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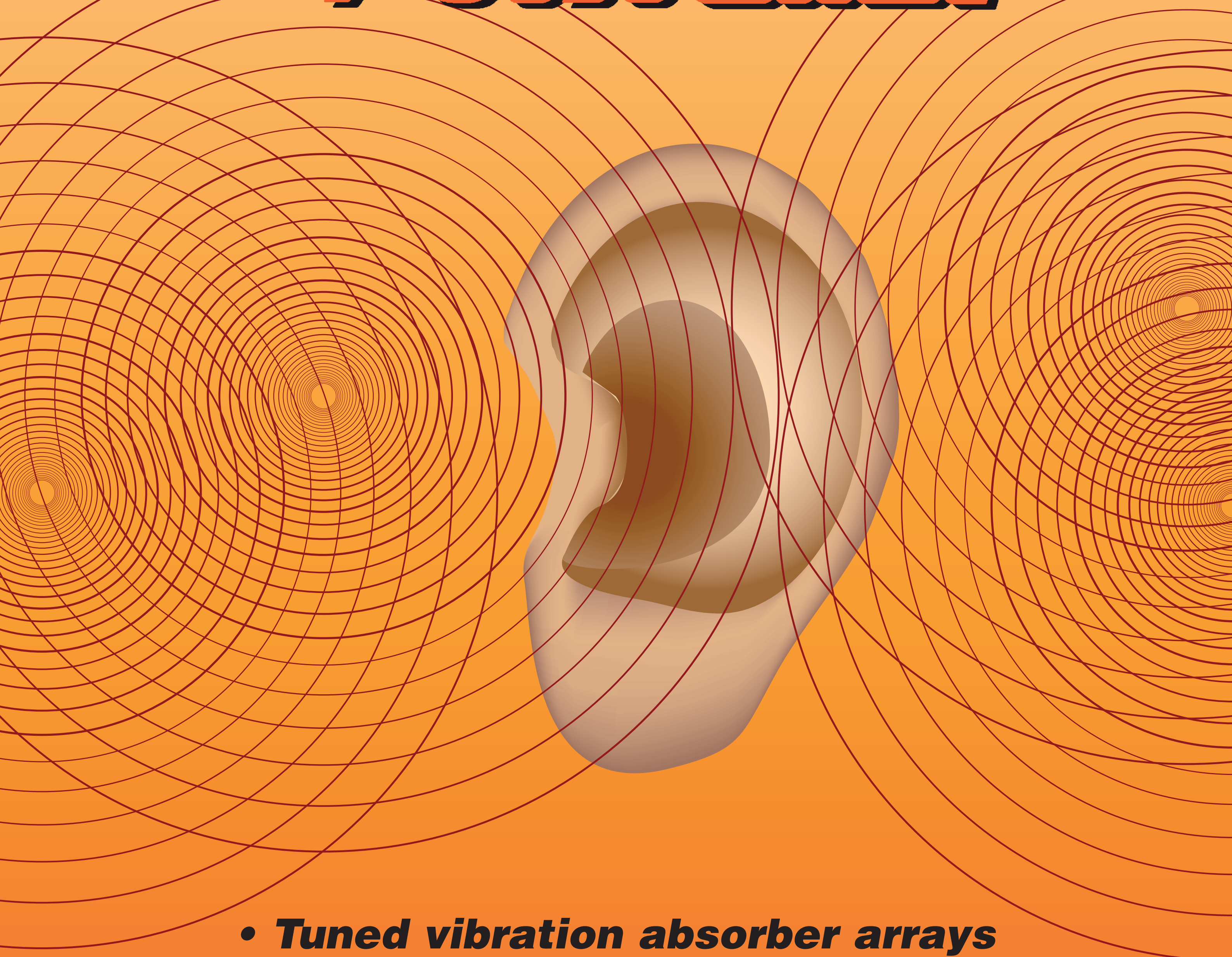

- Tuned vibration absorber arrays
- A virtual sensor and active noise control
- Bimodal binaural hearing systems

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*Cover illustration: Heidi Hereth.*

# Message from the President

Hello All,

It gives me great pleasure to address you in my new role as President. Firstly, I would like to thank our out-going President, Terry McMinn, for his great effort in leading the Society over the last two years. There is a fair bit of background activity going on all the time to keep the Society going and we appreciate Terry's effort in that regard.

Terry has also been the Society webmaster and has assisted our migration to a new web page layout. Hopefully, you will have visited the new site at http://www.acoustics.asn.au/joomla/ If you have any suggestions, please Email Terry and these will be considered.

The AAS website was very active in preparation for the recent Annual AAS Conference held in Geelong. By all accounts, the Conference was a resounding success (even if I say so myself as Conference Chair and Organiser) with some very interesting papers, a very nice location just outside Geelong and a full exhibition. Over 200 people attended which was a terrific turnout. A highlight of the Conference was the banquet when we were addressed by Andrew Bolt, who generated heated debate about the issue of Global warming and the awarding of Fellow status to John Davy, Charles Don, David Watkins and to Joe Wolfe.

**Left to right:** Charles Don, David Watkins, Norm Broner, John Davy, Joe Wolfe at the presentation of the Fellow Certificates during the Annual AAS Conference Banquet

The Award of Fellow to Dave Watkins was in recognition of his 13 years of faithful service to the AAS as General Secretary. David related some of his experiences and while we are happy that David can now take the time to tour Australia, we will miss his friendship and valuable input. Byron Martin has stepped up to the plate as the new General Secretary and we wish him success in this new endeavour.

Planning is already well underway for the next Annual AAS conference in November to be held in Adelaide. Planning is also well underway for the ICA conference to be held in Sydney in 2010. Watch out for announcements on our website and in Acoustics Australia for more details.

As this year draws to a close, I take the opportunity to wish everyone a safe and happy break and best wishes for the season. We look forward to an exciting 2009.

*Norm Broner*

# From the Editors

What would you like to see in Acoustics Australia? Several people have given me feedback lately, at the national conference and at a technical meeting in Brisbane. Most of them – like the editors – are disappointed at the balance of contributions: The journal currently has many more Papers than Technical Notes or Acoustics Forum pieces. These proportions, and the affiliations of the authors, do not reflect the make-up of the Society.

Of course, there are reasons for the current imbalance: for acousticians in universities and other research institutions, papers are very important: researchers work to create knowledge, but it is of limited usefulness until it is publicly available. For these authors, peer review is important for two reasons: First, the (free!) advice from two expert readers can often improve a paper's comprehensibility and, sometimes, remove errors. Second, research managers and government agencies have a propensity to count peer-reviewed papers, and to apply what they consider appropriate feedback.

Consulting engineers, of course, have a much more direct relationship with the users of their work. There are fewer incentives to write a public account of work done – and even some disincentives.

The journal is our journal, and it should reflect our broad and different interests. However, we shall not be able to read Forum pieces or Technical Notes if no-one contributes any.

At the national conference, a wide range of interesting work was presented. A revised version of the paper judged best at the conference – the winner of the President's Prize – is printed in this issue. Congratulations Carl Howard! But there were many ideas presented at the conference that would make good Technical Notes or journal papers, and many discussions that could be presented in the Acoustics Forum. So, for potential authors, here are two relevant paragraphs from the journal's information for authors.

*Papers should generally not exceed five journal pages in length. This implies a maximum of about 5000 words, with each normal single-column diagram being counted as 300 words, and pro-rata for diagrams of other shapes and sizes. Authors submitting longer articles may be asked to bear the extra publication costs involved. All papers will be submitted to independent peer review before being accepted for publication.*

*In addition to peer-reviewed articles, we also publish contributions to Acoustics Forum and shorter Technical Notes. These contributions are reviewed by the Editorial Committee before acceptance. Forum articles should generally not exceed three pages (3000 words) in length, but may be much shorter, and are generally aimed at generating awareness or discussion of a particular issue in the acoustics community. Technical Notes are generally no longer than one page (1000 words) and might serve to highlight the solution of a particular technical problem or to draw attention to a particular acoustical achievement.*

More information is on the Acoustics Australia page of the Society's new web site at www.acoustics.asn.au/joomla/

*Joe Wolfe*

# A REVIEW OF BIMODAL BINAURAL HEARING SYSTEMS AND FITTING

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ABSTRACT: Cochlear implants and hearing aids are both suitable for use by people with severe to profound hearing loss (greater than 70 dB HL), and the "bimodal" combination of one of each device in opposite ears has become a commonly recommended option. This paper reviews some of the experimental evidence assessing the performance of bimodal hearing. To obtain the best bimodal performance, it is recommended that both devices are fitted together; that loudness of the two devices is balanced for a wide range of input levels; that the signal to noise ratio is maximised in each ear separately; that speech should be presented to both ears; and noise should be presented to one ear only if possible.

## 1. INTRODUCTION

Over the last 25 years, Australia has been at the forefront of sound processing research for cochlear implants (CI) and hearing aids (HA) for people with impaired hearing [1-4]. During this time, speech perception of severely-to-profoundly deaf people using CIs has improved until it is comparable or better (at least in some circumstances) than speech perception of people with severe hearing loss using HAs. It has been estimated that a cochlear implant user performs equivalently to a person with 70 to 80 dB HL hearing loss [5-7]. However, this does not mean that the same types of speech information are provided by a CI and a HA. HAs usually provide more low frequency information than CIs and CIs usually provide more high frequency information than HAs. Therefore the combination of a CI and HA is likely to provide access to information from a wider frequency range than either device on its own. The combination is called "bimodal stimulation" when the CI and HA are in opposite ears [8-10], and "hybrid stimulation" when the hearing aid acoustically stimulates the implanted ear [11].

CIs usually stimulate neurons in the basal part of the cochlea that produce relatively high-pitched sensations, so the addition of a HA with low-frequency amplification will usually sound more natural than a CI on its own [9]. Frequency discrimination and resolution are usually better for acoustic than for electric stimulation. This means that the HA can provide more accurate information about voice pitch and better performance in background noise [12]. These benefits are available to both bimodal and hybrid listeners, but bimodal listeners can also benefit from binaural effects.

It is well-known that two ears are better than one in many situations, and that the advantages of binaural hearing come from three main perceptual effects:

- The listener can combine information from the two ears,
- The listener can pay attention to the ear with the greater signal-to-noise ratio, and
- The listener can use the time and intensity differences between the two signals.

This paper makes recommendations for the design of a bimodal binaural sound processor that takes maximum advantage of these three effects.

## 2. COMBINING INFORMATION FROM HA AND CI

A clinical study of CIs for severely hearing-impaired adults was commenced by Cochlear Corporation in 1988. The first bimodal prosthesis was reported in 1993 [8]. Over the last 15 years there have been consistent reports that bimodal stimulation provides significant benefits over and above a unilateral cochlear implant. These benefits come partly from the fact that acoustic and electric stimulation provide complementary information, and partly from binaural effects.

Binaural information can only be combined if the sound can be heard in both ears at the same time. Psychoacoustic studies of loudness in CIs and HAs indicate that the range of sound input levels where this fundamental requirement is met can be quite limited because the dynamic range of acceptable sounds, classified as "soft" to "comfortable" is narrow with both types of device and varies widely across frequency and between individuals [13].

The vertically striped regions in Figure 1 show the input dynamic range that produced very soft to comfortable outputs with the HA. The loudness classifications were derived from a psychophysical experiment that used a loudness scale with seven categories: "too soft", "very soft", "soft", "medium/comfortable", "loud", "very loud", and "too loud" [13]. The horizontally striped regions show the input dynamic range that produced very soft to comfortable outputs with the CI. The grey region shows the input dynamic range that was comfortable and audible in both ears at once. This is the "sweet spot" for bimodal listening where information from both ears can be combined most easily. For these profoundly-deaf patients, the sweet spot was not very big for

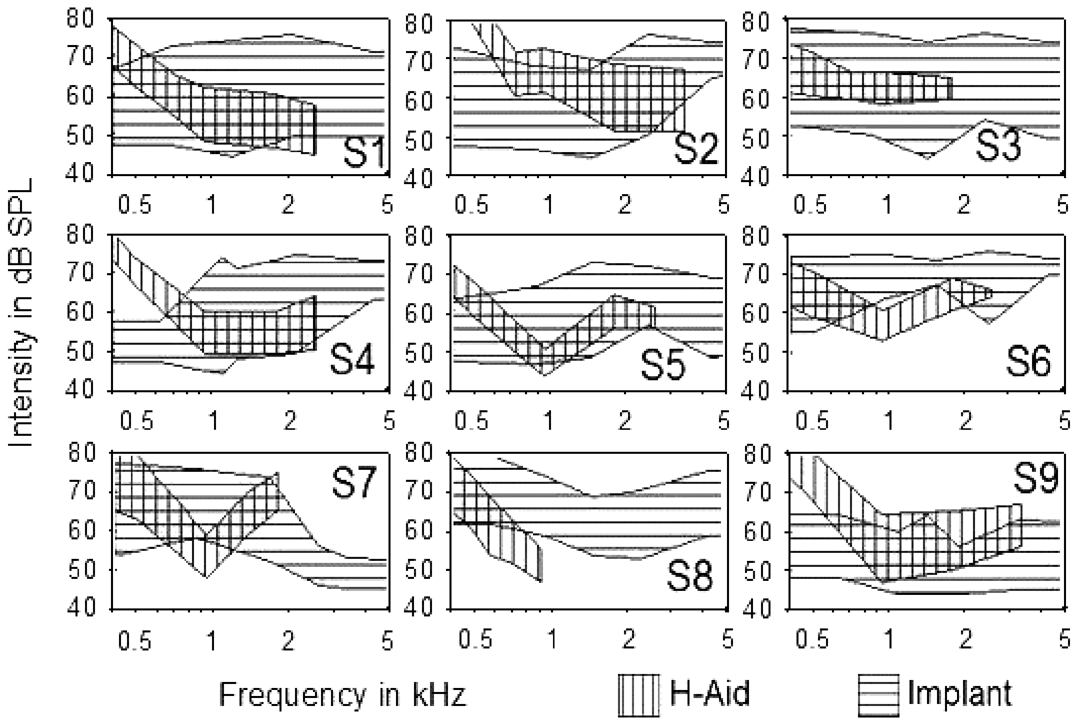


**Figure 1.** Acoustic and electric loudness scaling data for the CI and HA ears of nine patients overlaid on the same diagram. The "sweet spot" where sounds are audible and comfortable in both ears simultaneously is small and covers a narrow range of input levels.

conventional hearing aid fittings. Despite their limited range of hearing with conventional devices, most of these patients went on to become successful bimodal CI and HA users.

