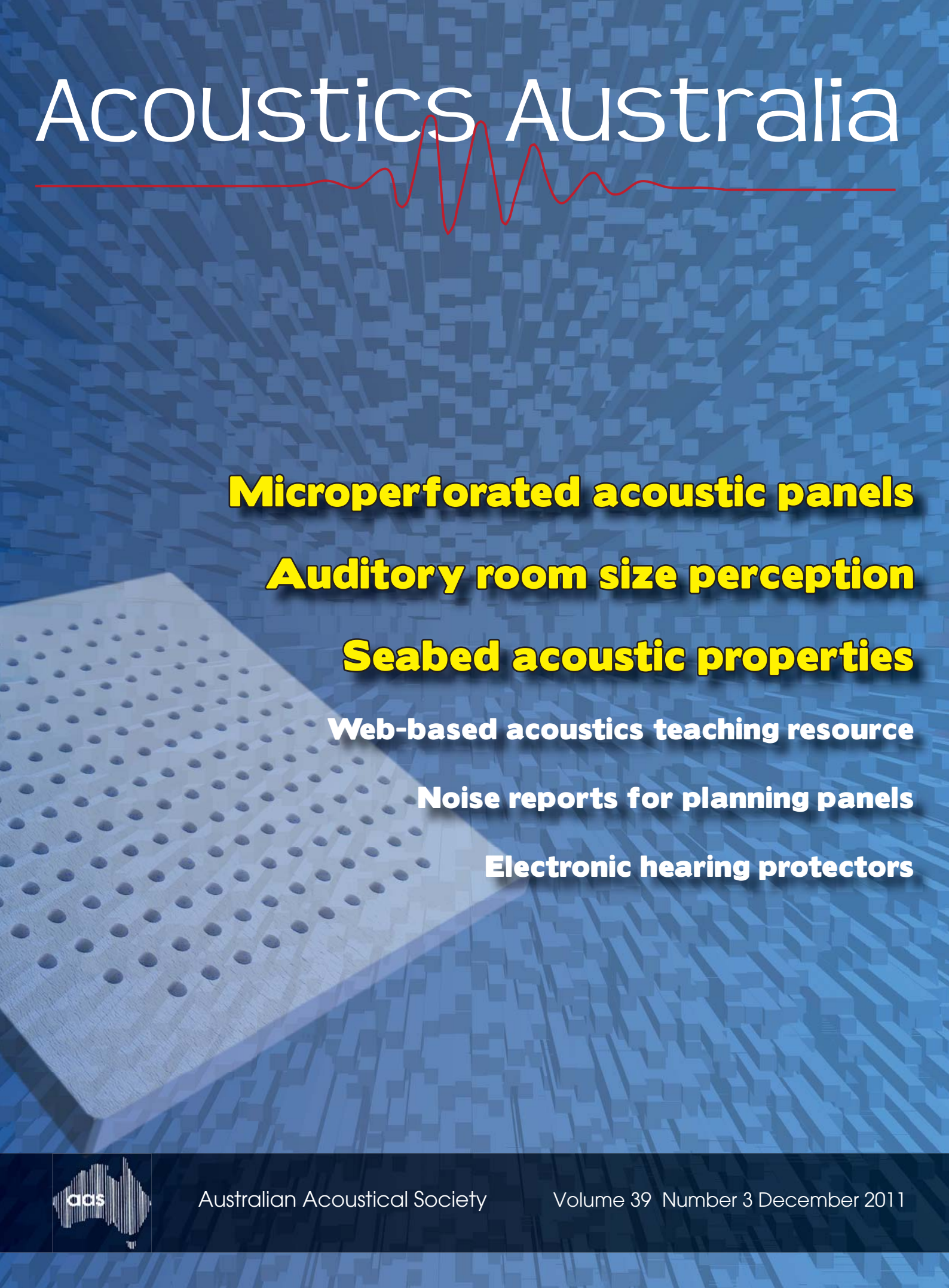
Acoustics Australia



Microperforated acoustic panels

Auditory room size perception

Seabed acoustic properties

Web-based acoustics teaching resource

Noise reports for planning panels

Electronic hearing protectors

Australian Acoustical Society Volume 39 Number 3 December 2011

SignalCalc ACE
QUATTRO

ACE-QUATTRO has:

- Standard FFT, Synthetic 1/3 Octave standard,
- Quality Control, Point & Direction,
- Sound Power, Sound Intensity,
- Acoustic Intensity, Human Vibration,
- Sound Quality, Demodulation,
- Disk Record & Playback Analysis,
- Frequency Domain Compensation,
- Real Time Octave Analysis, Event Capture,
- 4-32 Inputs (Abacus), 2-8 Outputs + Tachy,
- ActiveX command & control macro programs,
- Single to Multi-Plane Balancing ...and more

BSWA TECH

MEASUREMENT MICROPHONES.

microphones & accessories for Australian & NZ.

High quality, calibrated electret prepolarized microphones to class 1 & 2 & preamplifiers.

Some of the Accessories available:

- IEPE power sources, - portable sound level calibrators,
- USB powered 2 channel measurement soundcard
- a 12 speaker dodecahedral sound source,
- compact light weight 2 channel power amplifiers,
- a self contained Tapping Machine sound source for foot fall measurements.
- impedance tubes providing 125 Hz to 3200 Hz range,
- Outdoor noise monitoring, terminal and software
- Small Reverberation chamber,
- Artificial Ear, Mouth & Head

For more information phone: **02 9975 3272**
or visit: ***www.kingdom.com.au***

KINGDOM PTY LTD

Acoustics Australia

EDITORIAL COMMITTEE:
Nicole Kessissoglou , Marion Burgess, Tracy Gowen

BUSINESS MANAGER: Leigh Wallbank

Acoustics Australia
General Business
(subscriptions, extra copies, back issues, advertising, etc.)
Mrs Leigh Wallbank
P O Box 70
OYSTER BAY NSW 2225
Tel (02) 9528 4362
Fax (02) 9589 0547
wallbank@zipworld.com.au

Acoustics Australia
All Editorial Matters
(articles, reports, news, book reviews, new products, etc)
The Editor, Acoustics Australia
c/o Nicole Kessissoglou
School of Mechanical and Manufacturing Engineering
University of New South Wales
Sydney 2052 Australia
+61 401 070 843 (mobile)
AcousticsAustralia@acoustics.asn.au
www.acoustics.asn.au

Australian Acoustical Society
Enquiries see page 130

Acoustics Australia is published by the Australian Acoustical Society
(A.B.N. 28 000 712 658)
ISSN 0814-6039

Responsibility for the contents of articles and advertisements rests upon the contributors and not the Australian Acoustical Society. Articles are copyright, by the Australian Acoustical Society. All articles, but not Technical Notes or contributions to Acoustics Forum, are sent to referees for peer review before acceptance. Acoustics Australia is abstracted and indexed in Inspec, Ingenta, Compendix and Acoustics Archives databases, Science Citation Index Expanded and in Journal Citation Reports/ Science Edition.

Printed by
Cliff Lewis Printing
91-93 Parraweena Rd,
CARINGBAH NSW 2229
Tel (02) 9525 6588
Fax (02) 9524 8712
email: matt@clp.com.au
ISSN 0814-6039

Vol 39 No. 3 December 2011

PAPERS

Sound absorption characteristics of a single microperforated panel absorber backed by a porous absorbent layer
Kimihiro Sakagami, Seiji Kobatake, Ken'ichi Kano, Masayuki Morimoto and Motoki Yairi . . . **Page 95**

Auditory room size perceived from a room acoustic simulation with autophonic stimuli
Manuj Yadav, Densil Cabrera and William. L. Martens. . . . . **Page 101**

The effect of seabed properties on the receive beam pattern of a hydrophone located on the seafloor
Miles J.G. Parsons and Alec J. Duncan . . . . . **Page 106**

TECHNICAL NOTES

Road traffic controllers and the use of level dependent hearing protectors
W. Williams and B. Groothoff . . . . . **Page 113**

Effective noise reports and presentations for planning panels
Paul Mitchell .. . . . . **Page 117**

Physclips: a multimedia, multi-level introduction to mechanics, waves and sound
Joe Wolfe, George Hatsidimitris and John Smith . . . . . **Page 119**

News 121
New Products 123
Meeting Reports 123
Future Conferences. 123
Diary 126
Sustaining Members 128
Advertiser Index 130

Cover design: Helena Brusic

Acoustic Research Laboratories

Proprietary Limited A.B.N. 47 050 100 804

Noise and Vibration Monitoring Instrumentation for Industry and the Environment

CALIBRATION

ARL CAN NATA CALIBRATE A WIDE RANGE OF ACOUSTICAL INSTRUMENTS IN THE FOLLOWING FIELDS:

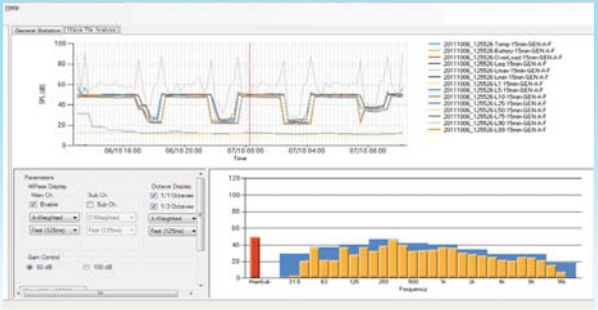
- SOUND LEVEL METERS
- ACOUSTIC CALIBRATORS
- NOISE LOGGERS
- OCTAVE BAND FILTERS

HIRE

- FULL RANGE OF NATA CERTIFIED NOISE LOGGERS, SOUND LEVEL METERS AND CALIBRATORS AVAILABLE
- VIBRATION LOGGERS ALSO AVAILABLE

A WIDE RANGE OF NOISE MONITORING INSTRUMENTS AND SOFTWARE:

- NGARA REAL TIME SOUND ACQUISITION SYSTEM
- FIREFLY POST PROCESSING SOFTWARE
- RION SOUND LEVEL METERS AND LOGGING KITS



www.acousticresearch.com.au

Ph: 02 9484 0800

cliff lewis printing

Specialists in Scientific Printing and Publishing

MORE THAN JUST PRINTING

- Art and Design
- Branding Design
- Stationery
- Binding & Finishing
- Promotional Material

t (02) 9525 6588 f (02) 9524 8712
e printing@clp.com.au
www.clp.com.au
91-93 Parraweena Road, Taren Point, NSW 2229

Matrix Resilient Wall Ties and Floor Mounts

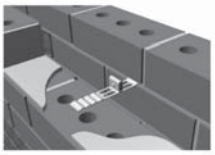
The Matrix range of resilient acoustic wall ties and floor mounts are a structural connection that reduces airborne and impact noise passing through masonry and stud walls. They are suitable when discontinuous construction is required in separating walls and any specialised room that requires high acoustic isolation.

MB01 - Resilient masonry wall tie for cavity width 40mm - 100mm.

SB06 - Resilient masonry wall tie for joining stud walls.

SB08 - Universal resilient masonry wall tie for stud or stud to stud cavity 20mm to 100mm.

SB03 - Resilient stud wall tie for attaching top plate or underside of slab or masonry wall.



FM01 - Resilient floor mount -reduces impact vibration passing through floors.

MB04 - Resilient masonry wall tie for attaching a pre-built masonry or stud wall.

SB10 and MB10 HD wide cavity acoustic wall mount in 2mm x 38 mm Gal or SS for 200mm to 450+ cavities.

MB08 - Universal resilient masonry wall tie for cavities 20mm - 100mm.

Matrix Industries Pty Ltd

144 Oxley Island Road, Oxley Island, NSW 2430
Phone: +61 2 6553 2577 Fax: +61 2 6553 2585
www.matrixindustries.com.au

Message from the President

It is that busy time of the year, with Christmas fast approaching, work and projects to be completed and holidays being planned for the Christmas and New Year break. This year has certainly passed quickly and I wish to reflect on the recent AAS Annual Conference and associated events.

The Queensland Division and their sponsors are to be congratulated for their very successful conference 'Acoustics 2011 – Breaking New Ground' held in Surfers Paradise on 2-4 November 2011. The success was due to the number of members, non-members and exhibitors attending; quality of and variation of papers; plenary presenters, presenters and workshops; the venue and catering; and the organizing committee (Matthew Terlich, Ian Hillock, Claire Richardson and Michael Caley) and their assistants. The interaction between attendees, and the exhibitors at morning, afternoon and lunch break sessions was commendable. It was pleasing to see so many younger people attending the conference.

Prior to and during these annual conferences the Federal Councillors attend their face to face meetings to conduct the official business of running the society, in accordance with our articles of association and registered companies requirements. On behalf of the society I thank the councillors for the preparation, time and effort in attending to these duties. It is worthy to highlight several outcomes from our recent meetings and these are noted below:

- Colin Speakman: Award of Fellow (see page 121)
- Student Members: Waive of annual membership fee (application fee still stands and journals provided via the AAS website on-line service)
- STA Membership: Resigned
- Website: Upgrade (sub-committee of Terry McMinn our current web manager/registrar, Matthew Stead and Peter Heinze)

If anyone has any suggestions, comments or recommendations, regarding our website (look, navigation, contents, etc) would you kindly email the above sub-committee who would be only too pleased to receive these for consideration in the upgrade.

Also due to the short term highly popular access to the current digitized journal articles that were placed on our website, www.acoustics.asn.au, in June 2011, the councillors have approved our webmaster to complete the digitizing of all journal articles and include these on our website.

It was an honour and pleasure to be part of the awards presentation during the congress dinner. These included:

- AAS Annual Conference President's Prize awarded to paper number 102 titled *Modelling the vibrational behaviour of composite archery bows* by Marianne Rieckmann, John Codrington and Ben Cazzolato. Accepted by Ben Cazzolato on behalf of Marianne Rieckmann. Thanks to the QLD division congress organizing committee for review and recommendations.
- AAS Education Grant awarded for further research in *Calculation of the angular and sensitivity response of an underwater acoustic beamforming system* by Shane Chambers, Ralph James and Alec Duncan. Accepted by Alec Duncan on behalf of Shane Chambers. Special thanks to our education grant subcommittee of Charles Don and John Davy.

PS. Whilst on this grant topic please note that there is a total of $15K available each year and we strongly encourage submissions, as multiple grants may be provided across several projects, and not necessary the full amount. The application form and details can be found at http://www.acoustics.asn.au/joomla/notices.html

- Colin Speakman's posthumous award of Fellow – I read part of his citation that Claire Richardson had prepared, and then invited Matthew Terlich and Richard Booker, both personal friends, to assist in presenting this award to Colin's wife Kate Niland.

Unfortunately this year there was no CSR award for Excellence in Acoustics, due to lack of submissions. We encourage applications from members that have demonstrated innovation from within any field of acoustics. The application form can be downloaded from the above referenced notices site.

My last comment regarding the conference relates to our AGM. It is a necessary legal requirement, and usually dispensed with in short time frame given all documents are issued prior to the meeting and located on our website. However, disparagingly we had initial difficulty reaching our quorum, surprisingly so when there so many members present at the conference. In future, if attending the annual conference please assist your federal representatives with this task.

I take this opportunity to welcome Barrisol as a new sustaining member of the Society.

The 2012 conference of the Australian Acoustical Society – ACOUSTICS 2012: Acoustics, Development and the Environment, is well into its planning and will be held in Perth, Western Australia from 21 to 23 November 2012. Please make a note in your calendars.

A more recent news highlight, on 29 November 2011, the I-INCE Congress Selection Committee officially approved the Inter-Noise 2014 Congress to be held in Melbourne. Congratulations to Norm Broner (Congress President) for the bid preparation and Charles Don who presented the bid to the congress selection committee. Norm will definitely require assistance and I trust that the acoustic fraternity, and those particularly from the VIC division, will assist him to provide a successful international congress.

Along with the federal councillors I take this opportunity to wish everyone a safe and enjoyable break over Christmas and New Year period and best wishes for 2012.

Peter Heinze

Message from the Editor

Yet another year has flown by. I hope you have enjoyed Acoustics Australia this year. I'd like to thank all the authors and reviewers who have contributed to the success of the journal. I would also like to thank the rest of the editorial team, Marion Burgess and Tracy Gowen, as well as the business manager, Leigh Wallbank, and the creative director, Louise Fraenkel, for their hard work this year. I can now relax for a while as the next issue of the journal (April 2012) is being organised by Dr Norm Broner and will be a special edition on wind turbine noise. If you would like to contribute an article to this edition, please send us your paper by the end of January 2012. My best wishes to everyone for the festive season and I look forward to your readership in 2012.

Nicole Kessissoglou

SAVTek Rentals

For a detailed list visit:
www.savtek.com.au/rental.html

Now renting a wide range of equipment including:

- Soundbooks
- Wireless Microphone System
- CESVA VC431 Vibrometer

Seen at the **2011 Conference of the Australian Acoustical Society** on the Gold Coast

SoundBook by SINUS

- Multi channel data acquisition of noise and vibration with powerful and flexible real time analysis using SAMURAI software
- 2, 4 or 8 channels with Lemo7 or BNC connectors

CESVA VC431 Vibrometer

- For building vibration (ISO 8041), hand/arm (ISO 5349-2) or whole body (ISO 2631-1) vibration
- Simple and easy to use
- Results are downloaded and analysed with the supplied software

AP1021 Microphone Wireless System

- Type 1 wireless transmission up to 100m outside, inside to outside or between rooms.
- 6 hours rechargeable battery life

SAVTek Pty Ltd
Sound and Vibration Technology

Phone: (07) 3300 0363 | **www.savtek.com.au**

SOUND ABSORPTION CHARACTERISTICS OF A SINGLE MICROPERFORATED PANEL ABSORBER BACKED BY A POROUS ABSORBENT LAYER

Kimihiro Sakagami[1]*, Seiji Kobatake[1], Ken'ichi Kano[1], Masayuki Morimoto[1] and Motoki Yairi[2]
[1]Dept. of Architecture, Graduate School of Engineering, Kobe University Rokko, Nada, Kobe 657-8501, Japan
***saka@kobe-u.ac.jp**
[2]Kajima Technical Research Inst., Chofu, 182-0036 Tokyo

A microperforated panel (MPP) is usually used with an air-back cavity backed by a rigid wall to form a Helmholtz-type resonance absorber. In the case of a common perforated panel with larger perforations, a porous absorbent is usually located behind the panel to add acoustic resistance for efficient sound absorption. In the case of an MPP, if a porous layer is inserted in the cavity, the absorption may be deteriorated by the large acoustic resistance due to the porous absorbent. However, if the resistance is suitably adjusted, it is expected that a porous layer can widen the absorption frequency range by the additional damping by the porous absorbent. In this study, a single-leaf MPP absorber backed by a rigid-back wall with a porous absorbent layer in the cavity is analysed using an electro-acoustical equivalent circuit model and its absorption characteristics are discussed through the numerical examples.

INTRODUCTION

A microperforated panel (MPP) was proposed by Maa [1-4] as a 'next-generation' alternative for porous sound absorbers which has various problems in health, sanitary and environmental aspects. Many studies have since been performed on MPPs [5-8]. The basic form of an MPP absorber is composed of an MPP and a rigid-back wall with an air-back cavity in-between. The microperforations and the air cavity form Helmholtz-type resonators. Comparing an MPP absorber with the traditional Helmholtz resonators and perforated panels (with larger perforations), MPP absorbers with microperforations in a very thin panel realise the optimal acoustic resistance and reactance. This results in a relatively wide sound absorption frequency range of around 2 octaves [9-11]. However, even though the sound absorption frequency range is much wider than usual resonance-type absorber, MPPs are still frequency-selective absorbers and no absorption can be expected except for the resonance frequency range.

Considering these circumstances, the authors have been trying various attempts to make more wideband sound absorbers with MPPs [12-16]. These methods, however, have shortcomings. For example, using more leaves than single absorbers, the system becomes more complex. Therefore, if it is possible to obtain a wider absorption frequency range with a simple method, it will be more efficient both in cost and practical aspects.

In this study, the effect of a porous material inserted in the back cavity of an MPP sound absorber is investigated. In the case of a common perforated panel with larger perforations, the acoustic resistance of the perforation is very low. Therefore, in order to add resistance and to obtain higher sound absorption, it is common practice to place a porous layer behind a perforated panel [17] (with larger perforation which is commonly used in room interior surfaces). On the contrary, in the case of an MPP, the acoustic resistance and reactance are in general already optimised. Therefore, additional resistance due to the porous layer may cause a too large resistance resulting in lower sound absorption. Furthermore, the resonance system may be damped by the additional resistance due to porous layer, and resonance-type absorption can be deteriorated. Porous-layer backed perforated panels have been investigated by many previous authors. Mechel [18, 19] studied porous-backed perforated panels in details, however the perforation considered in his studies is much larger than that of an MPP (which is typically of diameter and thickness less than 1 mm). The acoustic properties and behaviour of a typical perforated panel and an MPP are substantially different.

In the case of an MPP, the effect of the acoustic resistance on the peak absorption appears rather soft, and the optimal value is not very critical [13]. In other words, when the parameters are chosen properly, additional acoustic resistance by the porous layer can make the absorption frequency range broader without deteriorating the peak absorption.

An MPP is originally proposed as a substituting material for porous absorbers, it may seem a contradiction to use a porous layer in MPP absorption systems. However, new-type porous absorbents with sanitary and environmentally superior properties have been recently proposed [20]. In addition, in many cases using a porous layer behind an MPP does not deteriorate the advantageous design of MPPs. Therefore, using a porous layer behind an MPP can be considered to be one of the possible alternatives for improving the sound absorption performance of MPP sound absorption structures.

In this study, the case of the most basic form of an MPP absorber corresponding to a single-leaf MPP backed by a cavity and a rigid wall, with a porous layer inserted in the cavity, is analysed using a electro-acoustical equivalent circuit model.

As a preliminary study, the effect of an end-correction of the open ends of the perforations is initially investigated. Mechel's work gives a physical insight into this problem for a typical traditional perforation panel [18, 19]. However, his work is not applicable for MPP cases. Therefore, the end-correction for an MPP backed by a porous layer is derived using traditional theory [21]. The sound absorption characteristics of the porous-backed MPP and the possibility of wideband sound absorption are discussed through numerical examples.

BASIC ELECTRO-ACOUSTICAL EQUIVALENT CIRCUIT ANALYSIS: MAA'S THEORY

Figure 1 shows the model of a single-leaf MPP sound absorber backed by a rigid wall and a back-cavity filled with porous absorbent in-between. The figure also shows its electro-acoustical equivalent circuit model. The MPP has the following parameters: thickness t, hole diameter d, perforation ratio p. The depth of the back-cavity is D. The normal incidence of a plane sound wave of unit amplitude is assumed.

