaks in the ambiguity surface. For example, if the arrival angles corresponding to the real source location are Θ_0, the sum $\Theta_0 + \varphi$ may correspond to arrival angles at another source-depth grid. However, when the vertical linear array is near the ocean surface the introduction of the variable φ cannot give rise to the false peaks. It stems from the fact that the multipath arrivals are in pairs. In a pair, the first arrival is last reflected by the bottom while the second arrival is last reflected by the surface. The propagation path of an arrival is close to the path corresponding to its counterpart. For example, the bottom-reflected (B) and the bottom-surface-reflected (BS) arrivals are a pair of arrivals. The arrival angles of this pair of arrivals are almost symmetric about the horizontal direction as shown in Figure 1(a) and Figure 1(b), where the arrival angles of the B and the BS arrivals on a hydrophone of 60 m in depth are presented, respectively. Therefore, the arrival angles of multipath arrivals are almost symmetric under a near-surface vertical linear array. If Θ_0 is symmetric, $\Theta_0 + \varphi$ is not. That is, no source-depth grid would correspond to the arrival angles $\Theta_0 + \varphi$ and thus no false peaks would appear. The modified WSF-MF method is feasible when the vertical array is near the ocean surface.

It should be mentioned that the method is applicable whether the surface duct exists or not. The arrival angles of the bottom-reflected arrivals are little affected by the surface duct when these arrivals are in the surface duct and are not close to being cut off by that duct. Besides, the arrival angle of the surface duct arrival is around zero and it contributes little to the localisation of the source.

Depth estimation method

It has been demonstrated in [5] that the WSF-MF is effective in the estimation of the source range but not the source depth. Figure 1(a) and Figure 1(b) show that the arrival angles of the B and the BS arrivals are much more sensitive to the range change than to the depth change. As a result, the localisation results would be ambiguous along the depth direction. The information of source depth is included in the time delay between the multipath arrivals, especially for that between the B and the surface-bottom-reflected (SB) arrivals when the source is at the moderate range. It should be mentioned that the moderate range refers to the range where these arrivals are not close to be cut off by the SSP (Sound-Speed Profile). Hereafter, angles measured downward (from the hydrophone) are positive. Figure 1(a) shows that the arrival angles of the B arrival are smaller than 5º when the range is beyond 28 km and this arrival is close to be cut off. Therefore, the moderate range in this environment refers to the range smaller than 28 km. Figure 1(c) shows the time delays between the B and the SB arrivals. The time delay is more sensitive to the depth change than to the range change especially for a shallow source. Therefore, the source depth can be determined by comparing the simulated and the measured time delays as in the following steps:

First, using the standard ray approach with the source range estimated by the modified WSF-MF method, the arrival angles of the B and SB arrivals can be calculated. For a shallow source and shallow hydrophones, the two arrival angles are very close to each other. Second, a spatial filter is designed to get the signal consisting of the B and SB arrivals. Third, the autocorrelation function of the signal is calculated and the time delay between the two arrivals, which is denoted by T_m, is given by the strongest peak except for the peak at the origin. Fourth, the estimated time delay is subtracted by the time

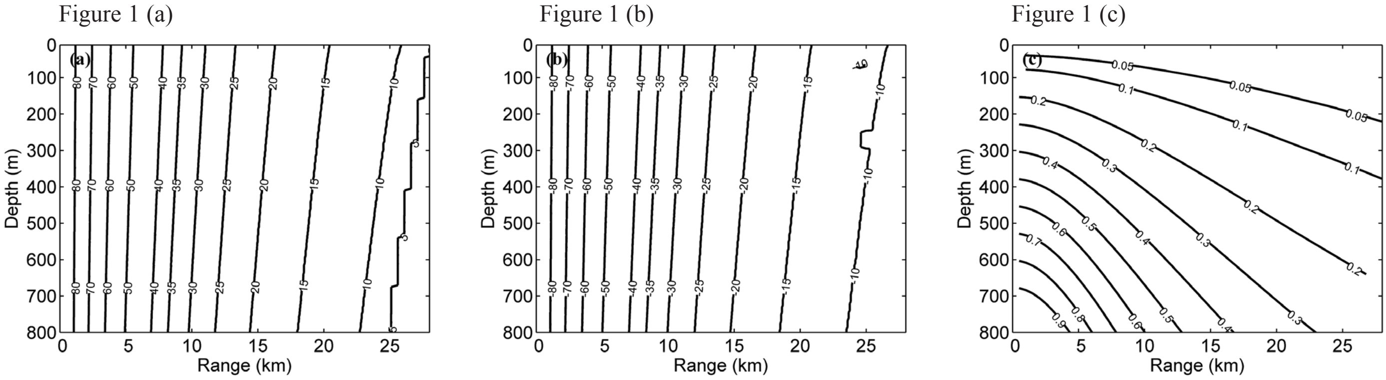

Figure 1 Simulated arrival angles and time delays on a hydrophone at a depth of 60 m under different source locations. The ocean depth is 3500 m. (a) Arrival angles of B arrival. (b) Arrival angles of BS arrival. (c) Time delays between the B and the SB arrivals.

delays at every range-depth grids calculated by the standard ray approach. Finally, the candidates for source location are at the grids with minimum difference. This method is referred to as the time delay of arrivals (TDOA) localisation method. The ambiguity surface is defined as

$$E_{\mathrm{T}} = -|T_{\mathrm{m}} - T(\mathrm{L}_h)|, \tag{10}$$

where T_{m} is the time delay between the B and SB arrivals, and is extracted from the received signals. $T(\mathrm{L}_h)$ is the time delay between the two arrivals at the hypothesised source location L_h and is calculated by the standard ray approach. E_{T} is the time difference between these two parameters. When the hypothesised source location is the same with the real source location, E_{T} is maximum and is 0 s.

It is noted that the ambiguity surface based on the TDOA method would be ambiguous along the contour of the time delays where the measured time delay stays constant. As the variation with depth is weak, the source depth can be estimated by combining the TDOA method with the source range estimated by the modified WSF-MF method. The ambiguity surface of the combined method is given by

$$E_{\mathrm{C}} = \frac{E_{\mathrm{N}}}{|m(E_{\mathrm{N}})|} + \frac{E_{\mathrm{T}}}{|m(E_{\mathrm{T}})|}, \tag{11}$$

where E_{N} and E_{T} are the ambiguity surfaces of the modified WSF-MF method and the TDOA method, respectively. $|m(E_{\mathrm{N}})|$ and $|m(E_{\mathrm{T}})|$ are the absolute values of the averages of the E_{N} and E_{T}, respectively. Eq. (11) is an ad hoc cost function and E_{C} is dimensionless.

DESCRIPTION OF THE EXPERIMENT

Experimental geometry and the ship track

The experiment was performed in the South China Sea. In the experimental area, the ocean bottom is almost flat and the ocean depth is 3450 m. A vertical Uniform Linear Array of 18 hydrophones spaced at 3.8 m was deployed near the ocean surface. The topmost hydrophone was 20 m below the ocean surface. The vertical array was moving slowly due to the ocean surface wave and subsurface ocean current during the experiment. A GPS receiver was on the buoy float to track the location of the vertical array. The explosive sources were deployed when the ship was moving away from the vertical array to a distance of 40 km. The preset explosive depth was 300 m and the mass of TNT in the explosive charges was 1 kg. The first bubble pulse period calculated by the method in Chapman [9] is 0.0177s. During the experiment, narrowband signals transmitted from a fixed source were also recorded. The source-array range was fixed to be about 8 km (the source level is not high enough for farther measurement). Therefore, the explosions were used to cover different ranges.

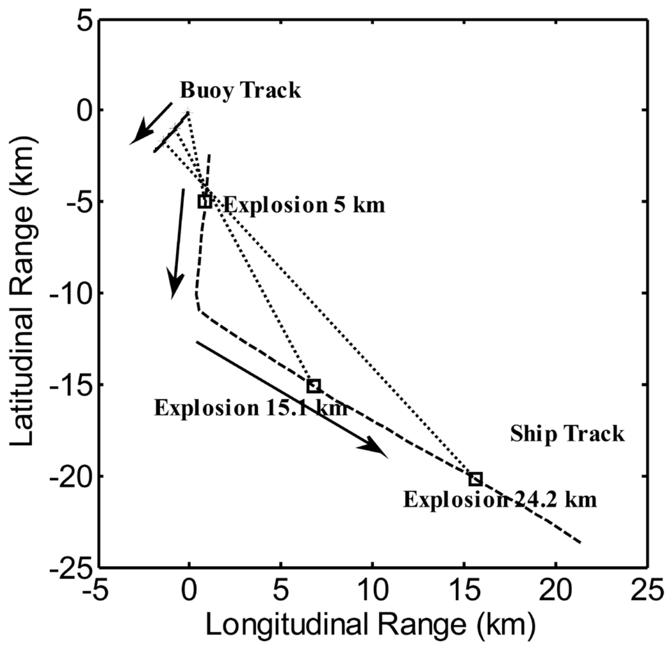

Figure 2 Illustration of the experiment. The motions of the buoy and the ship are shown by the solid line and dashed line, respectively. The geometries of three explosions relative to the buoy are denoted by the dotted lines.

The buoy and the ship tracks together with the direction of motion are shown in Figure 2. The buoy floated southwest and was driven by the prevailing wind. The ship moved south at first and then turned to southeast. The geometries of three explosions relative to the buoy are denoted by the dotted lines. The distances between the array and the three explosions are 5 km, 15.1 km and 24.2 km, respectively. Given that the currents were small and had little shear, the array tilt in such an environment would usually be opposite to the direction of motion of the buoy. It would result in the shifts of the arrival angles of the multipath arrivals impinging on the array. The array tilt is related with the motion speed of the buoy, the mechanical structure of the buoy, the currents etc. The model to calculate the tilt is complicated and is out of the scope of this paper.

Water column sound speed profile

The Conductivity-Temperature-Depth (CTD) sensor was used to measure the SSP before the experiment. The smoothed SSP is shown in Figure 3. It is observed that the surface duct with thickness 40 m exists and the average of the sound speeds in the surface duct is 1539 m/s.

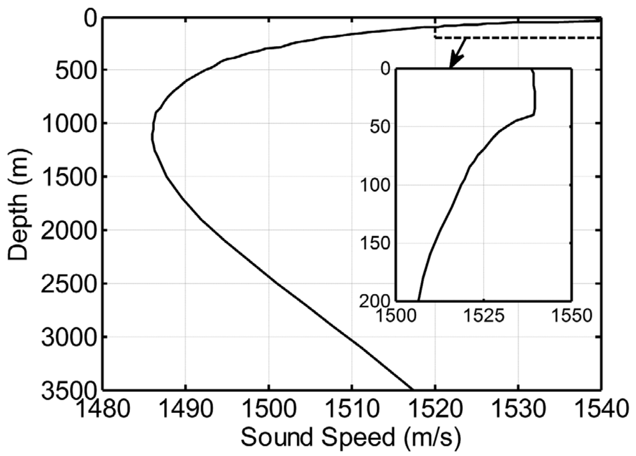

Figure 3 Sound-speed profile at the experiment location. The sound speeds above 1500 m were measured by the CTD before the experiment and the sound speeds below 1500 m were historical data (Simple Ocean Data Assimilation dataset).

Received signals

As the explosions and the array were both shallow, the received signals at moderate range (5 – 28 km) were dominated by the arrivals interacting with the ocean bottom. An example of the received signals of 18 channels is shown in Figure 4(a), where the source range is about 15.1 km. The surface duct arrival and the two groups of multipath arrivals are observed. Here, a group of arrivals denotes the arrivals having the same number of bottom reflections, which are one for the first group and two for the second group in Figure 4(a). As the source level of the explosive source was high, the signal-to-noise ratio (SNR) of the received signals was also high. Figure 4(b) shows the first group of arrivals in detail. From left to the right, the red lines denote the B, BS, SB and SBS arrivals generated by the shock pulse, respectively, and the yellow lines are the corresponding arrivals generated by the first bubble pulse. The time delay between the shock pulse and the first bubble pulse is about 0.017s from Figure 4(b). It is very close to the value calculated by the method in Chapman [9]. It is noted that the arrival times of the surface duct arrival, the first group and the second group are 9.86s, 11.03s and 13.56s, respectively, which are very close to the ray-tracing results, 9.84s, 11.00s and 13.57s correspondingly.

Figure 4 (a)

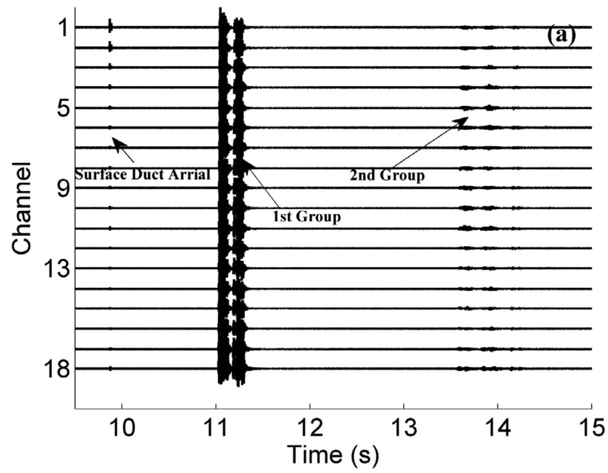

Figure 4 (b)

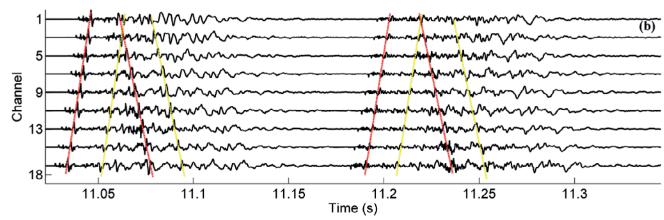

Figure 4 Received signals when the explosion is at 15.1 km. (a) Multipath arrivals impinging on all the hydrophones. The time axis begins at the instant of detonation. (b) Four obvious arrivals in the first group.

Signal preprocessing

This paper is aimed to verify the localisation methods for the narrowband signal under low SNR. Therefore, preprocessing of the signal was performed to obtain the desired signal. It is very important to demonstrate the frequency band within which the method is applicable using the array. Since the optimum wavelength for the array is 7.6 m, the optimum frequency for the array with the sound-speed of 1539 m/s would be 202.5 Hz. Provided that the signal frequency is below 202.5 Hz, the array would sample the depth-dependence of the acoustic field properly and consequently there would be no aliasing in plots of acoustic energy versus direction-of-arrival (DOA). However, when the ocean environment is taken into consideration the frequency band could be wider. It is shown in Figures 1(a) and (b) that when the source range is farther than 5 km, the DOA interval of the multipath arrivals in the first group is about from -50º to 50º. It indicates that when we focus on the sources at the moderate range, most of the signal energy would be limited in this DOA interval. Therefore, with it as *a*

Figure 5 (a)

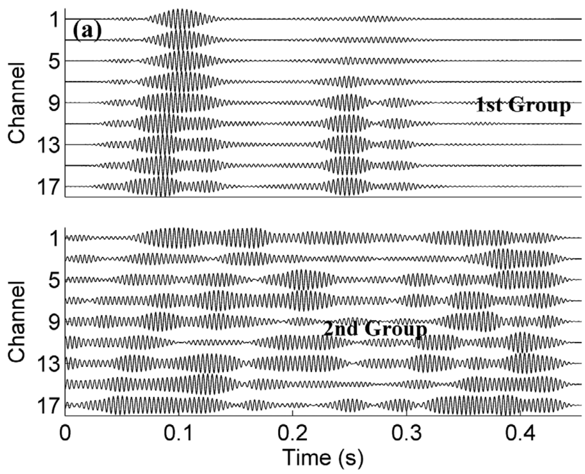

Figure 5 (b)

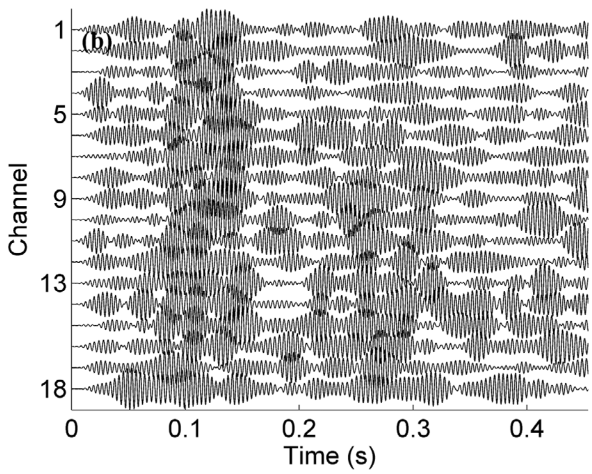

Figure 5 Illustration of the preprocessing of signals. (a) Time alignment of the two groups of multipath arrivals. (b) Narrowband signals with additive narrowband noise.

priori the proper frequency can refer to the one that does not bring in aliasing in this smaller DOA interval, rather than the interval from -90º to 90º. For a ULA, the wavelength should satisfy [10]

$$\frac{\lambda}{d} < 2\sin\Theta, \tag{12}$$

where λ is the wavelength, d is the spacing between the hydrophones and Θ is the maximum arrival angle. Consequently, the maximum frequency is 264 Hz based on this criterion.