The ideal conditions for bimodal listening occur when the information presented to each ear is maximised, and this can be done by using an optimizing amplifier such as adaptive dynamic range optimization, or ADRO® [14-16]. ADRO keeps sound in both ears within the listener's optimal dynamic range in many narrow frequency bands using two fuzzy logic rules. The comfort rule says if the sound is too loud, make it softer by slowly decreasing gain. The audibility rule says if the sound is too soft, make it louder by slowly increasing gain.

The effectiveness of ADRO as a bimodal amplifier was illustrated in a study conducted at the University of Osaka [17]. The participants were six patients who used a cochlear implant in one ear and a hearing aid in the other. The Japanese version of the Hearing in Noise Test (the Japanese HINT) was used to compare two devices using ADRO with two conventional devices that did not use ADRO. The ADRO combination provided a 5.2 dB advantage for speech reception threshold in quiet and a 3.0 dB advantage for signal-

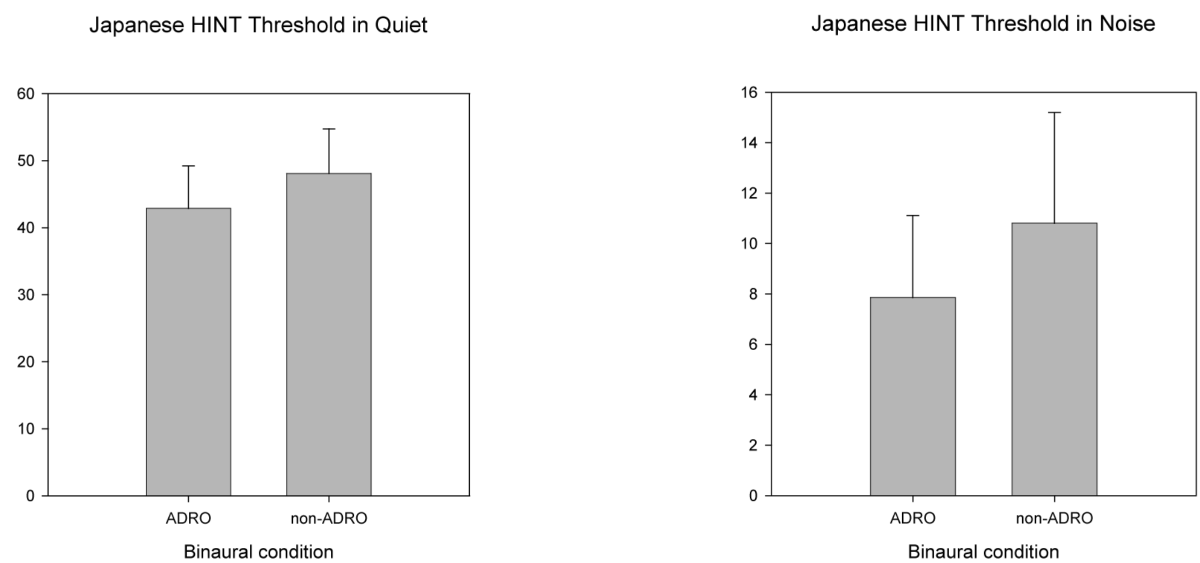


**Figure 2.** The ADRO bimodal combination provided a 5.2 dB advantage for speech reception threshold in quiet and a 3.0 dB advantage for signal-to-noise-ratio in background noise compared to the non-ADRO bimodal combination..

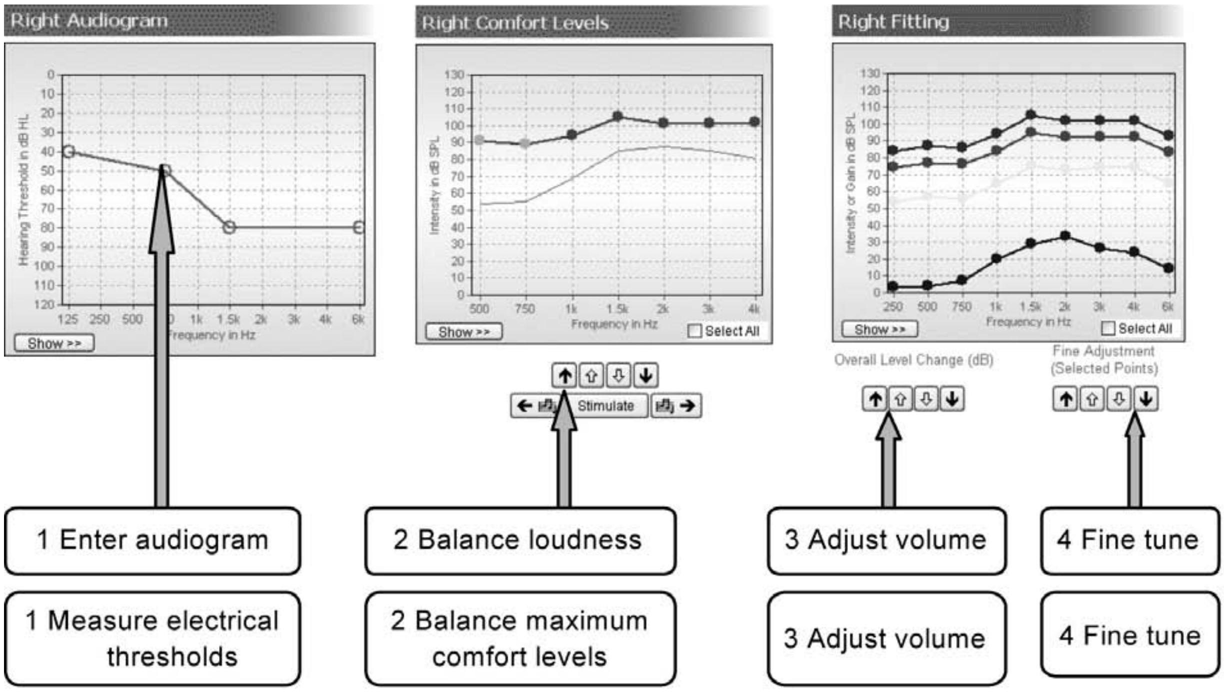


**Figure 3.** The four basic steps for fitting ADRO are the same in a CI (lower boxes) and HA (upper boxes).

to-noise-ratio in background noise (see Figure 2). The data were non-normally distributed, and a Wilcoxon signed rank test indicated that the differences between ADRO and non-ADRO conditions were statistically significant ($p < 0.05$). These advantages are attributed to the combined additional information delivered by the ADRO devices compared to the non-ADRO devices.

The effectiveness of bimodal fittings has now been more widely recognised [10,16] and special fitting methods for hearing aids have been devised to maximise bimodal benefit [18]. When ADRO is used, the same fitting method is used for each ear, and a binaural balance of loudness across frequencies is automatically achieved. Figure 3 summarises the four basic fitting steps for CI and HA [19]. It has also been shown that ADRO can improve speech perception scores and sound quality in unilateral CIs [20, 21] and unilateral and bilateral hearing aids [15, 22].

## 3. IMPROVING SIGNAL-TO-NOISE RATIO IN EACH EAR

In binaural listening, SNR at each ear can be improved by the head shadow effect and by directional microphones. Figure 4 shows the results of the HINT test for eight listeners with impaired hearing using ADRO behind-the ear hearing aids on both ears [23]. Speech was presented from the front and noise was presented from 3 different positions to the side and behind the listeners. Three different microphones were used: omni-directional, fixed directional with a supercardioid response pattern, and adaptive directional microphone. The adaptive directional microphone adopted an omni-directional response pattern for sound levels below 65 dB SPL. Above 65 dB SPL, an omni-directional pattern and a figure-eight dipole pattern were formed from the signals from two omni-directional microphones mounted on the hearing aid with a separation of about 1 cm. The omni-directional and dipole patterns were combined in a manner that kept the response gain from the front of the hearing aid constant, while minimising the total input sound level [24].

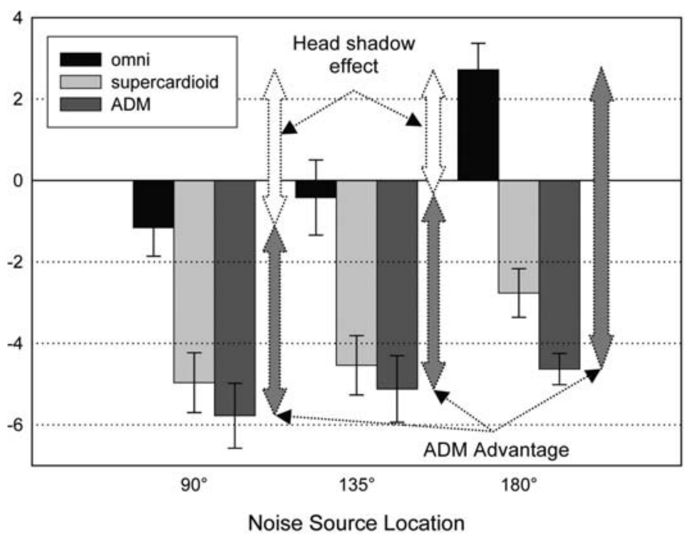


**Figure 4.** HINT thresholds using omni, fixed directional and adaptive directional microphones in background noise.

When noise came directly from behind the listener, the signal-to-noise ratio was the same at both ears and there was no head shadow effect. When the noise came from one side, there was a head shadow advantage of 3 to 4 dB in the omni-directional microphone condition. When the ADM was turned on, it improved the signal-to-noise ratio at both ears, giving an additional advantage of about 5 dB when noise was coming from the side, and about 7 dB when noise was coming from behind the listener. The combination of binaural hearing and adaptive directional microphones allowed these listeners to understand speech at -5 dB signal-to-noise ratio in these three noise conditions, which is similar to the performance of listeners with normal hearing. Paired t-tests showed that the fixed directional microphone performed significantly better than the omni-directional microphone in every noise condition ($t=10.15$, $p<0.001$ at 90º; $t=6.48$, $p<0.001$ at 135º; $t=8.57$, $p<0.001$ at 180º), the ADM performed better than the omni-directional microphone in every noise condition ($t=4.7$, $p<0.05$ at 90º; $t=6.09$, $p<0.001$ at 135º; $t=8.04$, $p<0.001$ at 180º), and the ADM performed better than the fixed directional microphone in noise from 180º ($t=2.59$, $p<0.05$). The head shadow effect (differences between HINT scores for the 90º, 135º and 180º noise directions in the omni-directional condition) were statistically significant: head shadow effect = 3.9 dB, paired-t = 6.27, $p<0.001$ for 90º; head shadow effect = 3.1 dB, paired-t = 5.00, $p<0.001$ for 135º.

These data clearly illustrate that binaurally aided hard-of-hearing listeners can benefit by listening to the ear with the better SNR. A similar head shadow effect was found in the Japanese bimodal study [17] where behind-the-ear microphones were used. The Japanese HINT thresholds in noise were 7.86 dB (SD 3.25 dB) with noise from the front, 5.62 dB (SD 4.26 dB) with noise from the implant side, and 2.37 dB (SD 8.68 dB) with noise from the HA side. These SNR values correspond to head shadow effects of 2.24 dB for noise from the CI side, and 5.49 dB for noise from the HA side. Although they were not statistically significant in the bimodal study, the observed head shadow effects were of the same order of magnitude as the statistically significant effects in the ADM study.