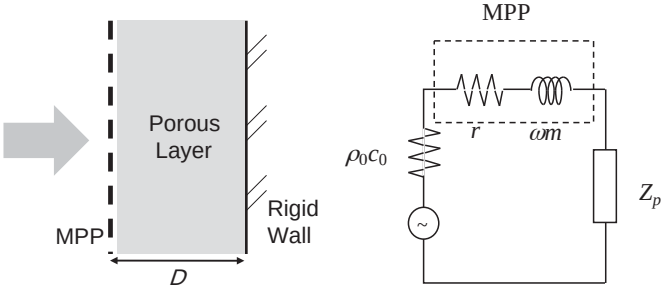


Figure 1. Geometry of a porous layer-backed single MPP absorber (left) and its electro-acoustical equivalent circuit model (right)

The specific acoustic impedance of the MPP, $Z_{mpp} = r - i\omega m$, is derived by the following formulae proposed by Maa [2]. These impedances are normalised to the air impedance $\rho_0 c_0$.

$$r = \frac{32\eta t}{p\rho_0 c_0 d^2}\left(\sqrt{1+\frac{K^2}{32}}+\frac{\sqrt{2}}{32}\,K\frac{d}{t}\right) \tag{1}$$

$$\omega m = \frac{\omega t}{\rho c_0}\left(1+\frac{1}{\sqrt{9+\frac{K^2}{2}}}+0.85\,\frac{d}{t}\right) \tag{2}$$

where

$$K = d\sqrt{\frac{\omega\rho_0}{4\eta}} \tag{3}$$

ρ_0 is the air density, c_0 is the sound speed in air, ω is the angular frequency, η is the viscosity of the air (1.789×10^{-5}[Pa.s]).

The impedance of the back-cavity with the depth D is given by the following formula with the propagation constant γ (Note that, in the case of air back-cavity, $\gamma = -ik_0$ with $k_0=\omega/c_0$, and $Z_a=\rho_0 c_0$):

$$Z_p = Z_a \coth \gamma D \tag{4}$$

From these impedances, the total acoustic impedance of the equivalent circuit Z_{total} is derived, from which the absorption coefficient of the absorption system α is obtained by $\alpha = \mathrm{Re}[Z_{total}] / [\{\mathrm{Re}[Z_{total}]+1\}^2 + \{\mathrm{Im}[Z_{total}]\}^2]$.

PRELIMINARY STUDY: END-CORRECTION FOR AN MPP BACKED BY A POROUS LAYER

The radiation impedance of the open end of a tube, Z_r, where the open end is regarded as a piston, is presented. The radiation impedance of the piston, Z_r, is expressed as follows [21]. (Note that Z_r is not normalised to the air impedance.)

$$Z_r = Z_k\left(\frac{(kd)^2}{8} - i\,\frac{4}{3\pi}\,kd\right) \tag{5}$$

k and Z_k are the wavenumber in the surrounding media to which the sound is radiated, and its characteristic impedance, respectively.

In the case of radiation to air

The wavenumber of air is k_0 and its characteristic impedance is $\rho_0 c_0$. Therefore, the radiation impedance of the open end (to the air), $Z_{r(air)}$, is expressed by Eq. (6), by using the acoustic resistance r_{air} and reactance ωm_{air}, in the following equation (note that $Z_{r(air)}$ is not normalised to the air impedance):

$$Z_{r(air)} = r_{air} - i\omega m_{air} \tag{6}$$

where

$$r_{air} = \frac{\rho_0 c_0}{8}\,(k_0 d)^2 \tag{7}$$

$$\omega m_{air} = \rho_0 c_0\left(\frac{4}{3\pi}\,k_0 d\right) \tag{8}$$

In the case of radiation to a porous layer

The wavenumber is k_1, propagation constant γ, and characteristic impedance is Z_a. The wavenumber and the propagation constant have the following relationship:

$$\gamma = -ik_1 \tag{9}$$

For the porous layer, the characteristic impedance and propagation constant are given by Miki's formulae [22] with its flow resistivity. (Note: Z_a is not normalised to the air impedance):

$$Z_a = \rho_0 c_0 (E_1 + iE_2) \tag{10}$$

$$\gamma = k_0 (E_3 - iE_4) \tag{11}$$

where

$$E_1 = 1+0.07\left(\frac{f}{R}\right)^{-0.632} \quad (12)$$

$$E_2 = 0.107\left(\frac{f}{R}\right)^{-0.632} \quad (13)$$

$$E_3 = 0.16\left(\frac{f}{R}\right)^{-0.618} \quad (14)$$

$$E_4 = 1+0.109\left(\frac{f}{R}\right)^{-0.618} \quad (15)$$

The radiation impedance of the open end of a tube to a porous layer $Z_{r(porous)}$ is in general expressed by Eq. (16) using the acoustic resistance r_{porous} and reactance ωm_{porous}, which are obtained by using Eq. (5) with k and Z_k of the medium and Eqs. (9) to (15) (Note: $Z_{r(porous)}$ is not normalised to the air impedance):

$$Z_{r(porous)} = r_{porous} - i\omega m_{porous} \quad (16)$$

where

$$r_{porous} = \rho_0 c_0 (E_1F_1 - E_2F_2) \quad (17)$$

$$\omega m_{porous} = -\rho_0 c_0 (E_1F_2 + E_2F_1) \quad (18)$$

$$F_1 = \frac{4E_3}{3\pi} k_0 d + \frac{1}{8}(k_0 d)^2\left(E_4{}^2 - E_3{}^2\right) \quad (19)$$

$$F_2 = \frac{1}{4}(k_0 d)^2 E_3 E_4 - \frac{4E_4}{3\pi} k_0 d \quad (20)$$

MPP impedance using the end-correction derived from the radiation impedance from the open end

In the case of an MPP backed by air, the MPP impedance Z_1 is expressed using the acoustic resistance r_1 and reactance ωm_1. Replacing the second term in brackets of Eq. (1) and the third term in brackets of Eq. (2), which express the end-correction, with Eqs. (7) and (8), respectively, results in the following equation for the radiation impedance of the open end:

$$Z_1 = r_1 - i\omega m_1 \quad (21)$$

where

$$r_1 = \frac{32\eta t}{p\rho_0 c_0 d^2}\sqrt{1+\frac{K^2}{32}} + \frac{1}{4p}(k_0 d)^2 \quad (22)$$

$$\omega m_1 = \frac{\omega t}{\rho c_0}\left(1+\frac{1}{\sqrt{9+\frac{K^2}{2}}}\right) + \frac{1}{p}\frac{8}{3\pi} k_0 d \quad (23)$$

For an MPP backed by a porous layer, the MPP impedance Z_2, with acoustic resistance r_2 and reactance ωm_2, the end-correction terms in Eqs. (1) and (2), that is, the second term in brackets of Eq. (1) and the third term in brackets of Eq. (2), are now replaced by Eqs. (7), (8), (17) and (18), resulting in the following equation for the radiation from the open end of the tube:

$$Z_2 = r_2 - i\omega m_2 \quad (24)$$

where

$$r_2 = \frac{32\eta t}{p\rho_0 c_0 d^2}\sqrt{1+\frac{K^2}{32}} + \frac{1}{8p}(k_0 d)^2 + \frac{1}{p}(E_1F_1 - E_2F_2) \quad (25)$$

$$\omega m_2 = \frac{\omega t}{\rho c_0}\left(1+\frac{1}{\sqrt{9+\frac{K^2}{2}}}\right) + \frac{1}{p}\frac{4}{3\pi} k_0 d - \frac{1}{p}(E_1F_2 + E_2F_1) \quad (26)$$

COMPARISON BETWEEN MAA'S THEORY AND THE PRESENT THEORY

From the above discussion, two different theories for the end-correction have been given (for the air-backed case given by Eqs. (1) and (2), and for the porous-backed case given by Eqs. (24) to (26)). The first theory is the end correction included in the Maa's formulae, and the second theory is the present theory obtained from the radiation impedance from the open end of a tube. The results from both theories for the case of an MPP backed by the air and a porous layer are compared in what follows.

The aim of the comparisons is twofold: One is to confirm that the two theories give almost the same results in absorption coefficients for the air-backed case. The other is to observe how much difference is caused in the results of the absorption coefficients for the porous-backed case. For the second purpose, first it is needed to confirm that the results using the two theories are in agreement for a certain MPP parameter in the air-back case. Then, the results using the two theories are compared for the same parameter in the porous-backed case.

The results of the comparison of the two theories in the air-backed case are presented in Fig. 2. Typical values are given for the MPP parameters. There is a small discrepancy at around the resonance peak. However, they show very good agreement in general.

As the theory with the radiation impedance is dependent on the MPP parameters d and t, it is found that differences may occur according to the change in these parameters. However, as long as $d/t < 1$, Maa's theory and the present theory are in fairly good agreement. Therefore, the comparison of the two theories in porous- backed case will have to be made within this range of the MPP parameters.

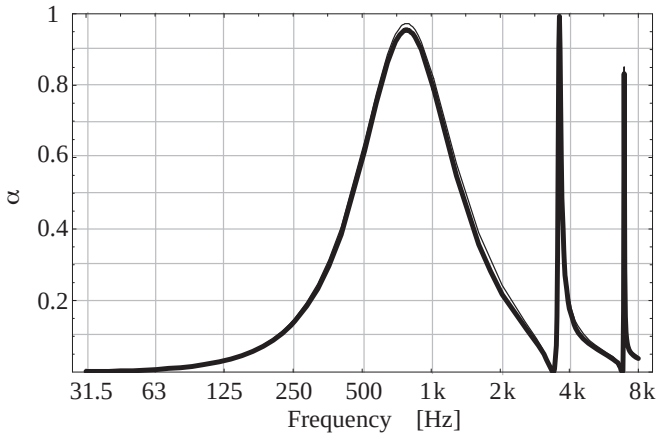


Figure 2. Comparison of the absorption coefficient using the impedance derived from the present theory and Maa's theory in the air-backed case: d=t=0.3 mm, p=0.8%, D=50 mm. Thick line: derived by the present theory, Eqs. (21) to (23); Thin line: Maa's theory, Eqs. (1) and (2)

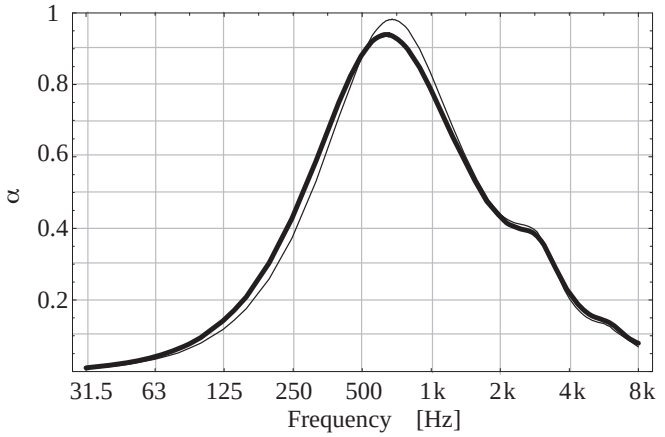


Figure 3. Comparison of the absorption coefficient using the impedance derived from the present theory and Maa's theory in the porous layer-backed case. d=t=0.3 mm, p=0.8%, D=50 mm, R=10 kPa.s.m^{-1}. Thick line: the present theory, Eqs. (24) to (26); Thin line: Maa's theory, Eqs. (1) and (2)

Figure 3 shows the comparison of the two theories in the porous-backed case for the same MPP parameters as in Fig. 2. In this case, the discrepancies between the two theories are slightly larger than those in the air-backed case. However, it can be observed that Maa's theory also offers a good approximation for the porous-backed case of an MPP. Therefore, in the following section, Mas's theory is used for calculation, through which the absorption characteristics of a single-leaf rigid wall-backed MPP with porous absorbent in the cavity will be discussed.

NUMERICAL EXAMPLES AND DISCUSSION

In this section, numerical examples of the calculated results for the absorption characteristics of single-leaf MPP absorbers backed by rigid back-wall and porous layer in-between. In the preceding section it was confirmed that Maa's theory can give reasonable approximation even in the porous-backed case, therefore in this section, the calculated results by Maa's theory are presented, and the absorption characteristics of the porous-layer backed MPP absorber are discussed through the numerical examples.

First, the basic feature of the porous layer-backed MPP is shown in comparison with the results for that backed by air-cavity. Figure 4 compares the typical numerical results for the single-leaf MPP absorber with an air-cavity and that with an absorbent-cavity.

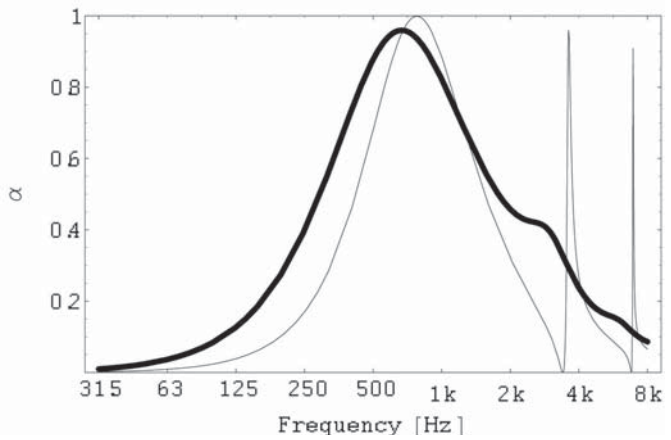


Figure 4. Comparison of the absorption characteristics of an MPP absorber backed by an air cavity (thin line) and that backed by a porous absorbent layer (thick line). Hole diameter d=0.3 mm, thickness t=0.3mm, perforation ratio p=0.8%, flow resistance of the absorbent R=10 kPa.s.m^{-1} and cavity depth D=50 mm

The results for the case of an MPP backed by an absorbent cavity show that, although the peak absorption coefficient is slightly lower than that for an MPP backed by an air cavity, the peak becomes broader and covers a wider frequency range. The peaks due to the higher resonance modes at around 4 kHz and 8 kHz observed in the air-cavity case disappear in the absorbent-cavity case. This is because the resonance in the cavity is damped by the porous absorbent. Thus, inserting a porous absorbent layer in the back cavity makes an MPP absorber more wideband.

The above effect of the porous absorbent can be varied with its acoustical parameters. In this study, the characteristic impedance and propagation constant are given by Miki's formulae, hence the only affecting parameter of the porous absorbent is its flow resistivity. The effect of the flow resistivity of the porous absorbent in the cavity of a single MPP absorber is discussed. As observed in Fig. 5, the peak becomes broader with increasing flow resistivity. However, whilst the peak is from 0.9 to 1.0 when the flow resistivity is from 5 to 20 kPa.s.m^{-1}, the peak value gradually decreases if the flow resistivity becomes higher, and the value becomes as low as around 0.7 when the flow resistivity is 80 kPa.s.m^{-1}. Therefore, in order to keep the high absorption as well as wideband absorption, the flow resistivity of the porous absorbent should not be too large. In this example, it should be lower than 20 kPa.s.m^{-1}. It should be noted that this tendency depends on the total acoustic resistance. Therefore, when the acoustic resistance of the MPP itself is already optimised, the

additional resistance makes the total resistance too large. This results in deteriorated absorption performance. Therefore, the suitable range of the flow resistivity of the porous absorbent, which affects the total resistance, should be considered in each case of MPP parameter.

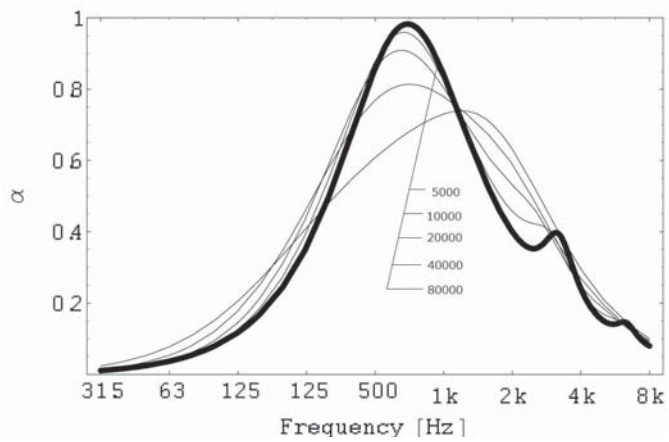


Figure 5. Effect of the flow resistance of the porous absorbent layer in the back cavity. Flow resistance of the absorbent R= 5 to 80 kPa.s.m^{-1}. Hole diameter d=0.3 mm, thickness t=0.3mm, perforation ratio p=0.8% and cavity depth D=50 mm.

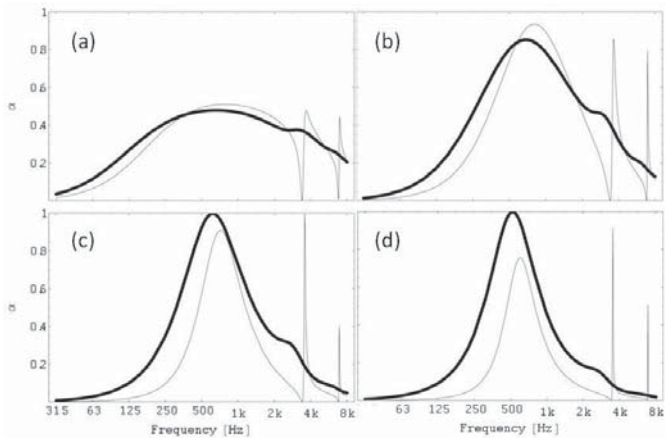


Figure 6. Effect of the hole diameter of the MPP of a porous layer-backed single MPP absorber. Thick line: porous layer-backed MPP; Thin line: air layer-backed MPP. Hole diameter d=0.1 mm (a), 0.2 mm (b), 0.5 mm (c) and 1.0 mm (d). Thickness t=0.3 mm, perforation ratio p=0.8%, flow resistance of the absorbent R=10 kPa.s.m^{-1} and cavity depth D=50 mm.

A numerical calculation is now performed to investigate how the effect of the porous layer changes with changing MPP parameters. Figure 6 shows the effect of the hole diameter when the flow resistivity of the porous layer is 10 kPa.s.m^{-1}.

When the hole diameter is 0.1 mm, the acoustic resistance of the MPP itself is too large which results in low absorption. Therefore, the porous layer does not have a significant effect. When the hole diameter is 0.2 mm, the absorption coefficient becomes lower when a porous layer is inserted. This is because the total acoustic resistance becomes too large due to the additional resistance of the porous layer. On the other hand, when the hole diameter is 0.5 and 1.0 mm, the peak becomes higher than that with air cavity. The peak also becomes wider. Thus, when the acoustic resistance of the MPP itself is unsatisfactorily low, the effect of the porous layer becomes significant and the absorption performance can be improved.

A similar tendency is observed when the thickness of the MPP is varied, that is, the effect of the porous layer becomes significant when the thickness is small (with low acoustic resistance), as shown in Fig. 7.

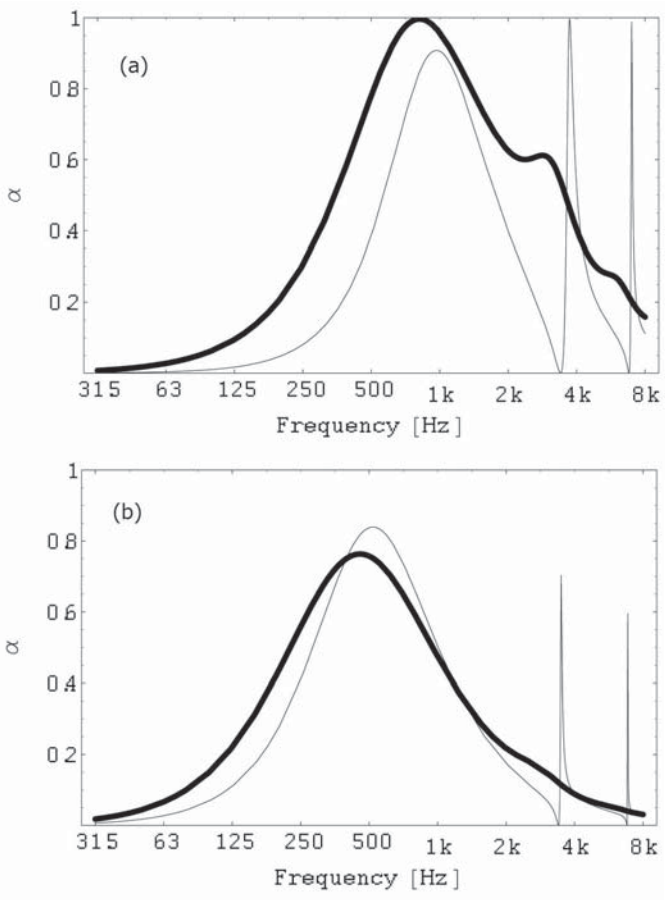


Figure 7. Effect of the thickness of the MPP of a porous layer backed single MPP absorber. Thick line: porous layer backed MPP; Thin line: air layer backed MPP. Thickness t=0.1mm (a), and 1.0 mm (b). Hole diameter d=0.3 mm, perforation ratio p=0.8%, flow resistance of the absorbent R=10 kPa.s.m^{-1} and cavity depth D=50 mm.

A different behaviour is observed when the perforation ratio of the MPP is changed. When the perforation ratio is low, the typical resonance-type absorption characteristics of an MPP can be observed. However, if the perforation ratio exceeds 1.0%, the acoustic properties of the porous layer inside the cavity become dominant to show totally different absorption characteristics and which are similar to those of a porous sound absorber. As an example for an extreme case, the results for the perforation ratio of 5.0% are shown in Fig. 8.

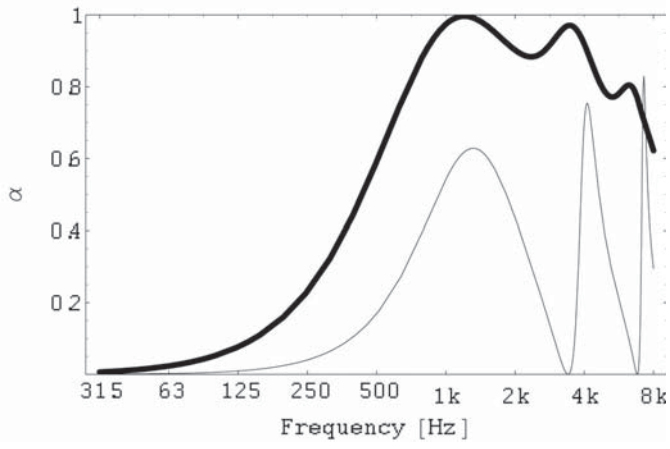


Figure 8. An example of the absorption characteristics of a porous layer backed single MPP absorber with a large perforation ratio. Thick line: porous layer backed MPP; Thin line: air layer backed MPP. Hole diameter d=0.3 mm, thickness t=0.3 mm, perforation ratio p=5.0%, flow resistance of the absorbent R=10 kPa.s.m^{-1}, and cavity depth D=50 mm.