Although the WSF has a high angular resolution, the performance may deteriorate with the decreasing SNR and the increasing position errors of the hydrophones. Therefore, the lower bound of the frequency band is estimated roughly using the Rayleigh resolution limit [10], which is

$$\alpha = \arcsin(\lambda / (Nd)), \tag{13}$$

where N is the number of the hydrophones. If the source range is within 28 km, the minimum DOA difference between the B and the BS arrivals from Figure 1 is about 10º and consequently the maximum wavelength from Eq. (13) is 12 m. Therefore, the lower bound of the frequency band is about 130 Hz. In conclusion, with the frequency within 130 Hz to 264 Hz, the method is applicable for the source localisation when the source is at the moderate range (5 km to 28 km). The frequency band must be reduced when the possible range interval of source becomes larger (e.g. 3 km to 30 km).

In the following, the narrowband signal with centre frequency 260 Hz would be analysed. Firstly, the obvious groups of multipath arrivals were extracted separately and processed by a narrowband filter. Then all groups were aligned with the first group to the start time of the time window for extracting the first group as shown in Figure 5(a), where the two groups of odd channels shown in Figure 4(a) are aligned in time. To retain the phase difference between groups, every group was multiplied by a corresponding phase term which was expressed as

$$p_i = e^{-j2\pi f(t_i - t_1)}, \tag{14}$$

where t_i is the start time of the time window for extracting the ith group and f is the centre frequency of the filter. Secondly, the ocean noise recorded between two explosive sources was filtered using the same filter as that in the first step. Then, the noise was amplified according to the desired SNR. Finally, the desired signal was obtained by adding the amplified noise to the narrowband signal. Figure 5(b) shows the desired signals under SNR 0 dB, where the centre frequency of the filter is 260 Hz and the bandwidth of the filter is 26 Hz.

RESULTS AND DISCUSSION

Modified WSF-MF method

For a SNR of 0 dB, the ambiguity surfaces using Eq.(9) are shown in Figure 6(a), where from the top to bottom panels the source ranges are 5 km, 15.1 km and 24.2 km, respectively. The lower and upper bounds of array tilt angle, $\varphi_{\min}$ and $\varphi_{\max}$ in Eq.(8), are chosen to be -10º and 10º, respectively. The centre frequency of the filter was 260 Hz. The real source locations are denoted by the asterisks.

The ambiguity surfaces present sloping straight striations across the real source locations. As it is shown in Figures 1(a) and 1(b), the contours of the arrival angles in the deep ocean are almost vertical and thus the modified WSF-MF can give a rough estimation of the source range using only the information of the arrival angles. However, this method fails in estimating the source depth. Along the depth direction the spaces spanned by the array manifold in Eq.(3) are very similar. Therefore, the signal space must be estimated accurately and agrees pretty well with the space spanned by the array manifold when the hypothesised source location is the same with the real source location. However, due to the low SNR and signal phase

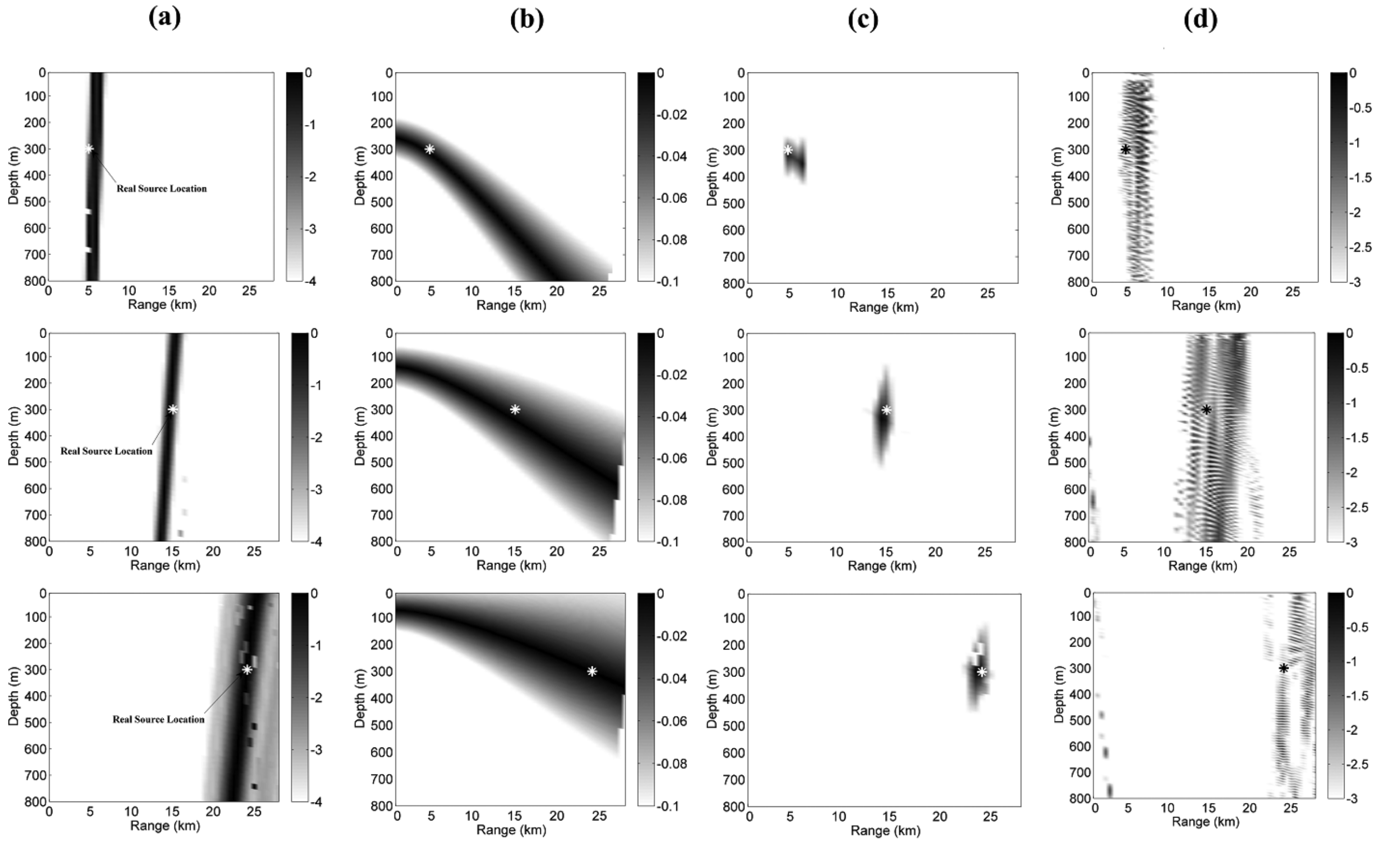

Figure 6 Source localisation results using four methods. From top to bottom panels, the source ranges are 5 km, 15.1 km and 24.2 km, respectively. The source depths are 300 m. The real source locations are denoted by the asterisks. (a) Modified WSF-MF method. (b) TDOA method. (c) Modified WSF-MF method combined with the TDOA method. (d) MFP technique using the Bartlett processor.

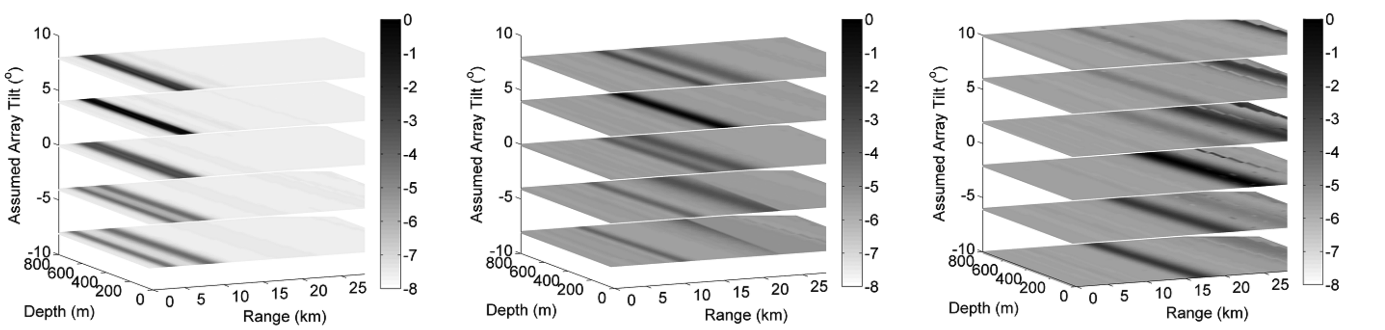

Figure 7 Ambiguity surfaces of the modified WSF-MF method under different array tilt angles. From the left to the right panels, the source ranges are 5 km, 15.1 km and 24.2 km, respectively.

fluctuation, the signal space is inaccurate, which results in the ambiguity along the depth direction.

Eq.(8) introduces the array tilt angle φ as an unknown parameter. The inversion of this parameter can be achieved by drawing pseudo-color plots over the R-Z plane for various values of φ (fixed for each plot), and selecting the plot that yields the smallest overall cost. Figure 7 shows the plots of Eq.(9) over the R-Z plane for some values of φ. From the left to the right panels, the source ranges are 5 km, 15.1 km and 24.2 km respectively. In the first two panels, when the assumed array tilt is 4° the plot yields the strongest overall value. Therefore, the array tilt angles are both 4° when the source ranges are 5 km and 15.1 km. In contrast, the array tilts towards another direction (-2º) when the source range is 24.2 km.

TDOA method

The first step of the TDOA method (see Section 2.2) is the estimation of the arrival angles of the B and SB arrivals based on the WSF-MF method's result. The arrival angle of either of the two arrivals presents little change when the source is along the dark striations in Figure 6(a). Therefore, the arrival angles are taken to be the average of these values. Taking array tilt into consideration, the arrival angles of B arrival impinging on the array are 47.4º, 18.8º and 13.4º, respectively (the corresponding source ranges are 5 km, 15.1 km and 24.2 km).

Secondly, spatial filters are designed to get the signals consisting of the B and SB arrivals based on the arrival angles of B arrival. It is noted that when the source and hydrophones are both near the ocean surface, the arrival angles of the B and SB arrivals are very close to each other. Consequently, the filtered signals contain both the two arrivals.

Finally, the time delay between the B and SB arrivals are estimated. Then based on Eq.(10) the ambiguity surfaces of the TDOA method are calculated and shown in Figure 6(b). The unit of the ambiguity surface is second. The results are ambiguous along curves which are contours of the time delays between the B and the SB arrivals as shown in Figure 1(c).

Combined method

It is noted that the real source locations are around the intersections of the straight striations in Figure 6(a) and the corresponding curves in Figure 6(b). The ambiguity surfaces using Eq.(11), which is the combination of the two ambiguity surfaces, are shown in Figure 6(c). The estimated locations are very close to the real source locations. In comparison, the results based on the MFP technique using the Bartlett processor are shown in Figure 6(d). The replica fields are calculated by the Bellhop model [11]. The localisation performance is poor due to the incompleteness of the bottom property and the array tilt.

SUMMARY

The modified WSF-MF technique is effective for source range estimation while the TDOA method has high resolution along the depth direction. The combination of the two methods shows much better performance than that of the MFP technique. It is because the replica fields include the phase and amplitude difference between all multipath arrivals. However, this information is influenced by the sound speed profile and the bottom properties greatly. In contrast, the arrival angles of some multipath arrivals and the time delays between the ocean-bottom-interface reflected arrivals (these arrivals do not penetrate into buried layers) are little affected by the uncertainty of the ocean environment. Therefore the presented method in this paper is robust.

ACKNOWLEDGMENTS

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Technical Note

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IRIS – THE SOUND OF SCIENCE

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Recently developed equipment provides unprecedented access to 3D room acoustic analysis.

Source loudspeaker

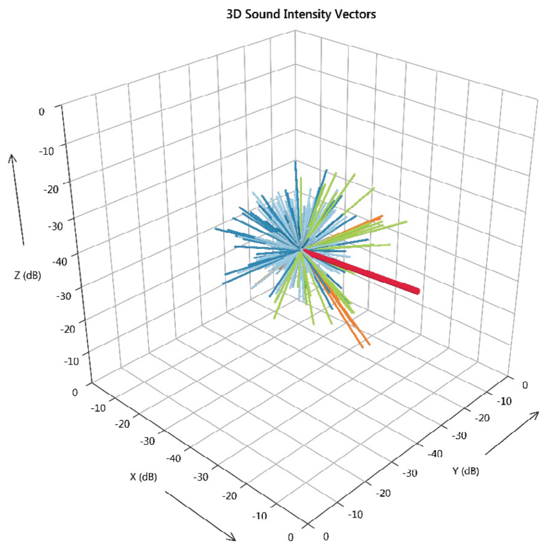
HISTORICAL BACKGROUND

Although many great concert halls were built prior to 1900, by the middle of the 20th century the science behind auditorium design had not progressed much beyond the estimation of reverberation time. However, the craft of understanding and analysing the acoustics of performance spaces has greatly developed in more recent times.

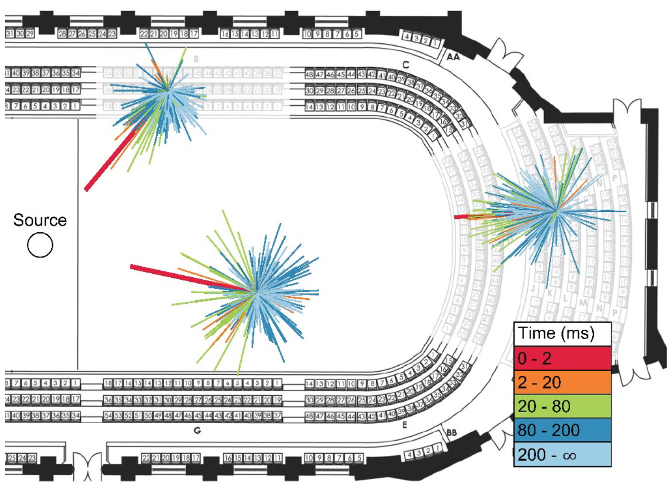
The sound in any concert hall comprises the direct sound generated by the performers, and reflections of this sound as it travels throughout the interior of the auditorium. It is now widely accepted that it is not just the timing and strength of these reflections, but also the direction of their arrival that influence the extent that a listener feels immersed in the sound of a performance.

In 1952, Rolf Thiele, a researcher in Germany, realised that reverberation time did not explain all the qualities of how a room sounds. He proposed a technique for measuring and visualising the directional distribution of reflections as "hedgehog patterns". The length and angle of each line corresponds to the strength and direction of each reflection compared to the direct sound.

In the late 1960s, while reviewing various designs for the Christchurch Town Hall, Harold Marshall investigated the effect of room shape on acoustical quality. He discovered that early lateral reflections, associated with narrow rectangular halls, were important in providing a sense of space. This effect was further investigated and quantified by Marshall in collaboration with Michael Barron in 1981. This work developed the concept of "spatial impression" in acoustics. This is now recognised as an important characteristic of good sounding concert halls, and is now considered to be a key factor in auditorium design and analysis.