## 4. SEPARATING SPEECH AND NOISE

Listeners with a cochlear implant and a hearing aid in opposite ears can also separate speech from noise using binaural cues. This is illustrated by a study in which speech and noise were presented in seven different binaural conditions as shown in Table 1 [25]. The noise was a white noise presented at a comfortable level. The speech stimuli were a small closed set of spondee words spoken by a female speaker and chosen so that every listener could score 100% recognition of the words with either hearing aid or cochlear implant when they were presented at the same comfortable level in quiet.

| Condition | Voice | Noise |
|---|---|---|
| HA-0 | HA | none |
| CI-0 | CI | none |
| HA-HA | HA | HA |
| CI-CI | CI | CI |
| Diotic | HA+CI | HA+CI |
| HA-CI | HA | CI |
| CI-HA | CI | HA |

**Table 1.** Seven conditions in which speech and noise were presented to the HA and CI ears of the participants.

Figure 5 shows the results averaged for the three listeners. In each of the seven conditions, the level of presentation of the noise was kept constant and the level of the voice was varied to find the level at which the listener scored 70% correct word recognition. In this graph 0 dB corresponds to the comfortable level of the noise for each participant. Negative levels mean that the speech was softer than the noise at the 70% correct level. ANOVA with subject and condition as independent variables was followed by post-hoc t-tests using the Bonferroni method to compare the SNRs in the different conditions. The mean SNRs for the HA-HA, CI-CI, and Diotic conditions were not significantly different from one another ($p>0.05$). The mean SNRs for CI-HA, HA-CI, HA-0, and CI-0 conditions were not significantly different from one another ($p>0.05$). However, all the SNRs for the first three conditions were significantly different from all the SNRs in the second group ($p<0.001$).

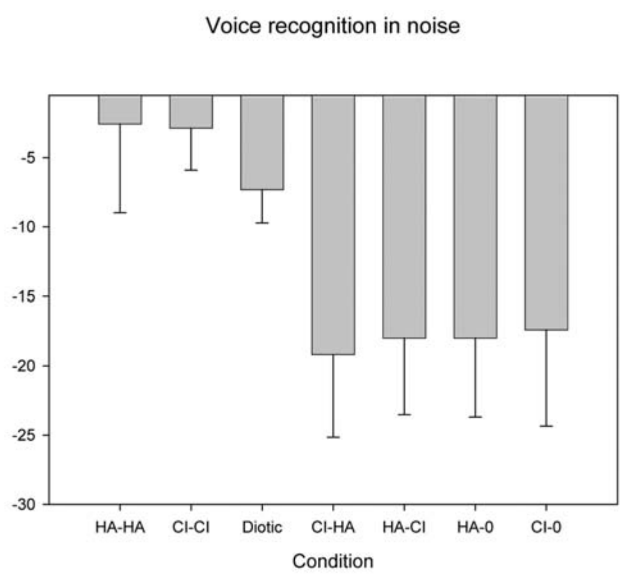


**Figure 5**. SNR for 70% correct recognition of words in seven monaural and binaural conditions.

The best results were for the four conditions on the right where there was no noise or the noise and voice were in opposite ears. There was no significant difference between these four conditions, showing that the subjects could easily separate the speech and the noise in opposite ears even when the noise was 15 to 20 dB louder than the speech.

The two monaural conditions on the left with speech and noise in the same ear gave signal-to-noise ratios of about -3 dB. The diotic condition gave a mean signal-to-noise ratio of -7 dB, indicating that there was a 4 dB advantage from combining the information from the two ears.

## 5. RECOMMENDATIONS

These three experiments together suggest that large improvements in the binaural perception of speech in noise can be obtained by using a combination of ADRO to provide ideal conditions for the combination of speech information from two ears, by using adaptive directional microphones to maximise the SNR in each ear, and by trying to keep speech and noise in opposite ears if possible. A 3 dB advantage was obtained with ADRO in the Japanese bimodal study, with a further 7 to 8 dB advantage from the head-shadow / ADM combination depending on the direction of the noise obtained in the microphone study. If complete separation of speech and noise into opposite ears is achieved, the total advantage may increase to 15 dB or above, as in the third experiment. It is our vision that one day implants and hearing aids will be fitted at the same time by the same person, with the same fitting software, and patients will have the freedom to choose two hearing aids, two implants, one of each, or even two of each. It is time to recognise that people have two ears and need to use them both in a coordinated way for maximum benefit.

## 6. REFERENCES


[1] Y.C. Tong, P.J. Blamey, R.C. Dowell and G.M. Clark, "Psychophysical studies evaluating the feasibility of a speech processing strategy for a multiple-channel cochlear implant" *J. Acoust. Soc. Am.* **74**, 73-80 (1983)

[2] D. Byrne and H. Dillon, "The National Acoustic Laboratories' (NAL) new procedure for selecting the gain and frequency response of a hearing aid" *Ear Hear*. **7(4)**, 257-65 (1986)

[3] G.M. Clark, P.J. Blamey, A.M. Brown, et al. "The University of Melbourne-Nucleus multi-electrode cochlear implant" *Advances Oto-rhino-laryngol.* **38**, 1-189 (1987)

[4] H. Dillon, *Hearing Aids* Thieme Medical Publishers (2001)

[5] A. Boothroyd and O. Eran, "Auditory Speech Perception Capacity of Child Implant Users Expressed as Equivalent Hearing Loss" *Volta Rev.* **96(5)**, 151-167 (1994)

[6] A.F. Snik, A.M. Vermeulen, J.P. Brokx, C. Beijk and P. van den Broek, "Speech perception performance of children with a cochlear implant compared to that of children with conventional hearing aids. I. The equivalent hearing loss concept" *Acta Otolaryngol.* **117(5)**, 750-4 (1997)

[7] P.J. Blamey, J.Z. Sarant, L.E. Paatsch, J.G. Barry, C.P. Bow, R.J. Wales, M. Wright, C. Psarros, K. Rattigan, and R. Tooher, "Relationships among speech perception, production, language, hearing loss, and age in children with impaired hearing" *J. Sp. Lang. Hear. Res.* **44**, 264-285 (2001)

[8] G.J. Dooley, P.J. Blamey, P.M. Seligman, J.I. Alcantara, G.M. Clark, J.K. Shallop, P. Arndt, J.W. Heller, and C.M. Menapace, "Combined electrical and acoustic stimulation using a bimodal prosthesis" *Arch. Otolaryngol.* **119**, 55-60 (1993)

[9] P.J. Blamey, M. Armstrong, and C. James, "Cochlear Implants, hearing aids, or both together?" *in Cochlear Implants* ed. G.M. Clark, Monduzzi Editore, (1997) pp. 273-277

[10] T.Y.C. Ching, "The evidence calls for making binaural-bimodal fittings routine" *Hear. J.* **58(11)**, 32-41 (2005)

[11] B.J. Gantz, C. Turner, and K.E. Gfeller , "Acoustic plus Electric Speech Processing: Preliminary Results of a Multicenter Clinical Trial of the Iowa/Nucleus Hybrid Implant" *Audiol. Neuro-otol.* **11suppl1**, 63-68 (2006)

[12] M. Armstrong, P. Pegg, C. James, and P.J. Blamey, "Speech perception in noise with implant and hearing aid" *Am. J. Otol.* **18**, S140-S141 (1997)

[13] P.J. Blamey, G.J. Dooley, C.J. James, and E.S. Parisi. "Monaural and binaural loudness measures in cochlear implant users with contralateral residual hearing" *Ear Hear*. **21**, 6-17, (2000)

[14] P.J. Blamey, "Sound processing in hearing aids and cochlear implants is gradually converging" *Hear. J.* **58(11)**, 44-52 (2005)

[15] L.F.A. Martin, P.J. Blamey, C.J. James, K.L. Galvin, and D. Macfarlane, "Adaptive dynamic range optimisation for hearing aids" *Acoust. Aust*. **29**, 21-24 (2001)

[16] P.J. Blamey, "Adaptive dynamic range optimization (ADRO): A digital amplification strategy for cochlear implants and hearing aids" *Trends Amplif*. **9(2)**, 77-98 (2005)

[17] T. Iwaki, P.J. Blamey, and T. Kubo, "Bimodal studies using Adaptive Dynamic Range Optimization (ADRO) technology" *Int. J. Audiol*. **47(6)**, 311-318 (2008)

[18] T.Y.C. Ching, P. Incerti, and M. Hill, "Binaural benefits for adults who use hearing aids and cochlear implants in opposite ears" *Ear Hear.* **25(1)**, 9-21 (2004)

[19] P.J. Blamey "Adaptive Dynamic Range Optimization for Hearing Aids" *9th Western Pacific Acoustics Conference, Seoul, June 26-28* (2006)

[20] P.W. Dawson, J.A Decker, and C.E Psarros, "Optimizing dynamic range in children using the Nucleus cochlear implant" *Ear Hear.* 25, 230-241 (2004)

[21] C.J. James, P.J. Blamey, L. Martin, B. Swanson, Y. Just, and D. Macfarlane, "ADRO (Adaptive dynamic range optimization) for cochlear implants: a preliminary study" *Ear Hear*. **23**, 49S-58S (2002)

[22] P.J. Blamey, L.F.A. Martin, and H. Fiket, "A digital processing strategy to optimize hearing aid outputs directly" *J. Am. Acad. Audiol.* **15(10)**, 716-728 (2004)

[23] Blamey, P.J., Fiket, H., & Steele, B.R. "Improving Speech Intelligibility in Background Noise with an Adaptive Directional Microphone" *J. Am. Acad. Audiol.* **17(10)**, 519-530 (2006)

[24] Steele, B. "Method and apparatus for producing adaptive directional signals" International patent application PCT/AU2004/001071, filed Aug. 11, 2004.

[25] P.J. Blamey, C. James, and L.F.A. Martin, "Sound separation with a cochlear implant and a hearing aid in opposite ears" *Acoust, Aust.* **29**, 9-12 (2001)

# ACTIVE NOISE CONTROL AT A MOVING VIRTUAL SENSOR IN THREE-DIMENSIONS


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ABSTRACT: A common problem in local active noise control is that the zone of quiet generated at the physical error sensor is limited in size. This requires that the physical error sensor (the microphone) is placed at the desired location of attenuation (the ear), which is often inconvenient. Virtual acoustic sensors overcome this by estimating the pressure at a location that is remote from the physical sensor and therefore, when combined with an active noise control system, generate a zone of quiet at the desired location of attenuation. While virtual acoustic sensors have shown potential to improve the performance of local active noise control systems, it is, however, likely that the desired location of attenuation is not spatially fixed. A method for generating a virtual sensor that tracks a three-dimensional trajectory in a three-dimensional sound field is summarised in this paper. The performance of an active noise control system in generating a zone of quiet at the ear of a rotating head in a three-dimensional cavity has been experimentally investigated and the results included here demonstrate that moving virtual sensors provide improved attenuation compared to fixed virtual sensors or fixed physical sensors.


## 1. INTRODUCTION

Active noise control involves the use of secondary sound sources to cancel the primary noise disturbance, based on the principle of superposition, in which antinoise of equal amplitude but opposite phase is combined with the primary noise to cancel both disturbances. Active noise control systems generally consist of three major components; a sensor component, an actuator component and a controller. The sensor component is usually a number of microphones that measure the sound pressure at a number of locations within the acoustic field and monitor the performance of the active noise control system. The actuator component is often a number of loudspeakers that generate the antinoise which destructively interferes with the primary noise disturbance. These loudspeakers are referred to as secondary sources and are driven by a control signal generated by the controller [1].

Local active noise control systems generate a localised zone of quiet at the physical error sensor using secondary sources to cancel the acoustic pressure produced by the primary noise source at the physical sensor location. While significant attenuation may be achieved at the physical sensor location, the zone of quiet is generally small and impractically sized. Also, the sound pressure levels outside the zone of quiet are likely to be higher than the original disturbance alone with the active noise control system present.

This is illustrated in Fig. 1 (a), where the zone of quiet located at the physical error sensor is too small to extend to the observer's ear and the observer in fact experiences an increase in the sound pressure level with the active noise control system operating. Virtual acoustic sensors overcome this by shifting the zone of quiet to a desired location that is remote from the physical sensor. This is shown in Fig. 1 (b) where the zone of quiet is projected from the physical sensor to a virtual sensor located at the observer's ear. Using the

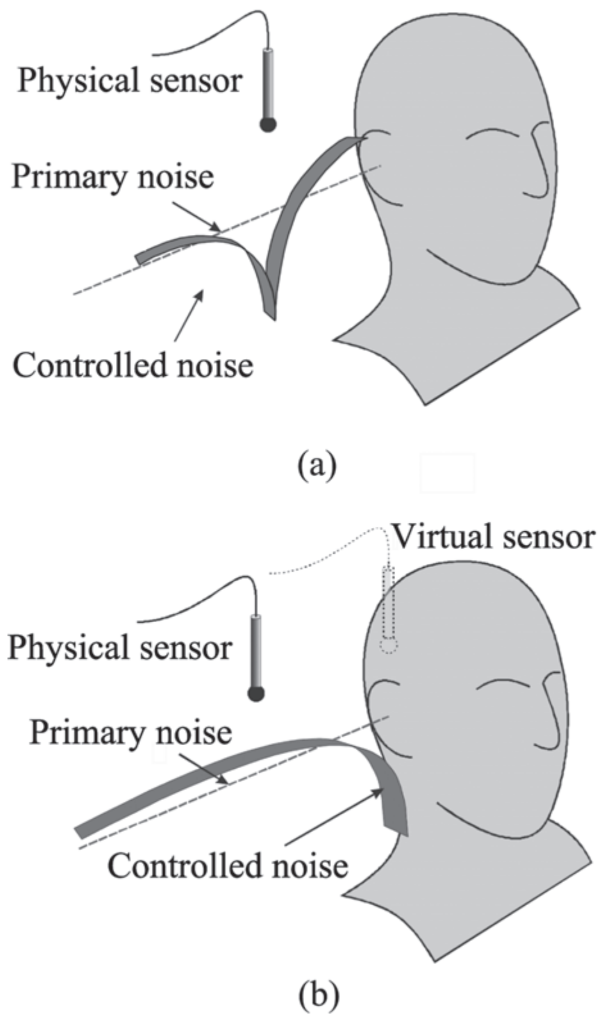


**Figure 1:** Comparison of local active noise control (a) at a physical sensor and (b) at a virtual sensor.

physical error signal, a virtual sensing method is used to estimate the pressure at the virtual sensor location. Instead of minimising the physical error signal, the estimated pressure is minimised to generate a zone of quiet at the virtual location. A number of virtual sensing methods have been developed to estimate the pressure at a fixed virtual location including *the virtual microphone arrangement [2], the remote microphone technique [3], the adaptive LMS virtual microphone technique [4] and the Kalman filtering virtual sensing technique [5].*

The virtual microphone arrangement [2] projects the zone of quiet away fromthe physicalmicrophone using the assumption of equal primary sound pressure at the physical and virtual locations. A preliminary identification stage is required in this virtual sensing method in which models of the transfer functions between the secondary source and microphones located at the physical and virtual locations are estimated. These secondary transfer functions, along with the assumption of equal sound pressure at the physical and virtual locations, are used to obtain an estimate of the error signal at the virtual location given the physical error signal. The remote microphone technique [3] is an extension to the virtual microphone arrangement that uses an additional filter to compute an estimate of the primary pressure at the virtual location using the primary pressure at the physical microphone location.