CONCLUDING REMARKS

In this study, the effect of the porous absorbent layer in the cavity of a single-leaf MPP sound absorber backed by a rigid wall is analysed using an electro-acoustical equivalent circuit model. The end-correction for an MPP backed by a porous layer was derived and compared with Maa's theory, which assumes the end-correction for air-backed case. It was observed that Maa's theory offers a fairly good approximation even in porous backed cases. Therefore, in the numerical study, Maa's conventional theory was used for the end correction for an MPP backed by a porous layer, through which the effect of the porous layer in the cavity was discussed. The results showed that inserting a porous absorbent layer in the back cavity, the peak value becomes slightly lower, but the absorption frequency range can be made wider. However, the effect is dependent on the flow resistivity of the porous layer. Hence it is necessary to choose a suitable value of the flow resistivity. Also the effect depends on the MPPs parameters such as hole diameter, thickness and perforation ratio.

ACKNOWLEDGEMENTS

This work was in part supported by the Grant-in-Aid for Scientific Research (C, 20560550).

REFERENCES

[1] D-Y. Maa, "Theory and design of microperforated panel sound-absorbing constructions", *Scientia Sinica* **17**, 55-71 (1975)

[2] D-Y. Maa, "Microperforated-panel wideband absorber", *Noise Control Engineering Journal* **29**, 77-84 (1987)

[3] D-Y. Maa, "Potential of microperforated panel absorber", *Journal of the Acoustical Society of America* **104**, 2861-2866 (1998)

[4] D-Y. Maa, "Practical single MPP absorber", *International Journal of Acoustics and Vibration* **12**, 3-6 (2007)

[5] H.V. Fuchs and X. Zha, "Einsatz mikro-perforierter Platten als Schallabsorber mit inharenter Dampfung", *Acustica* **81**, 107-116 (1995)

[6] M.Q. Wu, "Micro-perforated panels for duct silencing", *Noise Control Engineering Journal* **45**, 69-77 (1997)

[7] J. Kang and M.W. Brocklesby, "Feasibility of applying microperforated absorbers in acoustic window systems", *Applied Acoustics* **66**, 669-689 (2005)

[8] F. Asdrubali and G. Pispola, "Properties of transparent sound absorbing panels for use in noise barriers", *Journal of the Acoustical Society of America* **121**, 214-221 (2007)

[9] M. Yairi and K. Sakagami, "Absorption properties of microperforated panel absorber", *Journal of the Acoustical Society of Japan (J)* **63**, 76-82 (2007) (in Japanese)

[10] K. Sakagami and K. Fujimoto, "Devices for improving speech transmission performance – Next generation sound absorbing materials: Microperforated panels and polyester non-wovens", *Journal of the Institute of Noise Control Engineering/Japan* **33**, 307-316 (2009) (in Japanese)

[11] M. Yairi and K. Sakagami, "Absorption characteristics of a microperforated panel absorber and increasing its absorption frequency range", *Proceedings of the Spring Meeting of the Acoustical Society of Japan*, Tokyo, 1139-1142 (2010) (in Japanese)

[12] K. Sakagami, M. Morimoto and W. Koike, "A numerical study of double-leaf microperforated panel absorbers", *Applied Acoustics* **67**, 609-619 (2006)

[13] K. Sakagami, T. Nakamori, M. Morimoto and M. Yairi, "Double-leaf microperforated panel space absorbers: A revised theory and detailed analysis", *Applied Acoustics* **70**, 703-709 (2009)

[14] K. Sakagami, Y. Nagayama, M. Morimoto and M. Yairi, "Pilot study on wideband sound absorber obtained by combination of two different microperforated panel (MPP) absorbers" *Acoustical Science and Technology* **30**, 154-156 (2009)

[15] N. Okamoto, M. Kondo, K. Sakagami, M. Morimoto and M. Yairi, "A basic study on wideband sound absorbers with a combination of MPP and other absorbers", *Transactions of the Technical Committee on Architectural Acoustics, Acoustical Society of Japan*, AA2008-48 (2008) (in Japanese)

[16] K. Sakagami, I. Yamashita, M. Yairi and M. Morimoto, "Sound absorption characteristics of a honeycomb-backed microperforated panel absorber: Revised theory and experimental validation", *Noise Control Engineering Journal* **58**, 157-162 (2010)

[17] S. Kimura, "Experimental studies on the sound absorbing characteristics of acoustic materials", *Report of the Institute of Industrial Science, University of Tokyo 10*(5), 1-48 (1961) (in Japanese)

[18] F.P. Mechel, "About perforated metal sheet on porous absorbers", *Acta Acustica* **1**, 175-188 (1993)

[19] F.P. Mechel, "Helmholtz resonators with added porous absorbers" *Acustica* **80**(3), 268-279 (1994)

[20] K. Sakagami, "Next-generation acoustical materials and technical developments", *Proceedings of the Spring Meeting of the Acoustical Society of Japan*, Tokyo, 1137-1138 (2010) (in Japanese)

[21] L. Kinsler, A. Frey, A. Coppens and J. Sanders, *Fundamentals of Acoustics*, Wiley, New York, 1999

[22] Y. Miki, "Acoustical properties of porous materials – Modifications of Delany-Bazley methods", *Journal of the Acoustical Society of Japan* (E) **11**, 19-24 (1990)

AUDITORY ROOM SIZE PERCEIVED FROM A ROOM ACOUSTIC SIMULATION WITH AUTOPHONIC STIMULI

Manuj Yadav, Densil Cabrera and William. L. Martens
Faculty of Architecture, Design and Planning, The University of Sydney, Australia
manuj.yadav@sydney.edu.au, densil.cabrera@sydney.edu.au, william.martens@sydney.edu.au

By listening to the sound of their own voice in a room, a talking-listener receives useful information about the acoustical characteristics of the enclosed environment. The information they receive about a specific acoustical characteristic is generally supplemented by other sensory, especially visual, stimuli that can influence one's perception of (and in) these environments. One such characteristic is the size of the room perceived through the human auditory apparatus, which can be different from the room's physical size, as well as the visually perceived room size. This paper examines the relationship between judgements of the size of a room environment that is based on auditory stimuli, and relevant room acoustic parameters; where these judgements may contrast with the objective size as indicated by room acoustic theory. The room size judgements were collected from a study conducted in an auditory mixed-reality environment, in which a talking-listener can perceive the sound of his/her own voice in the simulated reverberant conditions of real rooms, while physically being in an anechoic room. In this study, human participants performed talking tasks, and rated the aurally perceived size of each room. The results indicate that the level of the acoustical support provided by the room's environment (quantified here as room gain) accounts for more of the variance in the associated room size judgements than any other predictor.

INTRODUCTION

The size of a room is one of its most basic attributes, and this preliminary study examines the perception of room size using sound alone. Although it can be argued that the most reliable judgement of room size can be arrived at from visual inspection, it is also possible to judge the size of a room using auditory stimuli, without accompanying visual stimulus [1-5]. This involves exciting the room with an appropriate sound source and hearing the characteristics of the acoustic reflections from the walls, furnishings etc. Experimental studies eliciting auditory room size judgements can provide insight to space perception processes of people with a significant visual impairment [1]; contribute to the understanding of reverberance in concert halls [6]; and extend the understanding of psychoacoustics relating to autophonic output [7] (one's own voice) in rooms [8, 9].

In listening to the sound of a room, the sound source can be the listener him/her-self (egocentric stimulus) or there can be a sound source physically distinct from the listener (exocentric stimulus). The scenarios arising from these exocentric and egocentric stimuli constitute exocentric and egocentric tasks, respectively. Previously, in mostly exocentric tasks, auditory room size perception has been shown to be more strongly affected by acoustical parameters (specifically the room's reverberation time, source-receiver distance, interaural cross-correlation and clarity index) than the room's physical volume [10].

This paper investigates auditory room size perception in an egocentric task, based on an auditory mixed-reality (MR) environment, a term consistent with the framework suggested by Milgram and Colquhoun [11] for visual MR, as explained in the following section.

MIXED-REALITY EXPERIMENTAL PROCEDURE

To avoid the complications implicit in conducting *in situ* experiments using different rooms with human participants, the experiment described by this paper employed real-time virtual room acoustic simulations applied to autophonic output, in order to render a MR auditory environment for each of the rooms tested, which has been described elsewhere by the authors [12]. The stages involved in stimulus preparation are briefly described in the following two sections. The subjective test is also described in what follows.

Measurement and processing of room impulse responses

Binaural impulse responses from the mouth to two ears of a head and torso simulator (HATS, Brüel & Kjær Type 4128C) were acquired at positions in six real rooms. In each room, successive measurements were made over a rotational range of -60° to +60° in yaw (by rotating the HATS at 2° increments), in a process described in detail by Cabrera et al. [13]. The measured oral-binaural room impulse responses (OBRIRs) were truncated by removing the first 7.6 ms (comprising the direct sound and first-order floor reflection), for the reasons identified in the next section. The truncated OBRIRs were then subjected to a MATLAB routine to suppress any noise in their tail, by multiplying the noise floor by an exponential decay function that matched the initial noise-free decay rate within each octave band.

As a reliability check, one of the rooms was measured in two conditions, differing only by the presence of a small curtain near the measurement position, leading to a slight change in the

acoustical parameters. These two conditions of the same room were included in the current experiment to test the variation in the room size judgements of essentially the same room, leading to a total of seven simulated room conditions.

Real-time room acoustic simulation system

The measured OBRIRs (as described in the previous section) were accessed by a real-time convolver (SIR2 VST plugin), hosted in a Max/MSP patch running on a Windows platform. The Max/MSP patch allowed rooms to be switched in real-time from a selection menu, which would load the corresponding OBRIRs for convolution (with no apparent delay). The AD/DA converter used was a RME ADI-8 QS unit with 48 kHz sampling rate and 32-bit quantization in a 1-in/2-out configuration. The electroacoustic latency of this system was 7.6 ms, which effectively becomes 0 ms as a result of the OBRIR truncation described in the previous section. Essentially, as the truncated OBRIRs contain no samples corresponding to the direct sound and first floor reflection, the system's output smoothly follows the direct sound and the floor reflection; neither of which is simulated because the direct sound is already present with the talking-listener's voice and the floor reflections are provided by adding a carpeted wooden floor to the anechoic room used in the experiment.

The headset microphone used for vocal input was a DPA 4066 and the ear-loudspeakers used for playing back the convolved output (the room reflections corresponding to the current OBRIR) to a talking-listener were a pair of AKG K1000 (loudspeakers near the ears, without any circumaural cushion or contact with the ears). The receiver unit of the headtracker was attached onto the strap of the ear-loudspeakers.

The headset microphone was positioned at a distance of 7 cm from the centre of lips on the right side of the face. This was done to eliminate the detrimental effects associated with plosives and fricatives when the microphone is placed in the direct air-stream from the mouth opening. A similar microphone position has been used in a recent study for egocentric sound in rooms [9]. The simulation system gain was calibrated by measuring its response (with a loaded OBRIR) using a HATS, and gain-adjusting the system response so that it matched the original OBRIR.

The presence or absence of the ear-loudspeakers had a negligible effect on the octave-band oral-binaural gains for microphones (Brüel & Kjær 4101 Binaural Microphone) placed at the entrance of each ear canal for five participants talking (measured separately), and a HATS (Brüel & Kjær 4128C) emitting pink noise [12]. The feedback from the loudspeakers to the headset microphone was also negligible (loop gain < -16 dB) [14].

The simulation system's headtracking (implemented in the Max/MSP patch), follows the yaw angle of the talking-listener's head, ranging from -40° to +40° (i.e., much, but not all, of the measured OBRIR yaw range), and continually selects the OBRIR to be convolved with the current vocal *input*; while the real-time convolution system *outputs* two channels of convolved audio that includes the *output* from the current head position combined with the residual audio generated for any other previous head positions (which may still be following a reverberant decay). This provides an auditory scene that is almost the same as the one that would be produced by vocal transduction in the measured real room for similar head movements.

Subjective room size judgements

Room size judgements were made by 8 participants (ages 23-45; 7 male, 1 female; 4 acoustically knowledgeable and 4 acoustically naïve university students), who were seated on a wooden chair placed on a carpeted floor in an anechoic chamber (with a large wooden board underneath the carpet, as described in the previous section). They were given a few sheets of printed text with the choice that they were free to either read from the text or to use any other speech or vocalisation that would enable them to judge the size of the simulated room, with typical or more exploratory head movements. The participants were tested in the seven room simulations according to a random order, with two trials per room: one with headtracking turned on and the other with headtracking turned off. They gave a room size rating for each trial using a numerical scale ranging from 1 (the size of the anechoic room in which the talking-listeners were physically present) to 10. This scale was merely conceived of as a simple vernacular scale, rather than a precise ratio scale.

DATA PROCESSING

The room size judgements of each participant were centred (by dividing each rating by their mean rating) so that the participants would have equal weight in the analysis of combined results. Following centring, the full set of results has a mean value of 1, and a standard deviation of 0.33. As the room size judgements did not differ significantly between the headtracked and non-headtracked trials, the mean value of these two trails per participant was used in the following analysis. Room size judgements were examined in relation to measures of physical room size (volume, V) and to acoustical parameters derived from the OBRIRs. The acoustic parameters include the following: mid-frequency (500 Hz) reverberation time (RT) with an evaluation range from -10 dB to -30 dB (amended from the more commonly used -5 dB to -25 dB range, to account for the higher gain of the direct sound); room gain (G_{RG}) derived from the amended procedure outlined by Pelegrín-Garcia [15], which was first proposed by Brunskog et al. [16] as a measure of the energy of the room-reflected sound that the talking-listener hears (power average of the two ears, expressed in dB); clarity index (C_{50}) [1,8,10]; and interaural cross-correlation ($IACC_{early}$) [10], using 80 ms as the boundary between early and late. One distinction in the calculation of the room gain values here from the procedure described by Pelegrín-Garcia [15] was the duration of direct sound, which in the current paper was taken as 7.6 ms and corresponded to the duration of the direct sound and first floor reflection of the OBRIR. In the case of the room gain, the values presented here corresponded to the energy summed over the entire duration of the 0° OBRIR starting from 8 ms. The RT, C_{50} and $IACC$ values were the

octave band mean values over the entire headtracking range of -40° to +40° yaw as described in Cabrera et al. [17]. Early decay time was not calculated because it is not well-defined for a source very close to a receiver V_{est} is a quasi-acoustical parameter calculated from an empirical function relating room volume to reverberation time ($RT \approx 0.26 \ln(V) - 0.75$) that was derived by Shabtai et al. [18]. The subjective room size ratings and physical parameters are shown in Table 1.

ANALYSIS AND DISCUSSION

To determine whether there was a variation in the rated values of room size with different room conditions, a one-way ANOVA was conducted, and the result indicates a significant effect ($F(6, 49) = 24.63$, $p < 0.01$). As the near-identical stimuli (rooms 4 and 5) received very similar size ratings (Table 1), this suggests that the participants were consistent in judging the size of the same room in two slightly different conditions. Condition 5 was excluded from further statistical analysis, as its subjective ratings and objective parameters were so similar to condition 4. Also, condition 7, which represented the autophonic perception in a large reverberant room environment (a recital hall) was identified as an outlier and consequently not included in further statistical analysis. In the following analysis, room number 6 in Table 1 will be referred to as room number 5.

Following these changes in the data, correlation analysis showed that none of the parameters are significantly correlated with the physical room volume ($p < 0.05$). However, considering these non-significant correlations for their polarity, a negative sign of the correlation coefficient (r) indicates that as the room volume increases, G_{RG} decreases (R = -0.31, p = 0.30), and *vice-versa*; whereas a positive sign indicates that as the room volume increases, C_{50} (R = 0.49, p = 0.20) and *IACC* increase (R = 0.59, p = 0.14), and *vice-versa*. These signs are at least partly consistent with expectations from room acoustics theory in that a greater diffuse field strength is expected in smaller rooms (leading to increased G_{RG}, and reduced *IACC*); and the expected relationship between C_{50} and room size is more subtle (see [19]). As an important design feature in this study, it is noteworthy that there is no correlation between reverberation time and room volume for the selection of rooms (R = 0.01), although a positive correlation might be expected for a wider selection of rooms (as represented by V_{est}, following [18]).

On the other hand, the room size judgements are significantly correlated with all the parameters that are listed in Table 1, except the room's physical volume and $IACC_{early}$. Figure 1 shows the linear regression model (R^2=0.99, F=220.6, p<0.001) that was yielded by room gain as the independent (predictor) variable, which can be expressed as

$$\text{Predicted room size} = 0.17 + 0.68 \ G_{RG} \quad (1)$$

Compared to G_{RG}, the linear regression models using RT (R^2=0.76, F=13.73, p<0.05), C_{50} (R^2=0.68, F=9.51, p=0.05), and V_{est} (R^2=0.84, F=22.68, p<0.05) as the predictors accounted for lesser variance in the room size judgement values and lower F values.

In recent research, higher room gain values have been shown to be important in providing greater vocal comfort and lesser vocal effort for talking-listeners, and vice-versa [16, 20]. The results of the present research are consistent with these findings, with respect to a negative correlation of physical room volume with room gain, as the strength of the reverberant field in a smaller room is generally higher than bigger rooms. Hence, from an objective perspective, room gain values could serve as an important component in the prediction of the room's size. However, the *positive* correlation of the subjective room size responses with the room gain values, modelled in equation (1) is interesting, as it points towards a conjecture that the strength of the reverberant field in the current experiments was used as an indicator of its reverberance (and that greater reverberance was interpreted as an indicator of greater room size). This conjecture is partly based on the post-experiment interview with the participants, who reported using the reverberation of the rooms as an indicator of their size. Note that the effectiveness of room gain as a predictor in the

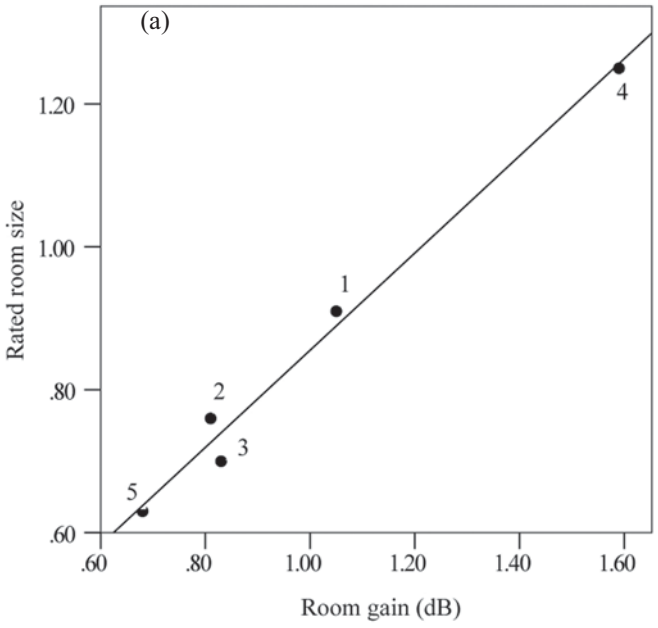
Table 1. The data used for the statistical analysis. The rooms are numbered from 1-7 with a bracketed number showing their index in the paper by Cabrera et al. [17], which characterised the rooms used in this paper in detail. The next columns consecutively show the mean rated room sizes; volumes; mid-frequency reverberation times; early room gains; clarity index; early *IACC* values; estimated volumes from the linear regression model described by Shabtai et al. [18] Rooms 4 and 5 were the same room measured in two slightly different conditions, but only room 4 is characterized in Cabrera et al. [17]

Room	Rated Size	V(m^3)	RT(s)	G_{RG}(dB)	C_{50}(dB)	$IACC_{early}$	V_{est}(m^3)
1 (3)	0.91	125	0.60	1.05	11.8	0.25	179
2 (6)	0.76	152	0.35	0.81	18.3	0.26	68
3 (7)	0.70	170	0.40	0.83	20.7	0.21	83
4 (8)	1.25	188	0.90	1.59	11.6	0.21	570
5	1.27	188	0.90	1.54	12.5	0.23	570
6 (10)	0.63	310	0.50	0.68	20.5	0.54	122
7 (11)	1.48	7650	1.70	0.29	31.6	0.54	12370

present study might be influenced by the zero correlation between reverberation time and room volume.

Future research should focus on studying the interaction between the strength and temporal aspects of reverberant sound fields with respect to auditory room size judgements, where these two parameters are manipulated within rooms of fixed volumes. Similar to the present study, where the reverberation times of the rooms were uncorrelated with their volumes, various levels of correlation between these parameters may be included as a design feature.

As the room size judgements from the headtracked and non-headtracked trials were not significantly different, it poses a question regarding the usefulness of headtracking in a simulation based room size perception tasks. In a recent study using the same room acoustical simulation system, it was shown that headtracking was detectable by five participants in an ABX task, where the threshold for correct detection was set to be just above chance (0.6) [21]. A study with more participants would be required to address the issue of incorporating headtracking in the present simulation for room size perception task (and perhaps similar tasks).



(b)	*B*	*SE B*	*β*
Constant	0.17	0.05	
Room gain	0.68	0.05	0.99

Figure 1. (a) The room size judgements by the participants, as a function of room gains Table 1, where the rooms are numbered 1-5 in an ascending order of their physical volume. Room number 5 corresponds to room number 6 in Table 1, due to the changes explained in the beginning of the current section. (b) The regression model for predicting perceived room size from room gain (G_{RG}). *B* and *SE B* represent the unstandardised coefficients and their standard error, respectively. β represents the standardized coefficient which gives the number of standard deviations the outcome (predicted room size) will change as a result of one standard deviation in the predictor (G_{RG}).

There is also scope for improving the experimental design of the current study, by including simulated room conditions with a more uniform scale in terms of their physical size and variety in terms of their purpose (e.g., residential rooms). A method more robust than magnitude estimation (e.g., paired-comparison, or photograph-matching [22]) could be employed to validate the findings of this study.