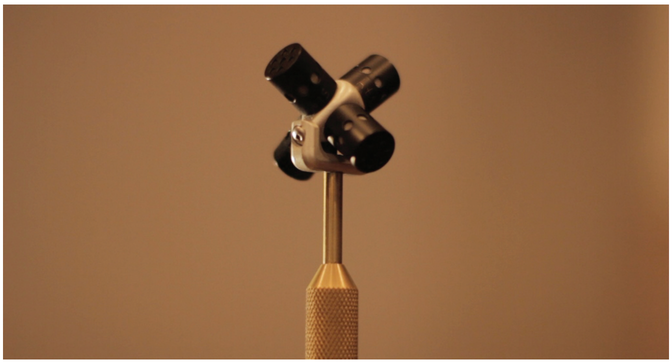
The IRIS Plot



Auckland Town Hall with IRIS measurement plots

ADVANCED MEASUREMENT

The acoustical characteristics of a room are traditionally determined using single channel impulse response measurements. These yield information about sound reflections in terms of time and strength, but not direction. Researchers have developed 3D impulse response measurement systems in the past, but these use custom, expensive or impractical equipment.



Tetrahedral microphone array

The IRIS measurement system developed by Marshall Day Acoustics enables 3D impulse responses to be captured and analysed through a commercially available tetrahedral microphone array and a four channel USB audio interface. The signals are calibrated to the measured responses from each of the 4 microphones in the array, and then correlated to derive the strength and direction of each reflection.

The IRIS plot is at the heart of the system. Sound reflections arriving at the microphone array are represented as a series of coloured spikes. The length and direction of each spike correspond to the reflection strength and direction. Spikes are coloured according to the time interval that reflections arrive after the direct sound.

The plot can be used to relate sound reflections to physical features of the room, observe the directional distribution of early and late sound energy, or identify surfaces causing problematic reflections. The graphical nature of the IRIS plot enables easy comparison between the acoustic conditions at different locations in a room.

Numerical magnitude, time and direction information can be obtained for a comprehensive analysis of individual reflections. This can indicate which reflections may be heard as late echoes, which reflections can produce a perceived image shift, and which can blend with other reflections to enrich the aural experience.

A standard impulse response waveform is also provided, and this allows the calculation of room acoustic parameters according to ISO 3382.

IRIS is considered to be a breakthrough in real-world acoustics. It puts spatial analysis into the hands of acousticians around the world.

AAS CODE OF ETHICS

INCLUDED ON A REGULAR BASIS FOR THE ATTENTION OF ALL AAS MEMBERS

1. **Responsibility**
   The welfare, health and safety of the community shall at all times take precedence over sectional, professional and private interests.
2. **Advance the Objects of the Society**
   Members shall act in such a way as to promote the objects of the Society.
3. **Work within Areas of Competence**
   Members shall perform work only in their areas of competence.
4. **Application of Knowledge**
   Members shall apply their skill and knowledge in the interest of their employer or client, for whom they shall act in professional matters as faithful agents or trustees.
5. **Reputation**
   Members shall develop their professional reputation on merit and shall act at all times in a fair and honest manner.
6. **Professional Development**
   Members shall continue their professional development throughout their careers and shall assist and encourage others to do so.

EXPLANATORY NOTES

1. RESPONSIBILITY

In fulfilment of this requirement members of the Society shall:

- avoid assignments that may create conflict between the interests of their clients, employers, or employees and the public interest.
- conform to acceptable professional standard and procedures, and not act in any manner that may knowingly jeopardise the public welfare, health, or safety.
- endeavour to promote the well-being of the community, and, if over-ruled in their judgement on this, inform their clients or employers of the possible consequences.
- contribute to public discussion on matters within their competence when by so doing the well-being of the community can be advanced.

2. ADVANCE THE OBJECTS OF THE SOCIETY

Appropriate objects of the Society as listed in the Memorandum of Association are:

Object (a)
To promote and advance acoustics in all its branches and to facilitate the exchange of information and ideas in relation thereto.

Object (e)
To encourage the study of acoustics, highlight excellence in acoustics and to improve and elevate the general and technical knowledge in any manner considered appropriate by the Society.

Object (g)
To encourage research and the publication of new developments relating to acoustics.

3. WORK WITHIN AREAS OF COMPETENCE

In all circumstances members shall:

- inform their employers or clients if any assignment requires qualifications and/or experience outside their fields of competence, and where possible make appropriate recommendations in regard to the need for further advice.
- report, make statements, give evidence or advice in an objective and truthful manner and only on the basis of adequate knowledge.
- reveal the existence of any interest, pecuniary or otherwise, that could be taken to affect their judgement in technical matters.

4. APPLICATION OF KNOWLEDGE

Members shall at all times act equitably and fairly in dealing with others. Specifically they shall:

- Strive to avoid all known or potential conflicts of interest, and keep employers or clients fully informed on all matters, financial or technical, that could lead to such conflicts.
- refuse compensation, financial or otherwise, from more than one party for services on the same project, unless the circumstances are fully disclosed and agreed to by all interested parties.
- neither solicit nor accept financial or other valuable considerations from material or equipment suppliers in return for specification or recommendation of their products, or from contractors or other parties dealing with their employer or client.

5. REPUTATION

No member shall act improperly to gain a benefit and, accordingly, shall not:

- pay nor offer inducements, either directly or indirectly, to secure employment or engagement.
- falsify or misrepresent their qualifications, or experience, or prior responsibilities nor maliciously or carelessly do anything to injure the reputation, prospects, or business of others.
- use the advantages of privileged positions to compete unfairly.
- fail to give proper credit for work of others to whom credit is due nor to acknowledge the contribution of others.

6. PROFESSIONAL DEVELOPMENT

Members shall:

- strive to extend their knowledge and skills in order to achieve continuous improvement in the science and practice of acoustics.
- actively assist and encourage those under their direction or with whom they are associated to advance their knowledge and skills.

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HISTORY AND REBIRTH OF A WELL-KNOWN INDUSTRY TOOL – THE ENTERTAINMENT INDUSTRY SOUND MONITOR

Ian McLean
Technology Sound and Vision, Hornsby NSW

In about 1977 the acoustic industry recognised the need for an electronic device to control the levels of sound in entertainment venues. The late Alan Elson had a company in Sailors Bay Rd, Northbridge in Sydney called Audio Developments Pty. Ltd. and in conjunction with and the inspiration of Peter Knowland and Richard Heggie, he designed and manufactured the original ADNM–1 Noise Monitor.

Figure 1 The original ADNM-1 Noise Monitor

The original innovative design concept was simply to keep track and automatically restrict noise levels in venues. The electronics were housed in a cream electrical type enclosure. The visual display unit was a wall mounted wooden box with three partitions, which housed three 60 watt 240 volt globes behind separate RED and BLUE and GREEN Perspex lenses that indicated the SET threshold, -6 and -12 DB. This was installed so the musicians could observe the sound level they were generating and if they did not heed having reached the required SET level they were warned that their power would be cut off after a set number of seconds.

The device certainly did its job and overcame lots of noise exceedence problems much to the delight of venue owners, but understandably generated a culture against it from musicians and their "roadies" who thrived on ways of "Beating it" – one popular one was putting chewing gum over the microphone, needles through the diaphragm, or unplugging it. To overcome this, several sensing microphones were installed in very inaccessible locations so no one was sure which microphone was live. One memorable public reaction to the Noise monitor turning off the power to the band, was at the Long Jetty Hotel in 1979 when an up and coming young band called "AC-DC" caused an audience riot and subsequently caused $30K damage.

Venue managements eventually realised there was a need for proper sound control rather than the Noise Monitor's "absolute control" and they should seek advice to make venues compliant with noise ordinances. Several Acoustic firms established specialty consultancy for venue owners to address the real problem of sound proofing and poor noise containment.

The production and distribution of the Noise Monitor in the early 80's moved to Sound Affair Pty. Ltd in Chatswood who became Sontec (NSW) Pty Ltd. They redesigned the Noise Monitor circuitry using updated components but with same original performance criteria and housed in a legendary "blue box" seen in many venues. Some consultants knew the rebadged monitor as a "Sontec Model PNM 1" (Programmable Noise Monitor) and enjoyed national distribution through the National Sontec network. Production ceased when Chubb acquired the Sontec Companies and stopped producing the Sound Monitor in 1999.

Figure 2 The current CSM-2 Sound Monitor

In 2000 the national Tecsound group of companies had the Noise Monitor redesigned using current technology and refinements to avoid an Intellectual property conflict with the new owners of Sontec and changed its description to "Sound Monitor." The refined SOUND MONITOR included a Low pass filter, an automatic cut off if the sensing microphone was removed or its cable damaged, and a clock accessory that automatically changes the setting of the activation threshold by 3dB after midnight. Tecsound was purchased by a public company in 2005 and subsequently ceased trading and the Sound Monitor became unavailable in 2012. Technology Sound and Vision (being the original Sound Affair Pty Ltd) bought the Intellectual Property Rights of the Tecsound CSM-1 (Calibrated Sound Monitor) and incorporated additional modifications requested by acoustical engineers and it is now known as the Technology Sound and Vision CSM–2.

The evolution of the device has always been by consultation with the Industry to provide a real world solution. The device is now available with a "SOFT BOX" option which selectively attenuates the signal to the Power Amplifiers rather than simply and abruptly turning off the power. New applications include monitoring sound levels in outdoor areas – beer gardens, restaurants and smoking areas. These applications utilise the device's existing "SOUND EXCEEDANCE" relay to activate an external remote device (e.g. light or pager) to alert Security or the Duty Manager of a potential sound problem. Proudly the original Iconic Noise Monitor, today known as a Sound Monitor, has returned to production and is available again housed in a cream coloured box with a modern LED remote visual display unit.

Inter-Noise 2014

MELBOURNE AUSTRALIA 16-19 NOVEMBER 2014

The Australian Acoustical Society will be hosting Inter-Noise 2014 in Melbourne, from 16-19 November 2014. The congress venue is the Melbourne Convention and Exhibition Centre which is superbly located on the banks of the Yarra River, just a short stroll from the central business district. Papers will cover all aspects of noise control, with additional workshops and an extensive equipment exhibition to support the technical program. The congress theme is *Improving the world through noise control*.

Key Dates

The dates for Inter-Noise 2014 are:
Abstract submission deadline: 10 May 2014
Paper submission deadline: 25 July 2014
Early Bird Registration by: 25 July 2014

Registration Fees

The registration fees have been set as:

Delegate	$840	$720 (early bird)
Student	$320	$255 (early bird)
Accompanying person	$140	
Congress Banquet	$130pp	

The registration fee will cover entrance to the opening and closing ceremonies, distinguished lectures, all technical sessions and the exhibition, a USB containing the full papers and light lunch plus morning and afternoon teas. The Congress Banquet will have a strong Australian theme and feature the opportunity for delegates to take photographs of themselves with native Australian animals, so should prove to be a major attraction.

The social program commences with the welcome reception on the Sunday evening after the opening and first plenary lecture. On each of the following days, the morning and afternoon refreshments and light lunch (all included in the registration fee) will be provided in the exhibition area. The optional banquet (additional charge applies) will be held at the venue and provide, along with great food and wine, an Australiana theme. After the final sessions the closing reception will bring the congress to an end. Additional features are included in the program for accompanying persons.

An exhibition of the latest developments in equipment and acoustic related materials will take place in the foyer of the Conference centre from Monday morning until Wednesday lunch-time. Over 50 out of 60 booths are already booked by international and Australian companies. More details on booking space in the exposition available from www.internoise2014.org.

Technical Program

The opening plenary lecture will be: "Sound Sketch: its Theory and Application using Loudspeaker Arrays" by Prof. Jung-Woo Choi of South Korea.

The closing plenary lecture will be: "Soundscape Planning as a Complement to Environmental Noise Management" by Prof. Lex Brown of Australia.

The four keynote topics, by world authorities on their subject, will complement major areas within the Congress. They cover Aircraft Noise, Active Noise Control, Wind Turbine and LFN as well as the Impact of Building Acoustics on Speech Comprehension and Student Achievement.

ABSTRACT SUBMISSION IS NOW OPEN and submissions are sought in relation to the broad theme of the Congress - "Improving the World through Noise Control" . The online abstract submission allows you to select the most appopriate session from the list of over 100 sessions. The Congress will feature 12 parallel sessions as well as an area for poster presentation.

Abstract deadline is 10 May 2014 and this date is firm and will NOT BE EXTENDED

During the year the details of technical study group meetings plus workshops and courses will be provided on the website.

More details on all aspects of the conference at www.internoise2014.org

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TRAFFIC NOISE AS A FACTOR DRIVING APARTMENT PRICES – A CASE STUDY OF A LARGE EUROPEAN URBAN AGGLOMERATION

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This paper presents an analysis of the correlations between apartment prices and road traffic noise levels in Olsztyn, the capital city of the Region of Warmia and Mazury in north-eastern Poland. The results of this study presented in graphic and analytical form indicate that noise pollution is an important determinant of the prices of residential property.

INTRODUCTION

Noise is a growing concern around the world, and this problem has been addressed by the European Union in Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise [1]. The main objective of the directive is to prevent and control traffic noise through the achievement of a high level of health and environmental protection across the European Union. The Directive places Member States under obligation to monitor the observance of allowable noise limits and to develop acoustic maps.

Annoyance caused by excessive noise levels is reflected in the prices of real estate. Neighborhood quality is an important factor that influences buyers' decision to purchase property. The objective of this study was to evaluate the correlations between traffic noise levels and prices on the local apartment market in Olsztyn, the capital city of the Region of Warmia and Mazury in north-eastern Poland.

TRAFFIC NOISE AND PROPERTY PRICES

Urban traffic noise has adverse economic consequences by driving down the prices of real estate [2]. The economic effects of noise pollution which are discussed in this paper are directly linked with social aspects. This problem is most visible in residential real estate. Noise pollution considerably influences the value of property because it lowers the quality of the living environment and compromises safety. A review of published sources clearly indicates that traffic noise has a detrimental impact on the value of residential property [3, 4, 5, 6, 7, 8, 9, 10, 11, 12]. The Noise Depreciation Sensitivity Index (NDSI) is one of the most popular indicators for describing the impact of road traffic noise on real estate prices. NDSI determines the percentage change in house prices per dB increase in noise levels [4]. In studies of road traffic noise, NDSI was determined in the range of 0.08% to 2.22%. In a different approach, the effect of noise is determined by estimating the direct decrease in the monetary value of property.

Most studies investigating the effects of traffic noise concern highly industrialized countries in North America and Europe that are characterized by high levels of awareness about the market value of real estate and the impact of various factors, including noise, on the prices of residential property. This study analyzes a city in Central Europe where the transition from centrally-planned to free-market economies began only in 1990. For this reason, Central European countries have much lower levels of awareness about the correlations between environmental quality and real estate value.

RESEARCH OBJECT

The effects of road traffic noise on the prices of residential property have been studied in selected districts of Olsztyn, a city in Central Europe. Olsztyn is the capital city of the Region of Warmia and Mazury in northern Poland (Figure 1). It is a city of supra-regional importance with a population of 200,000. Its suburban region comprises mostly single-family houses, and it stretches within a 20 km radius from the city's administrative boundaries. The suburban region has an estimated population of 120,000, and its inhabitants generate additional traffic by commuting to work, school and retail outlets on a daily basis.

The Olsztyn urban agglomeration is one of the main transport hubs leading to destinations in eastern and north-eastern parts of Europe. The entire urban agglomeration is characterized by low levels of road infrastructure development. Population density is 1998 persons per km^2 [13].

This study focuses on the neighboring districts of Jaroty and Pieczewo. Jaroty is the most populous unit of local administration in Olsztyn. Jaroty and Pieczewo constitute a compact functional area with an estimated population of 50,000 which is homogeneous in terms of infrastructure and architecture. This part of the city features mostly multifamily residential buildings with enclaves of single-family houses and a well-developed network of retail outlets. The road network comprises two municipal transit corridors that provide access to downtown Olsztyn. Those corridors serve local inhabitants who commute to work, public transport vehicles, heavy transport vehicles that supply large housing districts (7 large supermarkets and 4 hypermarkets) and vehicles transiting to suburban areas south of Olsztyn that are inhabited by around 35,000 people. The local transport network also includes main access corridors, estate roads and car parks. In view of the availability of data (transaction prices) and the homogeneity of analytical samples (similar parameters), the research object comprises one municipal transit corridor (Krasickiego street) and one main access corridor (Wilczyńskiego street).