The adaptive LMS virtual microphone technique [4] employs the LMS algorithm to adapt the weights of physical microphones in an array so that the weighted sum of these signals minimises the mean square difference between the predicted pressure and that measured by a microphone placed at the virtual location. Once the weights have converged they are fixed and the microphone at the virtual location is removed.

The Kalman filtering virtual sensing technique [5] uses Kalman filtering theory to obtain an optimal estimate of the error signal at the virtual location. In this virtual sensing method, the active noise control system is modelled as a state-space system whose outputs are the physical and virtual error signals. Estimates of the plant states are first calculated using the physical error signals and then estimates of the virtual error signals are calculated using the estimated plant states.

Even though the sound is significantly attenuated at the virtual location, the spatial extent of the zone of quiet generated with these virtual sensing algorithms is still impractically small. Large pressure gradients in the vicinity of the virtual sensor result in significant changes in the perceived sound pressure level as the observer moves around within the zone of quiet and this could be more annoying than the original disturbance alone. Subsequently, Petersen et al. [6, 7] developed a number of one-dimensional moving virtual sensing methods that create a zone of quiet capable of tracking a moving virtual location in a one-dimensional sound field. Hence if the observer moves their head, the small zone of quiet also moves with the observer. The one-dimensional moving virtual sensing methods developed by Petersen et al. [6, 7] use the adaptive LMS virtual microphone technique and the remote microphone technique. The performance of these one-dimensional moving virtual sensors has been investigated in an acoustic duct, and experimental results demonstrated that minimising the moving virtual error signal achieved greater attenuation at the moving virtual location than minimising the error signal at either a fixed physical or virtual microphone.

This paper reports on the development of three-dimensional moving virtual sensing methods. A method for generating a moving virtual sensor that tracks a three-dimensional trajectory in a threedimensional sound field is summarised here. The performance of an active noise control system in generating a zone of quiet at a virtual sensor located at the ear of a rotating head has been experimentally investigated and experimental results are presented.

## 2. THEORY

Full details of the method for generating a zone of quiet at a moving virtual microphone that tracks a three-dimensional trajectory are given in [8]. A summary of the three-dimensional moving virtual sensing algorithm is provided as follows.

To create a zone of quiet at a moving virtual location, the active noise control system must minimise the estimated virtual error signal, $\tilde{e}_v(n)$, at the moving virtual location, $x_v(n)$. It is assumed here that the desired position of the moving virtual microphone is known at every time step, $n$. In practice, the desired location of attenuation could be determined using a three-dimensional tracking system based on camera vision or on ultrasonic position sensing [7].

In this moving virtual sensing method, a number, $N_v$, of spatially fixed measurement locations are first selected. It is assumed here that the moving virtual location, $x_v(n)$, is confined to a three-dimensional region and that the $N_v$ spatially fixed measurement locations are therefore located within this region. The vector of the $N_v$ spatially fixed measurement locations is given by

$$\mathbf{x}_v = \left[ \begin{array}{cccc} x_{v1} & x_{v2} & \dots & x_{vN_v} \end{array} \right]. \tag{1}$$

Next, the remote microphone technique is used to obtain estimates of the virtual error signals, $\tilde{\mathbf{e}}_v(n)$, at the $N_v$ spatially fixed measurement locations in $\mathbf{x}_v$. The remote microphone technique requires a preliminary identification stage in which the transfer function between the control source and the physical microphone, $\tilde{G}_{pu}$, and the vector of $N_v$ transfer functions between the control source and the $N_v$ spatially fixed measurement locations, $\tilde{\mathbf{G}}_{vu}$, are measured. The vector of $N_v$ primary transfer functions at the spatially fixed measurement locations from the physical microphone location, M, is also estimated in this preliminary identification stage.

A block diagram of the moving virtual sensing algorithm is given in Fig. 2. As shown in Fig. 2, estimates, $\tilde{\mathbf{e}}_v(n)$, of the virtual error signals at the $N_v$ spatially fixed measurement locations in $\mathbf{x}_v$ are obtained by firstly estimating the primary disturbance at the physical microphone, $\tilde{d}_p(n)$, using

$$\tilde{d}_p(n) = e_p(n) - \tilde{y}_p(n) = e_p(n) - \tilde{G}_{pu}u(n), \tag{2}$$

where $e_p(n)$ is the total error signal measured at the physical microphone, $\tilde{y}_p(n)$ is an estimate of the secondary disturbance at the physical microphone and $u(n)$ is the control signal. Next, estimates of the primary disturbances at the $N_v$ spatially fixed measurement locations, $\mathbf{x}_v$, are obtained using

$$\tilde{\mathbf{d}}_v(n) = \mathbf{M}\tilde{d}_p(n). \tag{3}$$

Estimates, $\tilde{\mathbf{e}}_v(n)$, of the total virtual error signals at the $N_v$ spatially fixed measurement locations are now calculated as

$$\tilde{\mathbf{e}}_v(n) = \tilde{\mathbf{d}}_v(n) + \tilde{\mathbf{y}}_v(n) = \mathbf{M}\tilde{d}_p + \tilde{\mathbf{G}}_{vu}u(n). \tag{4}$$

As shown in Fig. 2, an estimate, $\tilde{e}_v(n)$, of the virtual error signal at the moving virtual location, $x_v(n)$, is now obtained by interpolating the virtual error signals, $\tilde{\mathbf{e}}_v(n)$, at the $N_v$ spatially fixed measurement locations. This estimate, $\tilde{e}_v(n)$, of the virtual error signal at the moving virtual location is minimised with the active noise control system to generate a zone of quiet that tracks a desired three-dimensional trajectory.

As the virtual error signal at the moving virtual location, $\tilde{e}_v(n)$, is estimated by interpolating the virtual error signals, $\tilde{\mathbf{e}}_v(n)$, at the $N_v$ spatially fixed measurement locations, $\mathbf{x}_v$, the accuracy of the estimate of the moving virtual error signal is dependent on the number and position of the spatially fixed measurement locations within the sound field. If the sound field varies significantly in magnitude and phase over a certain region then the spatially fixed measurement locations must be closely spaced within this region to ensure an accurate estimate of the moving virtual error signal is obtained.

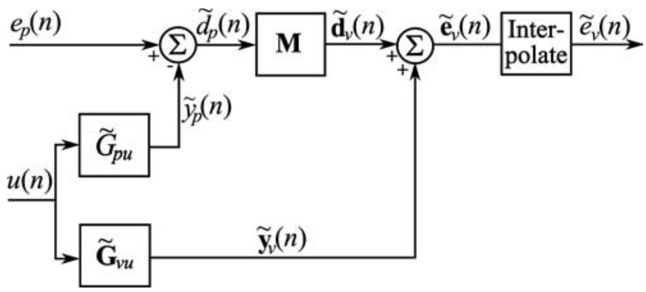


**Figure 2:** Block diagram of the moving virtual sensing algorithm using the remote microphone technique.

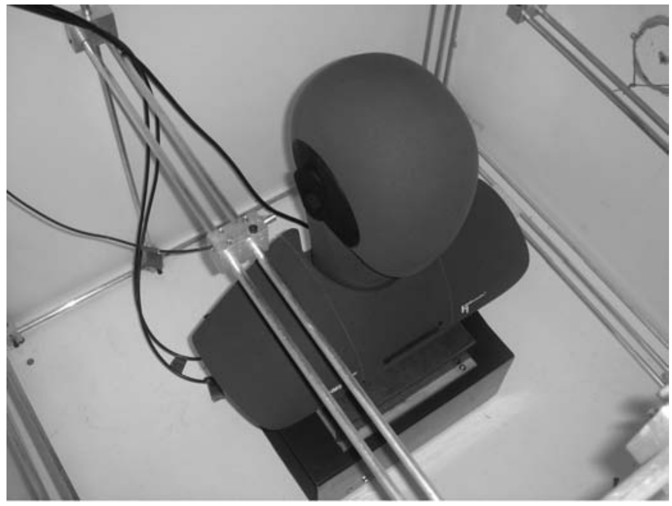

**Figure 3:** The HEAD acoustics HMS III.0 Artificial Head mounted on a turntable and located in them centre of the cavity. The fixed frame supports the physical microphone.

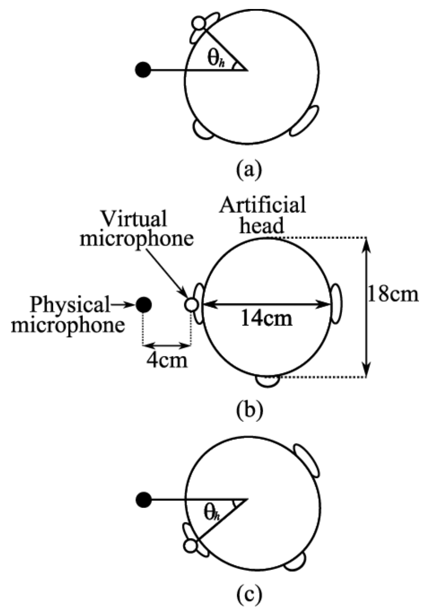


**Figure 4:** The physical arrangement of the artificial head and the physical and virtual microphones at (a) $\theta_h = -45^\circ$ ; (b) $\theta_h = 0^\circ$; and (c) $\theta_h = 45^\circ$. The physical microphone is indicated by a solid circle marker and the virtual microphone is indicated by an open circle marker.

## 3. EXPERIMENTAL METHOD

The performance of an active noise control system in generating a zone of quiet at a moving virtual sensor located at the ear of a rotating artificial head was investigated in real-time experiments. The experiments were conducted in a three-dimensional cavity with dimensions of 1m × 0.8m × 0.89m. A HEAD acoustics HMS III.0 Artificial Head mounted on a turntable to simulate head rotation was located in the centre of the cavity, as shown in Fig. 3. The turntable was position controlled to generate triangular head rotations from −45° to +45° which is typical of the complete head rotations capable of a seated observer.

The physical arrangement of the artificial head and the physical and virtual microphones is shown in Fig. 4. As shown in Fig. 4, a physical microphone was located 4cm from the virtual microphone when the artificial head position was $\theta_h = 0^\circ$. An electret microphone was located at the ear of the artificial head to measure the performance at the virtual microphone position.

Two loudspeakers were located in the corners of the cavity, one to generate the tonal primary sound field and the other to act as the control source. The performance of the active noise control system at the moving virtual location was investigated at the excitation frequency of 525Hz which corresponds to the 33rd acoustic resonance of the cavity. For the excitation frequency of 525Hz, the performance at the moving virtual location was measured for two different periods of 90° head rotation; $t_v = 5$s and $t_v = 10$s.

In the preliminary identification stage, the microphone at the ear of the artificial head was placed at $N_v = 31$ s spatially fixed measurement locations, $\mathbf{x}_v$, equally spaced along the $90^\circ$ arc of head motion. The required primary and secondary transfer functions were modelled as 2 coefficient FIR filters during this preliminary identification stage because the primary disturbance is tonal.

## 4. EXPERIMENTAL RESULTS

Fig. 5 shows the attenuation achieved at the moving virtual location for active noise control at the moving virtual microphone, a fixed virtual microphone located at the ear of the artificial head when $\theta_h = 0^\circ$ and the fixed physical microphone. The control performance at the ear of the artificial head is shown for the period of head rotation being $t_v = 10$s in Fig. 5 (a) and $t_v = 5$s in Fig. 5 (b). Fig. 5 (c) shows the desired trajectory of the artificial head compared to the actual controlled head position.