CONCLUSIONS

The work described in this paper shows something of the potential of a real-time simulation system for autophonic room acoustics studies involving human participants. The findings of the experiment point to a possible difference between the perception of room size and physical acoustic correlates of room volume, which raises questions for future study.

REFERENCES

[1] C.B. Pop and D. Cabrera, "Auditory room size perception for real rooms", *Proceedings of Acoustics 2005*, Busselton, Western Australia, November 2005

[2] R. McGrath, T. Waldmann and M. Fernström, "Listening to rooms and objects", *Proceedings of the 16th Audio Engineering Society International Conference*, Rovaniemi, Finland, April 1999

[3] S. Hameed, J. Pakarinen, K. Valde and V. Pulkki, "Psychoacoustic Cues in Room Size Perception", *Proceedings of the 116th Audio Engineering Society Convention*, Berlin, Germany, May 2004, paper no. 6084

[4] D.H. Mershon and L.E. King, "Intensity and reverberation as factors in the auditory perception of egocentric distance", *Perception & Psychophysics* **18**(6), 409-415 (1975)

[5] A. Tajadura-Jiménez, P. Larsson, A. Väljamäe, D. Västfjäll and M. Kleiner, "When room size matters: Acoustic influences on emotional responses to sounds", *Emotion* **10**(3), 416-422 (2010)

[6] T. Lokki, J. Pätynen, A. Kuusinen, H. Vertanen and S. Tervo, "Concert hall acoustics assessment with individually elicited attributes", *Journal of the Acoustical Society of America* **130**(2), 835-849 (2011)

[7] H. Lane, A. Catania and S. Stevens, "Voice level: Autophonic scale, perceived loudness, and effects of sidetone", *Journal of the Acoustical Society of America* **33**, 160-167 (1961)

[8] D. Cabrera, D. Jeong, H. J. Kwak and J-Y. Kim, "Auditory room size perception for modeled and measured rooms", *Proceedings of Inter-Noise 2005*, Rio de Janeiro, Brazil, August 2005

[9] D. Pelegrín-García, O. Fuentes-Mendizábal, J. Brunskog and C-H Jeong, "Equal autophonic level curves under different room acoustics conditions", *Journal of the Acoustical Society of America* **130**(1), 228-238 (2011)

[10] D. Cabrera, "Control of perceived room size using simple binaural technology", *Proceedings of the 13th International Conference on Auditory Display*, Montréal, Canada, June 2007

[11] P. Milgram and H. Colquhoun, "A taxonomy of real and virtual world display integration", in *Mixed Reality - Merging Real and Virtual Worlds*, edited by Y. Ohta and H. Tamura, Berlin, Springer-Verlag, pp. 1-16 (1999)

[12] M. Yadav, D. Cabrera and W.L. Martens, "A system for simulating room acoustical environments for one's own voice", *Applied Acoustics* doi: 10.1016/j.apacoust.2011.10.001 (2011)

[13] D. Cabrera, H. Sato, W.L. Martens and D. Lee, "Binaural measurement and simulation of the room acoustical response from a person's mouth to their ears", *Acoustics Australia* **37**, 98-103 (2009)

[14] M. Yadav, *A system for room acoustic simulation for one's own voice*, http://hdl.handle.net/2123/7889, Master of Philosophy, The University of Sydney, 2011

[15] D. Pelegrín-García, "Comment on "Increase in voice level and speaker comfort in lecture rooms" [J. Acoust. Soc. Am. 125, 2072–2082 (2009)]", *Journal of the Acoustical Society of America* **129**, 1161–1164 (2011)

[16] J. Brunskog, A.C. Gade, G.P. Bellester and L.R. Calbo, "Increase in voice level and speaker comfort in lecture rooms", *Journal of the Acoustical Society of America* **125**(4), 2072-2082 (2009)

[17] D. Cabrera, D. Lee, R. Collins, B. Hartmann, W.L. Martens and H. Sato, "Variation in oral-binaural room impulse responses for horizontal rotations of a head and torso simulator", *Building Acoustics* **18**(1), 227-252 (2011)

[18] N.R. Shabtai, Y. Zigel and B. Rafaely. "Room volume classification from room impulse response using statistical pattern recognition and feature selection", *Journal of the Acoustical Society of America* **128**(3), 1155-1162 (2010)

[19] D. Cabrera, "Acoustic clarity and auditory room size perception", *Proceedings of the 14th International Congress on Sound and Vibration*, Cairns, Australia, July 2007

[20] D. Pelegrín-García, B. Smits, J. Brunskog and C-H. Jeong, "Vocal effort with changing talker-to-listener distance in different acoustic environments", *Journal of the Acoustical Society of America* **129**(4), 1981-1990 (2011)

[21] M. Yadav, D. Cabrera, R. Collins and W.L. Martens, "Detection of headtracking in room acoustic simulations for one's own voice", *Proceedings of Acoustics 2011*, Gold Coast, Australia, November 2011

[22] J. Sandvad, "Auditory perception of reverberant surroundings", *Journal of the Acoustical Society of America* **105**(2), 1193 (1999)

FOR SALE

ARL Noise Logger Model EL316 Purchased Feb. 2009
Excellent Condition
$3000-00 or best offer
Contact: Warrick 0412106072

THE EFFECT OF SEABED PROPERTIES ON THE RECEIVE BEAM PATTERN OF A HYDROPHONE LOCATED ON THE SEAFLOOR

Miles J.G. Parsons and Alec J. Duncan
Centre for Marine Science and Technology, Curtin University, GPO Box U1987, Perth, WA 6845, Australia

Multi-path interference is often considered when modelling propagation of underwater sounds from source to receiver. When close to, or on the seabed, a hydrophone receives the direct and bottom reflected signals at nearly identical times. The resulting interference leads to an effective receive beam pattern that depends not only on source and receiver position and water depth, but also on the seabed characteristics, which affect the phase and magnitude of the reflection coefficient. Numerical acoustic propagation models account for this phenomenon automatically, however; it is important that it be taken into account when received signals are used to carry out simple calculations of source levels of nearby sources based on spherical spreading. Australian waters lie above seabeds of greatly differing acoustic properties. Compressional and shear sound speeds and absorption properties for four bottom types (basalt, calcarenite, sand and silt) were used to model the effective receive beam pattern of a hydrophone located on the seafloor. Modelling was carried out for all four seabeds as well as a seabed comprising differing thicknesses of sand over a calcarenite half space. The effects of the resulting receive beam pattern on estimations of source levels and locations are discussed.

INTRODUCTION

Underwater noise levels have increased significantly over the last few decades and the implications for marine fauna are far reaching [1-3]. Measurement and modelling of ambient noise and the source levels of biological and anthropogenic sounds are now conducted on a regular basis to evaluate impacts of sound on behaviour and hearing of animals, monitor movements of vocalising species and observe any reactions to environmental influences such as temperature and salinity [4-7].

The propagation of underwater sound is complex and dependent on numerous variables, such as source and receiver position, water depth, temperature and salinity profiles, multi-path interference and seabed acoustic properties [8].

For ease of long-term recording, and to reduce flow noise, hydrophones are often positioned on, or near, the seabed [9]. However, the combination of direct, reflected and head waves (waves that travel through the seabed and re-radiate into the water column) affect the receive beam pattern of the hydrophone. It is therefore not possible to assume that, in this position, a hydrophone is omni-directional and it is necessary to model the receive beam pattern to accurately understand the recorded sound pressure levels. Numerical acoustic propagation models automatically incorporate this effect, so it is of little consequence in situations where the positions of the source and receiver are known, information about the acoustic properties of the seabed is available, and it is practical to numerically calculate the transmission loss between source and receiver [10]. However, in bioacoustic experiments it is often the case that the source position, and particularly its height above the seabed, is unknown, and the seabed properties are only known approximately [11]. It is therefore important that this phenomenon be understood so that appropriate bounds can be put on source levels estimated from these experiments.

There has been little work done to estimate the effects of differing seabeds on the effective receive beam pattern of a hydrophone in close-proximity to the seafloor. The aim of this study was therefore to model the likely vertical plane receive pattern of a hydrophone on four typical seabeds found in waters around Australia. The impacts these receive patterns would have on estimates of range and source level were also investigated

METHODS

If the incident sound is a plane wave of amplitude p_0, then it is straightforward to show that the received pressure at a hydrophone a height h above the seabed is given by:

$$p = p_0(1 + \Re(\Theta)\exp(2ikh \sin \Theta)) \quad (1)$$

where $\Re(\Theta)$ is the complex plane-wave pressure reflection coefficient, k is the acoustic wavenumber, and Θ is the grazing angle (the angle between the wave vector and the plane of the seabed). (A time dependence of $\exp(-i\omega t)$ has been assumed.)

A number of computer programs exist that are capable of calculating the pressure reflection coefficient of a seabed consisting of an arbitrary number of fluid and elastic layers, so this leads to a simple method of calculating an equivalent vertical plane beam pattern, which is given by:

$$b(\Theta) = \frac{p}{p_0} = 1 + \Re(\Theta)\exp(2ikh \sin \Theta) \quad (2)$$

In the limiting case of a hydrophone much closer to the seabed than the acoustic wavelength, $kh << 1$ and

$$b(\Theta) \approx 1 + \Re(\Theta) \quad (3)$$

The results of plane wave reflection coefficient and phase for

each seabed presented in this paper were calculated using the plane wave reflection coefficient calculation program BOUNCE [12] via the AcTUP user interface [13].

Brekovskikh and Lysanov [14] deal in detail with seabed reflections of sound from point sources and show that in many practical cases the plane wave assumption is invalid as it ignores important transmission paths, particularly the head or lateral wave that enters the seabed at some distance from the receiver and propagates along the interface while re-radiating into the water column, and the Scholte wave, which is a low-speed wave that propagates along the interface between a fluid and an elastic medium. To account for these effects a numerical modelling approach was used to calculate the beam pattern as a function of both grazing angle and slant range for a hydrophone positioned 1 cm above the seabed. This was done by using the fast-field program, SCOOTER [12] to calculate the transmission losses between a source on the seabed and a grid of receiver locations spanning the desired horizontal ranges and grazing angles. This is a very efficient calculation and the principle of acoustic reciprocity ensures that transmission losses calculated in this way are the same as those between a grid of sources and a single receiver on the seabed [15]. Sea surface reflections were reduced to negligible levels by making the water depth 1000m. Once the transmission loss grid was calculated it was converted to an equivalent beam pattern by expressing each value as a pressure ratio and multiplying by the corresponding slant range between the source and receiver. Finally, these values were binned onto a uniform grazing angle.

A limitation of this method is that SCOOTER uses an exponential approximation to the Hankel function that is invalid at horizontal separations between the source and receiver that are less than a wavelength. This placed an upper limit on the maximum grazing angle at which beam pattern values for a given range could be calculated. Another assumption is that the direct, reflected and head waves all arrive within a time difference much less than the source signal duration, so that that the signals travelling via these different paths overlap.

Results obtained using SCOOTER were verified for both fluid and elastic half space seabeds by comparison to beam patterns obtained using the numerical integration approach outlined in Appendix A. The two approaches were found to agree to better than 0.5 dB.

The plane wave reflection coefficient method (Equation (3)), and the method based on SCOOTER were implemented for a number of seabed types, the acoustic properties of which are shown in Table 1. A comparison between the magnitudes and phases of their reflection coefficients is given in Figure 1. This figure illustrates the reflection coefficients for the seabeds with frequency independent reflection coefficients (left plots) and the reflection coefficients at three different frequencies for a 1 m layer of sand over a calcarenite substrate (right plots). The four chosen seabeds offer an example of a solid with shear

Table 1: Seabed acoustic data used in propagation modelling. Acoustic characteristics are taken from Hamilton [16] and Jensen et al. [17].

Seabed	Density (kgm^{-3})	Compressional wave speed (ms^{-1})	Compressional wave attenuation (dB per wavelength)	Shear wave speed (ms^{-1})	Shear wave attenuation (dB per wavelength)
Basalt	2700	5250	0.1	2500	0.2
Calcerenite	2400	2800	0.1	1400	0.2
Sand	2034	1836	0.7	n/a	n/a
Silt	1740	1575	1	n/a	n/a

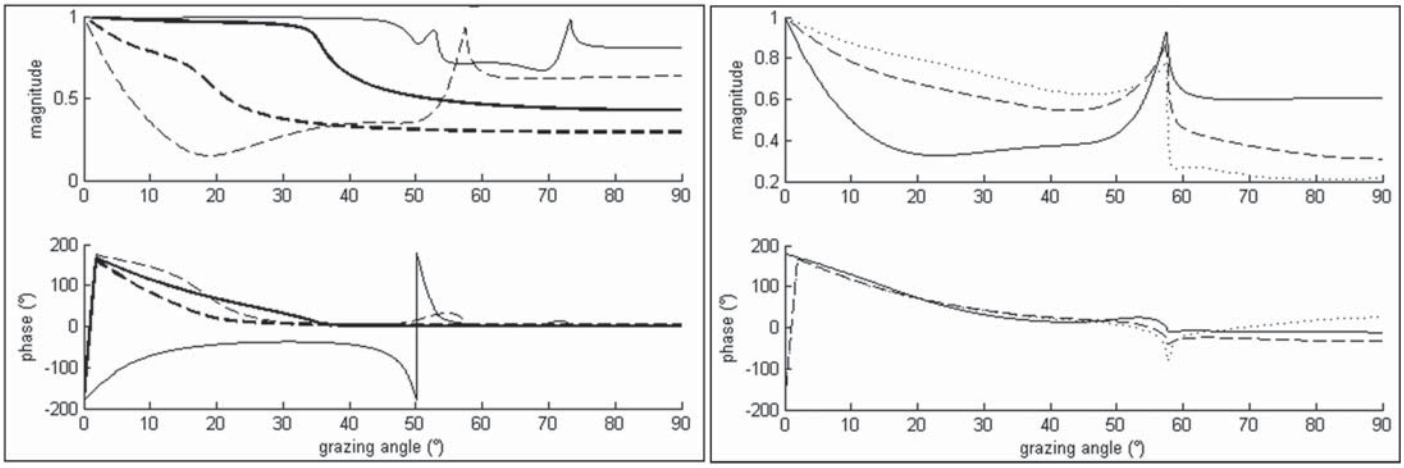


Figure 1: Reflection coefficient (top) and phase (bottom) with grazing angle for basalt, calcarenite, sand and silt half space seabeds (continuous thin, dashed thin, continuous thick and dashed thick lines, respectively in the left plot). Reflection coefficient and phase for a seabed comprising 1 m of sand over calcarenite at 100, 350 and 500 Hz (continuous, dashed and dotted lines, respectively, in the right hand plot). All values determined using the plane wave reflection coefficient calculation program, BOUNCE.

speed faster than the water column sound speed (basalt), a solid with shear speed slower than that of the water column sound speed (calcarenite) and two seabeds for which the shear effects are small and considered negligible for the purposes of this paper (sand and silt).

The analysis in Appendix B shows that for a hydrophone on the seabed, a frequency independent reflection coefficient leads to an effective beam pattern that is a function of range normalised by wavelength, rather than depending independently on these two parameters. The basalt, calcarenite, sand and silt half space seabeds have this property.

RESULTS

The results calculated using these models broadly illustrate the differences in receive beam pattern of bottom located hydrophones due to the acoustic properties of varying seabeds. In most cases the magnitude of the beam pattern varies between -5 and +5 dB. However, under certain conditions of grazing angle, range and seabed characteristics, the received level can be up to 10 dB greater than that expected if there was no seabed reflection.

Figure 2 illustrates the variation in receive beam pattern for a hydrophone sitting on the four different seabeds, each modelled as a homogeneous half space. The far-field result was calculated using the plane wave reflection coefficient and Equation (3), whereas the other results were calculated using the numerical modelling method based on SCOOTER described above. The response for each half space was frequency independent, but range dependent, with more variation with range shown by the basalt and calcarenite seabeds than the sand and silt seabeds, which do not support shear waves (Figure 2, thick lines compared with thin lines). There was significant change in both the magnitude and angle of sidelobes in the basalt beam pattern with increased range (Figure 2, thin continuous lines). By comparison, the silt and sand receive patterns varied very little with range.

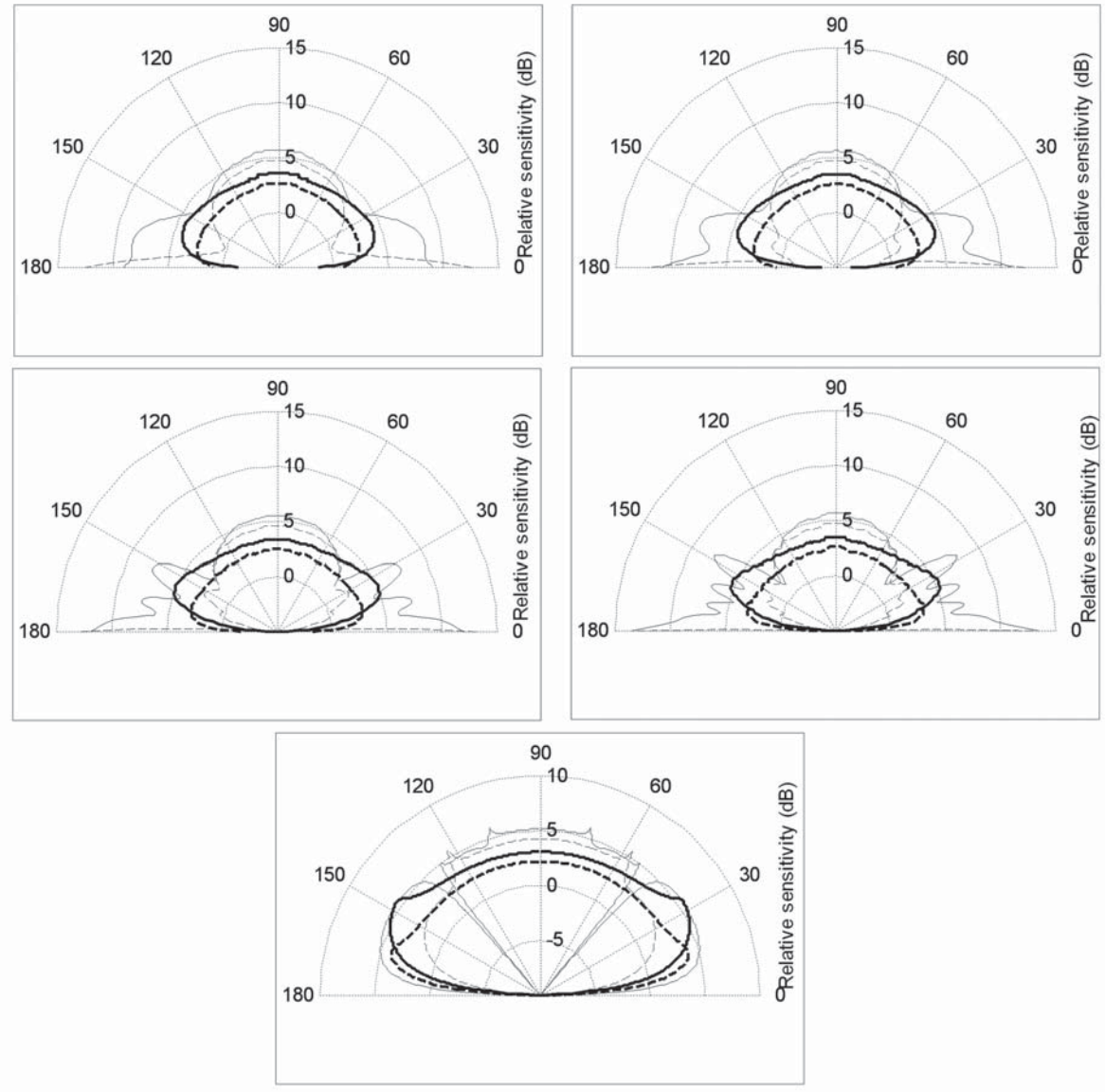


Figure 2: Hyrophone receive beam pattern for basalt (thin continuous line), calcarenite (thin dashed line), sand (thick continuous line) and silt (thick dashed line), for 3, 4, 8 and 12 wavelengths range (top left, top right, middle left and middle right, respectively) and the far field (bottom) as determined by the method using SCOOTER.

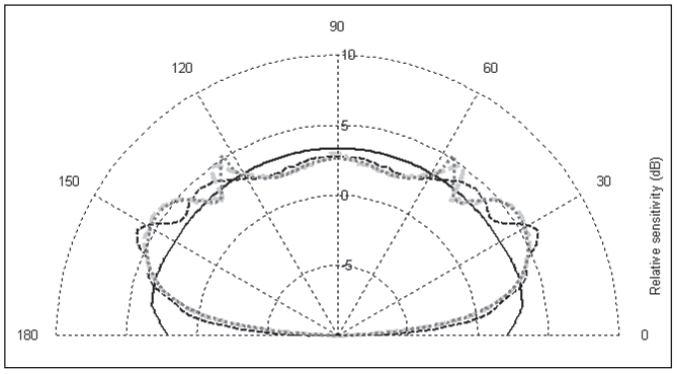


Figure 3: Hydrophone receive beam pattern for 1 wavelength of sand over calcerenite at ranges of 1 wavelength (thick continuous line), 10 wavelengths (thick dashed line), 100 wavelengths (thick grey dashed line) and the far field (thick black dotted line) as determined by method using SCOOTER.