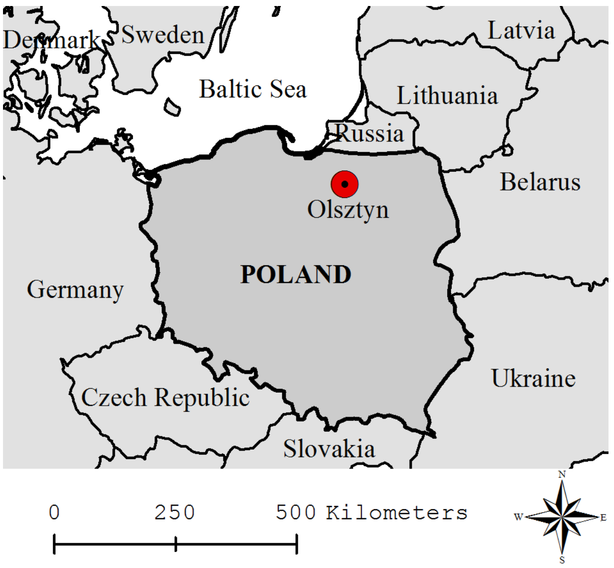

Figure 1. Location of the research object

ACOUSTIC MAP

Upon its accession to the European Union, Poland became subject to the provisions of the Environmental Noise Directive 2002/49/EC of 25 June 2002 [1]. Point 10 of the Resolution stipulates that strategic noise mapping should be imposed in certain areas of interest for capturing the data needed to provide a representation of noise levels perceived within that area. The national regulations of EU Member States place local authorities under the obligation to develop acoustic maps. In Poland, the applicable legal act is the Environmental Protection Law [14].

The cited directive defines environmental noise as unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport (road traffic, rail traffic, air traffic) and noise from sites of industrial activity. Excessive noise levels contribute to health problems. The following indicators are used to describe levels of environmental noise in an acoustic map:

1. L_{den} – (day-evening-night noise indicator) the noise indicator for overall annoyance.
2. L_{night} – (night-time noise indicator) the noise indicator for sleep disturbance.

All noise indicators are A-weighted long-term average sound levels as defined in ISO 1996-2: 1987, determined over all day and night periods of a year. In line with the provisions of the cited directive, the day is 12 hours, the evening – four hours, and the night – eight hours. The Member States may shorten the evening period by one or two hours and lengthen the day and/or the night period, provided that this choice is identical for all the sources. The beginning of the day and, consequently, the beginning of the evening and the night is chosen by the Member State, and that choice has to be the same for noise originating from all sources. In the directive, the default hours are 07.00 to 19.00, 19.00 to 23.00 and 23.00 to 07.00 local time.

Noise assessment points (L_{den}) for strategic noise mapping inside and near buildings have to be located 4.0 ± 0.2 m above the ground and on the most exposed facade. Other heights may be chosen, but they should not be less than 1.5 above the ground, and the results should be adjusted to the equivalent height of 4 m. The most exposed facade is defined as the external wall facing and nearest to the noise source.

METHODOLOGY, RESULTS AND DISCUSSION

The study was carried out on the assumption that the quality of the acoustic environment in the vicinity of a residential building (noise levels determined by the building's location relative to roads) influences prospective buyers' decision to purchase property. A total of 132 property transactions concluded between January 2012 and December 2013 in residential districts of Jaroty and Pieczewo were analysed. The evaluated real estate was apartments in multifamily residential buildings. To consolidate experimental samples and eliminate other price-shaping factors, the analysed data was sorted to produce transactions relating to apartments with the same legal status, apartments in buildings erected based on the same construction technology and in similar condition, apartments with similar area, situated in distinct housing estates. The main differentiating factor was location relative to a road. Significant variations in real estate prices resulting from changes in market demand or time were not observed in the analysed period. Unit prices per square meter were expressed in the principal currency of the European Union, the Euro (EUR), based on the average EUR/PLN exchange rate quoted by the National Bank of Poland.

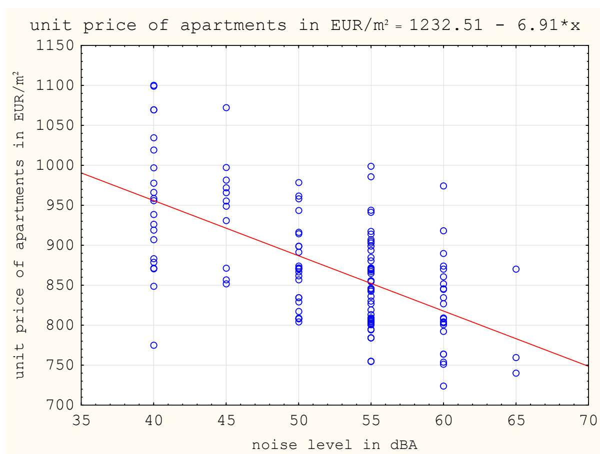

Figure 2. Distribution of apartment price vs noise level.

Table 1. Linear correlations between unit prices of apartments and noise levels.

Variable	Correlations (unit prices of apartments in EUR/m^2 - noise level in dBA) ; N = 132 Correlation coefficients are significant at p < .05000			
	Average	SD	unit price in EUR/m^2	noise level in dBA
unit price in EUR/m^2	873.22	77.79	1.00	- 0.61
noise level in dBA	51.97	6.82	- 0.61	1.00

The study was carried out in four principal stages:

1. Traffic noise levels were determined based on the acoustic map [15] which is prepared using CadnaA (Computer Aided Noise Abatement) - noise prediction software. The analysis of noise levels is based on the L_{den}.
2. The distribution of unit prices of apartments was mapped relative to noise levels. The distribution of prices for the entire analysed area is presented in Figure 2. An increase in noise levels by 1 dB was accompanied by a drop in the unit price of apartments by EUR 6.91/m^2.
3. Linear correlations between unit prices of apartments and noise levels were analysed. A statistical correlation between a dependent variable (unit price of an apartment) and an independent variable (noise level) was determined by Pearson's linear correlation analysis. The correlation coefficient for the analysed districts was determined at -0.61 (Table 1), which points to a significant relationship between the evaluated parameters. A negative value of the correlation coefficient indicates that unit prices of apartments decrease with an increase in noise levels.
4. The distribution of unit prices of apartments was mapped by ordinary kriging. Isoline interpolation tools available in ArcGIS 10 software were used. Kriging is a geostatistical estimation method that accurately estimates the values of the analysed variables. Kriging estimates are assumed to be a weighted, linear combination of random regionalized variables. Kriging methods and their applicability in various areas of science and technology are widely discussed in literature. The use of kriging in analyses of the spatial distribution of property prices expands our knowledge of those methods' capabilities and applicability [16, 17, 18, 19]. The following value is a kriging estimator (1) represented by a random function $Z(s_i)$ [16]:

$$Z^*(s_0) = \sum_{i=1}^{n} w_i Z(s_i) \tag{1}$$

where:

$Z^*(s_0)$ – estimated value in location s_0,
$Z(s_i)$ – observed value of the analysed variable in location s_i,
w_i – kriging weights (calculated on the assumption of minimum error variance; the sum of weights has to be equal to 1).

The acoustic map of the analysed area illustrating the exposure to road traffic noise is presented in Figure 3. The highest noise levels (65–70 dBA) were noted along the municipal transport corridor (Krasickiego street) and the main access corridor (Wilczyńskiego street). Noise levels were somewhat lower along estate roads (55–65 dBA), and they reached the lowest values (below 45 dBA) in enclaves surrounded by buildings in the proximity of transit corridors. High noise levels in the analysed districts are confirmed by the distribution of unit prices of apartments (Figure 2) and linear correlations between unit prices (Table 1).

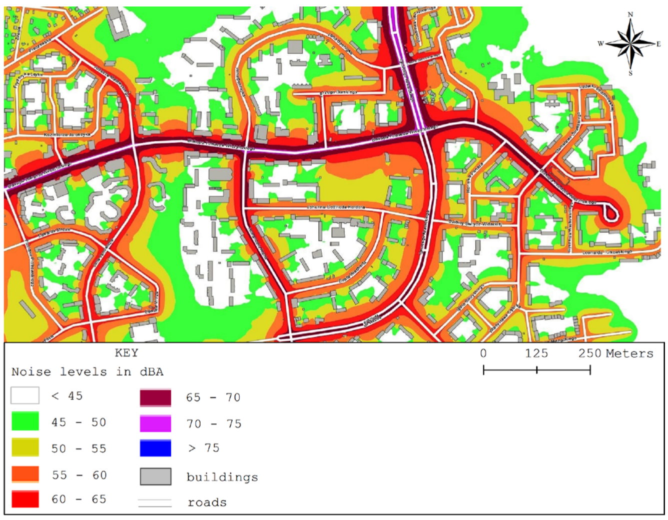

Figure 3. Acoustic map of Olsztyn – districts of Jaroty and Pieczewo.

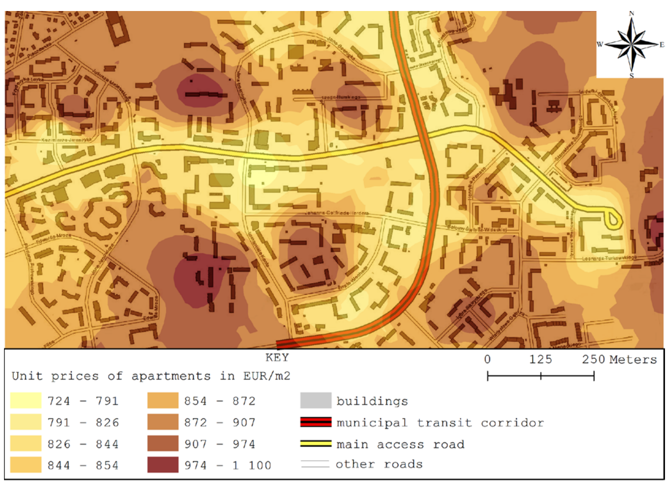

Figure 4. Distribution of unit prices of apartments in districts of Jaroty and Pieczewo.

The distribution of unit prices of apartments in the districts examined is presented in Figure 4. The lowest prices were reported for apartments situated along the municipal transit corridor and the main access corridor. Higher prices were quoted for apartments away from transit and access corridors where noise levels are considerably lower. The average price was EUR 873/m^2, and the maximum difference between the analysed transaction prices was EUR 376/m^2. The high difference between the minimum (EUR 724/m^2) and the maximum (EUR 1100/m^2) price and the spatial distribution of prices clearly indicate that road traffic noise considerably influences apartment prices in the evaluated districts in Olsztyn.

CONCLUSIONS

Acoustic maps developed for large cities in the European Union are an abundant source of analytical data concerning the spatial distribution of traffic noise sources. Maps indicating road traffic noise levels can be used to identify the correlations between road traffic noise and prices on the local real estate market. The results of this study, presented in graphic and analytical form, indicate that noise pollution is an important determinant of the prices of residential property.

Isoline maps developed with the use of GIS tools are a rich source of information about the spatial distribution of property prices. Isoline maps and acoustic maps are useful tools in the process of planning new residential property and road networks. The resulting information supports the implementation of planning measures to prevent the devaluation of real estate and the deterioration of the living environment.

The results of our study indicate that road traffic noise is one of the key factors driving the prices of residential property. Noise traffic levels, in particular the highest local noise values, considerably determine the prices of apartments in large cities.

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Technical Note

Note: Technical notes are aimed at promoting discussion. The views expressed are not necessarily those of the editors or the Australian Acoustical Society. Contributions are not formally peer-reviewed.

A NOTE ABOUT ASSESSING CHARACTERISTICS OF ENVIRONMENTAL NOISE

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INTRODUCTION

Numerous guidance documents for environmental noise assessment ([1] [2] [3] [4] [5] [6] [7]) recognise that sounds with certain characteristics can be perceived as more annoying to a listener. For example, Section 4.1 of the New South Wales Industrial Noise Policy [6] notes:

> *Where a noise source contains certain characteristics ... there is evidence to suggest that it can cause greater annoyance than other noise at the same noise level.*

Similarly Appendix B of NZS6808:2010 [5] notes:

> *Sound that has special audible characteristics ... is likely to cause adverse community response at lower sound levels, than sound without such characteristics.*

These characteristics cannot be sufficiently described by broadband sound level alone as other features of the sound create a response for listeners. Examples of characteristics, referred to here as special audible characteristics or SACs, encountered in environmental acoustics are listed in Table 1.

This note outlines the mechanisms used in guidance documents for addressing SACs, such as penalties. Consideration is then given to general approaches for assessing SACs which can comprise objective and/or subjective methods and which can be evaluated either on-site or using unattended measurements. A number of advantages and disadvantages for these various approaches are discussed, with examples provided in the context of wind farm noise assessment.

MECHANISMS FOR ADDRESSING SACS IN GUIDANCE DOCUMENTS

SACs are not always directly evaluated during a noise assessment as many noise sources do not exhibit them. When SACs are evaluated, assessments are typically undertaken at receptor locations such as residential dwellings, where annoyance is likely to occur, and are generally addressed in two steps:

- Assessment: SAC(s) are evaluated using objective measures or a subjective appraisal or both.
- Penalty: If the assessment (Step 1) indicates significant presence of one or more SACs, measured sound levels are typically adjusted through the addition of a penalty or rating level to account for the additional character.

For example, Section 6.1 of ISO 1996-1:2003 [1] comments:

> *Research has shown that the frequency weighting A, alone, is not sufficient to assess sounds characterized by tonality, impulsiveness or strong low-frequency content. To estimate the long-term annoyance response of a community to sounds with some of these special characteristics, an adjustment, in decibels, is added to the A-weighted sound exposure level or A-weighted equivalent continuous sound pressure level.*

Similarly, Section 8 of British Standard 4142:1997 [2] notes:

> *Certain acoustic features can increase the likelihood of complaints over that expected from a simple comparison between the specific noise level and the background noise level. Where present at the assessment location, such features are taken into account by adding 5 dB to the specific noise level ...*

The magnitude of an applicable penalty depends on the guidance document and, in some cases, the type of SAC. As noted, BS 4142:1997 applies a penalty of 5 dB for the presence of a SAC and, by implication, a penalty of 0 dB when no SAC is present: the penalty takes the form of a step function with a value of either 0 dB or 5 dB. Conversely, for an assessment

Table 1: Examples of characteristics of sound considered during environmental noise assessments

Characteristic	**Definitions**
Amplitude modulation (AM)	Sound with a noticeable regular and repeating change in sound level can in some cases be describe as amplitude modulation.
Impulsiveness	"*... sound characterized by brief bursts of sound pressure* *NOTE The duration of a single impulsive sound is usually less than 1s.*" [1]
Low frequency noise	"*… sound containing frequencies of interest within the range covering the one-third octave bands from 16 Hz to 200 Hz.*" [8]
Tonality	"*… noise containing a discrete frequency component …*" [9]

of tones, ISO 1996-2:2007 [8] details a sliding penalty scale ranging from 0dB to 6dB such that the size of the penalty applied to the measured sound level is, approximately, in proportion to the audibility of the tone.

Some guidance documents recommend a single penalty regardless of the number of SACs identified in a sound. For example, Section B4 of NZS 6808:2010 states that:

> *Only one adjustment value ... shall be applied to each measurement, even if more than one type of special audible characteristic is present.*

Conversely, the *South Australia Environment Protection (Noise) Policy 2007* [7] details an accumulating penalty:

> *(3) If the noise from the noise source contains characteristics, the source noise level (continuous) must be further adjusted in the following way ...:*
>
> *(a) if the noise from the noise source contains 1 characteristic, 5 dB(A) must be added to the source noise level (continuous);*
>
> *(b) if the noise from the noise source contains 2 characteristics, 8 dB(A) must be added to the source noise level (continuous);*
>
> *(c) if the noise from the noise source contains 3 or 4 characteristics, 10 dB(A) must be added to the source noise level (continuous).*

SAC ASSESSMENT METHODS

As noted, SAC assessment methods can be subjective or objective. Subjective methods, such as listening studies, are directly referenced in some guidance documents, for example Section B1 of NZS 6808:2010 states:

> *Subjective assessment can be sufficient in some circumstances to assess special audible characteristics.*

Objective methods are also commonly cited in guidance documents ([5] [8] [10]) and typically involve processing measured sound levels and comparing results with a pre-determined threshold.