The control profiles in Fig. 5 demonstrate that for both periods of head rotation, minimising the moving virtual error signal achieves the best control performance at the moving virtual location. For $t_v = 10$s, attenuation between 30dB and 40dB is achieved at the ear of the artificial head for active noise control at the moving virtual microphone, as shown in Fig. 5 (a). Minimising the fixed virtual microphone signal achieves a maximum attenuation of 30dB at the ear of the artificial head when $\theta_h = 0^\circ$ and a minimum attenuation of 10dB when $\theta_h = 45^\circ$. Similarly, active noise control at the physical microphone achieves 22dB of attenuation at the ear of the artificial head when $\theta_h = 0^\circ$ and only 6dB of attenuation when $\theta_h = 45^\circ$. The transient behaviour seen at time $t/t_v = 0$ is caused by the controller initialising.

When the period of head rotation is reduced to $t_v = 5$s, Fig. 5 (b) shows that minimising the moving virtual error signal results in attenuation of between 20dB and 35dB being achieved at the ear of the artificial head. This is a significant improvement in control performance compared to active noise control at either the fixed virtual or physical microphones where attenuation levels again fall to 10dB and 6dB respectively when $\theta_h = 45^\circ$. As expected, when the period of rotation is reduced, the control performance reduces. This is because it takes a finite time for the controlled sound field to stabilise, so once the period of rotation nears the reverberation time of the cavity the control performance is compromised.

## 5. CONCLUSION

In this paper, a method for generating a moving virtual sensor that tracks a three-dimensional trajectory has been presented. The performance of an active noise control system in generating a zone of quiet at a single ear of a rotating artificial head has been experimentally investigated and real-time experimental results demonstrated that greater attenuation can be achieved at a single ear of the artificial head when a three-dimensional moving virtual sensing algorithm is employed.

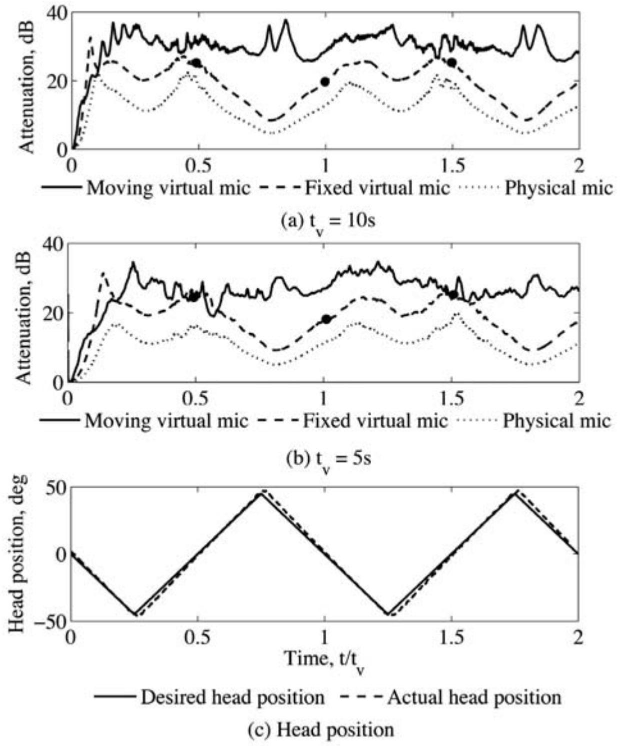


**Figure 5:** Tonal attenuation achieved at the moving virtual location for active noise control at the moving virtual microphone, the virtual microphone spatially fixed at the ear of the artificial head when $\theta_h = 0^\circ$ and the physical microphone, for period of rotation (a) $t_v = 10$s,; (b) $t_v = 5$s ; and (c) head position. The fixed virtual microphone position at $\theta_h = 0^\circ$ is indicated by a solid round marker.

## REFERENCES


[1] S.M. Kuo, D.R. Morgan, *Active Noise Control Systems, Algorithms and DSP Implementation*, John Wiley and Sons Inc, New York (1996).

[2] S.J. Elliott, A. David, "A virtual microphone arrangement for local active sound control", *Proceedings of the First International Conference on Motion and Vibration*, 1027-1031 (1995).

[3] A. Roure, A. Albarrazin, "The remote microphone technique for active noise control", *Proceedings of Active 99*, 1233-1244 (1999).

[4] B.S. Cazzolato, "An adaptive LMS virtual microphone", *Proceedings of Active 02*, 105-116 (2002).

[5] C.D. Petersen, R. Fraanje, B.S. Cazzolato, A.C. Zander, C.H. Hansen, "A Kalman filter approach to virtual sensing for active noise control", *Mechanical Systems and Signal Processing*, **22**, 490-508 (2007).

[6] C.D. Petersen, B.S. Cazzolato, A.C. Zander, C.H. Hansen, "Active noise control at a moving location using virtual sensing", *ICSV13: Proceedings of the 13th International Congress of Sound and Vibration*, Vienna (2006).

[7] C.D. Petersen, A.C. Zander, B.S. Cazzolato, C.H. Hansen, "A moving zone of quiet for narrowband noise in a one-dimensional duct using virtual sensing", *Journal of the Acoustical Society of America*, **121(3)**, 1459-1470 (2007).

[8] D.J. Moreau, B.S. Cazzolato, A.C. Zander, "Active noise control at a moving location in a modally dense three-dimensional sound field using virtual sensing", *Proceedings of Acoustics 08*, Paris (2008).

# TRANSMISSION LOSS OF A PANEL WITH AN ARRAY OF TUNED VIBRATION ABSORBERS

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This paper was awarded the **2008 President's Prize** for the best technical paper presented at the Australian Acoustical Society's conference, Geelong, Victoria. A version was published in the conference proceedings, edited by Terrence McMinn.

ABSTRACT: This paper presents a numerical model for the calculation of the transmission loss of a panel with an array of tuned vibration absorbers attached. The transmission loss of the panel is calculated for the case of the bare panel, with tuned vibration absorbers attached, and equivalent blocking masses. The theoretical predictions of transmission loss are compared with experimental measurements.

## 1. INTRODUCTION

Many noise control applications require panel partitions with high transmission loss and low weight. Partitions with high transmission loss are characterised by a high surface density, which can result in excessive weight. For weight-critical aerospace applications, the judicious use of stiffening ribs is often employed. The optimisation goal for these applications is to obtain a configuration that achieves the highest transmission loss for an acceptable weight penalty.

It was shown in previous conference papers by the author [1,2] that the attachment of discrete masses to a panel can result in transmission loss results greater than merely increasing the thickness, and hence the surface density, of the panel by an amount that would result in the same total weight. The work presented here is an extension of the previous work, by including comparisons of theoretical and experimental results of the transmission loss of a panel with an array of cantilever beams attached that act as vibration absorbers. A Polytec Scanning Laser Vibrometer was used to measure the vibration of the cantilever absorbers during transmission loss tests.

The first part of this paper describes a mathematical model to predict the transmission loss of a panel with discrete masses and / or single degree of freedom oscillators. This model is used to predict the transmission loss for three cases namely a bare panel, a panel with an array of 49 discrete 'blocking' masses, and a panel with 49 single degree of freedom oscillators. In the second part of this paper, numerical predictions of transmission loss are compared with experimental results for these three cases.

## 2. PREVIOUS WORK

The use of secondary oscillators attached to a primary structure to reduce vibration or improve transmission loss was investigated in 1928 [3]. More recently researchers have described methods for the optimisation of their parameters [4] and methods for designing an absorber with multiple resonances to reduce the vibration of a beam [5]. Relevant to the work presented here, researchers have used dynamic absorbers to reduce interior noise within a cylindrical shell [6]. The results showed that the addition of dynamic absorbers if correctly positioned can successfully reduce the vibration of the shell and the interior acoustic pressure of the sound field enclosed by the shell. This technique has been used in real aircraft [7,8]. Su et.al [9] used statistical energy analysis to examine the attachment of six dynamic vibration absorbers to a stiffened aircraft panel, all tuned to 101Hz, and found improvement in the transmission loss. However the work here involves the investigation of vibration absorbers to improve the transmission loss due to broadband acoustic excitation, of which there has been little work.

The following section describes the development of a mathematical model to enable the prediction of the transmission loss of a panel with tuned vibration absorbers.

## 3. MATHEMATICAL MODEL

The mathematical model for the prediction of the transmission loss of a panel incorporating the effects of the addition of an array of lumped masses or oscillators is similar to previous work [2] and involves calculating the:

- modal forcing vector due to pressure loading on a panel from an incident plane wave;
- vibration response of the panel, including the effects of the attached devices;
- sound pressure radiated from the panel and integrating the results to determine the radiated sound power; and
- transmission loss of the panel as the ratio of the incident to radiated sound power.

**Incident Plane Wave**

Consider an acoustic plane wave of pressure amplitude $P_i$ incident at angles θ and ϕ on a simply supported panel with edge lengths $L_x$ and $L_y$, as shown in Figure 1. The pressure that is incident on the panel $P(x,y)$ is given by

$$P(x,y) = P_i \exp[\, j(\omega t - kx\sin\theta_i \cos\phi_i - ky\sin\theta_i \sin\phi_i)] \quad (1)$$

This can be written as a modal pressure that acts on the panel and is calculated by multiplying the pressure distribution by the mode shape matrix of the structure $\mathbf{\Psi}$, and dividing by the modal mass matrix of the structure $\mathbf{\Lambda}$ (for consistency with later equations) as $\mathbf{\Psi}P(x,y)/\mathbf{\Lambda}$, and can be written as $p_{m,n} = L_x L_y \bar{Y}_m \bar{Y}_n$ where

$$\bar{Y}_m = (m\pi)\frac{1-(-1)^m e^{-j\alpha}}{(m\pi)^2 - \alpha^2} \quad (2)$$

$$\bar{Y}_n = (n\pi)\frac{1-(-1)^n e^{-j\beta}}{(n\pi)^2-\beta^2} \qquad (3)$$

$\alpha = kL_x \sin\theta\cos\phi$ , $\beta = kL_y \sin\theta\sin\phi$ , $k=\omega/c$ is the wavenumber, $\omega$ is the frequency, $c$ is the speed of sound in air. This modal force (pressure) can be applied to the dynamics of the panel to calculate the structural modal participation factors $w_p$.

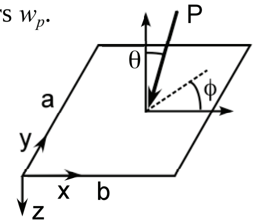



**Figure 1.** Coordinates for an incoming acoustic plane wave striking a simply support rectangular panel.

### Vibration of a Simply Supported Panel

The displacement $w$ of a simply-supported panel at position $(x,y)$ can be written as an infinite sum of its vibration modes as

$$w(x,y) = \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} w_{m,n}\sin(m\pi x/L_x)\sin(n\pi y/L_y) \qquad (4)$$

where $w_{m,n}$ are the modal participation factors. The equations of motion for the panel can be written as [10]

$$\ddot{w}_p + 2\xi_p\omega_p\dot{w}_p + \omega_p^2 w_p = \Gamma_p \qquad (5)$$

where $w_p$ is the $p^{\text{th}}$ modal participation factor, $\omega_p$ is the viscous damping coefficient of the shell at the $p^{\text{th}}$ mode, $\omega_p$ is the resonance frequency of the $p^{\text{th}}$ mode, and $\Gamma_p$ is the $p^{\text{th}}$ modal force which is applied to the panel for and is defined as

$$\Gamma_p = \frac{1}{\rho_p h N_p}\int_0^{L_x}\int_0^{L_y}\left[q_z U_{zp} + T_x U_{zp} + T_y U_{zp}\right]dy\,dx \qquad (6)$$

where $q_i$ and $T_i$ represent the point forces and point moments applied along each axis, which could be due to point forces, point impedance due a lumped mass, or point impedance due to an attached absorber, and is defined as

$$q_{zJ} = F_{zJ}\,\delta\left(x-x_J\right)\delta\left(y-y_J\right)e^{j\omega t} \qquad (7)$$

$$T_{iJ} = \frac{M_{iJ}}{R^2}\delta\left(x-x_J\right)\delta\left(y-y_J\right)e^{j\omega t} \qquad (8)$$

where $F_{iJ}$ and $M_{iJ}$ are the forces and moments applied to the panel at locations $(x_J, y_J)$ in the directions $i = x,y,z$ , δ is the Dirac delta function, $U_{ip}$ is the modal response in the $i^{\text{th}}$ direction, and for the vibrations of the panel considered here where only the out-of-plane transverse vibration is considered, the expressions can be written as

$$U_{xp} = 0 \quad U_{yp} = 0 \quad U_{zp} = [\psi]\mathbf{w}_p \qquad (9)$$

and

$$N_s = \int_0^{L_x}\int_0^{L_y} U_{zs}^2\ dy\,dx = L_x L_y/4 \qquad (10)$$

The force and moment loads on the panel are assumed to be point loads, which can be described with Dirac delta functions. Making use of the relationship

$$\int_\alpha F(\alpha)\frac{\partial}{\partial\alpha}\left[\delta\left(\alpha-\alpha^*\right)\right]d\alpha = -\frac{\partial F(\alpha^*)}{\partial\alpha} \qquad (11)$$

the integral in Eq. (6) can be evaluated as

$$\Gamma_s = \frac{1}{\Lambda_s}\left[[\psi_J]^{\mathrm{T}}F_J - \frac{\partial[\psi_J]^{\mathrm{T}}}{\partial y}M_{Jx} + \frac{\partial[\psi_J]^{\mathrm{T}}}{\partial x}M_{Jy}\right] \qquad (12)$$