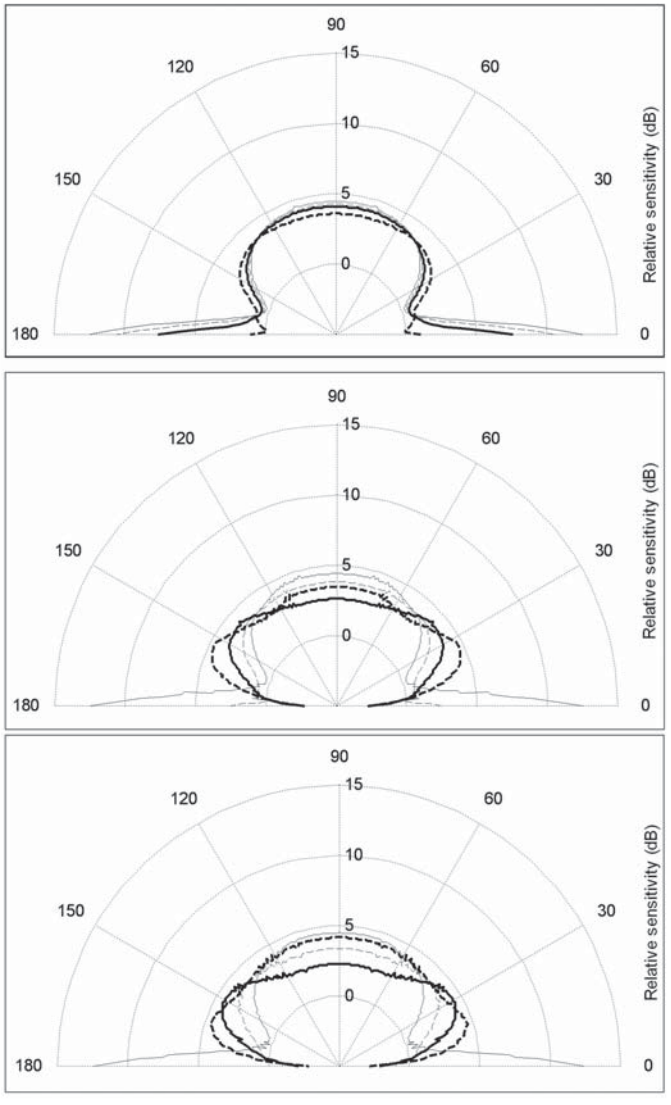


Figure 4: Hydrophone receive beam pattern for bare calcarenite (thick continuous line), then a layer of 0.5 m (thin dashed), 1 m (thick grey continuous line) and 2 m (thick grey dashed line) of sand above calcarenite for 100, 350 and 500 Hz (top, middle and bottom, respectively) at 3 wavelengths range, as determined by the method using SCOOTER.

Figure 3 illustrates the beam pattern for a hydrophone on a 1 wavelength thick layer of sand over a calcarenite substrate at 500 Hz, for different ranges (also normalised by wavelength). This shows how the pattern changes from the response at 1 wavelength range (Figure 3, thick continuous line) until by 100 wavelengths range (thin dashed line) it is very similar to the far-field, plane wave response (thin continuous line).

As the thickness of a layer of sand above a calcarenite half space is increased the beam pattern varies significantly (Figure 4, compare the different lines on each plot). At high grazing angles, near the normal to the seabed, the hydrophone response decreases with increasing thickness of sand layer, however, at lower grazing angles the response increases (Figure 4). The increased sand thickness has greater effect on the changes in beam pattern at the higher frequencies (Figure 4, compare the top plot for 100 Hz, with the bottom plot for 500 Hz).

The variation of response with range and angle from the hydrophone can be seen in Figure 5. This comparison between the responses for basalt (top image) and sand (bottom image) highlights not only the differences in complexity of beam patterns which can occur, but also the considerable variation in magnitude of response. At small grazing angles and ranges of 15-20 wavelengths a basalt seabed may display a relative response of 15 dB, while at the same angle the hydrophone located on sand would exhibit a response nearly 25 dB lower at -10 dB.

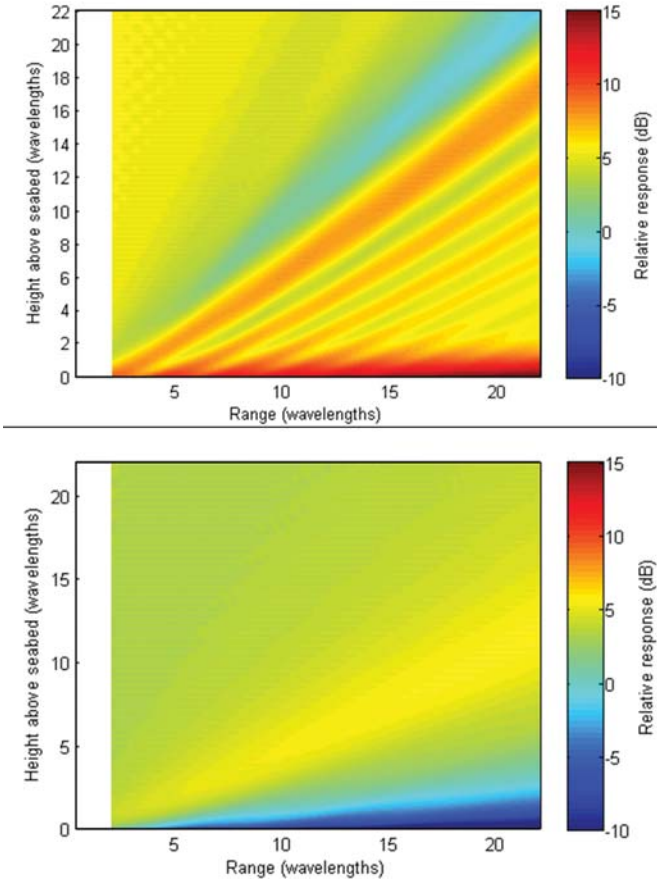


Figure 5: Relative hydrophone response as a function of source location at 500 Hz for basalt (top) and sand (bottom), as determined by the method using SCOOTER.

DISCUSSION

This study has shown that the receive beam pattern of a bottom located hydrophone can vary significantly with range, angle and frequency, with some seabeds displaying a maximum variation of over 10 dB. The variation in response for a given angle, range and frequency for two different seabed types can be as high as 25 dB. The implications for ground truthing modelled received levels and estimating the source level of underwater sounds are significant. For example, one method of localising marine animals is to use the relative received energy from multiple hydrophones [11]. If the estimated received levels do not account for variation in the received beam pattern, the uncertainty in the location of the animal can increase dramatically.

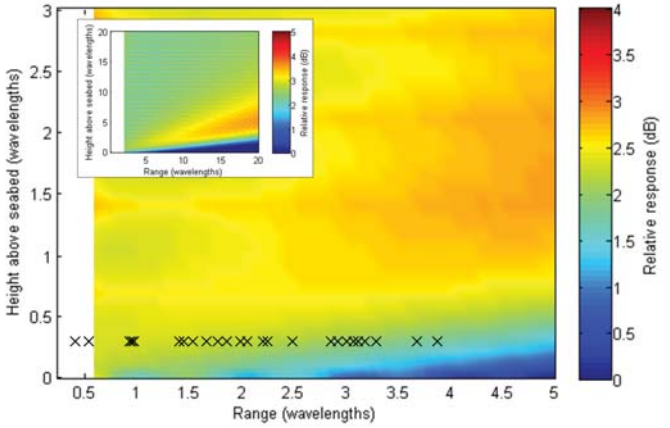


Figure 6: Relative intensity of receive beam pattern of a hydrophone located on silt seabed with range (inset, top left) with a magnification ranging between 0 and 5 wavelengths range. Black crosses mark the range of a call by a mulloway (*Argyrosomus japonicus*), as reported by Parsons et al. [19, 21].

A simple application of the effects of variations in the receive pattern can be seen in Figure 6. Mulloway (Argyrosomus japonicus) are a vocal species of fish and frequently found producing sounds in the Swan River, Western Australia while spawning [5, 18]. Parsons et al. [19] ranged calls of mulloway from a single hydrophone. Over 24 calls the fish was positioned at various ranges, between 1.6 and 18 m from the hydrophone. As calls of an individual fish are often considered to be comparatively constant [5, 20], the sound pressure levels of each ranged call could be considered to be a relative estimate of range. However, as the fish moved towards and away from the hydrophone it passed through different areas of the receive beam pattern. The inset in Figure 6 shows the response with range for a hydrophone located on a silt seabed similar to that of Mosman Bay, in the Swan River Western Australia, where the recordings of A. japonicus took place. The larger image magnifies a small section of this beam pattern for up to 5 and 3 wavelengths range on the x and y axes respectively. Parsons et al. [21] ranged the fish between approximately 0.3 and 4 wavelengths range in the x-direction and it was estimated to maintain an altitude of approximately 0.3 wavelengths or less above the riverbed, during the recording (shown by the Xs in Figure 6). These positions occurred across regions of the receive pattern which varied in response between 1.5 and 2.5 dB.

In the described case the receive pattern would have a comparatively minor effect on the received levels, producing an over estimate in source level of only 1-2 dB. However, with more reflective seabeds which support shear waves it is easy to see how a lack of understanding of the effective hydrophone receive pattern could lead to significant under-, or overestimates of the source level. This variation is an important factor, especially when assessing the environmental impacts of anthropogenic noise.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Fisheries Research and Development Corporation (FRDC) for funding of this work.

REFERENCES

[1] H. Slabbekoorn, N. Bouton, I.V. Opzeeland, A. Coers, C.T. Cate and A.N. Poppers, "A noisy spring: the impact of globally rising underwater sound levels on fish", *Tre. Eco. Evo.* **22**(7), 419-27 (2010)

[2] B.L. Southall, A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W. J. Richardson, J.A. Thomas and P.L. Tyack, "Marine mammal noise exposure criteria: Initial scientific recommendations", *Aqua. Mam*., **33**(4), 411-521 (2007)

[3] R.D. McCauley, S.R. Rennie, J.R. Hughes, and A.J. Duncan, "Transmission of marine seismic signals in Australian waters". *Bioacoust*. **17**, 130-132 (2008)

[4] D.H. Cato, R.D. McCauley and M. Noad, Passive acoustics as a key to the study of marine animals, in *Sounds in the Seas: Introduction to Acoustical Oceanography*, (editor H. Medwin), Chapter 13, Cambridge University Press, 2005

[5] M.J.G. Parsons, *An investigation into active and passive acoustic techniques to study aggregating fish species*, PhD Thesis, Curtin University of Technology, Western Australia, 2010

[6] R.D. McCauley, C.P. Salgado Kent, C.J.K. Burton and C. Jenner, "Blue whale calling in Australian waters", *J. Acoust. Soc. Am.*, **120**(5), pp. 3266 (2006)

[7] A. Širović, J. A. Hildebrand and S. M. Wiggins, "Blue and fin whale call source levels and propagation range in the Southern Ocean," *J. Acoust. Soc. Am.*, **122**, 1208–1215 (2007)

[8] R.J. Urick, *Principles of underwater sound*, MacGraw-Hill, New York, 1983

[9] A.J. Duncan and R.D. McCauley, "Environmental impact assessment of underwater sound: Progress and pitfalls", *Proceedings of Acoustics 2008*, Geelong, Victoria, Australia, 24-26 November 2008

[10] P.C. Etter, *Underwater acoustic modelling and simulation*, 3rd edition, Spon Press, London, 2003

[11] D.H. Cato, "Simple methods of estimating source levels and locations of marine animal sounds" *J. Acoust. Soc. Am.* **104**, 1667-78 (1998)

[12] M.B. Porter, *Acoustics Toolbox*, available from http://oalib.hlsresearch.com/Modes/AcousticsToolbox/

[13] A.J. Duncan and A.L. Maggi, "A consistent, user friendly interface for running a variety of underwater acoustic propagation codes", *Proceedings of the First Australasian Acoustical Societies' Conference*, Christchurch, New Zealand, 20-22 November 2006, pp 471-477

[14] L.M. Brekovskikh and Y.P. Lysanov, *Fundamentals of ocean acoustics*, Springer, New York, 2002

[15] L.E. Kinsler, *Fundamentals of acoustics*, 4th edition, Wiley, New York, 2000
[16] E.L. Hamilton, "Geoacoustic modelling of the sea floor", *J. Acoust. Soc. America*, **68**,(5), 1313-1340 (1980)
[17] F.B. Jensen, W.A. Kuperman, M.B. Porter and H. Schmidt, *Computational ocean acoustics*, Springer-Verlag, New York, 2000
[18] M.J.G. Parsons, R.D. McCauley and M.C. Mackie, "Spawning sounds of the mulloway (*Argyrosomus japonicus*)", *Proceedings of the First Australasian Acoustical Societies' Conference*, Christchurch, New Zealand. 20-22 November 2006, pp. 401-6.
[19] M.J.G. Parsons, R.D. McCauley, M.C. Mackie and A.J. Duncan, "A comparison of techniques for ranging close-proximity mulloway (*Argyrosomus japonicus*) calls with a single hydrophone" *Acoust. Australia.* **38**(3), 145-151 (2010)
[20] M.A. Connaughton, M.H. Taylor, and M.L. Fine, "Effects of fish size and temperature on weakfish disturbance calls: Implications for the mechanism of sound generation", *Journ. Exp. Bio.* **203**, 1503-1512 (2000)
[21] M.J.G. Parsons, R.D. McCauley, M.C. Mackie, P.J. Siwabessy and A.J. Duncan, "Localisation of an individual mulloway (*Argyrosomus japonicus*) within a spawning aggregation and their behavioural characteristics throughout a diel spawning period" *ICES J. Mar. Sci.* **66**, 1007-14 (2009)
[22] W.H. Press, S.A. Teukolsky, W.T. Vetterling and B.P. Flannery, *Numerical recipes, the art of scientific computing*, 3rd edition, Cambridge University Press, New York, 2007

APPENDIX A

Numerical integration computation of the effective beam pattern of a hydrophone located on a half space seabed

To verify the results obtained using the method detailed in the body of this paper, an alternative numerical approach was developed, based on the integral transform methods described in Jensen et al. [17], chapters 2 and 4. This approach is outlined here.

The acoustic field due to a source in a horizontally stratified fluid medium can be represented by

$$\psi(\mathrm{r}\,,\,\mathrm{z}) = \int_{-\infty}^{\infty} \mathrm{S}_{\omega}\mathrm{G}_{\omega}(k_r,z,z_s)\mathrm{H}_0^{(1)}(k_r r)k_r dk_r \qquad \text{(A1)}$$

where z and z_s are respectively the vertical positions of the receiver and source, r is horizontal range, k_r is the horizontal wavenumber, S_{ω} is the wavenumber spectrum of the source, and ψ is the displacement potential. G_{ω} is the solution of the corresponding depth equation which, for a fluid medium of constant density, is

$$\left[\frac{d^2}{dz^2} + (k^2 - k_r^2)\right]\mathrm{G}_{\omega}(k_r,z,z_s) = \frac{\delta(z - z_s)}{2\pi} \qquad \text{(A2)}$$

Here k is the acoustic wavenumber and a time dependence of $\exp(-i\omega t)$ has been assumed. For an elastic medium the result involves the sum of compressional wave and shear wave potentials, each of which satisfies equations analogous to (A1) and (A2).

The case of interest here is for a uniform fluid water column of infinite depth, sound speed c_1 and density ρ_1 over an infinite elastic seabed with compressional wave speed c_{p2}, shear speed c_{s2} and density ρ_2. The z coordinate is taken as positive downwards, with $z = 0$ at the seabed. For this case the Greens function in the water column, $\mathrm{G}_{\omega 1}$, is given by:

$$\mathrm{G}_{\omega 1}(k_r,z,z_s) = A_1 \exp(-ik_{z1}z) - \frac{\exp(-ik_{z1}|z - z_s|)}{4\pi i k_{z1}} \qquad \text{(A3)}$$

where $k_{z1} = \sqrt{k_1^2 - k_r^2}$ and $k_1 = \omega/c_1$ is the acoustic wavenumber. The second term in Equation (A3) represents the signal coming directly from the source whereas the first term is the signal reflected from the seabed.

The compressional wave and shear wave Greens functions in the seabed are given respectively by:

$$\mathrm{G}_{\omega p2}(k_r,z,z_s) = A_2 \exp(ik_{z2}z) \qquad \text{(A4)}$$

$$\mathrm{G}_{\omega s2}(k_r,z,z_s) = B_2 \exp(i\kappa_{z2}z) \qquad \text{(A5)}$$

with $k_{z2} = \sqrt{k_2^2 - k_r^2}$, $\kappa_{z2} = \sqrt{\kappa_2^2 - \kappa_r^2}$, $k_2 = \omega/c_{p2}$ and $\kappa_2 = \omega/c_{s2}$.

The constants A_1, A_2 and B_2 are determined from the boundary conditions at the seabed interface which require continuity of vertical stress and vertical displacement, and vanishing horizontal stress.

An expression for the displacement potential can then be obtained by solving for A_1, substituting the result back into Equation (A3), $\mathrm{S}_{\omega} = \dfrac{-4\pi}{\rho\omega^2}$, which corresponds to a point source with unit pressure amplitude at 1 m, and evaluating Equation (A1). Making use of the relationship between pressure and displacement potential, $p = \rho\omega^2\psi$, then leads to the following expression for the received pressure at the seabed ($z = 0$):

$$p(r,0) = \frac{i}{2}\int_{-\infty}^{\infty}(1+\Re(k_r))\frac{\exp(ik_{z1}z_s)}{k_{z1}}\mathrm{H}_0^{(1)}(k_r r)k_r dk_r \qquad \text{(A6)}$$

Here $\Re(k_r)$ is the plane wave reflection coefficient, which is given by

$$\Re(k_r) = \frac{T_1 - T_2}{T_1 + T_2} \qquad \text{(A7)}$$

where $T_1 = \rho_2 k_{z1}\left\{(2k_r^2 - k_2^2)^2 + 4k_r^2 k_{z2}\kappa_{z2}\right\}$, $T_2 = \rho_1 k_{z2}\kappa_2^4$.

The effective beam pattern is obtained by referring the received pressure back to a distance of 1m from the source assuming spherical spreading, giving

$$\begin{aligned} b(r,z_s) &= R|p(r,0)| \\ &= R\left|\frac{i}{2}\int_{-\infty}^{\infty}(1+\Re(k_r))\frac{\exp(ik_{z1}z_s)}{k_{z1}}\mathrm{H}_0^{(1)}(k_r r)k_r dk_r\right| \end{aligned} \qquad \text{(A8)}$$

where $R = \sqrt{r^2 + z_s^2}$ is the slant range between source and receiver. Note that the integration range in Equation (A8) includes the evanescent region where $|k_r| > |k_1|$ and k_{z1} is imaginary. It is important that this region is included when numerically evaluating Equation (A8) because Scholte interface waves, which decay exponentially either side of the

interface, occur in the evanescent region and are an important contributor to the received field when the source and receiver are both close to the seabed.

Brekhovskikh and Lysanov [14] (p. 88) give an exact integral formula for the reflected wave from a point source over a fluid seabed. For the limiting case of a receiver on the seabed, their result is identical to Equation (A6), but with $1+\Re(k_r)$ replaced by $\Re(k_r)$ (because only the reflected wave is considered, whereas Equation (A6) gives the total field) and Equation (A7) replaced by an appropriate expression for the plane wave reflection coefficient of a fluid-fluid interface. They go on to derive analytic formulae for the received signal in terms of geometrically reflected and lateral waves, however their derivation requires assumptions that are invalid for a receiver located on the seabed, so for the case of interest here it is necessary to proceed by numerical integration of Equation (A8). This was achieved using the extended midpoint rule (Press et. al. [22]), with the integration step being progressively reduced until convergence was obtained.

APPENDIX B

Invariance of the effective beampattern for constant range/ wavelength ratios

The frequency dependence of Equation (A8) can be made explicit by changing the integration variable to $u = k_r / \omega$, and making use of the relation $k_1=\omega/c_1$, leading to:

$$b(r,z_s) = R|p(r,0)| = \omega R\left| \frac{i}{2} \int_{-\infty}^{\infty} (1+\Re(\omega u)) \frac{\exp(iv\omega z_s)}{v} \mathrm{H}_0^{(1)}(u\omega r) u du \right| \quad \text{(B1)}$$

where $v = \sqrt{\frac{1}{c_1^2} - u^2}$.

With these definitions u and v are independent of range and frequency. Using Equation (A7) it is straightforward to show that $\Re(\omega u)$ is independent of ω for an elastic half space seabed. This is true for a seabed without attenuation, but also for a seabed with attenuation that is proportional to frequency. The effects of attenuation can be included in the usual way by making the compressional and shear wave speeds, and hence k_2 and κ_2 complex (Jensen et. al. [17], pp 33-34).

If ωR is held constant, then for the same beam angle, ωr and ωz_s will also be constant, and the effective beam pattern computed by (B1) is invariant. The acoustic wavelength in the water column is given by $\lambda = 2\pi c_1 / \omega$, so the effective beam pattern will be unchanged with changes in frequency if r / λ is held constant.

Note that this invariance requires the hydrophone to be on the seabed, and the seabed reflection coefficient to be independent of frequency. It is not generally the case for a hydrophone located above the seabed or for a more complicated seabed with a frequency dependent reflection coefficient.

BACKGROUND NOISE AFFECTS THE TASTE OF FOODS

The level of background noise affects both the intensity of flavour and the perceived crunchiness of foods, researchers have found. Blindfolded diners assessed the sweetness, saltiness, and crunchiness, as well as the overall flavour, of foods as they were played white noise. Louder noise reduced the reported sweetness or saltiness, and increased the impression of crunchiness. The research is reported in the industry journal Food Quality and Preference.

It may go some way to explaining why airline food is notoriously bland, a phenomenon that drives airline catering companies to season their foods heavily. Researchers from the Unilever Research and Development laboratories in the Netherlands and the University of Manchester, UK, say that there is a general opinion that airline foods are less than fantastic. Airlines do their best, but the researchers wondered if there were other reasons why the food would not be so good. One thought was that perhaps the background noise had some impact. NASA gave their space explorers very strong-tasting foods, because for some reason they could not food very strongly. Again, perhaps the background noise was affecting their perception. There was no previous research on this, so the team started to investigate whether the hunch was correct.

In a comparatively small study, 48 participants were fed sweet foods such as biscuits, or salty ones such as crisps, while listening to silence or noise through headphones. They then rated the intensity of the flavours, and rated their liking of the foods presented. In noisier settings, foods were rated less salty or sweet than they were in the absence of background noise, but were rated to be more crunchy. The evidence points to the effect being down to where the person's attention was focused. If the background noise was loud it might draw your attention, and thus away from the food.

Also in the group's findings there is the suggestion that the overall satisfaction with the food was correlated with the degree to which diners liked what they were hearing, and this is a finding the researchers are pursuing in further experiments.

In the words of the experimenters (from the School of Psychological Sciences, University of Manchester, UK, and Unilever Research and Development, Vlaardingen, Netherlands), they investigated the effects of auditory background noise on the perception of gustatory food properties (sugar level, salt level), food crunchiness and food liking. Participants blindly consumed different foods whilst passively listening to either no sound, or quiet or loud background white noise. The foods were then rated in terms of sweetness, saltiness and liking (experiment 1) or in terms of overall flavour, crunchiness and liking (experiment 2). Reported sweetness and saltiness was significantly lower in the loud compared with the quiet sound conditions, but crunchiness was reported to be more intense. This suggests that food properties unrelated to sound (sweetness, saltiness) and those conveyed via auditory channels (crunchiness) are differentially affected by background noise. A relationship between ratings of the liking of background noise and ratings of the liking of the food was also found in experiment 2. It was concluded that background sound unrelated to food diminishes gustatory food properties (saltiness, sweetness) which is suggestive of a cross-modal contrasting or attentional effect, whilst enhancing food crunchiness.