A combination of approaches is also possible, such as in UK document ETSU-R-97 [9] which states:

> *The determination of the character of the noise emitted by wind turbines is performed by both a subjective and an objective test. This takes the form of listening to the emitted noise at the affected property and/or performing objective measurements of the incident noise at the property.*

SUBJECTIVE METHODS

The success of subjective methods depends critically on the experience of the assessor and the time and location of the assessment. Outcomes will naturally vary with differences in opinion between assessors, meaning subjective assessments will not be appropriate in all cases. However it is considered that variations will be reduced provided assessors are sufficiently qualified and experienced with the sound being evaluated. Objective methods can also be helpful for validating a subjective appraisal, particularly in cases of dispute.

On-site subjective assessments will only address the source operating conditions encountered during the visit, which could be limiting for sources that vary with time or occur irregularly. For example, as wind turbine sound levels vary with wind speed, direction and shear, on-site SAC assessments have often required multiple many trips to site to assess a sufficient range of turbine operating conditions ([11] [12] [13]). On-site assessments are, however, generally less prone to influence from extraneous noise as, on-site, an assessor can distinguish whether a particular SAC originates from the source of interest.

It is also possible to carry out subjective assessments using audio recordings, during post-processing. However, this may misrepresent the significance of a SAC because of variability or limitations of the audio playback system, as recently noted by Hansen [14]:

> *There are several reasons why the replayed levels would not be accurately reproduced and these include: self-noise of the instrumentation (headphones/computer), ambient noise in the listening room, frequency roll-off of the headphones and/or sound card and inaccurate amplification.*

Additionally, field recordings from sound level meters are generally single channel rather than stereo which reduces an assessor's ability to localise a sound and/or discriminate between two different sounds from different locations. These issues of variability could be particularly significant if assessing a SAC with a sliding penalty, where comparatively subtle influences of the recording and playback systems could affect the prominence of the identified SAC, resulting in a penalty which differs by several decibels from what may have been determined from an on-site assessment. In light of such issues, subjective review of unattended recorded audio samples may be best suited simply for source identification.

OBJECTIVE METHODS

Efficient objective assessment methods should:

- Identify a SAC when it is present at a sufficient level
- Not identify a SAC when there are none present
- Where a SAC is present, provide a relationship between the objective results and expected levels of annoyance and/or an applicable penalty

Indentifying a SAC when it's present

Objective methods can be reasonably efficient at identifying SACs provided there is a good signal to noise ratio for the source of interest. As an example, a set of planning conditions for a proposed wind farm in the UK included a method for assessing high levels of amplitude modulation (AM). In broad terms, the method involves reviewing a time series of $L_{Aeq,125ms}$ values, evaluating local minimum-maximum-minimum combinations in this series across 2 second windows and tallying the number of windows in a one minute period where the minimum-maximum-minimum variation is greater than 3 dB [15]. The method has been reported ([16], [17]) as having a low rate of false negatives or, in other words, it can identify high levels of wind turbine AM when they are present. Figure 1 shows how the method would apply to a 2 s window of $L_{Aeq,100ms}$ sound levels of a wind turbine at a distance of approximately 120 m (an IEC 61400-11:2006 [10] test position).

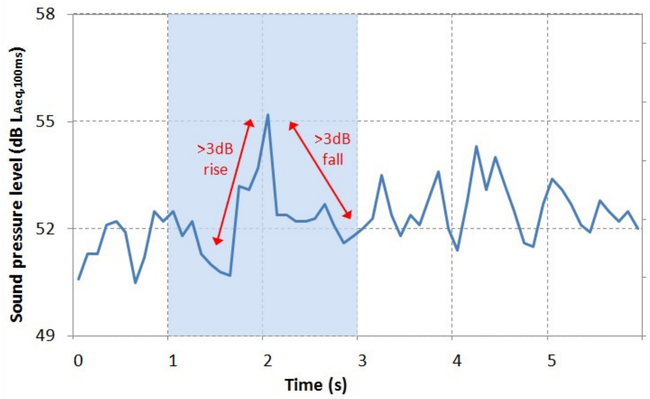

Figure 1: An $L_{Aeq,100ms}$ time series, wind turbine sound power level test location

Some objective methods do, however, give rise to false negatives in some circumstances. For example, NZS6808:2010 prescribes a 'simplified' tonality assessment method based on one-third octave bands but notes in Section B2.1 that:

> *If the simplified method does not indicate tonality, it may still be necessary to use the reference method to confirm the presence or absence of tonality.*

Objective methods may also include inherent assumptions about the nature of a SAC which may limit its general application in some cases. For example, the tone assessment procedure detailed in IEC 61400-11:2006 notes:

> *In exceptional cases (for example very broad tones consisting of many lines or masking noise with very steep gradients) this [tone assessment] method may not give the correct results. In such cases, deviations from the prescribed method may be needed and must be reported.*

Indentifying a SAC when it is not present

A significant risk with objective SAC assessment methods is false positives. That is, identifying a SAC as being part of a sound when it is not. Arguably the greatest cause of false positives is the influence of extraneous noise.

Continuing the AM example above, it has been documented [15] that the minimum-maximum-minimum method demonstrated a high rate of false positives when "*...applied to a large body of acoustical data obtained from two rural sites where no wind turbines exist and where there is therefore no possibility of wind turbine induced AM being present.*" Bird chirp, for example, could cause a brief spike in an otherwise flat $L_{Aeq,125ms}$ time series to trigger the 3 dB minimum-maximum-minimum criteria for a 2 s window. Clearly an isolated bird chirp should not register as AM from a wind turbine, however, this objective assessment method would falsely produce a positive result in a 2 s window. The crux of this example is that the proposed method was likely developed with an inherent, and quite reasonable, assumption that the sound of interest dominates the sound field: ambient or extraneous noise is not significant. In many cases, such as at receptor locations which are sufficiently far from a noise source, this fundamental assumption of the assessment method may not be satisfied.

In practice, false positives can usually be managed during an on-site objective assessment as the assessor can identify extraneous noise events. False positives are a much more significant issue with unattended measurements which rely on automated processing (as it is generally impractical to listen to large amounts of audio data). Significant effort can be required to reduce their occurrence, as noted in a recent study of wind farm amplitude modulation by Cooper & Evans[18]:

> *The advantage of the more intensive signal analysis techniques is that they can be used to automatically calculate the level of amplitude modulation during long-term measurements of several weeks duration. The disadvantage of these methods is the susceptibility of extraneous noise, which may be falsely identified as amplitude modulation, or may make identification of the level of amplitude modulation due to the wind farm noise indistinguishable from other sources.*

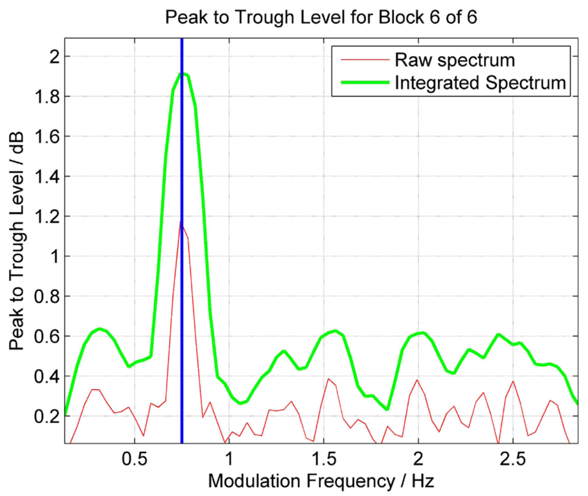

Figure 2: Example Power spectrum from an $L_{Aeq,100ms}$ time series

Cooper & Evan's study documents development of automated routines to assess AM in accordance with NZS6808:2010, where AM is described as "... *a greater than normal degree of fluctuation as a function of the blade passing frequency*" (BPF). A key component of the study is establishing the BPF, which is estimated by calculating modulation spectra for sets of one-third octave band $L_{eq,100ms}$ time series. Figure 2 shows an example spectrum calculated from the $L_{Aeq,100ms}$ referenced in Figure 1, using the RenewableUK AM tool [20].

Cooper & Evan's study provides an example of extraneous noise corrupting initial attempts at the automated routines and several sophisticated refinements are employed to better identify the BPF and, in turn, the potential occurrence of wind farm AM, including:

- Averaging a number of individual modulation spectra across a nominated 2 minute assessment period rather than determining a single spectrum for that entire period.
- Preferential weighting of potential BPF bins across time periods such that a particular BPF is considered more likely in time period X if it had just been identified in period X-1.

The refinements employed work well and allow for a helpful assessment of AM at the investigated site, across a broader range of conditions than could reasonably be assessed with discrete site visits.

It is important, however, to balance the advantages offered by such refinements with limitations that they may introduce. For example, focusing an assessment using BPF, typically around 1Hz for a multi-MW three-bladed turbine, may discount any potential AM that occurs at a less regular rate: such as at a rotational frequency of around 0.3Hz as could occur if the AM characteristics were attributable to only one of the rotating blades. Similarly, while the preferential weighting filter is likely to work well during periods where turbine operation is relatively constant it may unduly discount periods when the turbine operation is changing. For example, at cut-in wind speeds when the turbine is beginning to generate power or when the turbine is yawing. Pragmatically in the context of wind farms, comparatively short term events such as these may not influence study outcomes which typically rely on regression analysis of large data sets. Nonetheless, it may be that the short term events are a significant cause of neighbour annoyance that a wind farm operator may wish to address.

Relationship between objective results and expected levels of annoyance and/or penalty

The relationship between objective SAC assessments methods and the subjective impressions of a 'typical' listener is variable and uncertain in many cases. For example, a recent review of two different tone assessment methods demonstrated that each method achieved a different level of correlation with the subjective assessment of 23 different listeners [19].

Moreover, not all objective methods include information about applicable penalties. For example, IEC61400-11:2006 specifies a method for assessing tones from wind turbines but provides no guidance about penalties.

Also, in cases where a step penalty applies, it can be unclear where the onset of the penalty should occur. For example the New Zealand Standard NZS 6808:1998 [4], which is still used as a guidance document for some Australasian wind farm projects, requires application of a 5 dB penalty where wind farm sound is identified as having clearly audible tones and references the Joint Nordic Method (JNM) as being an appropriate assessment standard. Version 2 of the JNM, as described [19] in Annex C of ISO 1996-2:2007, provides a sliding penalty scale for tonality meaning a degree of interpretation is required to estimate what level of *sliding* tonality penalty may be appropriate as an onset for the 5 dB step penalty required by NZS608:1998.

DISCUSSION

Recent developments with sound level meters and noise loggers, such as audio recording and SD-card based data storage, readily allow detailed sound data to be collected during medium and long term unattended measurements. This has created new opportunities for detailed post-processing of data, including assessment of SACS. Indeed, intensive data collection methods are beginning to be integrated into guidance documents for wind farm noise assessment. For example, Section 2.3.4 of the recent IOA Wind Farm Working Group Consultation Draft of Supplementary Guidance Note 5 Post-completion measurements, [21] states:

> *... it may be useful to carry out audio recordings for 2 minute samples in every 10 minute interval in all cases to allow for subjective evaluation of any noise effects and particularly of any time histories produced to assist with any discussions about the acoustic character of the noise.*

However, from the discussions above it is apparent that the merits of any particular SAC assessment method should

Table 2: SAC assessment methods pros and cons

SAC Assessment outcome	Assessment Type			
	Attended		Unattended	
	Objective	Subjective	Objective	Subjective
All potential SACs considered*	✘	✔	✘	✘
All relevant operating conditions considered	✘	✘	✔	✔
Assessment of applicable penalties	✘	✔	✘	✔
Copes with extraneous noise influences	✔	✔	✘	✔
Avoids intensive data analysis	✘	✔	✘	✔
Generally repeatable outcomes	✔	✘	✔	✘
Avoids influence of audio playback systems	✔	✔	✔	✘

* There is no combination of objective SAC methods that will ensure all SACs are always identified. Also, some SACs may not be identifiable from recorded audio samples.

be judged with a degree of pragmatism. Table 2 summarises a number of key advantages and disadvantages for the approaches considered.

Recent experience with wind farm noise assessment suggests that intensive, unattended data collection can demand prolonged periods of data post-processing which produce less reliable results, because of extraneous noise effects, but across a wider range of weather conditions. This can mean that assessments are not necessarily any better informed than more conventional attended studies which could produce results of greater reliability but for a limited range of conditions.

It is therefore considered that SAC assessments are often best approached using a combination of subjective and objective methods. In particular, it is recommended that any objective assessment of unattended measurements should generally be complemented by attended subjective and objective assessments as a check on the nature and magnitude of the SACs that are being assessed. If a SAC assessment is proposed to address a specific complaint, it is recommended that an on-site subjective evaluation of the SAC should occur in the first instance, ideally making reference to a complaint diary or some other record of the type of sound causing annoyance and the periods when it occurs. The subjective review can be used to assess not only the significance of the potential SAC but also its classification. For example, a 2006 UK study investigating low frequency noise complaints [22] found that what residents were describing as low frequency noise was perhaps better classified acoustically as amplitude modulation:

> *The common cause of complaints associated with wind turbine noise at all three wind farms is not associated with low frequency noise but is the audible modulation of the aerodynamic noise ...*

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Gerald A B Riley

1918 - 2014

Gerald Addison Brook Riley, one of Australia's specialists in architectural acoustics passed away on 13-Jan-2014, aged 95, after a shortish illness. His was a long, challenging and interesting life. Though we know little of his earlier education apart from having gained his Leaving Certificate in 1930, he showed that he was technically inventive.

Gerald's professional life began in 1937 as a radio announcer and technical officer in the transmitter room of Radio 3XY. Here he developed an interest in the many possible uses of the Cathode Ray Oscilloscope [CRO]. He joined the Public Service and went to the ABC in mid-1938, as a duty announcer with all-round duties. In 1940 he moved to the Victorian Engineering Division of the PMG, to its transmission section, closely associated with the PMG Research Laboratories. Here, he continued his interest in the CRO, particularly as a timing device, with its radar implications. From 1941-45 he worked on long-distance communications with Reg Booth, an honors science and engineering graduate who was most advanced in communications engineering.

In 1950, he was transferred to the Australian Broadcasting Control Board, where, with a full set of B&K acoustical instruments, he studied studio acoustics and measured reverberation times and background noise levels in ABC studios. For speech, he found the optimum reverberation time to be around 0.4 s, with, as far as possible, a uniform frequency response. Some studios had problems with acoustic and structural resonances. Here also, he would have experienced some of the earlier architectural and acoustical work of Vivian Taylor, who had designed broadcasting studios for the ABC in the 1930s. In 1957, his work was extended to inspecting the general administration and programs of commercial radio stations. At the end of 1958, he took some leave and, on enquiring of architects, discovered a need for precise acoustical information on the materials used in building design and construction.

In early 1959, Gerald made a significant career change, resigned from the Public Service and went into business as an acoustical consultant. Now without the quality acoustical instruments previously available to him, he had to start from scratch and build up a new set of measuring instruments. Here, he was greatly helped by Ken Connor [RMIT, physics].

An early consulting experience involved the quietening of a typing room. The CSR acoustic tiles he used for this were local copies of overseas tiles made here under licence. The result was a failure. He therefore had the local tiles checked by the CSIRO Department of Building Research at Highett, where it was found that, while the original overseas tiles had a coefficient of acoustical absorption of 0.90 to 0.95, the maximum coefficient of the local tiles was about 0.20.

Accordingly, as Vivian Taylor had done in the 1930s, Gerald set up a laboratory for measuring the acoustical properties of absorptive and barrier materials. This was necessary as some existing measurements for barrier materials [eg, from an RMIT lab] gave STLs of 30 dB, whereas by mass law calculation they were only 20 dB. In 1961, he set up the Australian Acoustical Laboratory, and was able to obtain the use of a concrete air raid bunker in Maribyrnong as a pair of reverberation rooms, in which he erected a partition with a 2.36 m square opening of 5.57 m^2 in area, and a volume of 101 m^3 in each room. He was later able to obtain the use of a larger bunker, which enabled him to make measurements according to ISO and BSI standards, after which his laboratory was able to be registered by NATA [National Association of Testing Authorities]. For measurements of the acoustical impedance of absorptive materials, he obtained an Impedance Tube similar to that at the CSIRO DBR, so that if his measurements were questioned, they could be directly corroborated.

From 1960 to 1984, Gerald and his staff spent much time testing acoustical materials, designing the acoustics of auditoriums and noise reducing systems. The excellent acoustics of the Llewellyn Auditorium in Canberra are a fine tribute to his design work.

In 1973, Gerald formed the partnership of Riley, Barden and Kirkhope with Ron Barden and Jim Kirkhope, a partnership which continued until Gerald's retirement from active acoustical work in 1984.