The rotations of the panel are given by [10]

$$\theta_s = \frac{v}{R} - \frac{1}{R}\frac{\partial w}{\partial\theta} \qquad (13)$$

$$\theta_\theta = -\frac{1}{R}\frac{\partial w}{\partial s} \qquad (14)$$

The partial differentials of the mode shapes [ψ] with respect to the spatial co-ordinates in Eq. (12) are the mode shapes in the rotational directions. Hence Eq. (12) can be written as

$$\Gamma_s = \frac{1}{\Lambda_p}\left[[\psi_J]^{\mathrm{T}}F_J - [\psi_{J\theta x}]^{\mathrm{T}}M_{Jx} + [\psi_{J\theta y}]^{\mathrm{T}}M_{Jy}\right] \qquad (15)$$

where $[\psi_{J\theta x}]$ and $[\psi_{J\theta y}]$ are the rotational mode shapes about the $\theta_x$ and $\theta_y$ axes, respectively and are

$$\psi_{J\theta_x} = \frac{\partial\psi_J}{\partial y} = \sin\left(m\pi x/L_x\right)\left(n\pi/L_y\right)\cos\left(n\pi y/L_y\right) \qquad (16)$$

$$\psi_{J\theta_y} = \frac{\partial\psi_J}{\partial x} = \left(m\pi/L_x\right)\cos\left(m\pi x/L_x\right)\sin\left(n\pi y/L_y\right) \qquad (17)$$

The impedance of the $J^{\text{th}}$ mass attached to the panel is included as point translational and rotational inertias by using Eqs. (7) and (8) where

$$F_J = \omega^2 m_J \qquad (18)$$

$$M_{J\theta_x} = \omega^2 J_{J\theta_x} \qquad (19)$$

$$M_{J\theta_y} = \omega^2 J_{J\theta_y} \qquad (20)$$

where $m_J$ is the mass of the block, $J_{J\theta_x}$, $J_{J\theta_y}$ are the rotational inertias of the blocks along the $\theta_x$, $\theta_y$ axes, respectively. The attachment of an array of cantilever absorbers is modelled here as multiple single degree of freedom resonators or Tuned Vibration Absorbers (TVAs) ($J$=1… $N_{\mathrm{TVA}}$), that have mass $m_J^{\mathrm{TVA}}$, stiffness $k_J^{\mathrm{TVA}}$, and are driven by a harmonic force at the attachment point of the spring to the structure. This framework can be used accommodate multiple modes of vibration along translational and rotational axes. However, it will be shown by comparison with the experimental results that for the system examined here it is sufficient to only consider vibration of a single translational mode normal to the panel. The equations for the vibration of the structure and the TVAs can be written in matrix form as

$$\begin{bmatrix} k_J^{\mathrm{TVA}} - \omega^2 m_J^{\mathrm{TVA}} & -k_J^{\mathrm{TVA}}\left[\psi_J\right] \\ -\left[\psi_J\right]^{\mathrm{T}} k_J^{\mathrm{TVA}} & \begin{bmatrix} \Lambda_p\left(\omega_p^2 - \omega^2\right) + \\ \left[\psi_J\right]^{\mathrm{T}} k_J^{\mathrm{TVA}}\left[\psi_J\right] \end{bmatrix} \end{bmatrix} \times \begin{bmatrix} x_J^{\mathrm{TVA}} \\ w_p \end{bmatrix} = \begin{bmatrix} \mathbf{0} \\ \mathbf{F}_p \end{bmatrix} \tag{21}$$

where $\left[\psi_J\right]$ is the structural mode shape vector evaluated at the $J^{\text{th}}$ connection point of the TVA to the structure, T is the matrix transpose operator, and $\mathbf{F}_p$ is the vector of modal forces from $\Gamma_p$. The equations derived thus far have not included damping terms. Damping can be included by using a hysteretic structural loss factor, so that the stiffness value for the TMD becomes a complex number. Hence the complex stiffness can be written as $k_J^{\mathrm{TVA}} = k_J^{\mathrm{TVA}}(1 + j\eta)$, where $\eta$ is the structural loss factor.

The resonance frequencies of a simply-supported panel $\omega_{m,n}$ are given by

$$\omega_{m,n}^2 = \omega_p^2 = \frac{D\pi^4}{\rho h}\left[\left(\frac{m}{L_x}\right)^2 + \left(\frac{n}{L_y}\right)^2\right] \tag{22}$$

$$D = \frac{Eh^3}{12(1-\nu^2)} \tag{23}$$

where $D$ is the bending stiffness of the panel, $E$ is the Young's modulus, $h$ is the thickness, $\nu$ is the density of the panel, $\nu$ is the Poisson's ratio.

**Sound Power Radiated from the Panel**

Once the modal participation factors $w_p$ are calculated, the transmitted pressure at a point remote from the panel due to the vibration of the panel is calculated using the Rayleigh integral and can be written as [11,12]

$$p_{m,n}^t = -j(j\omega w_p)k\rho c\frac{e^{jkr}}{2\pi r}L_x L_y Y_m Y_n \tag{24}$$

$$Y_m = (m\pi)\frac{1-(-1)^m e^{-j\alpha}}{(m\pi)^2 - \alpha^2} \tag{25}$$

$$Y_n = (n\pi)\frac{1-(-1)^n e^{-j\beta}}{(n\pi)^2 - \beta^2} \tag{26}$$

and the transmitted intensity is calculated as $I^t = \left|\sum_m\sum_n p_{m,n}^t\right|^2/(2\rho c)$. The total power $\Pi^t$ that is radiated by the panel is calculated as the integral of the intensity over an imaginary far-field hemisphere as

$$\Pi^t = \int_{\phi_t=0}^{2\pi}\int_{\theta_t=0}^{\pi/2} I^t r^2 \sin\theta_t \, d\theta d\phi \tag{27}$$

**Transmission Loss of the Panel**

The transmission loss (TL) of a panel is the ratio of the incident to transmitted sound power and for an incident plane wave is given by

$$\mathrm{TL} = 10\log_{10}(\tau(\theta_i,\phi_i)) = 10\log_{10}(\Pi^i/\Pi^t) \tag{28}$$

where the sound power incident on the panel is given by [13]

$$\Pi^i = (|P_i|^2 L_x L_y \cos\theta_i)/(2\rho c) \tag{29}$$

A diffuse field is characterised by an infinite number of uncorrelated plane-waves [14]. The sound field inside the reverberation chamber used in the experimental part of the work conducted here is assumed to be a diffuse field. The transmission loss for a diffuse field is calculated as [12,15-17]

$$\begin{aligned} \mathrm{TL}_{\text{diffuse}} &= \frac{\int_0^{2\pi}\int_0^{\pi/2}\tau(\theta_i,\phi_i)\sin\theta_i\cos\theta_i \, d\theta_i d\phi_i}{\int_0^{2\pi}\int_0^{\pi/2}\sin\theta_i\cos\theta_i \, d\theta_i d\phi_i} \\ &= \frac{\int_0^{2\pi}\int_0^{\pi/2}\tau(\theta_i,\phi_i)\sin 2\theta_i \, d\theta_i d\phi_i}{2\pi} \end{aligned} \tag{30}$$

| | | |
|---|---|---|
| Width $L_x$ | 1.0 | m |
| Height $L_y$ | 1.5 | m |
| Thickness $t$ | 0.0015 | m |
| Density $\rho$ | 2700 | kg/m$^3$ |
| Young's Modulus $E$ | 70 | GPa |
| Poisson's ratio $\nu$ | 0.33 | No units |
| Loss factor $\eta$ | 0.01 | No units |

**Table 1.** Geometry of the panel

## 4. EXPERIMENT SETUP

A panel with the properties listed in Table 1 was tested in The University of Adelaide's transmission-loss test facilities. The panel was also tested with an array of cantilever absorbers, and with rigid 'blocking' masses of the same weights as the cantilever absorbers that had a total mass of 1.18kg, 19% of the mass of the panel. High amplitude pink noise was played in the source reverberation chamber of the test facility which excited the test panels. The radiated sound power from the panels was measured in the receiving reverberation chamber by a traversing microphone.

The rigid masses or absorbers were attached to the panel in a regular pattern, as shown in Figure 2, with no regard given to optimising their locations for this initial study. The lightest blocking mass (also highest resonance-frequency oscillator) was placed in the top left corner, and the heaviest blocking mass (also the lowest resonance-frequency oscillator) was placed in the lower right corner of the panel. The weight of the rigid blocks and cantilever absorbers had an almost linear distribution. Each absorber had an equivalent rigid block of the same mass, as shown in Figure 3. The resonance frequencies of the absorbers had a distribution as shown in Figure 4. By restraining the beams at their midpoints creates two symmetric cantilever absorbers. Hence each device has two first bending mode resonance frequencies that are similar, as shown in Figure 4. The resonance frequencies of the absorbers are between 270-430Hz. It can be seen that the theoretically predicted resonance frequencies used in the design of the beams is higher than experimentally measured. This is to be expected as the beams were modelled as cantilevers having fully clamped ends, whereas in reality the beams were held at their midpoint with a nut and bolt resulting in non-ideal clamping conditions and hence lower resonance frequencies.

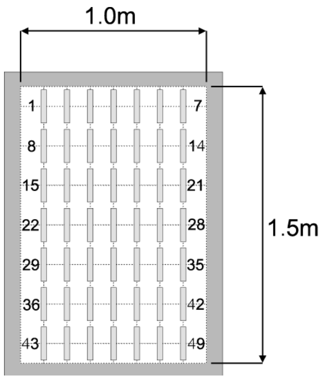



**Figure 2.** Location of the devices on the panel.

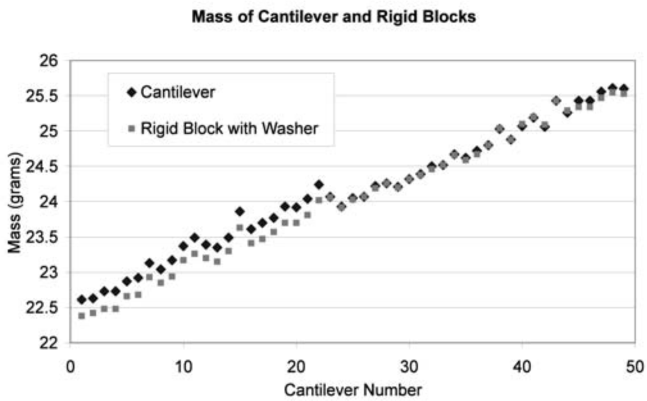



**Figure 3.** Mass of rigid blocks and cantilever absorbers.

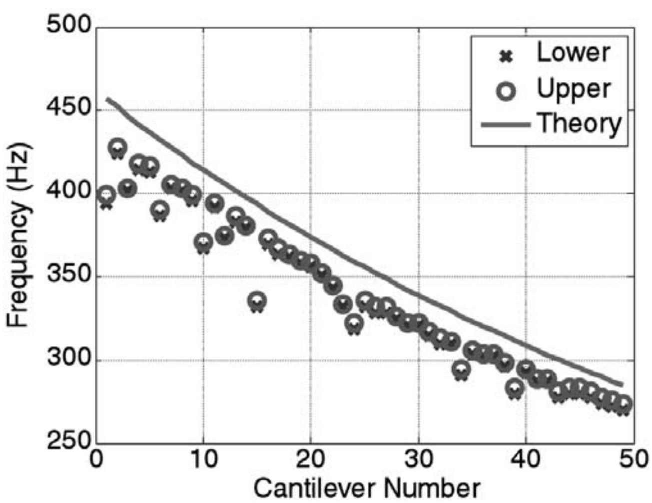



**Figure 4.** Resonance frequencies of the cantilever absorbers.

## 5. RESULTS

Figure 5 shows the experimentally measured transmission loss of the bare panel and theoretical predictions using the modal model described here, and the solid curve shows the predicted transmission loss for a finite panel based on the work by Sewell [8], and discussed in Ref [12]. These results are from [2] and are included here for completeness. It can be seen that the measured TL above 10kHz does not follow the theoretical predictions as the measured T60 reverberation times were erroneous due to insufficient sound level in the receiver room above the background level. The low-frequency accuracy of the measurements is limited by the largest dimension of the chambers and is valid above 125Hz, hence comparisons between experimental results and theoretical predictions can be made at and above 125Hz. The predictions using the modal model are accurate from about 50-1000Hz. Above 1kHz it can be seen that the results diverge and the inaccuracy is caused by using an insufficient number of modes in the analyses; 2000 structural modes for these analyses. As the purpose of the work here is to investigate the improvement of TL at low-frequencies, the frequency range between 125-1000Hz will be considered.

Figure 6 shows the transmission loss results for experimental measurements and theoretical predictions with and without blocking masses [2]. The theoretical predictions show that the addition of the rigid blocking masses, which had a total mass of 1.18kg, increases the transmission loss of the panel between 100-315Hz, which was confirmed by experimental measurements. It was shown that if this added mass had been smeared over the panel, achieved by increasing the panel thickness, the TL would be 1.2dB greater than the bare panel [2]. However the improvement in TL for the rigid blocking masses exceeds 1.2dB.