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.

ROAD TRAFFIC CONTROLLERS AND THE USE OF LEVEL DEPENDENT HEARING PROTECTORS

W. Williams[1] and B. Groothoff[2]

[1]National Acoustic Laboratories, Chatswood, NSW. [2]Environmental Directions, Aspley, QLD

Constant, clear radio and voice communication is of crucial importance in safe working conditions for traffic controllers. The provision of electronic, level dependent, sound-restoration ear muffs would seem to offer an ideal solution to a working environment where the daily noise exposure is below the regulated level but frequently experiences periods of high continuous and impulsive noise. This report shows that careful thought and good consultation with the intended users must occur before these devices are introduced and accepted into the workplace

INTRODUCTION

Electronic, level-dependent hearing protectors designed for use in areas with occasional high level impulsive noise, have been recommended and readily available on the market for many years (Berger: 2000). With the inclusion of 'environmental' microphones that allow the immediate work environment of the wearer to be clearly monitored ('*sound-restoration ear-muffs*' (ISO/TR 4869-4)) and the inclusion of radio communication connectivity in many devices through the development of improved technology, there should be an increasing use of these devices seen at workplaces. However from anecdotal evidence this does not seem to be the case.

Having previously seen the successful use of this type of hearing protectors in a difficult work environment, such as firing ranges (Williams 2011), the authors decided to see if uses could be extended to similar workplaces. That is workplaces where intermittent loud noise, continuous and/or impulsive, is interspersed with periods of lower noise and where for safety purposes good communication must be maintained. One area where these characteristics are common is with traffic control personnel who are responsible for maintaining smooth and safe traffic flow in and around large civil construction sites.

METHOD

Participants were recruited from amongst individuals who work for a company which contracts to supply trained, experienced operators responsible for traffic flow and control on or around various active, large construction or work sites. In total there were 12 full participants, ten males, one female and one undeclared, the average age of the ten who supplied their age was 48 years with an age range of 21 to 63 years. Ethical approval was provided by the Australian Hearing Human Research Ethics Committee.

Participants were asked to wear a *350 dBadge Personal Sound Exposure Meter* (a dosimeter) manufactured by Casella, UK, for at least one typical work shift during participation in order to ascertain what could be considered a typical day's noise exposure level ($L_{Aeq,8h}$) for the traffic control tasks carried out. All measurements were carried out in accordance with the relevant sections of AS/NZS 1269.1 (2005).

The work group from which the participants were drawn undergo regular workplace health and safety training and tool-box talks including the use and application of hearing protectors. Participants were supplied with a well-known brand of electronic, level dependent, sound-restoration, communication earmuffs. The sound level from the internal earphones in these ear muffs was variable, according to the desires of the user, but capped to an upper limit of 82 dB, A-weighted, sound pressure level, for both audio input from a radio or environmental sound from external microphones mounted on the ear-cups. The passive attenuation of the devices was appropriate for the situation meeting the requirements of international standards (ISO 4869) with an SNR of 31 dB.

Participants were rostered for working in and around large civil construction sites where there was an intermingling of construction activity such as: road construction machinery; excavation equipment; and pavement breaking and cutting operations; together with traffic movement from heavy vehicles, cars, trucks and buses.

Individuals were encouraged to use the hearing protectors as often as possible during the trial between March and July 2011 particularly while wearing the dosimeter. At the conclusion participants were requested to fill out a questionnaire (see the Appendix) that had been developed during previous such trials (Williams 2011).

Data and statistical analyses were carried out using the commercial statistical package Statistica® by StatSoft Pacific.

RESULTS AND DISCUSSION

Dosimetry results

Satisfactory noise exposure readings were only available from three dosimeters for the duration of the day's 'noisy' work. The mean $L_{Aeq,8h}$ was 81 dB with exposures ranging from 78 dB to 84 dB. These are below the $L_{Aeq,8h}$ exposure

standard for noise of 85 dB for any Australian jurisdiction. Within the working day noise levels for individual events (L_{Aeq}) varied between lows of around 65 dB to highs of around 95 dB – the dosimeters recorded one minute L_{Aeqs} for a minimum of seven hours. The maximum L_{Cpeak}s recorded were around the 135 dB, just below the peak exposure standard for noise of 140 dB. While these levels do not exceed the regulated levels they do not represent 'safe' levels under the recommendations of the WHO (1980) ($L_{Aeq,8h}$ less than 75 dB) but rather a level of acceptable risk.

Periodic exposures to such high noise at levels less than the exposure standard are capable of producing auditory fatigue and/or temporary threshold shift (TTS) (Sataloff and Sataloff 1987). For workers responsible for the safe movement of traffic in and around large work areas communication is very important whether by radio or face-to-face (Robinson and Casali 2000). For this reason the use of a level-dependent, sound-restoration, communication noise-excluding headset, such as those supplied during this project, would seem to offer an advantage over uncovered ears. The results from the applied questionnaire (see Appendix) indicate that this was not necessarily the case for both groups who self-reported a hearing loss and those who did not.

Questionnaire results

Twelve completed questionnaires were received from the participants. Analysis of the four hearing health and hearing protector use questions were:

QUESTION	YES	NO
Do you think you have a hearing loss?	6	6
Do family/close friends ever say they think you have a hearing loss?	3	9
Do you have trouble hearing conversation in background noise?	6	6
Do you ever experience tinnitus (ringing/buzzing in ears)?	6	6
Do you like wearing hearing Protectors?	5	7
What is your preferred style of hearing protector?	Plugs (4)	Muffs (8)

Except for the specific points discussed below there were no statistically significant differences with respect to questionnaire responses at the $p = 0.05$ level, between those who self-reported a hearing loss and those who did not.

Analysis showed that there were statistically significant positive correlations ($p < 0.05$) between increasing age and: self-reported hearing loss; self-reported tinnitus; family and close friends reporting that they thought that the individual may have a hearing loss; and the dislike of wearing hearing protectors. There was also a significant difference with feelings of stress. In general most people felt stressed when wearing hearing protectors however, those who self-reported a hearing loss felt more stressed when wearing hearing protectors than those with no self-reported loss ($p = 0.016$). Those who self-reported no hearing loss felt less stressed when wearing the earmuffs under trial than those who self-reported a loss - indicated by a lower ordinate value in Figure 1. Self-reported hearing loss has been shown to be a reliable indicator of a measurable loss (Williams and Purdy 2008) with individuals who self-report showing an average measured loss of 26 dB.

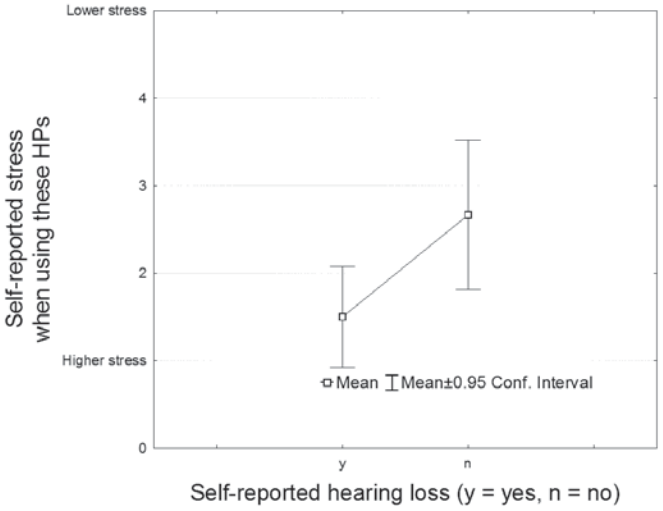


Figure 1. This graph shows a statistically significant difference ($p = 0.016$) between the self-reported stress of those individuals who self-reported a hearing loss (y) and no hearing loss (n). A lower score implies higher stress.

In general, on the negative side, the results from the questionnaire survey showed that the traffic controllers do not like wearing hearing protectors and find them uncomfortable to wear even for short periods. They also find that hearing protectors put excess pressure on their ears; increase feelings of isolation; interfere with some work tasks; and are a bit of a hassle to carry and wear. Those with a self-reported hearing loss felt more isolated while wearing the issued protectors than those without a self-reported loss and they also found it harder to converse with others. On the positive side the issued protectors: were easy to fit and use; facilitated talking to others while eliminating unwanted noise; made it a bit easier to hear wanted sounds; and facilitated talking to others.

The response to the question on the percentage of wear time while what the user thought was 'loud noise' varied widely with a mean of 33% and a standard deviation of 18%. The wear time on a typical work day was estimated to average around 55 minutes with a standard deviation of 74 minutes.

GENERAL

The main outcome of the project was that the traffic controllers did not like using the communication, level-dependent sound-restoration ear muffs supplied. It was expected, as has been observed in other workplaces (Williams et al. 2002; Rabinowitz et al. 2007), that individuals may not necessarily be favourably disposed to wearing hearing protectors in workplaces where the noise levels are considered by workers to be relatively 'low', 80 dB for example, when

compared to areas where noise levels would be considered high, such as 95 to 100 dB. However it was anticipated that the issued hearing protectors would be more acceptable given that they had external microphones to enhance situational awareness. They also had inbuilt radio communication and some included Bluetooth® connectivity. These apparent advantages were not of sufficient advantage to encourage users to substantially increase their wear time.

Hearing protector use has also been observed to be underutilised in 'low noise' work environments, as in the case of the current trial, where exposure levels are at or below the regulated level of 85 dB (Rabinowitz et al. 2007). Rabinowitz reported that in areas of low or intermittent loud noise where the use of hearing protectors can interfere with communication users are more likely to remove or be reluctant to use hearing protectors in preference for what they perceive as better communication. Users in high noise areas where noise exposure is perceived as a greater hazard tend to be more conscientious with the use of hearing protectors.

Previous experience with workplaces involving high level impulse noise exposure from firearm training, showed that similar electronic, level dependent, sound restoration hearing protectors were well accepted (Williams 2011). The advantages of level dependent, environmental microphones and radio and Bluetooth® communication apparently did not outweigh the perceived disadvantages of wearing the headset in the 'noise' environment of the traffic controllers. The implication here, being that from the perspective of the wearer the advantages offered through the use of the hearing protector need to be greater than the disadvantages for the devices to be willingly worn.

The limitations of the outcomes of this study arise mainly from the difficulty of recruiting and maintaining active participants. Thus the relatively small number of participants does restrict the wider interpretation of the results.

CONCLUSION

This trial revealed that electronic, level-dependent sound-restoration hearing protectors that have application and acceptance in particular workplaces may not necessarily be useful in all workplaces even if conditions may appear similar. It would seem that the advantages from using such devices must outweigh the disadvantages and that careful thought and consultation with the users must occur before their introduction to the workplace.

ACKNOWLEDGEMENTS

The authors would like to thank Mr John Scales and Traffic Group Australia Pty Ltd for their participation in this project.

REFERENCES

[1] *Australian/New Zealand Standard AS/NZS 1269.1: 2005 Occupational noise management Part 1: Measurement and assessment of noise immission and exposure*, Standards Australia, Sydney

[2] *Australian/New Zealand Standard AS/NZS 1269.3: 2005 Occupational noise management – Part 3: Hearing protector program,* Standards Australia, Sydney

[3] *Australian/New Zealand Standard AS/NZS 1270: 2002 Acoustics – Hearing protectors*, fifth edition, Standards Australia, Sydney

[4] E.H. Berger, "Hearing protection devices", in *The Noise Manual Fifth Edition*, edited by E.H. Berger, L.H. Royster, J.D. Royster, D.P. Driscoll and M. Layne, American Industrial Hygiene Association, Fairfax, VA, 2000

[5] *ISO 4869 Acoustics – Hearing protectors*, International Organisation for Standardisation, Geneva

[6] *ISO 4869-4 Acoustics – Hearing protectors, Part 4: Measurement of effective sound pressure levels for level-dependent sound-restoration ear-muffs*, International Organisation for Standardisation, Geneva, 1998

[7] P.M. Rabinowitz, D. Galusha, C. Dixon-Ernst, M.C. Slade and M.R.Cullen, "Do ambient noise exposure levels predict hearing loss in a modern industrial cohort?", *Occupational & Environmental Medicine* **64**, 53–59 (2007)

[8] G.S. Robinson and J.G. Casali, "Speech Communications and Signal Detection in Noise", in *The Noise Manual Fifth Edition*, edited by E.H. Berger, L.H. Royster, J.D. Royster, D.P. Driscoll and M. Layne, American Industrial Hygiene Association, Fairfax, VA, 2000

[9] R.T. Sataloff and J. Sataloff, *Occupational Hearing Loss*, Marcel Dekker, New York, 1987

[10] WHO *Environmental Health Criteria* 12 NOISE, World Health Organization, Geneva, 1980

[11] W. Williams, "A qualitative assessment of the performance of electronic, level dependent earmuffs when used on firing ranges", *Noise & Health* **13**(51), 189–194 (2011)

[12] W. Williams, L. Forby-Atkinson, S. Purdy and G. Gartshore, "Hearing loss and the farming community", *Journal of Occupational Health and Safety, Australia and New Zealand* **18**(2), 181–186 (2002)

[13] W. Williams and S.C. Purdy, "The reliability of self-reported hearing difficulties from occupational noise exposure", *Journal of Occupational Health and Safety, Australia and New Zealand* **24**(2), 143–153 (2008)

APPENDIX

Electronic hearing protector questionnaire

Date: *Age:*
Gender: *Job:*
Typical duties:

1) Do you think you have a hearing loss? Y/N

2) Do family/close friends ever say they think you have a hearing loss? Y/N

3) Do you have trouble hearing conversation in background noise? Y/N

4) Do you ever experience tinnitus (*ringing/buzzing in ears*)? Y/N

5) Do you like using Hearing Protectors? Y/N

6) If NO why?

7) What is your preferred style of hearing protectors?
Plugs or Muffs?

8) What percentage of the time you are exposed to loud noise would you wear hearing protectors? 0_____100%

9) About how long you generally wear hearing protectors each day when you work? 0- ½ hour ½-1hr 1-2hrs 2-3hrs 3-4 hours 4+ hours

10) Do you have any comments or suggestions about hearing protectors? (*e.g if you could design the "perfect" HP, what would it be like?*)

11) What is your opinion of the 'electronic' hearing protectors you used?

☑ Tick the box representing your thoughts about your protectors

	No		Don't know		Yes
a) They are comfortable to wear for up to 1 hour	☐	☐	☐	☐	☐
b) They cut out unwanted noise	☐	☐	☐	☐	☐
c) They are easy to put on/fit properly	☐	☐	☐	☐	☐
d) It is a hassle to carry/wear them	☐	☐	☐	☐	☐
e) I am less stressed at work when I wear them	☐	☐	☐	☐	☐
f) I need to make lots of adjustments while I am wearing them	☐	☐	☐	☐	☐
g) They allow me to concentrate better at work	☐	☐	☐	☐	☐
h) They are time consuming to fit/adjust	☐	☐	☐	☐	☐
i) They put a lot of pressure on my ears	☐	☐	☐	☐	☐
j) They interfere with face-to-face communication	☐	☐	☐	☐	☐
k) They help me to hear the sounds I want to hear	☐	☐	☐	☐	☐
l) I feel isolated from co-workers when I wear them	☐	☐	☐	☐	☐
m) They interfere with my work tasks	☐	☐	☐	☐	☐
n) It is easier to talk with others when I wear them	☐	☐	☐	☐	☐
p) They are easy to use	☐	☐	☐	☐	☐
q) They are comfortable to wear all day	☐	☐	☐	☐	☐

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.

EFFECTIVE NOISE REPORTS AND PRESENTATIONS FOR PLANNING PANELS

Paul Mitchell
Managing Director, EMGA|Mitchell McLennan, St Leonards NSW 2065, pmitchell@emgamm.com

GROWING ROLE OF PLANNING PANELS

In NSW and other states there is increasing use of specialist panels to determine applications for larger scale development proposals. Primary examples in NSW are the Planning Assessment Commission (PAC) and Joint Regional Planning Panels (JRPPs). These are technical bodies designed to make merit based decisions on the facts, including consideration of community views. Such panels are typically composed of experienced professionals, often town planners and public administrators, sometimes assisted by specialist advisors such as acousticians.

This paper provides guidance on preparing reports for and making presentations to such planning panels.

OUTLINE OF ASSESSMENT PROCESS

Applications for large development proposals are made to either local councils or state planning agencies. These organisations arrange for the exhibition of the application and receipt of submissions from interested parties. They are then assessed by the council or departmental planners with advice from internal and external technical bodies such as those dealing with pollution, traffic or ecology. The planners interact with panels at various points commencing with a pre-assessment briefing where issues requiring particular attention in the assessment are identified.

Following exhibition and receipt of submissions from the public and advice from specialist agencies, the planners prepare their assessment reports with a recommendation on how the application should be determined - approval with conditions, deferral or refusal.

There are a number of points in the application preparation and assessment process where technical specialists, like acousticians, should be involved. The first is a pre-application meeting where the proposal is explained in conceptual terms to the assessing planners. Here it is important to explain whether or not noise is likely to be a significant issue. If noise is likely to be a significant issue, then the major noise sources, potentially affected receptors and planned background monitoring locations should all be explained. The aim is to get at least in principle agreement on the methodology. Once the application is sufficiently advanced to determine the likely noise levels that receptors will experience, a further meeting with the assessing planners is desirable to explain potential impacts and how they will be controlled. Again, an in-principle response on the acceptability of these controls and impacts should be sought.

The overall goal during the preparation and assessment process should be to establish open communication with the assessors so that a clear understanding of requirements and likely responses can be obtained. Too often, the first time acousticians interact with assessors directly is after the latter's report and recommendation has been prepared. If the recommendation is for refusal it is difficult to change this as the application may require amendments which would need further assessment as they are unlikely to be accepted at face value.

PREPARING CLEAR NOISE REPORTS

Acousticians often seem to assume that their primary audiences - planners and affected persons - have a technical understanding of noise issues. In my experience this is unwise; town planners are must consider and evaluate a very wide range of policy and technical matters and it is unrealistic to expect them to be expert in them all. A related point is that assessment reports are often voluminous describing the application, regulatory context, submissions received and conclusions on all relevant matters. Thus, to be effective, noise reports must be clear and concise.

Given the above what does a good noise report look like? It would have two main sections. The first provides an overview of the development proposal, its setting, mitigation measures and residual noise impacts to provide readers with a general understanding without getting lost in technical detail. The specific things covered are:

- the setting - what the area is like now prior to the development occurring;
- the proposed development and its noise emissions;
- the receivers: where they are and what they do;
- factors affecting transmission of noise between source and receivers;
- noise levels received and their acceptability;
- the need for, type and likely effectiveness of mitigation measures; and
- a conclusion – how the noise climate will change as a result of the development.

The second section provides technical details. Descriptions and tables of background noise measurements, and the conditions under which they were recorded. The same for noise emissions or, if they were not measured, how they were derived, how accurate they are and can they be independently verified.

Details of the modelling used to simulate noise transmission to receivers - what assumptions were used about key variables and how accurate are the estimates likely to be at receiver locations? The mitigation measures proposed – are they well proven or novel? Is there a need for post-commissioning verification. And, finally, what is the predicted impact - will the mitigated noise be noticeable or imperceptible?

The key point is to keep these two parts of the report separate. The first outlines the overall picture while the second gives all the technical detail. Two often these aspects are combined and readers soon become lost in pages of table about background noise, noise emissions, meteorology and the like. Acousticians might like to remember that most readers are unlikely to warm to pages of numbers dealing with unfamiliar terms such as dBs, sound power levels, logarithmic scales, temperature inversions and atmospheric stability classes.

APPEARING AT PANEL HEARINGS

To be effective in making your case two things are essential:

- being concise and sticking to the issues- your time will normally be limited (and if its not chances are the panel members have stopped listening!); and
- being reasonable and balanced by acknowledging the concerns of objectors even if you feel their technical basis is weak and never personalise responses - 'he clearly doesn't understand' or 'he is being unrealistic'.

A good approach is to identify the issues, run through them identifying points of difference between you and other experts and conclude with your findings are technically more robust. A final point is to talk to the panel and use graphic aids if they assist. For any communication to be effective any speaker must know who their audience is and address their interests.

CONCLUSIONS

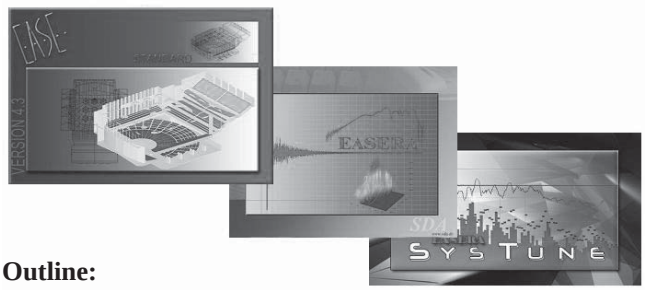
All specialists, not only acousticians, should be mindful that panels deal with a wide range of issues in virtually every application. As such, if the findings of your noise report are buried within a mass of technical information there is a real risk that they will be lost. Ensuring you provide an overview of the whole story; what a noise environment is like now, what change a development will bring, how it will be mitigated and the acceptability of the result is essential. In presentations, define the issues, explain your points of difference and give a professional opinion on the acceptability of the outcome. Keep the sharing of complex tables of numbers to your acoustical colleagues!

Ease Training in Australia

27 February 2012

Empire Theatre, Toowoomba

Wesleyan Church Venue



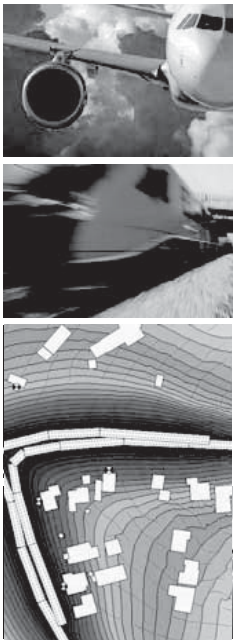
Outline:

Starts with basic model construction of the Wesleyan Church itself and possibly one other, advanced features and techniques added, closing holes, short cuts, scattering coefficients etc. Progress through modelling in Sketchup and Autocad. Loudspeaker selection, placement and mapping.

Advanced analysis techniques - Auralisation, Aura Response derivation of Impulse Responses - export to Easera.

Final day finishes with measurement and analysis module using Easera & SysTune.