In 1964, he became a foundation member of the Australian Acoustical Society Victoria Division, and served on its committee. In 1980, he also was the AAS national president, and was a FAAS.

Though Gerald published few technical papers, he produced many reports on his acoustical measurements and designs. His paper on the Llewellyn Auditorium included in an ASA publication on the Acoustics of Auditoriums in Public Buildings [published in 1986 and 1994] pays tribute to a great Australian architectural acoustician. He is survived by his wife, Norma, to whom we offer our condolences and sympathy on his passing.

C Louis Fouvy

LETTER TO THE EDITOR

Annoyance from wind turbines: role of the middle ear muscles

There is a simple, though unappreciated, explanation for the annoyance that some people experience when near a rotating wind turbine or inside an anechoic chamber (Neville Fletcher, AA, 41, 174-175 and Peter Alway, AA, 41, 195). The explanation involves understanding that the ear is not just a microphone, as a lot of people seem to think.

Rather, the ear is part of a sophisticated gain control mechanism. This is not unexpected when you consider its enormous dynamic range – 120 dB or a million million times. No linear detector could work satisfactorily over such a huge input range.

It is known that there is some neural gain control, but there is also a physical gain control mechanism – the 'acoustic reflex' involving the middle ear muscles – which is frequently overlooked. The acoustic reflex automatically comes into play at loud sound levels or when you speak, touch your ears or face, or even when you blink, in each case causing the muscles to contract and protect the incredibly sensitive cochlea. If you close your eyes tightly, you can hear a 'fluttering' and that is the sound of the middle ear muscles at work. Interestingly, some people are able to contract the middle ear muscles voluntarily. A standard way to evoke the middle ear reflex is to blow a puff of air on the face.

Like all muscles, the middle ear muscles come in pairs – one works against the other in an agonist/antagonistic fashion. In the middle ear there is the stapedius muscle attached to the stapes and the tensor tympani muscle attached to the ear drum, both working together to attenuate sound as it is conducted from ear drum to cochlea.

It is not always appreciated that when the middle ear muscles contract, the pressure in the cochlea – the intracochlear fluids – must rise as the tensor tympani pulls on the ear drum and pushes the stapes into the cochlea (and the round window bulges out). As hypothesized by Gellé in the middle 1800s, this pressure signal is a way by which the cochlea can regulate gain, a mechanism known as the intralabyrinthine pressure (ILP) theory of middle ear action. There is a range of diverse evidence in favour of the ILP theory, work which has been reviewed in Bell (2011).

The ILP theory makes sense of observations of wind turbine syndrome. A low frequency pressure pulse from a wind turbine blade has an enormous amplitude (relative to 20 μPa), even though at about 1 Hz it is below audibility. Nevertheless, a consideration of the physics of pressure waves propagating through air will help us see that that a high pressure signal will inevitably have a direct effect on the ear drum, even if it doesn't stimulate a suitable nerve ending in the cochlea. When the ear drum moves in response to a large air-borne pressure pulse, this is likely to interfere with the functioning of the ear's gain control mechanism as the attached muscles try to keep the drum at the middle of its operating range. And that activity will repeat whenever a pulse comes along, about every second in fact. No wonder some people will soon feel "pressure" in their ears, and fatigue may set in. A wind turbine is similar to a constant sequence of "air puffs" blowing against the ear.

The important thing to recognise is the physical movement of the ear drum at about 1 Hz. It's rather beside the point that a 1 Hz pulse is inaudible because its physical manifestation – motion of air particles – will always lead to ear drum motion. The fallacy, of course, is to say that because wind turbine noise is below perceived sound levels that the sound will have no biological effects and can be ignored. It doesn't help that normal SPL measurement protocols use an 'A' weighting which automatically discounts low frequencies and so tends to sweep the problem under the carpet.

Another way to disrupt the hearing system's set point is to go into a sound proof room: with no background sound and no output, the hearing system will, as Peter Alway relates, start hunting around for an operating point, a sensation which the owner of the apparatus senses as "pressure" in the ear. Indeed, pressure well describes what is happening, as the middle ear muscles hunt around for a set point for the pressure in the cochlear fluids (with no output signal to provide feedback, the loop is open and the action of the muscles in trying to set the gain is fruitless). Such a mechanism is well explained by the intrabyrinthine pressure theory, but it is not at all apparent from the standard idea of middle ear muscles causing "sound attenuation" in the ossicular chain.

The above explanation needs to be confirmed, but it makes sense of the diverse observations from wind turbines and sound proof rooms. The problem is that middle ear muscles are difficult to observe, and their movements are minute – micrometres and less. Nevertheless, micrometer movements are significant when the intracochlear fluids – which are essentially water – are incompressible. A tiny movement leads to an appreciable rise in pressure.

A similar disruption to the middle ear muscles can be observed in people with Meniere's disease. Suddenly they have an 'attack', which can be seen as a spasm of the muscles. They suffer fluctuating hearing loss (the gain is being shunted up and down), tinnitus (the sensation you get when static ear pressure is applied to anyone's ear canal), vertigo (when pressure of the intralabyrinthine fluids is abnormal and affects the balance organs in the inner ear), and, of course, "pressure or fullness in the ears" (which, precisely, it is).

In the present discussion of wind turbines, the action of the middle ear muscles and the intralabyrinthine pressure theory which explains their anatomical function deserve more attention. The middle ear muscles are an essential part of an intricate hearing system, although they have become poor cousins to the cochlea. Unless we recognise their essential function, we will, as Peter Alway again relates, begin to doubt the reports of people who "feel pressure" in their ears even though the sound (or lack of it) which causes the problem is inaudible.

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AAS COUNCIL NEWS

AAS Membership Fees

The membership fees for the Australian Acoustical Society have been static since 2007. At the 2013 Council meeting it was decided that due to the increasing costs of running the Society, a small increase in the fees across the board was required. The fees applicable from 2014 are $150.00 for Members, Fellows and grade 4 Graduates, $140 for grade 3 Graduates, $127 for grade 2 Graduates and reinstated members, $115 for grade 1 Graduates, Associates and Subscribers. A fee of $45 is applicable to retired and those on Maternity leave while students continue to have no annual fee for membership.

AAS Website upgrade

The new website will be the main portal with which members will interact with the Society, especially in maintaining their membership, paying subscriptions and accessing member-specific information. The first phase of the rollout is expected in April and will include subscription payments and a more streamlined system for membership applications/upgrades and transfers. The second phase of the roll out will have an improved appearance and access for the all the content such as journals, conference proceedings, forums, video and audio, notices of meetings etc.

AAS Members will need to be able to log in to the members only area to access the most important features. If you have not yet logged onto this area, or have not updated/checked your records recently, please do so as soon as possible to ensure that you will be able to access the full functionality of the new website. The current link to log on is on the right hand side of the home page http://www.acoustics.asn.au/joomla/.
After log in, check and update your records under the "Your Details" menu item.

Acoustics Australia Future

The production and distribution of a hard copy of the journal to all members has become financially unviable without a substantial increase to the membership fees for all members and advertisers. The Council has taken into consideration the options and the results from the survey in late 2013 (for the full findings, after log in go to Members Area, then scan down to find Acoustics_Australia_Review_Survey-2013.pdf).

The decision from the 2013 Council meeting is that the April issue is the last hard copy issue that will be distributed to all members. The same layout style will be maintained but commencing with the August issue all members will receive an email with a low resolution version (aim is for <6 MB) and a link to the website for the high resolution version.

A small print run will be made to provide for those that elect to continue to receive a hard copy mailed to them. This will be provided at cost recovery, which for 2014 will be $40.00 per copy, i.e. $120.00 per year. This cost will be reviewed annually to maintain the rate at cost recovery. The option to elect to receive a hard copy will be included on the subscription notice so that one payment can be made for the annual subscription plus, if the option is selected, the extra fee for the hard copy of the journal for the August, December and April issues.

AAS Research Grant Assistance

This month AAS has announced the AAS Research Grant Scheme. AAS intends to assist timely research to help achieve the objectives of the Society. A Research Grant Plan was developed collaboratively with the membership of the AAS via a survey and the Research Committee with representation from each division. This led to identification of strategic research needs that are appropriate to the aims and objectives of the AAS.

Key research topics including wind farm noise assessment, underwater noise monitoring & detection and environmental noise modelling & assessment have been identified by you (our members). The Research Grant committee will evaluate and prioritise the applications against the key research topics so that the applications that best address these topics are funded first.

The limit for individual grants is currently $50,000 with a pool of funding up to $ 100,000 over 3 years. Successful applicants will be required to provide matching funding from other sources and report to the AAS at predetermined stages.

For more information go to the **Awards, Prizes and Grants** page of the AAS website: http://www.acoustics.asn.au/joomla/notices.html.

Inter.noise 2014 and AAS Annual Conference

The Melbourne Convention Centre will be the venue for Inter.noise 2014, from 16 to 19 November 2014 which incorporates the 2014 AAS conference. A strong technical program will consider all aspects of noise and vibration in sessions organised by over 120 international experts.

Abstracts should be submitted through the congress website at www.internoise2014.org, with a closing date of 10 May. Full papers will be due by 25 July. Heading the technical program are six distinguished lectures. On Sunday afternoon the opening plenary lecture will be by Prof. Jung-Woo Choi of South Korea on "Sound Sketch: its Theory and Application using Loudspeaker Arrays" while the final plenary lecture on Wednesday will be by Prof. Lex Brown of Australia, entitled "Soundscape Planning as a Complement to Environmental Noise Management". In addition there will be four keynote lectures by world authorities on their subject, which will complement major areas within the Congress. They cover Aircraft Noise, Active Noise Control, Wind Turbine and LFN as well as the Impact of Building Acoustics on Speech Comprehension and Student Achievement. More details are available on our website. A comprehensive exhibition will showcase instrumentation and acoustical materials. Early bird registration fees of AU$720 for delegates and AU$255 for students will finish on 25 July.

The optional Congress banquet will feature a fascinating Australian theme, including the opportunity to take photos with some Australian native animals.

For updated information on this important international conference being held in Australia go to www.internoise2014.org

Inter.noise 2014 – Gerald Riley Award for Best Paper by AAS member

In place of the usual Presidents Prize awarded at the Annual AAS conferences, the Victoria Division has decided to provide a $2500 Award for the best paper presented at Inter.noise 2014, where at least one of the authors is a member (full, graduate or student) of the AAS. The Award is in honour of Gerald Riley who was a founding member of the Society and who served the Victorian Division for many years. Gerald passed away in January 2014. The Gerald Riley Award will be presented at the AAS annual meeting which will be held during the time of Inter.noise 2014.

For all information on Inter.noise 2014 including abstract submission and registration www.internoise2014.org

DIVISIONAL NEWS

QLD Division

The QLD Division had a busy end to the year 2013, with a number of technical meetings being held along with our Christmas party and AGM. In August, Rob Jones from Autex presented information to our members regarding the in-situ performance of their Quietspace Fabric and the new products Autex are bringing to the marketplace. It was interesting to see how the absorption performance of a thin absorptive product behaved at lower frequencies compared to the results obtained via laboratory testing.

Embelton presented a technical talk titled "Isolation that Goes Swimmingly, Building on a Solid Foundation" on the 9th of October. The talk enabled Embelton's Chief Engineer, Timothy Murray, to provide our members with some very relevant knowledge regarding the isolation of swimming pools and building structures. On the 13th of November our AGM was held along with a technical presentation from Ray Walsh, Senior Systems Engineer/ Trainer for Bose Australia. Ray's talk was titled "Influence of Radiation Performance of Sound Reinforcement Systems on Tonal Balance Consistency".

On the 21st of November a workshop was held at the Floth consultancy office to review and comment on the Queensland Department of Environment and Heritage Protection's (QDEHP) "Draft Guideline: Planning for Noise Control". For those who were unable to attend the workshop, the opportunity was given for members to submit comments to accompany the submission that was made on behalf of the Society. Many comments were received and these were compiled and submitted to QDEHP for consideration.

On Thursday 5th of December our Christmas party was held at the Queensland Cricketers' Club. A/Prof William Martens from the Faculty of Architecture, Design and Planning at the University of Sydney gave an informative and entertaining talk titled "Exploring Virtual Acoustic Environments: Listening through Other Ears". The strange effects that can be experienced by swapping over the earpieces on a topophone were described in detail and provoked some interesting feedback from the audience. The Christmas party was enjoyed by everyone who attended and was made special by the announcement of two new Fellows of the Society and the presentation of the Acoustic Bursaries. It provided an ideal end to the technical and social program presented by the Queensland Division in 2013.

WA Division

On December 13 the WA Division held its annual Christmas Lunch at The Brown Fox in West Perth. The lunch was a great opportunity for AAS members to catch up and celebrate another year of being involved in acoustics. During the lunch, two important presentations were made. Firstly, Norbert Gabriels was presented a certificate in acknowledgment of being elevated to the membership grade of Fellow. Norbert has been working in the field of acoustics for the past forty years and has been a leader in this field, particularly in the area of architectural acoustics. Initially working in the Environmental Design Branch of the State Public Works, Norbert started his own consultancy (Gabriels Environmental Design) in 1994. Both his company and Norbert are well respected by clients and fellow consultants. Norbert has been a member of the Australian Acoustical Society since 1976 and has supported the Society in various roles.

Secondly, the 'AAS WA Tertiary Prize in Acoustics and Vibration' was awarded to Rhianne Ward, a research student from Curtin University. The prize was awarded to Rhianne due to her honours research project titled "The whistle repertoire of Indo-pacific bottlenose dolphins (Tursiops aduncus) in the Fremantle Inner Harbour, Western Australia". Rhianne plans to continue research in the field of bioacoustics. She is intending to gain further experience in underwater acoustics at the Centre for Marine Science and Technology, with the aim of starting a PhD in 2014 or early 2015.

NSW Division

The NSW Division is pleased to announce the 2014 Travel Grants to attend Inter.noise 2014, Melbourne, Victoria, 16-19 November, 2014. The Division is offering three different types of awards:

- AAS NSW Travel Award for Research Students in Acoustics to attend Inter. noise. Up to three (3) awards to the value of $1000 are open to all research students in acoustics who are AAS student members of the NSW Division as well as research students endorsed by AAS members of the NSW Division.
- AAS NSW Travel Award for Early Career Researcher in Acoustics to attend Inter.noise. An early career researcher is a young professional who has completed his/her doctorate in acoustics in the past five years and is working in a research capacity in the field of acoustics. One (1) award to the value of $1500 is open to all early career researchers in acoustics who are AAS members of the NSW Division. If not already a member, the applicant must apply to become a member of the Australian Acoustical Society before submitting his/her application.
- AAS NSW Travel Award for a NSW Division Member to attend Inter.noise. One (1) award to the value of $1500 is open to all current AAS NSW Division members who have held membership for 12 months or more.

For more information about the AAS NSW Travel Awards for 2014, see Divisional Notices on http://www.acoustics.asn.au/joomla

SA Division

The South Australian division kicked off its 2014 series of technical meetings on 6 March with a presentation by André Almeida, entitled "Predictions and observations of oscillation thresholds in a clarinet-like system". André is an Associate Professor at Université du Maine, in Le mans, France. He is currently researching the physics of musical instruments, focusing mainly on wind instruments. He is presently collaborating with UNSW, with whom he previously undertook a post-doc (2007-2009) with Joe Wolfe on the interaction between musicians and their instruments. André's highly interesting talk focussed on modelling the interaction between the musician and a self-oscillating instrument, the clarinet. His work used dynamic bifurcation theory to predict the behaviour of this system when one of its control parameters varies regularly, or with some randomness through time. The predictions were compared to both the simulated system and to measurements in real systems. André's talk stimulated some lively discussion which continued over dinner – overall a very enjoyable and educational evening.

In other news, the South Australian division awarded University of Adelaide student Daniel Wardle a $500 prize for the highest mark in the 2013 course "Engineering Acoustics". Additionally, at the University of Adelaide MechExpo 2013, Vipac Engineers and Scientists Ltd awarded $500 to Linjun Zhao for the "Best acoustics-vibration project prize", which is for the best project in design and research in areas of vibration, acoustics, noise control, dynamics, and condition monitoring.

NEWS

Educators in Acoustics

The Educators in Acoustics group is network of people actively involved in training and research in the numerous disciplines within acoustics. It was initiated by Carl Howard during the time of the AAS 2013 conference in Adelaide.