Figure 6 also shows the transmission loss of the panel with and without the addition of the cantilever absorbers. The results show that the addition of the cantilevers improves the transmission loss in the frequency range between 125-200Hz and compares favourably with the theoretical predictions. It can be seen that the transmission loss between 250-400Hz is less than the case of the bare panel. In this frequency range it can be seen that the theoretical predictions under-predict the effect of the oscillators. The effect of the oscillators is modelled as single-degree-of-freedom resonators acting normal to the panel. However the absorbers have translational and rotational modes and the effects of the rotational modes were not included in the theoretical analysis.

A Polytec 3D Scanning Laser Vibrometer was used to measure the motion of the beams during the transmission loss testing. Figure 7 shows an image from the Scanning Laser Vibrometer system where the panel under test is in the background and the motion of the 49 absorbers were measured at 5 points along each absorber. The image shows the operating deflected shape of the absorbers at 220Hz and the rectangular box highlights two adjacent absorbers undergoing significant rotational motion. If the effects of the rotational motion of the absorbers were included in the theoretical analysis, one would expect that the absorbers would impart rotational impedance to the structure limiting bending vibrations, and hence the transmission loss of the panel would be greater, closer to the experimentally measured transmission loss results.

Figure 6 shows the surprising result that the greatest improvement in transmission loss occurred for the panel configuration with the rigid blocking masses and not for the case where the TVAs were attached to the panel. It was hypothesised that the use of the TVAs would provide significant benefits in transmission loss, and that by using 49 absorbers with closely spaced resonance frequencies would be sufficient to achieve a 'fuzzy' structure configuration, where the master structure, the panel, would have significant vibration reduction by the attachment of a large number of oscillators. Howard et.al [19] showed that the attachment of a large number of oscillators to a master structure could result in significant vibration reductions and improvement in transmission loss due to broadband acoustic excitation, and that the accurate placement of the oscillators on the master structure was not important, suggesting a robust noise control technique. However this was not the outcome for this project and further investigation of the laser vibrometer data is warranted.

The resonance frequencies of the cantilever absorbers, shown in Figure 4 corresponds to the frequency range where the transmission loss is no greater than the bare panel. This result suggests that the effect of the discrete masses acted to restrain the local motion of the panel, whereas the attachment of the cantilever beams did not. These results are similar to previous work [20] where the addition of tuned vibration absorbers reduced the vibration of a cantilever beam.

The mechanical impedance of an absorber at resonance is approximately given by $m^{TVA}\omega_r Q$, where $m^{TVA}$ is the mass of the absorber, $\omega_r$ is its resonance frequency, $Q$ is the quality factor [21]. At resonance, greater mechanical impedance is achieved by increasing $Q$, the sharpness of the resonance peak. However at frequencies off-resonance, the impedance of the absorber is proportional to the mass, and thus a higher mass will therefore be more effective.

## 6. CONCLUSIONS

A mathematical model was presented to enable the calculation of the transmission loss of a simply-supported panel with an array of discrete blocking masses attached or an array of single-degree-of-freedom oscillators attached, and is an extension of previous work [2].

The calculation of the transmission loss described in this paper involved the analysis 370 plane waves, which was achieved using a distributed computing network. Hence this calculation method is limited to investigators with extensive computational resources. An alternative calculation method using blocked patch pressures could be used [22], which avoids the double integration calculation over all incident angles for the calculation of the transmission loss. Work will be conducted in the future to incorporate this calculation technique, which will reduce the calculation time and enable the optimisation of the locations of the rigid-masses and absorbers by using a genetic algorithm [19].

It was shown previously [2] that the attachment of blocking-masses improved the transmission loss of the panel, greater

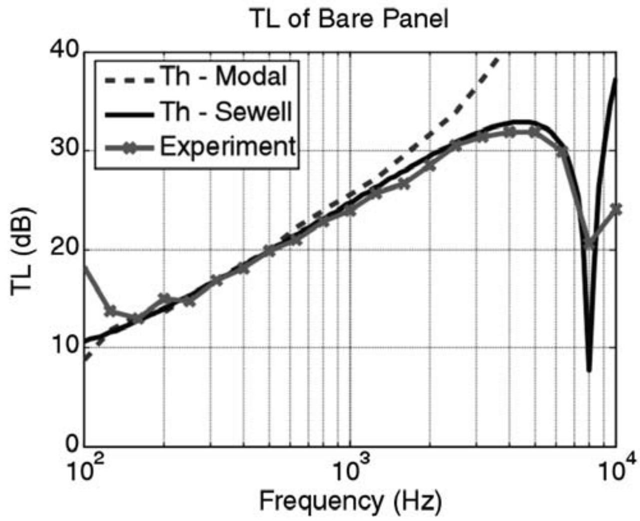



**Figure 5.** Transmission loss of the bare panel [2].

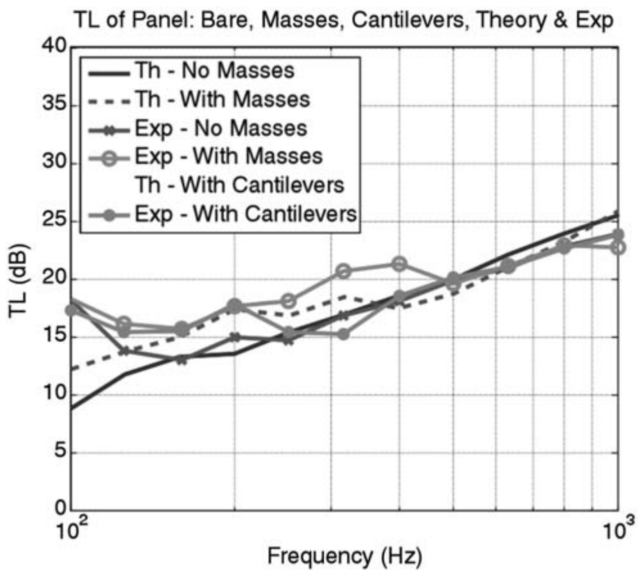



**Figure 6.** Transmission loss of the bare panel, with rigid blocks, and with cantilever absorbers attached.

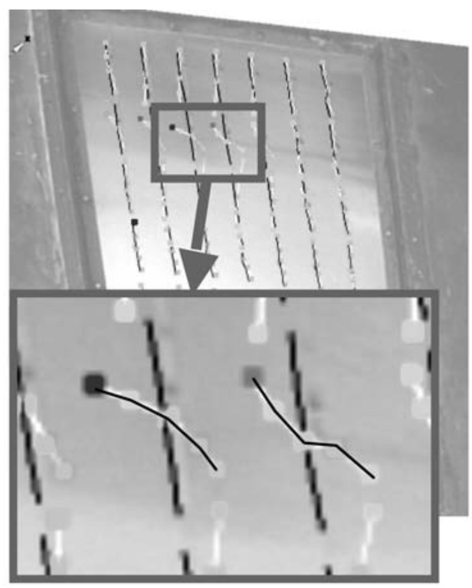


**Figure 7.** Vibration of cantilever absorbers attached to panel at 220Hz.

than could be achieved by smearing the mass of the absorbers across the panel, which could be achieved by increasing the thickness of the panel. When cantilever absorbers replaced the blocking-masses, the transmission loss of the panel only improved in the frequency ranges outside the resonance frequencies of the absorbers, which was not expected. The likely reason for this is that the impedance that the absorbers present to the panel is less than the rigid-blocking mass presents to the panel. Further investigation is warranted for this noise control technique, as studies involving fuzzy structure theory point to potential benefits in vibration reduction of panels, and hence there is also likely to be corresponding improvement in transmission loss.

## REFERENCES


1. Howard, C.Q. and Kidner M.R.F., *Experimental validation of a model for the transmission loss of a panel with an array of lumped masses.* Proceedings of Acoustics 2006: Noise of Progress, pages 169-177, Clearwater Resort, Christchurch, New Zealand, AAS (2006).
2. Howard, C.Q., *Theoretical and Experimental Results of the Transmission Loss of a Panel with Discrete Masses Attached,* ICSV14, Cairns, Queensland, Australia, 9-12 July, Paper 14 (2007).
3. Ormondroyd, J. and Den Hartog, J.P., *The Theory of the vibration absorber,* Transactions of the American Society of Mechanical Engineers, **49**, A9-A22 (1928).
4. Liu, K. and Liu, J., *The damped dynamic vibration absorbers: revisited and new result,* Journal of Sound and Vibration, **284**, p1181–1189 (2005).
5. Nishida, E., and Koopmann, G. H., *A Method for Designing and Fabricating Broadband Vibration Absorbers for Structural Noise Control,* Journal of Vibrations and Acoustics, **129**, p397-405 (2007).
6. Huang, Y.M., and Fuller, C.R., *The Effects of Dynamic Absorbers on the Forced Vibration of a Cylindrical Shell and its Coupled Interior Sound Field*, Journal of Sound and Vibration, **200** (4), p401–418 (1997).
7. Halvorsen, W.G., and Emborg, U., *Interior noise control of the SAAB 239 aircraft,* SAE Paper 891080 (1989).
8. Waterman, E.H., Kaptein, D., and Sarin, S.L., *Fokker's activities in cabin noise control for propeller aircraft*, SAE Paper 830736 (1983).
9. Su, Z., Sun, J., Wang, C., Dai, Y., *Dynamic vibration absorbers used for increasing the noise transmission loss of aircraft panels,* Applied Acoustics, **48**(4), August, p311-321, (1996).
10. Soedel, W., *Vibrations of Shells and Panels*, Marcel Dekker (1993).
11. Wallace, C.E., *Radiation resistance of a rectangular panel.* The Journal of the Acoustical Society of America, **51**(3), p946–952 (1972).
12. Fahy, F.J., *Sound and Structural Vibration: Radiation, Transmission and Response*, Academic Press (1994).
13. Roussos, L.A., *Noise transmission loss of a rectangular panel in an infinite baffle*, NASA technical paper TP2398, March, Langley Research Center, Hampton, Virginia, USA (1985).
14. Langley, R.S. and Shorter, P.J., *Diffuse wavefields in cylindrical coordinates*, Journal of the Acoustical Society of America, **112** (4), October, p1465-1470 (2002).
15. Guigou-Carter, C. and Villot., M., *Modelling of sound transmission through lightweight elements with stiffners*, Building Acoustics, **10** (3), p193-209 (2003).
16. Chiello, O., Sgard, F.C., and Atalla, N., *On the use of a component mode synthesis technique to investigate the effects of elastic boundary conditions on the transmission loss of baffled panels*, Computers and Structures, **81**, p2645–2658 (2003).
17. Wang, J., Lu, T.J., Woodhouse, J., Langley, R.S., and Evans, J., *Sound transmission through lightweight double-leaf partitions: theoretical modelling*, Journal of Sound and Vibration, **286**, p817–847 (2005).
18. Sewell, E.C., *Transmission of reverberant sound through a single-leaf partition surrounded by an infinite rigid baffle*, Journal of Sound and Vibration, **12** (1), p21-32 (1970).
19. Howard, C.Q., Hansen, C.H., and Zander, A.C., *Vibro-acoustic noise control treatments for payload bays of launch vehicles: discrete to fuzzy solutions*, Applied Acoustics, **66** (11), November, p1235-1261 (2005).
20. Brennan, M.J., and Dayou, J., *Global Control of Vibration Using A Tunable Vibration Neutralizer,* Journal of Sound and Vibration, **232** (3), May, p585-600 (2000).
21. Fuller, C.R., Maillard, J.P., Mercadel, M. and Von Flotow, A.H., *Control of aircraft interior noise using globally de-tuned vibration absorbers*, Journal of Sound and Vibration, **203** (5), June, p745-761 (1997).
22. Chazota, J.D. and Guyader, J.L., *Prediction of transmission loss of double panels with a patch-mobility method*, Journal of the Acoustical Society of America, **121** (1), January, p267–278 (2007).

# Is there really no sound in space?

Maintaining web sites about acoustics guarantees this editor a regular supply of emailed questions. “Space isn’t quite empty” wrote one correspondent, “so can it transmit sound?” Obviously not audible sound, I thought, but can we put a lower bound on the wavelength?

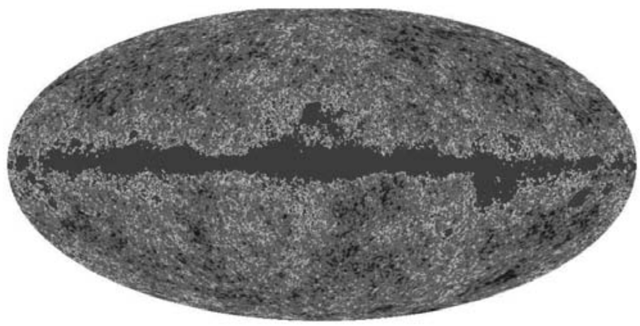
The first problem is having enough atoms or molecules: pressure is a macroscopic concept, and its usual use presumes a scale large compared with the mean free path (m.f.p.) between molecular collisions. In air, the m.f.p. is rather less than a micron, but in space? Just from dimensions, we can write m.f.p. ~ [(scattering cross section)(number density)]$^{-1}$. (There is also a numerical factor, of order one, which depends on the velocity distribution.)