Registration & other details at **www.scientific-acoustics.com.au**



Cadna A®

State-of-the-art noise prediction software

CadnaA is the premier software for the calculation, presentation, assessment and prediction of noise exposure and air pollutant impact. It is the most advanced, powerful and successful noise calculation and noise mapping software available in the world.

. One button calculation
. Presentation quality outputs
. Expert support

Renzo Tonin & Associates is now the distributor for CadnaA in Australia & NZ.

Contact us for a quote!

RENZO TONIN & ASSOCIATES
inspired to achieve

p 02 8218 0500
f 02 8218 0501
e sydney@renzotonin.com.au
www.renzotonin.com.au

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.

PHYSCLIPS: A MULTIMEDIA, MULTI-LEVEL INTRODUCTION TO MECHANICS, WAVES AND SOUND

Joe Wolfe, George Hatsidimitris and John Smith
School of Physics, The University of New South Wales, Sydney NSW 2052, J.Wolfe@unsw.edu.au

Physclips is a web-based learning, teaching and reference resource in introductory physics. It is aimed at levels from senior high school to early university. The volume Waves and Sound has recently been completed and added to the volume Mechanics. Together, these present an introduction to acoustics and vibration, with resources for students and teachers.

The volume on Waves and Sound contains chapters on oscillation, travelling waves, sound, the Doppler effect, quantifying sound, interference and standing waves. The last chapter, called Human Sound, introduces speech and hearing.

While the content is fairly standard for introductory physics, the platform is not. We have constructed it using multimedia

Figure 1. This screen grab from section 5.1 is from a clip demonstrating the Doppler effect using a piezo buzzer mounted on either a bicycle or a fixed stand. Three sections of the sound track are expanded to show the period for stationary, approaching and receding source. Below the main screen is a list of the html support pages and, below that, the top of the directory of downloads.

and hyperlinks, aiming to make it highly flexible and easily navigable, so that each learner can construct a learning path that suits his/her needs and abilities, so that teachers can readily find and download film clips and animations for use in lessons and so that elements can be readily found for revision or reference.

Each chapter in Physclips covers much the same material as does a chapter in a traditional text book. Each Physclips chapter has a rich multimedia tutorial, which gives an overview and a logical development of the material, and which includes film clips of key experiments and demonstrations. The film clips are central to our philosophy: physics is an experimental science and a film clip shows the real situation, not an idealisation. Film clips are, however, often combined with or complemented by animations.

The tutorials are brief—typically ten minutes in length—but information-rich. For this reason, pauses with 'click to continue' buttons are included, and each screen has a scroll bar to allow repeats. Navigation is facilitated by icons below the scroll bar (see Fig 1).

Rigour and breadth are maintained, without interrupting the flow of the tutorials, by including hyperlinks that branch to a series of html pages that give deeper and broader material as well as sections that introduce calculus, vectors and other needed materials.

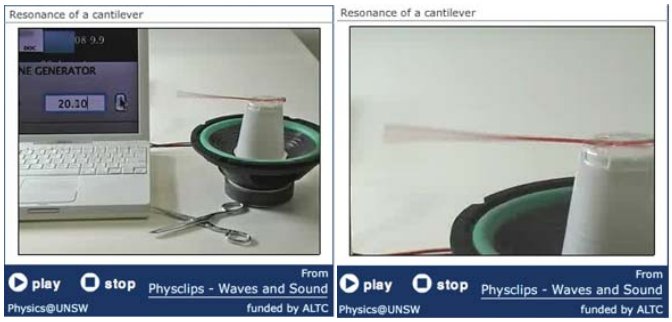


Figure 2. This home experiment, from the chapter Oscillations, uses a cable tie to investigate cantilever resonance. Scissors vary its length. It is driven by a downloadable signal generator, an audio amplifier, a loudspeaker and a disposable cup.

Other pages present simple experiments that may be performed using only readily available and/or cheap components, plus a computer and in some cases software developed for the project (see Fig 2).

The film clips and animations from each chapter are available for download, either separately or compressed into one folder, for teachers to use directly in lessons.

For many students, what is difficult about physics is also what makes it such a powerful discipline: the process of seeing, in a real world problem, the relevant principles and variables, then quantifying and analysing them. For this reason, the combination of film clip and animation is a powerful pedagogical tool: animations superimposed on film clips can show abstractions such as force, phasors, energy, etc; quantities that the expert 'sees' with the mind's eye. These then allow the beginner to experience an expert view of a physical situation.

The layout and presentation of Physclips is consistent with and guided by evidence-based guidelines in the field of multimedia learning with respect to principles known in that field as modality, segmentation, spatial contiguity, personalisation and signalling [1]. The collaborative design process between educator and designer is further moderated by user-feedback [2]. We describe its construction elsewhere in more detail [3].

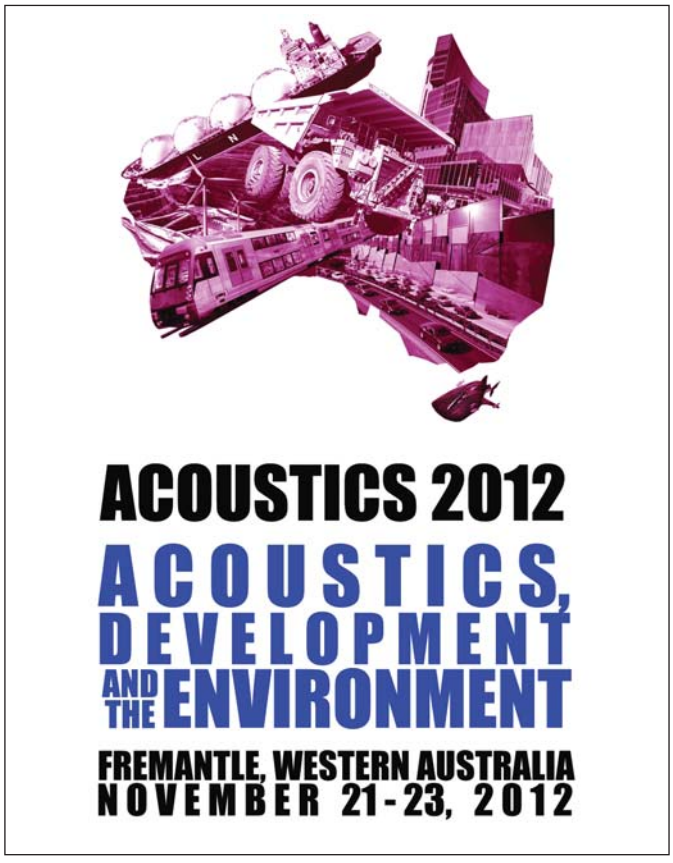
Physclips and its components have won several international awards. Elements of it are used in lessons at Harvard and MIT, but also in outback Australia and Africa. It is also proving popular: typically a few thousand different users access Physclips every day. Because each user usually downloads a few dozen files, the hit rate is in the tens of thousands per day. Physclips is at www.animations.physics.unsw.edu.au.

REFERENCES

[1] Mayer, R. 2008 Research-Based Principles for Learning with Animation, In R.K. Lowe & W. Schnotz (Eds.), Learning with animation. Research implications for design (pp. 30-48). New York: Cambridge University Press.

[2] Hatsidimitris, G. and Wolfe, J. (2009) "Intuition, evidence-based guidelines and user feedback in multimedia teaching: The Physclips project" In *Same places, different spaces*. Proceedings ascilite Auckland 2009 (pp. 447-451).

[3] G. Hatsidimitris and J. Wolfe. (2011) "Building an on-line learning resource, from inception to dissemination" *Proc. World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education* 2011 (pp. 185-187). Chesapeake, VA: AACE.



News

Inter-Noise 2014 in Melbourne

It's now official! The Victoria Division will be hosting Inter-Noise 2014 from 17-19 November 2014. So get your thinking caps on and start planning to be there and present a paper. Contact the Congress President, Norm Broner, if you would like to help on the Technical Committee. The location will be the Melbourne Convention and Exhibition Centre near the scenic Southbank.

Special issue of Acoustics Australia on wind turbine noise

As a result of a very successful session on wind turbine noise and a well attended workshop on wind turbine and low frequency noise at the recent AAS Annual Conference on the Gold Coast, Norm Broner is organising a special edition of the Acoustics Australia journal on wind turbine noise. The topics to be covered include: criteria for low frequency noise and wind turbines; annoyance and health effects due to low frequency noise and wind turbines; Australian Standard, SA and NZ guidelines; wind turbine and farm sound power measurement.

If you would like to contribute either a paper or a technical note to this special issue, please contact Norm at nbroner@globalskm.com. Articles are required by the end of January 2012.

Posthumous Fellowship for Colin Speakman

Colin Speakman has been posthumously awarded the Grade of Fellow of the Australian Acoustical Society. Colin was a diligent and ethical practitioner of acoustics and mechanical engineering. He worked tirelessly for his employers and gave significant service to the AAS over a period of 13 years. His elevation to the Grade of Fellow has been granted on the basis of his conspicuous service to the Society.

Concrete road pavement noise workshop

On 19 September 2011, a joint workshop on concrete road pavement noise between the AAS and the Australian Society for Concrete Pavements (ASCP) was held in Ryde, NSW. This one-day workshop included topics on concrete road surfacing, pavement noise, diamond grinding and next generation concrete surfaces. Speakers included John Roberts (International Grooving & Grinding Association and American Concrete Pavement Association), Dr Gayle Greer (AECOM), Ben Lawrence (Wilkinson Murray) and Geoff Ayton (RTA). The workshop was well attended by representatives from the acoustic and pavement industries and from both the private and public sector. The event was fully sponsored by the NSW Division, an opportunity made available to us as a result of the profit made from the ICA conference in Sydney last year.

Safe Work Australia

Safe Work Australia intends to develop new model Codes of Practice to provide advice on minimising the hazards of vibration in the workplace by the end of 2012. In September 2011, people from all industries were invited to attend public consultation workshops, so that a broad range of ideas on the scope, application and approach for these codes could be obtained. The co-ordinator for the project is Dr Paul Taylor.

Workplace Health and Safety Act and Regulations

At the time of going to press it is unclear how many jurisdictions will be implementing the harmonised Workplace Health and Safety Act and Regulations on 1 January 2012 as originally intended. However, the section dealing with noise in the model WHS Regulations has been amended as a result of comments received during public consultation and now contains requirements for 2-yearly audiometric testing and duties on designers, manufacturers, importers and suppliers of plant.

See:http://www.safeworkaustralia.gov.au/AboutSafeWorkAustralia/WhatWeDo/Publications/Pages/Model-WHS-Regulations.aspx

New approach sure to resonate

Resonate Acoustics has just opened its first office in Adelaide. Headed by Matthew Stead, formerly AECOM Global Practice Leader for Acoustics, this dynamic consultancy brings a three-tiered approach to acoustic engineering by providing client value, insight from experience and engaging in collaboration. Stead, who has worked on major projects both in Australia and internationally for over 19 years, believes the role of acoustics, particularly in building, transport and planning, has become vital given the blurring of demarcation lines between residential and non-residential land use.

Stead says noise challenges typically include sites constrained by roads and other buildings; transportation as a major noise source; and a requirement for sealed windows to mitigating the impact exterior noise, resulting in a requirement for air conditioning and the associated energy penalties. Solutions to these problems naturally vary according to the circumstance, but may include improved building facade construction; traffic noise attenuation via low noise road surfaces, noise barriers, cuttings and earth mounds; and the important consideration of orientation and location of sensitive spaces within a development.

"We want to demystify acoustics for our clients. Through the use of auralisation, we are able to illustrate the impact acoustic decisions play on both project costs and outcomes. This ultimately empowers clients to make informed choices." Auralisation, Stead explains, is to acoustic consultants what a sketch is to designers.

Resonate Acoustics services an Australia-wide client base. The firm offers a full suite of acoustic consulting services for a range of sectors and stages of project delivery, among them buildings, transport and environment – from policy and planning to design, documentation and construction. It combines the skill and experience of a team of in-house staff with consultants and international partners – many of whom offer niche skills such as underwater acoustics, wind farms, vibration, studios and auralisation.

For more information visit:

www.resonateacoustics.com

Pyrotek's research commitment

Pyrotek Noise Control has become part of the NZi3 Innovation Institute, a partnership between the New Zealand government and the University of Canterbury. In collaboration with NZi3, the Technical Manager of Pyrotek Noise Control, Michael Latimer, is running the following acoustic research projects:

- Development of vibration damping compounds
- New lightweight sandwich panels
- Sound transmission loss of composite panels.

I-INCE 2011 General Assembly

On behalf of the AAS, I attended the General Assembly Meeting of I-INCE on 4 September 2011, in Osaka, Japan. In his report, the President, Gilles Daigle, placed emphasis on new initiatives of the Institute which include increasing the number of Young Scientist Awards and the commencement of the I-INCE Symposium Series. The first of these was in Paris in July 2010 on "Buy Quiet" and one on health problems from vehicle noise is planned for 2012.

The Secretary-General commented on the Institute making more use of Corresponding Members, who act as the primary contact of the Member Society with the I-INCE Secretariat on matters involving the control of Noise. As a Member Society, the AAS has one nominated member.

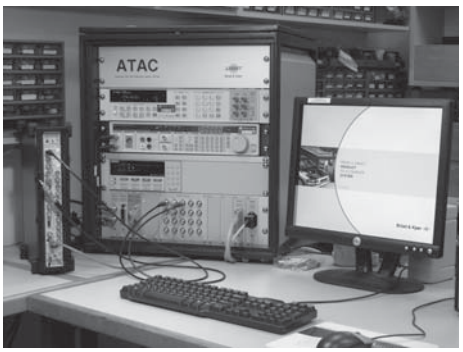
As her term 2009-2011 had expired, Marion Burgess retired from the Congress Selection Committee as a Vice-President for the Asian Pacific Region. It is anticipated that Marion will join the Board in a different capacity during 2012.

Reports on the status of the technical activities of the Institute and of its journal Noise News International indicated that the Institute was thriving. The journal is now available in electronic form and past papers can be accessed on-line.

A preview was given of the next Inter-Noise Congress, which will be in New York from 19-22 August 2012. The following year it

More than just calibration...

Brüel & Kjær provides that extra level of service



Brüel & Kjær offers:

- Accredited Calibration and Repair Services
- Microphone, Accelerometer and Instrumentation Calibration
- Calibration available for Third Party Products
- Easy to use booking system – no lengthy delays

NATA
Accredited
Lab No 1301

Call Brüel & Kjær's Service Centre today on 02 9889 8888

www.bksv.com.au

SERVICE AND CALIBRATION

HEAD OFFICE, SERVICE AND CALIBRATION CENTRE
Suite 2, 6-10 Talavera Road * PO Box 349 * North Ryde * NSW 2113
Telephone 02 9889 8888 * 02 9889 8866
e-mail: bk@spectris.com.au * www.bksv.com.au

Brüel & Kjær

---

www.soundlevelmeters.NET.au

Sound Level Meters & Octave Analysers

Acoustic Calibrators

Sound Exposure Kit

Outdoor Logging Kit

Safety Professional Kit

The Assessor

Quantifier

Model 14 SLM

Model 30 RTA

Model 33 RTA

pulsar Instruments Plc

Call Adrian
0403 333 490

NATacoustic

National Acoustic Calibration Laboratory

NATA Calibration of
- Sound Level Meters
- Loggers
- Analyzers
- Calibrators

We Calibrate All SLMs & Calibrators
- B & K
- Norsonics
- Rion
- NTI
- ARL
- RTA Technology
- Svantek
- Larson Davis
- Cesva
- CEL
- 01dB
- Pulsar
- Sinus

NATA
WORLD RECOGNISED ACCREDITATION

National Acoustic Calibration Laboratory
A Division Of
Renzo Tonin & Associates (NSW) Pty Ltd
ABN 29 117 462 861
1/418A Elizabeth St, Surry Hills, NSW 2010
PO Box 877 STRAWBERRY HILLS, NSW 2012
Ph (02) 8218 0570
Email: service@natacoustic.com.au
Web: natacoustic.com.au

will be held in Innsbruck, Austria from 15-18 September 2013. Inter-Noise 2014 will be held in Melbourne, Australia, from 17-19 November 2014.

Charles Don

New Products

Portable noise dose meter

Brüel & Kjær has launched a wireless, lightweight, personal noise dose meter. The Noise Dose Meter Type 4448 is a shoulder-mounted, cable-free noise dose meter and has been designed to accompany employees throughout their working day, in order to measure and register all relevant data about their noise exposure. Type 4448 can be used to assess the risk of hearing damage to workers in noise environments such as machinery workshops, forestry sites and music venues. Special versions are also available for use in hazardous areas where only certified equipment can be legally used, such as mining and petrochemical facilities.

For more information visit:

www.bksv.com.au/Type4448

Meeting Reports

NSW Division

On 27 October, Joon-Pil Hwang, a senior project consultant with SLR Consulting, gave a technical talk on the topic *Bridge maintenance and repair – can you see the light?* His presentation described a method of quantifying physical damage to a pin mounting plate critical to a lifting span of a bridge.

The 41st AGM of the NSW Division was held on 8 November at AECOM.

The NSW Division Christmas Breakfast was held on 1 December at AECOM. During the breakfast, a presentation was given by Dr Roger Kinns on *Meeting noise and vibration requirements for cruise ship propellers – From predictions to full-scale trials*. Roger Kinns is a Senior Visiting Research Fellow in the School of Mechanical and Manufacturing Engineering at the University of New South Wales. He joined YARD Ltd in Glasgow during 1975, to develop and apply techniques for the acoustic design of ships and submarines. He lives in Scotland and has worked as an independent consultant since 1999, with principal research interests in underwater noise due to marine propulsion systems.

Victoria Division

The VIC Division had a very interesting technical talk by Dr Christian Nocke of Akustikbüro Oldenburg, Oldenburg, Germany on 7 November 2011, in SKM's office. Christian was in Australia on behalf of Barrisol and spoke on the topic *Properties and applications of micro-perforated materials*. Christian described that the theoretical background of micro-perforated sound-absorbing panels was first described by D.-Y. Maa in 1975. Since Maa's seminal contribution, many variations of micro-perforated sound absorbing materials have been introduced. Micro-perforations have been applied to metal, wood, plastics and many other materials. In 2001, a nearly invisible micro-perforation was applied to stretched membrane material, yielding high sound absorption performance, while not being an overtly obvious sound absorbing material. Stretch membranes are custom manufactured to any panel size, offering an acoustic solution for rooms not restricted by fixed prefabricated panel sizes. Christian also detailed the sound absorption coefficient results of various laboratory based tests with micro-perforated stretch membranes that he has conducted (with and without additional acoustic materials) and finally presented some examples of room acoustics before and after the installation of micro-perforated ceiling and wall membranes. One example of an installation is in Melbourne's very own Federation Square.

South Australia Division

On 13 September, the South Australian Division of the AAS and the Audio Engineering Society took the exciting opportunity to tour the new facilities at the Glenside SA Film Corp under the guidance of Michael Rowan and Adrian Medhurst (SA Film Corp). Peter Swift (AECOM - Acoustic Consultants) spoke about the acoustic design of the building fabric and internal spaces. David Murphy of Krix Loud Speakers spoke about the speaker systems installed in the facility, which is aiming to achieve Dolby Premier certification.

The SA Division held their 35th AGM on Tuesday 27 October 2011 at the University of Adelaide. The AGM was followed by a technical talk by Stewart Page of Resonance Technology, entitled Big-time Acoustics or Vibration with a Purpose. Stewart is the Chief Technology Officer and principal engineer of Resonance Technology Pty and has over 30 years experience in product development and manufacturing. In his talk he discussed the development of the resonant pile driving and drilling system, and the Acoustic Mine-sweeping system.

On 22 November a technical presentation entitled Insights to Ministers Specification: SA8 construction requirements for the control of external sound was presented by Darren Jurevicius. Darren is the Associate Director at AECOM and leads both the environment and acoustic teams in South Australia. He has 16 years consulting experience. Darren's talk provided insights to the creation of the new SA8 specification and also gave an overview of how it will work in practice.

The SA Division will be holding its Christmas Dinner on Friday 9th December at the Red Ochre restaurant.

Future Conferences

NOVEM 2012

Noise and Vibration: Emerging Methods (NOVEM) 2012 will be held in Sorrento, Italy, from 1-4 April 2012. NOVEM 2012 is the 4th in the conference series. The goal of the conference is to promote significant discussion and exchange of scientific information. The conference is targeted specifically at persons from research establishments and from industry who are responsible for developments in the field of noise and vibration control. The emphasis of the conference is on new and emerging methods, techniques and technologies in acoustics and vibration, focusing on specially selected thematic areas which represent today's major scientific challenges.

More information from:

http://www.novem2012.unina.it

Railway Technology

The First International Conference on Railway Technology: Research, Development and Maintenance (Railways 2012), will be held in Las Palmas de Gran Canaria, Spain, from 18-20 April 2012. The purpose of this conference is to provide opportunities for scientists and engineers to meet and to discuss current research, new concepts and ideas and to establish opportunities for future collaborations in all aspects of Railway Technology.

More information from: http://www.civil-comp.com/conf/railways2012.htm

Acoustics 2012 - Nantes

Acoustics 2012 - Nantes joining the 11th Congrès Français d'Acoustique and the 2012 Annual IOA Meeting will be held in Nantes, France, from 23 to 27 April 2012. The congress is co-organised by the French Acoustical Society (SFA) and the Institute of Acoustics (IOA) from the UK. This congress is also supported by the European Acoustics Association (EAA).

Acoustics 2012 will be held at the Cité Internationale des Congrès de Nantes (La Cité – Nantes Events Center). This congress centre is located in the heart of the city, located at walking distance from the TGV Railway station and a large number of hotels and easily accessible from the Nantes -

Atlantique International Airport connected to the main French and European cities by direct or connecting flights. We are sure you will enjoy all aspects of the Congress and Nantes is the 6th largest town in France and is considered to be a town of art and history. Nantes is conveniently located for other tourist destinations such as the Atlantic coast, Brittany, the River Loire Castles and Vendée.

More information from:

www.acoustics2012-nantes.org

Euronoise 2012

The Ninth European Conference on Noise Control, Euronoise 2012, is to be held in Prague, Czech Republic, from 10-13 June 2012.

More information from:

http://www.euronoise2012.cz

ICSV19

Abstracts can now be submitted for the 19th International Congress on Sound and Vibration (ICSV19), sponsored by the International Institute of Acoustics and Vibration (IIAV) and Vilnius University, which will be held from 8-12 July 2012 at Vilnius University in Vilnius, Lithuania. Vilnius is the historical capital of Lithuania and dates back to the 14th century. Vilnius has since been awarded the status of World Cultural Heritage by UNESCO and Vilnius University, the congress venue, is one of the oldest universities in Eastern Europe. Theoretical and experimental research papers in the fields of acoustics, noise, and vibration are invited for presentation. Participants are welcome to submit abstracts and companies are invited to take part in the ICSV19 exhibition and sponsorship.