Currently there are members that cover disciplines in acoustics such as building, musical, linguistics and speech, audio engineering, sound design, vibro-acoustics, aeroacoustics, and many more. The group intends to share information, resources, discuss successful (and unsuccessful) teaching methods, organise guest lectures either in person or by video conference. If you are involved in acoustics education and would like to join this group, please contact Carl Howard on carl.howard@adelaide.edu.au at the University of Adelaide.

There will be a special session devoted to education and outreach at Inter.noise2014. This international conference will be held in Melbourne 16-19 November 2014; for more information see www.internoise2014.org

For many educators, it is the start of an academic year and the time to inspire a new group of students. The first day of lectures can make a lasting impression in the minds of students. Memorable lectures often include an in-class demonstration and there are many great ones that can be easily shown in large lecture theatres. If readers can recall an inspiring lecture in acoustics, please tell us about it.

Academics from the University of Sydney have released another opensource software package called AARAE, which stands for 'Audio and Acoustical Response Analysis Environment' and is pronounced like the word "array", that is a Matlab-based measurement, processing and analysis environment for audio and acoustic system responses. It is intended primarily for use in education and research. The software is available from www.psysound.org.

Carl Howard

WA Noise Regulation Amendments

A substantial package of amendments to the Western Australian Environmental Protection (Noise) Regulations 1997 was gazetted on 5 December 2013. The purpose is to improve the regulation and management of environmental noise by establishing appropriate approvals procedures for certain activities and by clarifying and updating existing provisions. The amendments were developed following a statutory review, a series of consultative working groups, a lengthy drafting process and a full public consultation in 2011, with further development of the amendments made since that time.

The key aspects of the amendments are:

- New regulations to provide more certainty and better noise management for motor sport venues, shooting clubs, major concert venues, and essential services activities such as garbage collection. The new regulations establish exemption pathways to allow an activity in any of these classes – that cannot comply with the existing allowable levels – to occur under special approval. Applications for these approvals will be determined (under delegation) by the CEO of the relevant local government allowing these decisions to be made at the local level.
- A 5dB reduction in airblast limits from blasting, to bring Western Australia into line with National best practice. Revision also included the application of the reduced airblast limits at the 'sensitive site' only (typically a house and its curtilage) and retaining the current levels at the boundary of the receiving premises and at non-sensitive receivers.
- Relaxation of the industry-to-industry noise limits in the Kwinana Industrial Area (KIA), in recognition that there are a number of industries in the KIA whose noise emissions exceed the allowable levels at the boundary with an industrial neighbour.

Further information is available at www.der.wa.gov.au

Noise on Vessels

In November 2013 AMSA (Australian Maritime Safety Authority) published an updated Part C1 to its National Standard for Commercial Vessels. This deals with design and construction of new vessels in relation to arrangement, accommodation and personal safety. See http://www.amsa.gov.au/domestic/standards/national-standards/index.asp

At section 4.8.6 this requires accommodation spaces on a vessel to be arranged and equipped to comply with the new IMO 2012 Code on Noise Levels On Board Ship available at: http://www.imo.org/KnowledgeCentre/IndexofIMOResolutions/Documents/MSC%20-%20Maritime%20Safety/337(91).pdf

The Australian Standard previously used by most people to assess noise on vessels, AS2254:1988, is likely to soon be declared Obsolescent by Standards Australia.

Workplace Health and Safety News

There have been two new UK vibration prosecutions for HAVS and CTS. See: http://www.hse.gov.uk/press/2013/rnn-nw-woodall-nicholson.htm?eban=govdel-noise&cr=16-Aug-2013. This case is interesting to Australia as the symptoms suffered by the workers are not just Vibration White Finger, as in most previous UK cases, but include sensory ones not so dependent on a cold environment. Also it says one of the workers was only 25 years old! The company, a limousine and hearse manufacturer, has since bought lower vibration tools and reduced exposure times.

The second case at: http://www.hse.gov.uk/press/2013/rnn-em-rolls-royce.htm?eban=govdel-noise&cr=16-Aug-2013 involved a worker who suffered bilateral Carpal Tunnel Syndrome from holding turbine blades being blasted by water jets. The company, Rolls Royce, has since automated the process.

A new HSE Research Report on the effectiveness of retro-fit anti-vibration devices for HAV is at http://www.hse.gov.uk/research/rrpdf/rr990.pdf . An interesting report though rather disappointing results.

WorkSafe WA produced a poster for workplaces aimed at raising awareness of noise-induced hearing loss as part of Hearing Awareness Week 2013. The poster, an initiative of the WA Commission for Occupational Safety and Health, can be downloaded from WorkSafe's website and printed for display in workplaces.

See: http://www.commerce.wa.gov.au/worksafe/PDF/Hazard_identification/Noise_poster.pdf

Risk of Hearing Loss from combined exposure to hand-arm vibration and noise, a PhD thesis by Hans Pettersson from the well-respected Swedish Umeå University, has been published at: http://www.diva-portal.org/smash/get/diva2:589455/FULLTEXT01.pdf. Among other findings it demonstrates that long-term exposure to HAV and noise increases the risk of NIHL, but concludes that further studies into the various interactions are needed. Hans Pettersson is currently working as a Postdoctoral Researcher at the Finnish Institute of Occupational Health on the project "Physiological responses from combined exposure to hand-arm vibrations and cold". The project will study how combined exposure from hand-arm vibrations and cold affects muscles, peripheral nerves, and vascular responses in hand and arm and to guide preventive actions. So this may help us better understand the role temperature has to play in the development of HAVS.

Canadian IRSST researchers, Larouche et al have published a paper in Noise & Health Comparison of sound propagation and perception of three types of backup alarms with regards to worker safety. It can be read on-line at: http://www.noiseandhealth.org/article.asp?issn=1463-1741;year=2013;volume=15;issue=67;spage=420;epage=436;aulast=Vaillancourt

It concludes that alarms with broad frequency content appear to present some advantages over conventional tonal alarms, including: (i) A much more uniform sound propagation pattern behind vehicles; (ii) lower alarm output levels to meet the requirements set forth in ISO 9533; (iii) higher urgency ratings at high SNR without HPDs and (iv) better sound localization performance. However, some disadvantages were also noted. Firstly, higher SNR are required for detection of the broadband alarm, at least in noises rich in high-frequency content. Secondly, detection thresholds and urgency ratings appear to be more severely affected by the use of HPDs for the broadband alarm than the tonal alarm. Overall, however, the most salient finding is that the broadband alarm yields a more uniform sound field behind heavy vehicles than the conventional tonal alarm and that this advantage overshadows smaller alarm differences found in the laboratory.

A new Chinese study on hearing loss in workers exposed to ethylbenzene in the petrochemical industry has been published in JOEM: http://www.ncbi.nlm.nih.gov/pubmed/23969497 . This study, thought to be the first in humans, showed that almost four times as many petrochemical workers had hearing loss compared to workers in a power station with similar noise levels. In all cases the mean noise levels and ethylbenzene levels were below Australian exposure standards.

SKM joins Jacobs

Jacobs Engineering Group and Sinclair Knight Merz (SKM) have combined to form one of the world's largest and most diverse providers of technical professional and construction services across multiple markets and geographies. The merger transaction was completed in late 2013, with Jacobs purchasing SKM for approximately AUS$1.3 billion.

Founded in 1964, SKM is an employee-owned company with broad consulting, planning, engineering, architecture, scientific and construction management capabilities. The company has significant operations in Australia, Asia, South America, and the U.K., and serves clients in multiple industries, including Mining and Metals, Building and Infrastructure, Water and Environment, and Power and Energy. SKM's 2013 revenue was approximately AUS$1.3 billion.

In announcing the merger, Jacobs President and CEO Craig Martin stated "The combination of Jacobs and SKM further diversifies our geographic offerings and the end-markets we serve. We look forward to integrating the two companies and see many excellent opportunities ahead to support our clients, develop our people, and grow our business." SKM is expected to transition to the Jacobs brand across its global operations by August 2014 www.jacobsskm.com

Wind Turbine Award

The 2013 Create the Future Design Contest — sponsored by COMSOL, SAE International, and Tech Briefs Media Group (publishers of NASA Tech Briefs) — recognised innovation in product design in eight categories. The 2013 winner in the Sustainable Energy division was Lux Wind Power Ltd., Saskatoon, Saskatchewan, Canada for the Lux Wind Turbine. This is a vertical axis wind turbine (VAWT) which rotates around a vertical axis and does not require a tower or central column, lowering the total weight to less than half of the conventional turbines. This design uses six blades connected to a hub at the top and bottom of the rotor. The blades are also supported with cross cables running from blade to blade, forming a hexagon. Other advantages include an extremely low centre of gravity (ideal for offshore applications), the mechanical components are at ground level, traction drive eliminates the need for an expensive gearbox, and the blades are fully recyclable. Computer models, developed by the National Research Council's Institute of Aerospace Research (IAR) in Ottawa, Canada, show the blades have very little displacement, even in hurricane winds. LUX turbines are quieter because the blades rotate slower and they are not subjected to the tower shadow. The mechanical components are located at ground level, so the sound doesn't travel as far, and they can be easily and economically sound insulated.

More information from http://luxwindpower.com.

New Zealand Building Code

The New Zealand Ministry of Business, Innovation and Employment has recently held 3 workshops to "road test" the latest draft revision of section G6 of the New Zealand building code. This section of the code is currently titled "Airborne and Structureborne sound" and is the only document in NZ dealing with inter-tenancy noise. The current requirements are extremely limited, and the proposed revision aims to introduce requirements to control a much wider range of noise sources, including plumbing noise and external noise intrusion. It also specifically addresses issues that have proved to be controversial under the current provisions, issues such as horizontal and diagonal sound transmission. The revision has been in process for a number of years, and the acoustics fraternity are looking forward to finally seeing it completed. A number of issues were identified and recorded at the 3 meetings. A cost benefit study is underway and is expected to be completed in early April. MBIE intend seeking Cabinet approval of the proposed code clause in June. All going well it is intended that the revised clause will become operational by the end of 2014.

Pickering Award for Harold Marshall

Emeritus Professor Sir Harold Marshall from the School of Architecture and Planning at the University of Auckland has been awarded the Pickering Medal by the Royal Society of New Zealand, in recognition of his innovative acoustic design. Sir Harold, who is a former Professor of Architecture and also headed the Acoustics Research Centre at the University, is the co-founder of Marshall Day Acoustics, a world-renowned firm of acoustic consultants. For over thirty years Sir Harold has explored asymmetry in acoustic design, and his work includes the Christchurch Town Hall, the Guangzhou Opera House and more recently the Philharmonie de Paris. The Guangzhou Opera House received an RIBA International Award for architectural excellence, with the citation stating 'for all the auditorium's asymmetry, the acoustics are perfect'. The Pickering Medal is awarded annually. Named after William Pickering, a New Zealand born, world-acclaimed rocket scientist, the medal is bestowed on a person who, while in New Zealand, has through design, development or invention, produced innovative work of importance both nationally and internationally, or which have led to significant commercial success.

New Products

Event Comms Solution

In an industry-changing move, Australia's leading Event Communications supplier The P.A. People has partnered with Australia's number one digital two-way radio network, Orion - to bring Motorola's MOTOTRBO™ technology to the events industry. For the first time, the combination of The P.A. People communications experience and the reach and flexibility of the Orion network means deeply integrated, multi-site two-way communications are finally within the budgets of short-term events. The P.A. People has been granted access via IP to Orion's network, allowing them to patch any and all radio channels through digital matrix keystations. This enables any control room or production centre in Australia to monitor any channel of radio, from any site, at any time.

The P.A. People fleet of Motorola DP4801 radios have already been tested and deployed on several large-scale, multi-site urban events, such as Sydney New Year's Eve and Chinese New Year Celebrations, and the massive St Kilda Festival in Melbourne, which draws over 300,000 people to sites across the bayside suburb. The Motorola DP4801 was chosen for its durability in event conditions and its features such as; intelligent audio that automatically adjusts volume according to conditions, text message support, and a large, easy to navigate full-colour screen with excellent low and bright light readability that can be customised to display event logos.

Information: eventcomms@papeople.com.au tel 02 8755 8700

Regupol® Regufoam® Sound Range

The NEW Regupol® Regufoam® Sound range will revolutionise the way we look at building design and the ongoing treatment of impact sound here in Australia.

There are four unique products making up the NEW Regupol® and Regufoam® Sound Range, offering reduction in impact sound by up to ΔLW, 34dB. These products have remarkable stability under great static and dynamic loads. Each product is documented with its unique material composition and sound absorption characteristics shown in the new Regupol® Regufoam® Under-Screed Impact Sound Insulation catalogue.

Information: Nishi Kant Grover Tel: 02 4624 0050, nishi@regupol.com.au, http://www.regupol-vibration-technology.com.au/au/impact-sound-insulation/under-screed-impact-sound-insulation/downloads

New versions of MITHRA-SIG and MITHRA-REM.

MITHRA-SIG is a prediction software package dedicated to sound propagation modeling; MITHRA-REM is an electromagnetic field mapping software. They are both based on the powerful Geographic Information System Cadcorp SIS. They combine CSTB engines (powerful ray/beam tracing engine, accurate physical engines for noise propagation or electromagnetic wave propagation) and the Cadcorp technology at the cutting edge of GIS functionality and Industry standards. MITHRA-SUITE represents the culmination of 30 years of methodical research, led by the CSTB in France; the results have been validated by many field measurements.

MITHRA SIG is designed to compute noise maps up to towns or regions in a single operation

- Calculation method: Harmonoise, ISO 9613-2, NMPB2008& 1996 (NF S31-133, EU interim method),
- Road, Railway (train, light tramway), Industry (Wind farm incl.) including the Imagine database (EU database of more than 1000 sources spectrum),
- Automatic noise barrier design,
- Strategic noise mapping (simultaneous calculation of Lday, Levening, Lnight, Lden or by hour)
- Creation of dynamic maps: maps on receivers placed by the operator, 2D maps, 3D maps showing noise distribution on building facades and vertical sections,
- Calculation of population affected by noise and calculation of areas by noise levels,
- Data analysis showing maps before and after implementation of noise reduction procedures e.g. acoustics barriers or traffic rerouting.
- MITHRA-REM is a benchmark for population exposure to the electromagnetic fields produced by the antennas of the mobile phone operators. It allows:
- Settings of antennas and frequency bands,
- Display of radiation patterns (horizontal and vertical) from a selected antenna,
- Dynamic Horizontal, vertical, facade, receiver maps by switching electromagnetic transmitters on/off.

Information: noiseconsult@bigpond.com

CATT-Acoustic™

Audiometric & Acoustic Services have recently become the Australia and New Zealand distributor for the room acoustics and sound system prediction and auralization software CATT-Acoustic™. The software has a long history being used commercially for more than 20 years in mainly Europe and USA. In 2011, version 9 was released being based on the new TUCT™ (The Universal Cone-Tracer) which was a near total rewrite of all prediction and auralization algorithms giving a wider range of application and opened up for further future development. One such example was true early edge diffraction (screen formulas are not applicable in rooms with finite edges) that was introduced with v9.0c in 2012 and the next step is a total change and fundamental improvement of how sound sources and arrays are handled. Array modeling will be based on a new and very flexible array file format that also will handle curved line arrays with high-frequency line elements. Visit www.catt.se for examples of available features and a free comprehensive demo version.

Information: noiseconsult@bigpond.com

SONarchitect™

SONarchitect™ is the ultimate software tool for computation of acoustic insulation in buildings regarding EN 12354 in entire buildings. Airborne noise insulation, impact noise insulation, façade noise insulation, indoor-outdoor noise emission and reverberation time in the whole building. Just draw plan by plan, assign materials, creates the requirements and, in a matter of seconds, you'll get all the results.

One-third octave band parameters for assessing:

- Airborne and impact sound insulation between rooms (EN 12354-1,- 2)
- Airborne sound insulation against outdoor sound (EN 12354-3)
- Transmission of indoor sound to the outside (EN 12354-4)

Arbitrary geometries, more than 2000 materials in the database, fast and aesthetic data entry and results display: be more productive, challenge big projects.

Insert your own constructive solutions from your tests or from analytic models thanks to SONequation and SONmultilayer tools.