More information from http://www.icsv19.org

Inter-Noise 2012

Inter-Noise 2012 will be held at the Marriott Marquis Hotel in New York City, USA, 19-22 August 2012. It is expected to be a large congress of over 1000 delegates, including:

- Three days of technical papers spanning many areas of noise and vibration, including the congress theme: *Quieting the world's cities*.
- Around 60+ exhibitors of noise and vibration control materials, analysis software, and measurement systems and instrumentation.
- Three plenary sessions on (1) city noise codes, (2) the effects of noise on children, and (3) airport noise.
- A series of short courses on noise and vibration control.

Abstracts are due on 15 February 2012

More information from:

http://www.internoise2012.com

ISMA 2012

The 25th edition of the international ISMA Noise and Vibration Engineering Conference (ISMA2012) will be held in Leuven, Belgium, from 17-19 September 2012. It will be organised in conjunction with the 4th International Conference on Uncertainty in Structural Dynamics (USD2012).

Abstract submission 15 January 2012

More information from:

http://www.isma-isaac.be/conf/

ACOUSTICS 2012

The annual conference of the Australian Acoustical Society will be held at the Esplanade Hotel in Fremantle, Western Australia, from 21-23 November 2012. The theme for this conference is "Acoustics, Development, and the Environment" and the conference will include plenary sessions addressing acoustical and vibration aspects of major infrastructure projects from transportation and construction in the urban context through to mining. In addition to papers on this theme, papers on all aspects of acoustics are welcome including Transportation noise and vibration, Noise and Health and Underwater Acoustics. Acoustics 2012 will cover in-depth many topics of interest to professionals including architects, developers, consultants, researchers, town planners, government authorities, noise officers and contractors.

More information from: http://www.acoustics.asn.au/joomla/acoustics-2012.html

Portable Solutions for
Sound & Vibration Analysis

REALWAVE POCKET ANALYSER

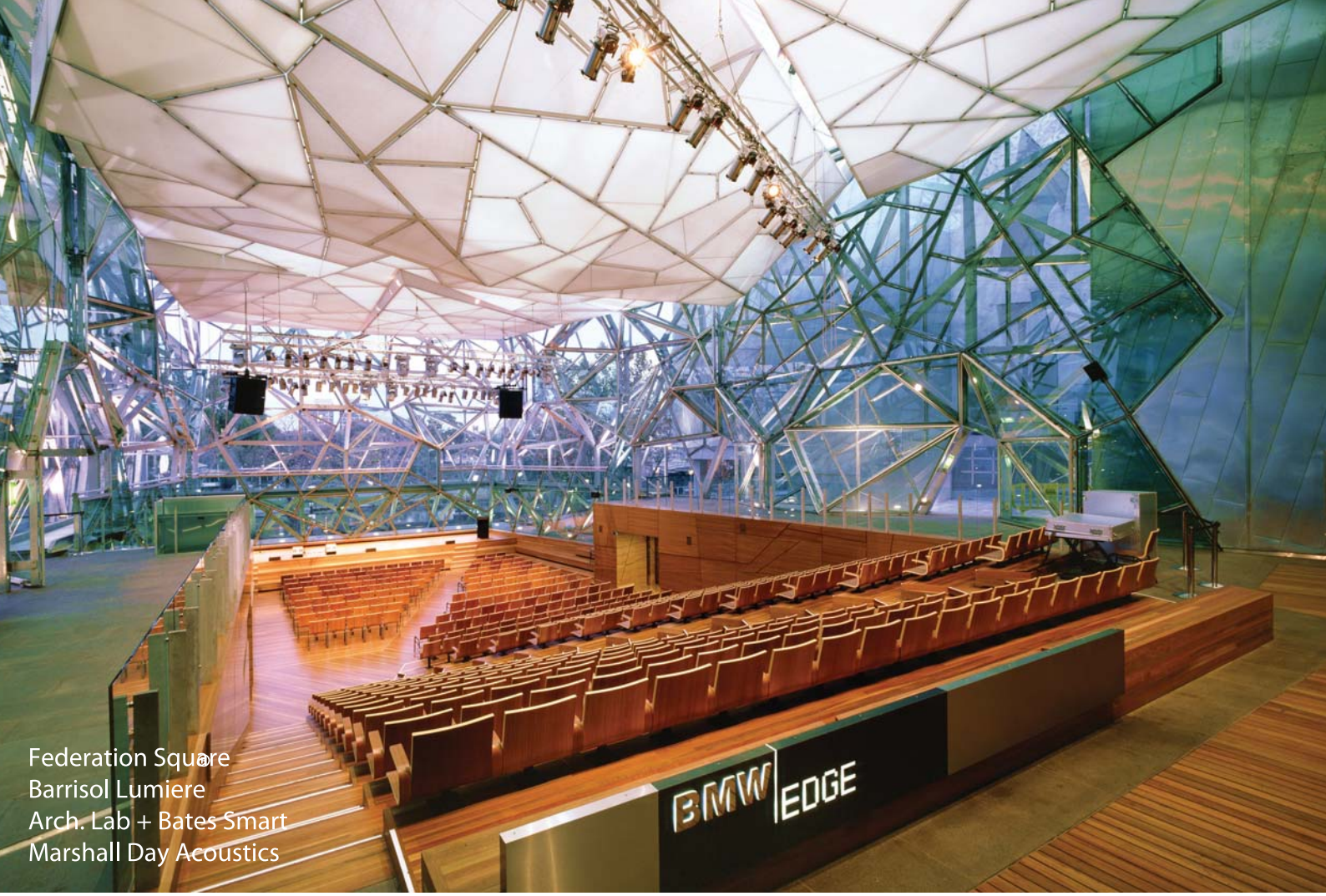
Ideal for measuring and analysing
- general sound and vibration
- environmental noise
- construction and blast sound and vibration
- architectural acoustics
- ship vibration

Powerful analysis in the palm of your hand
- Real time FFT analysis
- Spectrograms
- FFT based octave analysis
- Digital filter based octave analysis
- Vibration level meter with human vibration filter
- Sound level meter
- FFT based RPM meter
- 1, 2, 3 and 4 channel models available

HW Technologies

Sales, Hire & Service

Tel: (02) 9872 9995 Fax: (02) 9872 9907 www.hwtechnologies.com.au



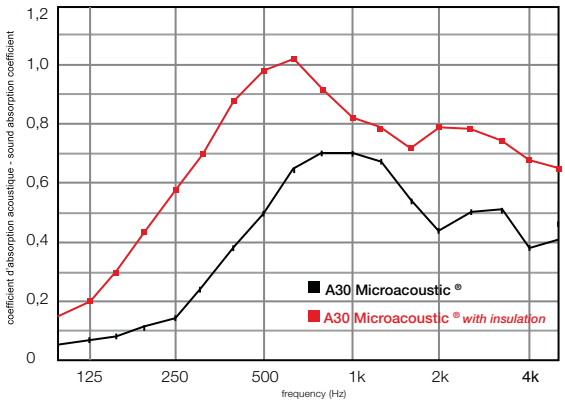
Federation Square
Barrisol Lumiere
Arch. Lab + Bates Smart
Marshall Day Acoustics

These exceptional micro-perforated and perforated projects have one thing in common

BARRISOL®

WORLD LEADER OF STRETCHED CEILINGS

Barrisol® Acoustics® - A30 Microacoustic
Oslo Opera House - 50 sq metre panels
2009 European Award for Contemporary Architecture



A30 Microacoustic ®
SAA : 0.50
NRC : 0.50

A30 Microacoustic ® *with insulation*
SAA : 0.78
NRC : 0.80

www.barrisol.com.au

melbourne 03 98790628 **sydney** 02 96606044 **brisbane** 07 38510055 **adelaide** 08 82926600 **perth** 08 92482245 **nz** +61 3 98762872

DIARY

2012

20 – 25 March, Kyoto, Japan
IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2012)
http://www.icassp2012.com

1 – 4 April, Sorrento, Italy
Noise and Vibration: Emerging Methods (NOVEM) 2012
http://www.novem2012.unina.it

18 – 20 April, Las Palmas de Gran Canaria, Spain
Railways 2012
http://www.civil-comp.com/conf/railways2012.htm

13 – 18 May, Hong Kong, China
Acoustics 2012 Hong Kong
http:// acoustics2012hk.org

2 – 6 July, Edinburgh, UK
11th European Conference on Underwater Acoustics (ECUA 2012)
http://www.ecua2012.com

8 – 12 July, Vilnius, Lithuania
19th International Congress on Sound and Vibration (ICSV19)
http://www.icsv19.org

22 – 27 July, Porto, Portugal
15th International Conference on Experimental Mechanics (ICEM15)
http://paginas.fe.up.pt/clme/icem15

12 – 15 August, New York, USA
Inter-Noise 2012
http://www.internoise2012.com

9 – 13 September, Portland, USA
nternational Conference on Noise and Vibration Engineering (ISMA 2012)
http://www.isma-isaac.be/conf/

17 – 19 September, Leuven, Belgium
ISMA Noise and Vibration Engineering Conference (ISMA2012)
http://www.isma-isaac.be/conf/

21 – 23 November, Perth, Australia
ACOUSTICS 2012
http://www.acoustics.asn.au/joomla/acoustics-2012.html

2013

26 – 31 March, Vancouver, Canada
IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP)
http://www.icassp2013.com

2 – 7 June, Montréal, Canada
21st International Congress on Acoustics (ICA 2013)
http://www.ica2013montreal.org

7 – 11 July, Bangkok, Thailand
20th International Congress on Sound and Vibration (ICSV20)

5 – 18 September, Innsbruck, Austria
Inter-Noise 2013
http://www.internoise2013.com

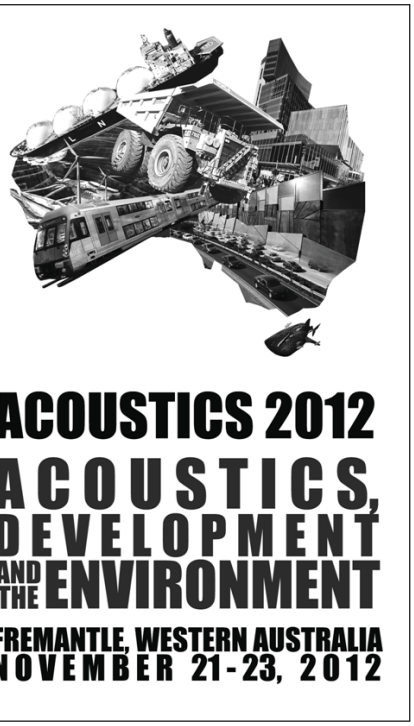
2014

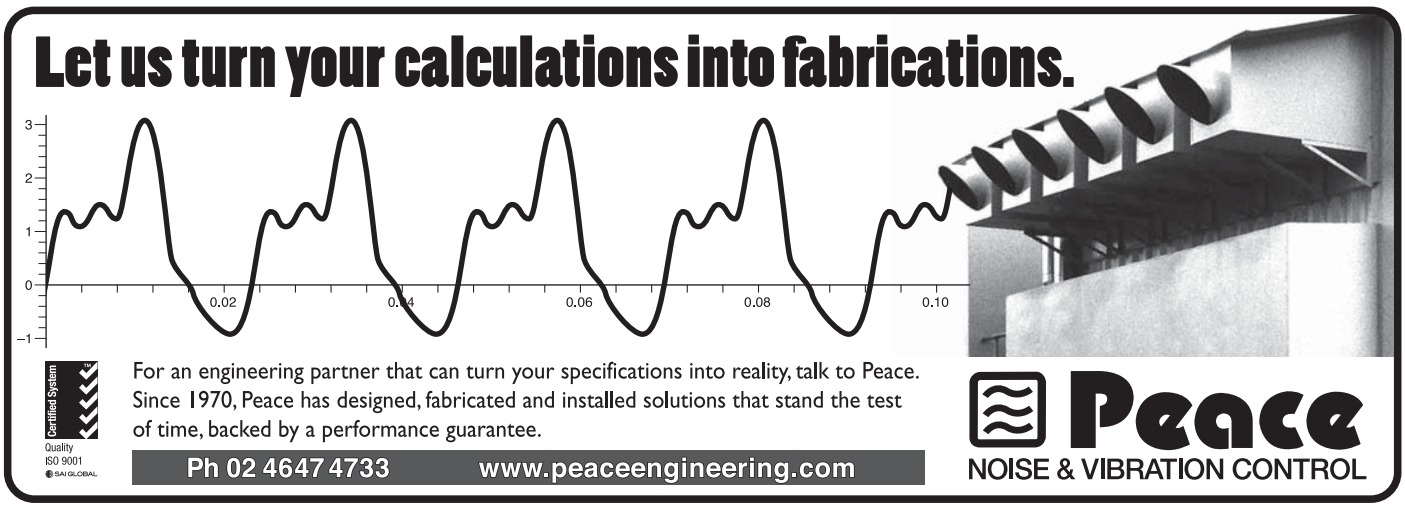
25 – 30 May, Florence, Italy
IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP)
http://www.icassp2014.org

6 – 10 July, Beijing, China
21st International Congress on Sound and Vibration (ICSV21)

17 – 19 November, Melbourne, Australia
Inter-Noise 2014

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





SOUNDPROOFING SO GOOD

we don't need to shout

Noise - unwanted sound.
As the world gets busier, people are demanding quieter places to work rest and play. With our products covering transmission loss, noise absorption, isolation and vibration damping we can help you with a specification to solve a range of noise problems.

As a sustaining member of the Australian Acoustical Society, we have a time tested relationship with the society and its members. Since 1972, our engineers and product specialists have created and refined a full suite of soundproofing materials to meet complex and changing needs.

Pyrotek noise control

Call us direct on 1300 WAVEBAR
or visit our website www.pyroteknc.com
to see how we can help

WAVEBAR ◆ SOUNDLAG ◆ SILENTSTEP ◆ ECHOHUSH ◆ REAPOR ◆ SYLOMER
SOUNDPAINT ◆ VIBRADAMP ◆ SUBDUE ◆ SORBERFOAM ◆ SORBERBARRIER

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

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 COLPRO
industrialacoustics.com/australia

NSW DEPT OF ENVIRONMENT & CLIMATE CHANGE
www.environment.nsw.gov.au

PEACE ENGINEERING
www.peaceengineering.com

PYROTEK NOISE CONTROL
www.pyroteknc.com

SINCLAIR KNIGHT MERZ
www.skm.com.au

SOUND CONTROL
www.soundcontrol.com.au

SOUND SCIENCE
www.soundscience.com.au

VIPAC ENGINEERS AND SCIENTISTS
www.vipac.com.au

RT60 Measurements in a Snap

THE Fast and Easy-to-use Solution for Reverberation Time Measurements

- Calculate Reverberation Time to ISO 3382-2 and ASTM E2235 Standards
- Supports Interrupted Noise and Integrated Impulse Response Methods
- ISO-3382-2 Measurement Uncertainty
- Built-in Pink and White Noise Generator
- Complete Quality Indicators for background noise, non-linearity, curvature, and standard deviation.
- Field upgradeable – start testing the same day
- Complete line of Noise Sources available

LARSON DAVIS
A PCB PIEZOTRONICS DIV.

Total Customer Satisfaction
LARSON DAVIS
A PCB PIEZOTRONICS DIV.

ThermoFisher SCIENTIFIC

For customer service, call 1300-735-295
Email: InfoIndustrialAU@thermofisher.com
Visit us online: www.thermofisher.com.au

©2011 Thermo Fisher Scientific Inc. All rights reserved. A.B.N. 52 058 390 917

AUSTRALIAN ACOUSTICAL SOCIETY ENQUIRIES

NATIONAL MATTERS

* Notification of change of address
* Payment of annual subscription
* Proceedings of annual conferences

Richard Booker - General Secretary
Australian Acoustical Society
PO Box 1843 Toowong DC QLD 4066
Tel: (07) 3122 2605
email: GeneralSecretary@acoustics.asn.au
www.acoustics.asn.au

SOCIETY SUBSCRIPTION RATES

For 2011/12 Financial Year:

Fellow and Member	$130.00
Graduate, Associate and Subscriber	$100.00
Retired	$40.00
Student	$30.00

Including GST

DIVISIONAL MATTERS

Enquiries regarding membership and sustaining membership should be directed to the appropriate State Division Secretary

AAS - NSW Division
Laura Allison
c/- AECOM
Level 21, 420 George Street
Sydney, NSW 2000
Tel: (02) 8934 0035
Fax: (02) 8934 0001
Laura.Allison@aecom.com

AAS - Queensland Division
PO Box 760
Spring Hill Qld 4004
Sec: Richard Devereux
Tel: (07) 3217 0055
Fax: (07) 3217 0066
rdevereux@acran.com.au

AAS - SA Division
AECOM,
Level 28, 91 King William St
ADELAIDE S.A. 5005
Sec: Darren Jurevicius
Tel: (08) 7100 6400
Fax: (08) 7100 6499
darren.jurevicius@aecom.com

AAS - Victoria Division
c/- Simon de Lisle
Arup Acoustics
Level 17, 1 Nicholson Street
Melbourne VIC 3000
Tel: (03) 9668 5580
Fax: (03) 9663 1546
simon.delisle@arup.com.au

AAS–WA Division
Unit 3
2 Hardy Street,
SOUTH PERTH 6151
Sec: Norbert Gabriels
Tel (08) 9474 5966
Fax (08) 9474 5977
gabriels@iinet.net.au

ACOUSTICS AUSTRALIA INFORMATION

GENERAL BUSINESS

Advertising Subscriptions

Mrs Leigh Wallbank
PO Box 70, OYSTER BAY 2225
Tel (02) 9528 4362
Fax (02) 9589 0547
wallbank@zipworld.com.au

ARTICLES & REPORTS NEWS, BOOK REVIEWS NEW PRODUCTS

The Editor, Acoustics Australia
c/o Nicole Kessissoglou
School of Mechanical & Manufacturing Engineering
University of New South Wales
NSW 2052 Australia
Mobile: +61 401 070 843
acousticsaustralia@acoustics.asn.au

PRINTING, ARTWORK

Cliff Lewis Printing
91-93 Parraweena Road
CARINGBAH NSW 222
Tel (02) 9525 6588 Fax (02) 9524 8712
email: matthew@clp.com.au

SUBSCRIPTION RATES

	Aust	Overseas
1 year	A$77.20	A$88.33
2 year	A$133.10	A$157.30
3 year	A$189.00	A$227.27

Australian rates include GST.
Overseas subscriptions go by airmail
Discounted for new subscriptions
20% Discount for extra copies
Agents rates are discounted.

ADVERTISING RATES

B&W	Non-members	Sus Mem
1/1 Page	$784.00	$699.15
1/2 Page	$509.40	$457.40
1/3 Page	$392.00	$352.90
1/4 Page	$326.70	$294.00

Spot colour: available
Prepared insert: $424.70 Conditions apply
Column rate: $26.40 per cm (1/3 p 5.5cm width)
All rates include GST

Discounted rates for 3 consecutive ads in advance

Special rates available for 4-colour printing

All enquiries to: Mrs Leigh Wallbank
Tel (02) 9528 4362 Fax (02) 9589 0547
wallbank@zipworld.com.au

ACOUSTICS AUSTRALIA ADVERTISER INDEX - VOL 39 No 3

Kingdom . . . . . Inside front cover
ARL 92
Cliff Lewis Printing. 92
Matrix 92
Savtech 94
Belcur 105
Scientific Acoustics 118
Renzo Tonin & Associates 118
Bruel & Kjaer 122
Sound Level Meters 122
Renzo Tonin & Associates 122
HW Technologies 124
Barrisol 125
Peace Engineering 126
Pyrotek 127
Thermo Fisher Scientific 129
ACU-VIB . . . . . inside back cover
Bruel & Kjaer . . . . . back cover

SVAN 979 ANALYSER

Sound & Vibration Analyser

Product description

The Most Advanced & Powerful Single Channel Instrument Ever Made!

- Two DSP for superior performance
- 3 parallel independent profiles
- 1/1 & 1/3 octave RT & FFT anallysis
- 1/6 or 1/12 octave real-time analysis
- Advanced logger with audio events
- Reverberation time measurements
- Time-domain signal recording
- Wireless data transfer
- Signal generator
- Micro SD card
- User programmable Band-Pass Filters

TOPSELLER
Best Choice

More info: www.acu-vib.com.au

NATA Calibrations

Acoustic and vibration instrument calibration laboratory servicing the whole of Australia and Asia Pacific region. FAST turnaround. NATA registered. All brands

Sales & Service

We supply instruments from several manufacturers, giving you a wider selection to choose from. We also service ALL brands and makes.

Instrument Hire

We have a wide range of acoustic and vibration instruments for hire. Daily, weekly or monthly rental periods available. Call for advice on the best instrument to suit you

ACU-VIB ELECTRONICS- 14/22 Hudson Ave - Castle Hill 2154 - Phone 02 9680-8133 - eMail info@acu-vib.com.au

NEW TYPE 4448 PERSONAL NOISE DOSE METER

Damaged hearing costs you dearly

Preventing it doesn't

Type 4448 – Helping to improve workplace noise assessment

Simple reliability
No cables, no connectors

Forget it is there
Secure shoulder mount with pin or clip attachment

Ready when you are
Long 28 hour battery-life

Verify your Standards compliance
HML option – verify hearing protection requirements

Works with Protector PC software – for intuitive analysis and reporting

TYPE 4448 FROM BRÜEL & KJÆR

Home of the world's best sound and vibration instrumentation

www.bksv.com/Type4448

BN 1070–11

HEADQUARTERS: DK-2850 Naerum · Denmark · Telephone: +45 4580 0500
Fax: +45 4580 1405 · www.bksv.com · info@bksv.com

Bruel & Kjaer Australia
Suite 2, 6-10 Talavera Road, PO Box 349, North Ryde NSW 2113 Sydney
Tel: +61 2 9889 8888 • Fax: +61 2 9889 8866 • www.bksv.com.au • auinfo@bksv.com

MELBOURNE: Suite 22, Building 4, 195 Wellington Road, Clayton VIC 3170
Tel: +61 3 9560 7555 Fax: +61 3 9561 6700 • www.bksv.com.au • auinfo@bksv.com

Local representatives and service organisations worldwide.

Brüel & Kjær

creating sustainable value