You can eventually generate a complete PDF report (or XML) with all the results and the acoustic quality of your building. Since you have all the acoustic insulation values, you can classify your building regarding the acoustic performance! Hear your building! It also performs 3D auralization of airborne noise insulation.

Suppliers can have their materials added to the database of SONarchitect ISO for free

Information: noiseconsult@bigpond.com

EcuDap EQD-Watchdog™

The EcuDap EQD-Watchdog™ is a multiband sound limiter/register (dynamic attenuation via DSP) which performs spectral limitation with analogical and digital input/output, configurable via the USB port. The software tool kit EcuDap Toolbox™ allows you to perform adjustments of the maximum emission level of the limiter on the premises (hearing conservation of patrons) and of the level transmitted to the most affected property (noise limits re State EPA policy control of music noise from public premises). It permits the use of one-third octaves level difference DnT(f) determined according to AS ISO 140-4-2006 or the weighted value DnT,w defined by the AS/ISO 717.1-2004.

As a register it allows the use of two microphones, with the capacity to measure both in dB (A) and dB(C) (Class 2). Hence Watchdog can monitor the levels in the venue and outside to report to the responsible authority.

Main Features:

- Dynamic attenuation via DSP
- Symmetric, balanced by TRF analogic XLR I/O
- D/D for great venues as theatres or concert halls. AES EBU / SPDIF I/O
- 24 bits A/D & D/A converters, 48kHz, TDH+N <0,002%
- 1/3 octave bands analysis, limitation (50Hz – 20 0000 Hz)
- Dynamic range (>110dB) and low latency (<100ms)
- 2 Microphones indoor/outdoor monitoring

- Logging data and Leq,60S (storage capacity: a month)
- Real time data transmission via Ethernet,
- A Citizen Awareness System : information about the environmental situation
- Configuration via USB port, software included
- Protected by electronic keys

All data provided is processed by the Inspection System (SIAC). It provides daily information about the incidences (Level, sensor disconnection, closing time, abnormal operations).

Information: noiseconsult@bigpond.com

SPIDER NV1

Integrated Remote Noise and Vibration Monitoring

Cloud based monitoring system that offers a cost effective, reliable and versatile platform dedicated to noise and vibration monitoring/data acquisition, data post-processing and reporting. The SPIDER NV1 noise and vibration platform is a complete hardware and software solution that can be used for simple hand held attended measurements to fully automated remote monitoring. The SPIDER NV1 can resolve any noise or vibration measurement requirements. This versatility makes the SPIDER NV1 system not only unique but it makes it very user-friendly and adaptable to a multitude of uses.

Main features of the system:

- Accessories - Up to six of the following devices can be plugged in to the Spider NV1 logger: Type 1 or Type 2 Microphones x2, Tri axial accelerometer x1 or Uniaxial accelerometer x3, Webcam x1
- Works anywhere in the world with mobile coverage
- Internal data storage as well as cloud if connected
- Data management, processing and reporting on cloud
- Light, portable and easy to operate
- Availability of measured data through a customizable website or any Wi-Fi device (smartphone or tablet) through a customizable application that connects to the SPIDER NV1 Wi-Fi network
- Real-time alarms sent via sms or email for user defined threshold

Information: www.telemetrix.com.au

SONarchitect ISO database

SONarchitect ISO database has more than 300 generic constructive solutions, more than 900 commercial solutions and continues to expand!

Contact: noiseconsult@bigpond.com if you want to add your materials to the database of SONarchitect ISO just for free.

Bruel & Kjaer

Noise Sentinel on Demand

Noise consultants - performing surveys, complaint assessment or compliance monitoring - no longer have to choose between buying expensive equipment or turning down work, with a new subscription-based service called Noise Sentinel On Demand. Investing in brand new equipment for one project is not viable, especially as it may not be used on a regular basis and can quickly become outdated. To overcome this, Brüel & Kjær designed Noise Sentinel On Demand, which is ideal for short term noise monitoring projects, including spot surveys or compliance monitoring for short construction projects.

Noise Sentinel is a web based system that displays real time noise, alerts the operator to any threshold exceedances and delivers regular noise compliance reports. Consultants can order the service online and everything needed for the job is delivered, so they can start measuring straightaway. The cloud based service makes the data immediately accessible from anywhere over the internet. When the monitoring project is complete, the equipment is returned, but the user can still access the measurement data.

Noise Sentinel On Demand is based on Brüel & Kjær's award winning Noise Sentinel, designed for permanent or long-term noise monitoring. The technology has been used over several years for long-term tunnelling and construction projects, as well as other noisy applications such as mines, ports, industrial premises and entertainment venues all over the world.

Information from Bruel & Kjaer Australia at auinfo@bksv.com or +61 2 9889 8888

SAVTek

24 Bit Apollo PCIe cards

SAVTek are proud to offer a range of new 24 bit acquisition cards – the same accuracy and flexibility of the SoundBook in a compact PCIe format. The acquisition cards have 4 or 8 channels of Lemo 7, BNC or SMB connectors.

The Apollo card can be plugged into any PC of your choice. The acquisition cards can be used with SAMURAI or MATLAB software (with SINUS MATLAB Toolbox). Sample rates of up to 204 kHz for each individual channel (each channel is independent) with 2 Tacho channels and ICP or 200V polarised power.

Industrial PCs are available with up to twelve PCIe cards! That's up to 96 synchronised channels in one computer! From as low as $800 per hardware channel. The German Aerospace Centre (DLR) is using a 300 channel system for laboratory research of noise and vibration.

Information from Darryl Watkins at SAVTek on 07 3300 0363 or dwatkins@savtek.com.au

CadnaR Room Modelling Software –2.2

CadnaR is the most efficient software for room acoustics modelling, to reduce noise in production facilities, to optimize the speech interference levels in open plan offices or to design professional acoustic spaces. The new version 2.2 expands its usability by adding various new functionalities.

- Stereoscopic 3D View: The last step of an acoustical consultation is the presentation of measures and effects to a third party which is often not an acoustician. Together with a 3D enabled screen (3D Monitor, 3DTV) and 3D passive glasses, CadnaR projects can be presented in three-dimensional form.
- The ObjectTree: CadnaR has a sophisticated concept for organizing large projects. All objects can be structured hierarchically within the ObjectTree or organized in groups. Based on this organizational scheme, it's easy to assign groups and subgroups to different variants and to compare several scenarios in one file. CadnaR version 2.2 now allows to move and copy objects and ObjectTree groups by Drag & Drop. Furthermore, it enables to import whole machineries and complex systems from other CadnaR files. With the help of these new features, available systems can be combined, copied or modified to build new scenarios in a very simple and intuitive way
- 3D Symbol Library: 3D-Objects and models (like people, furniture, etc.) can be imported and applied to any CadnaR project. These objects can help to provide a clear overview for people who are not familiar with the local situation. Furthermore, it enables a better understanding of the acoustical problems within a project. With the new "Symbol 3D Local Library" you can import 3D models designed in CAD software. All visual details, like textures and transparency can be edited and included.

Information from: Rodney Phillips at Renzo Tonin & Associates on 02 8218 0500 or

http://www.datakustik.com/en/products/cadnar/why-cadnar/demo-version/

FUTURE EVENTS

AIRAH Acoustics Workshop 2014

AIRAH is calling for abstracts (200-300 words) for the Acoustics Workshop 2014 which will be held in Sydney on Thursday, September 18. Topics must be relevant to acoustics, and may include, but are not limited to:

- Acoustics and sustainability
- Environmental design initiatives and acoustics
- Standards and regulations
- Building services acoustics, including HVAC&R
- Open building spaces/services acoustics
- Vibration
- BIM and acoustics tools

Abstracts should be sent to AIRAH conference organiser Laura Atkinson by Monday, April 28 and should also include a 100-word author biography and high-resolution author photo.

Information from Events at www.airah.org.au or conferences@airah.org.au

Noise-Con 2014

The next in the series of INCE USA conferences, Noise-Con 2014, is to be held at the Westin Beach Resort & Spa in Fort Lauderdale, Florida, 8-10 September, 2014. The theme for this conference is "Advancing the Technology and Practice of Noise Control Engineering". Noise-Con 2014 will feature, along with the technical program,

- Exposition of vendors displaying noise and vibration control materials, analysis software, and measurement systems and instrumentation
- Several short courses on noise and vibration
- Special events for students, women in noise control engineering, and young professionals
- Plenary sessions on Noise and Vibration Control on HVAC Systems, Archeo-Acoustics, and Marine Bioacoustices

The Westin Beach Resort & Spa is located along the beach front, with prime access to diving, sailing, fishing, and restaurants. Catch the water taxi for a tour of the inner coastal or to access prime shopping in the heart of Fort Lauderdale.

Information: www.inceusa.org/nc14

BOOK REVIEWS

Principles of Occupational Health and Hygiene

Editors Sue Reed, Dino Pisaniello, Geza Benke & Kerrie Burton

ISBN 978 1 74331 129 5 Published by Allen & Unwin, 2nd edition 2013

This is the 2nd edition of this reference book, which is published in association with the Australian Institute of Occupational Hygienists (AIOH). The provenance goes back to a 1992 Guidebook for Workplace Health and Safety Officers by Dr David Grantham. Dr Grantham ceded the rights to the AIOH and many members of that Institute freely contributed to the first edition, which was published in 2007. Similarly the content of the 17 chapters of the 2nd edition has been freely contributed by AIOH members and the guidance of the fourperson editorial panel. The target audience is primarily occupational hygienists, however it is a relevant reference book for all those working in allied fields.

Acousticians working in the area of noise and vibration control may also be involved in workplace noise and vibration investigations and this book has a relevant chapter on noise and vibration. However the acoustician can gain a valuable insight of the other areas of occupational health and hygiene. For example, the conflicts that can arise from multiple personal protective devices, the guidance on the number of data samples necessary for similar exposure groups, the concept of exposure standards etc. The layout of the book is clear and each section commences with a table of contents for that section allowing the reader to quickly find the section of particular interest.

The chapter on 'Noise and Vibration' has been written by Beno Groothoff, a member of both the AIOH and the AAS. After working in the area of occupational hygiene for the Qld Government he is now in private practice. The topics covered in the 47 pages include the exposure limits, measurement options, control options, personal hearing protectors, acoustic shock, ototoxins, audiometry plus an introduction to human vibration in the workplace. Coverage of all the topics at the necessary level is achieved effectively. Of course there are always topics one would like to see further explained or included. For example, impulse noise is barely mentioned except in relation to the LCpeak limit and there is no guidance on double hearing protection (muffs and plugs). Reference is made to the relevant Australian Standard but it would be useful to supplement the explanation in the text of the daily noise exposure determination with a worked example. In contrast, while acoustic shock is an important issue, the incidence in the workforce would hardly justify 2.5 pages on this topic alone.

Particularly because of the Australian focus, this would be a useful reference book for any acoustics organization that may be involved with workplace noise assessments or noise control. It would also be valuable reference for those involved with presenting or undertaking noise courses.

Marion Burgess

Noise Mapping in the EU: Models and Procedures

Editor Gaetano Licitra

ISBN 978-0-203-84812-8 (eBook) Published by CRC Press, 2013

This book comprises 18 chapters covering the aspects of noise mapping issues of relevance to all the stakeholders involved. The EU Directive 2002/49/EC set the scene for requirements of noise mapping throughout the EU. Since then there has been a concerted effort to develop, validate and improve noise mapping software so that the quality of the information provided is useful. Noise mapping is a challenging task with the complexity of the sound sources and the propagation in and around cities. This book, from 17 contributors, discusses all the main issues associated with noise mapping from within the context of the EU Directive.

Chapter 1 is on fundamentals of sound and the other 17 chapters are conveniently grouped within 4 parts. Part 1 on Noise Evaluation and Mapping commences with the legal basis in the EC and the following 7 chapters deal with noise sources, measurement, modelling and, importantly, uncertainty and quality assurance for the modelling outcomes. Part 2 has 3 chapters on Noise Mapping and Geographic Information Systems (GIS). When blended properly, the combination of the acoustics with GIS can produce visual information over a region that can be understood by the authorities, planners and the public. Part 3 has two chapters dealing with Noise Mapping in Europe including a very useful overview. Part 4 on Communication and Action Plans comprises 3 chapters which should be compulsory reading before any authority embarks on the task of producing whole-of-city noise maps. The purpose for the maps and their limitations should be fully appreciated and especially how the information will be used to provide an improved acoustic environment for the community involved. The final chapter on Future Perspectives opens the discussion on extending the regulatory requirement for noise mapping to annoyance mapping with a consideration of soundscape.

While the context is the requirements in the EU, this book is an excellent reference on relevant aspects of noise mapping. It achieves the goal of being readable and of value to all the stakeholders that may be involved at any stage of a noise mapping project. The variety of authors bring a wealth of experience and knowledge to each chapter and this more than offsets any changes in style or small overlaps in content. Personally, I find trying to read such a technical book as an eBook very challenging, so it is good to see that a hardback edition is also available.

Marion Burgess

Marion Burgess is a research officer in the Acoustics and Vibration Unit of UNSW, Canberra. She is involved with presenting courses, research projects and consulting that include occupational and environmental noise and vibration

DIARY

2014

1 – 5 June, Nara, Japan
11th International Congress on Noise as a Public Health Problem (ICBEN 2014)
http://www.icben2014.com/

16 - 18 June, Paris, France
Ecology and acoustics: emergent properties from community to landscape
http://ecoacoustics.sciencesconf.org/

6 – 10 July, Beijing, China
21st International Congress on Sound and Vibration (ICSV21)
http://www.iiav.org/index.php?va=congresses

7 - 12 September, Krakow, Poland
Forum Acusticum 2014
http://www.fa2014.pl/

8 - 10 September, Fort Lauderdale, Florida
Noise-Con 2014
http://www.inceusa.org/nc14

29 September - 1 October, Berlin, Germany
Low Frequency Noise & Vibration & its Control http://www.lowfrequency2014.org

16 – 19 November, Melbourne, Australia
Inter-Noise 2014
http://www.internoise2014.org/

2015

10 – 15 May, Metz, France
International Congress on Ultrasonics (2015 ICU)
http://www.me.gatech.edu/2015-ICU-Metz/

31 May - 3 June, Maastricht, Netherlands
Euronoise 2015
https://www.euracoustics.org/events/events-2015/euronoise-2015

12 - 16 July, Brescia, Italy
22nd International Congress on Sound and Vibration (ICSV22)
http://www.iiav.org/index.php?va=congresses

9-12 August, San Francisco, USA
Inter-Noise 2015
http://internoise2015.com

6-10 December Singapore,
Wespac 2015
wsgan@acousticaltechnologies.com

2016

10-14 July, Athens, Greece
23rd International Congress on Sound and Vibration (ICSV23)
http://iiav.org/index.php?va=congresses

5-9 September, Buenos Aires, Argentina
22nd International Congress on Acoustics (ICA 2016)
http://www.ica2016.org.ar/

12-16 September 2016, Terrigal, NSW, Australia
International Workshop on Rail Noise (IWRN)
http://www.acoustics.asn.au/IWRN12

Meeting dates can change so please ensure you check the conference website: http://www.icacommission.org/calendar.html

Sustaining Members

The following are Sustaining Members of the Australian Acoustical Society.
Full contact details are available from http://www.acoustics.asn.au/sql/sustaining.php

3M AUSTRALIA
www.3m.com

ACOUSTIC RESEARCH LABORATORIES
www.acousticresearch.com.au

ACOUSTICA
www.acoustica.com.au

ACRAN
www.acran.com.au

ACU-VIB ELECTRONICS
www.acu-vib.com.au

ADAMSSON ENGINEERING
www.adamsson.com.au

AERISON PTY LTD
www.aerison.com

ASSOCIATION OF AUSTRALIAN ACOUSTICAL CONSULTANTS
www.aaac.org.au

BARRISOL AUSTRALIA
www.barrisol.com.au

BORAL PLASTERBOARD
www.boral.com.au/plasterboard

BRUEL & KJAER AUSTRALIA
www.bksv.com.au

CSR BRADFORD INSULATION
www.bradfordinsulation.com.au

EMBELTON
www.vibrationisolation.com.au

HOWDEN AUSTRALIA
www.howden.com.au

IAC ACOUSTICS (AUSTRALIA)
www.iac-acoustics.com/au/

INSTYLE CONTRACT TEXTILES
www.instyle.com.au

JACOBS
www.jacobs.com

MASON MERCER AUSTRALIA
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