Taking the atomic scattering section as ~ $10^{-20}$ m$^2$, and number density as ~ $10^6$ molecules.m$^{-3}$, we get a m.f.p. of about $10^{14}$ m or 0.01 light years. Collisions are rare. So, to talk of cosmic sound waves, we’d need to consider wavelengths much longer than this. The frequency would be expressed in femtohertz.

But that’s now. When the universe was younger, hotter and denser, the mean free path was shorter and the speed of sound higher. Younger than about 400,000 years, the temperature was above 3000 K and the medium was a plasma. Much earlier than that and the universe would have been a very noisy place, although the section on relativistic acoustics seems to be a lacuna in acoustics texts.

As the universe expanded, the scale of the local variations in average density expanded. Some of the variations in density were exaggerated by effects that are usually ignored by acousticians: gravity and star formation. Measuring the remaining ultralong wavelength acoustic waves directly is difficult.

We can, however, infer the acoustics of the young universe. When the universe was a plasma, matter and radiation were strongly coupled, so the cosmic microwave background (CMB) reports the spatial variations in temperature and therefore density of the hot, pre-stellar, pre-galactic universe.



*Q band map of the CMB and our galaxy, courtesy of NASA. The grayscale shows ± 0.2 mK*

The CMB is of course of interest to astrophysicists and cosmologists. Mark Whittle of the University of Virginia came to our lab to talk about it and Alex Tarnopolsky, then a postdoc in our lab, converted some of his density files, transposing them up 50 octaves (yes, 50) to put them into the audible range. Mark now uses it in his seminars and calls it the “primal scream of the infant universe”. Mark has a good, popular account of these density variations, including that sound file, on his web page at www.astro.virginia.edu/~dmw8f/. And our FAQ is at www.phys.unsw.edu.au/jw/musFAQ.html

*Joe Wolfe*

*Acoustical Interludes were an innovation of a previous editor, Neville Fletcher. They appeared when the contents of an issue was a little less than 4n pages, where n is a positive integer.*

# AUSTRALIAN ACOUSTICAL SOCIETY
# CODE OF ETHICS

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

## EXPLANATORY NOTES

1. **Responsibility**
   In fulfilment of this requirement members of the Society shall:
   (a) avoid assignments that may create conflict between the interests of their clients, employers, or employees and the public interest.
   (b) conform to acceptable professional standard and procedures, and not act in any manner that may knowingly jeopardise the public welfare, health, or safety.
   (c) endeavour to promote the well-being of the community, and, if over-ruled in their judgement on this, inform their clients or employers of the possible consequences.
   (d) contribute to public discussion on matters within their competence when by so doing the well-being of the community can be advanced.
2. **Advance the Objects of the Society**
   Appropriate objects of the Society as listed in the Memorandum of Association are:
   Object (a)
   To promote and advance acoustics in all its branches and to facilitate the exchange of information and ideas in relation thereto.
   Object (e)
   To encourage the study of acoustics, highlight excellence in acoustics and to improve and elevate the general and technical knowledge in any manner considered appropriate by the Society.
   Object (g)
   To encourage research and the publication of new developments relating to acoustics.
3. **Work within Areas of Competence**
   In all circumstances members shall:
   (a) inform their employers or clients if any assignment requires qualifications and/or experience outside their fields of competence, and where possible make appropriate recommendations in regard to the need for further advice.
   (b) report, make statements, give evidence or advice in an objective and truthful manner and only on the basis of adequate knowledge.
   (c) reveal the existence of any interest, pecuniary or otherwise, that could be taken to affect their judgement in technical matters.
4. **Application of Knowledge**
   Members shall at all times act equitably and fairly in dealing with others. Specifically they shall:
   (a) Strive to avoid all known or potential conflicts of interest, and keep employers or clients fully informed on all matters, financial or technical, that could lead to such conflicts.
   (b) refuse compensation, financial or otherwise, from more than one party for services on the same project, unless the circumstances are fully disclosed and agreed to by all interested parties.
   (c) neither solicit nor accept financial or other valuable considerations from material or equipment suppliers in return for specification or recommendation of their products, or from contractors or other parties dealing with their employer or client.
5. **Reputation**
   No member shall act improperly to gain a benefit and, accordingly, shall not:
   (a) pay nor offer inducements, either directly or indirectly, to secure employment or engagement.
   (b) falsify or misrepresent their qualifications, or experience, or prior responsibilities nor maliciously or carelessly do anything to injure the reputation, prospects, or business of others.
   (c) use the advantages of privileged positions to compete unfairly.
   (d) fail to give proper credit for work of others to whom credit is due nor to acknowledge the contribution of others.
6. **Professional Development**
   Members shall:
   (a) strive to extend their knowledge and skills in order to achieve continuous improvement in the science and practice of acoustics.
   (b) actively assist and encourage those under their direction or with whom they are associated to advance their knowledge and skills.

# 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

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**ACOUSTIC RESEARCH LABORATORIES**
**www.acousticresearch.com.au**

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**www.acran.com.au**

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**www.soundguard.com.au**

**SINCLAIR KNIGHT MERZ**
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**VIPAC ENGINEERS AND SCIENTISTS**
**www.vipac.com.au**

# News

## New Office Bearers for AAS Council

At the time of the 2008 Council meetings, Terry McMinn's two-year term as president came to an end. The excellent work Terry has done for the society during that time was acknowledged at the 2008 conference dinner. Norm Broner is now the president and is supported by Terry McMinn as vice president and registrar and Geoff Barnes as the treasurer. The other councillors are Neil Gross, Stephen Pugh, Colin Speakman, Peter Heinze, Matthew Stead and Alec Duncan.

After 13 years in the position, David Watkins has retired from the role of general secretary and is replaced by Byron Martin. Byron's contact details are:

General Secretary, AAS
PO Box 2183
MAGILL NORTH S.A. 5072
Phone/Fax 08 7225 0112
Email: GeneralSecretary@acoustics.asn.au

## New Look Web Page for AAS

The AAS webpage has been redesigned thanks to the outstanding efforts of webmaster Terry McMinn. The new look page includes many new features and offers the opportunity for much expansion. As well as familiar pages from the old site, there is now much greater scope for inclusion of elements that will allow better communication with and between members. It will also present an improved face for the society to 'site visitors', including a search function, newsflash etc. As with any new site, it may take a little time for all the headings and page layouts to become familiar. So please go to the site, www.acoustics.asn.au/joomla/ and pass any suggestions, comments, corrections, etc onto the webmaster WebMaster@acoustics.asn.au

## AAS 2008 Annual Conference

This was held in Geelong from 24-26 November and was an outstanding success with an attendance around 200. The technical program had two plenary sessions, then two full streams of high quality papers. The technical exhibition was extensive and well frequented. The venue and the catering were excellent and all went together for a most enjoyable and convivial conference. Congratulations to the Conference Organising Committee led by Norm Broner.

The President's Prize for the best paper at the conference was awarded to Dr Carl Howard from University of Adelaide for his paper on 'Transmission loss of a panel with an array of tuned vibration absorbers". An abridged version is published in this edition – see page 98.

We look forward to another high standard conference in Adelaide from 23-25 November 2009. Photos from the 2008 conference can be found from the photo gallery menu item on the AAS site. www.acoustics.asn.au

## Four new AAS Fellows

Four Members of the AAS were elevated to the grade of fellow during the 2008 AAS annual conference dinner. David Watkins has served the AAS for many years. First in the Victorian Division, then for 13 years as the general secretary for the AAS. This has been a time for much change and growth of the Society and David has always more than met the needs. Charles Don has served the Society in council and as president and Vice-President. He has also organised both international and national conferences. For over 30 years he has lectured and carried out research in acoustics firstly at the Chisholm Institute of Technology and then Monash University. Joe Wolfe leads one of the most prominent research groups concerned with musical acoustics and he has done much to promote the discipline, both in Australia and overseas. He contributes to the Society through as an editor of Acoustics Australia. John Davey has contributed to the Society as a committee member and councilllor. He has worked in acoustics for over 30 years both as a researcher at CSIRO and as a lecturer at RMIT. A photo of the new fellows, with the new president, appears on page 85.

## Excellence in Acoustics Award 2008

The AAS CSR Bradford Insulation Excellence in Acoustics Award for 2008 was presented to Matthew Stead and colleagues Simon Moore, Jon Cooper and Andrew Mitchell from Bassett Acoustics for their work on the Monash Centre of Electron Microscopy (MCEM) Noise and Vibration Design. This research facility conducts world-leading research, and provides expertise and training in electron microscopy. The laboratory is purpose built with rooms for nine highly sensitive electron microscopes. The building was commissioned with noise levels lower than those in a concert hall 20 dB(A) and vibration levels approximately 1000 times less than can be felt. There were significant unknowns in the noise and vibration criteria for the electron microscope at the time of the building design. Consequently the design needed to acknowledge these uncertainties and allow for flexibility in the equipment to be installed.

Information about the Excellence in Acoustics Award for 2009 will be posted on the AAS website (www.acoustics.asn.au) early in 2009.

*Ray Thompson from CSR Bradford Insulation presenting the 2008 Excellence in Acoustics Award to Matthew Stead on behalf of the application from Bassett Acoustics*

## AAS Travel Scholarship Announced

At the 2008 Council meeting it was agreed that an AAS travel scholarship of $2500 be made available annually to members of the Society to attend a conference to present a paper. This travel scholarship will not be available to Sustaining and Subscriber members, or members of the conference organising committee. The details on this scholarship will be available from the AAS website (www.acoustics.asn.au) early in 2009.

## Education Grants

The president announced the recipients of the education grants:

- A grant of $3,250 to Renzo Tonin and Dr Kanapathipillai (UNSW) for the project: "Air-conditioner Noise Attenuation Provided by Residential Balconies."
- A grant of $8,440 to S. Chambers, R. James and A. Duncan (UWA) for the project: "Physically Verifying Acoustical and Topographical factors as a plausible role in the cause of Mass Cetacean Stranding".
- A grant of $3,310 to M. Schier (Swinburne Uni.) for the project "Real-time feature extraction method from Auditory Brainstem Response".

## Ron Rumble & Renzo Tonin Merger in Qld

As of 1st September 2008, Renzo Tonin & Associates (Qld) Pty Ltd and Ron Rumble Pty Ltd have expanded their operations in Queensland by means of a successful merger. The merged companies now operate under the name Ron Rumble Renzo Tonin as a division of Renzo Tonin & Associates (Qld) Pty Ltd. The new company operates with the same directors and key personnel, and will continue to operate from the Ron Rumble Pty Ltd premises at 96 Petrie Terrace, Brisbane, with the same contact details. Ron Rumble Pty Ltd is a well-established firm of acoustical engineers with 25 years experience operating in Brisbane. Renzo Tonin & Associates is an consulting firm with over 25 years experience in acoustics, vibration and structural dynamics with offices in Sydney, Melbourne, Brisbane, Gold Coast and Kuwait. The merger of these two firms involves a gathering of strengths, technical capabilities and increased resources in order to provide increased benefits to their existing and new clients.

## Health risks of personal music players

Pam Gunn draws readers attention to a thorough report that has been published by the European Commission Scientific Committee on Emerging and Newly Identified Health Risks.

It can be found at: http://ec.europa.eu/health/opinions/en/hearing-loss-personal-music-player-mp3/about-hearing-loss-personal-music-player-mp3.htm#content

## Getting heard: effective prevention of hazardous occupational noise

A two-year occupational noise research and prevention project is being undertaken by the Standards and Research Branch of the Federal Office of SafeWork Australia (formerly the OASCC). AIOH members Beno Groothoff (Qld) and Joe Crea (SA), along with Pam Gunn (WA) have been appointed to an expert panel that will help guide the project.

Hearing loss associated with occupational exposures is a significant cause of health and economic burden in Australia. In 2004–05 there were more than 4,000 claims for deafness (about 3 % of all claims), with a median direct cost of about $10,000. The major cause of this burden is exposure to excessive noise in the workplace. Excessive occupational noise has also been linked to annoyance, fatigue, accidents and to serious health conditions such as hypertension and cardiovascular disease.

In general, we know about the harmful effects of excessive occupational noise, and that with proper design, equipment and training, hazardous exposure can be controlled. Why, then, should the incidence of deafness compensation claims remain stable over the last five years?

The 'Getting Heard' project (funded by the Australian Government Department of Health and Ageing under the Hearing Loss Prevention Program, 2008–10) aims to determine the key factors (barriers and enablers) in the effective control of hazardous occupational noise. Outcomes from this multi-stage project will provide the Office of Hearing Services and other key occupational health and safety stakeholders with a greater understanding of why occupational noise-induced hearing loss (ONIHL) still occurs among Australian workers. The findings will also assist key stakeholders in the design, implementation and evaluation of strategic initiatives for overcoming barriers and strengthening enablers for better control of hazardous occupational noise.

The project will involve a range of activities, including a review of the evidence for the key barriers and enablers in the control of hazardous occupational noise, collection and analysis of qualitative and quantitative data to demonstrate plausible causal relationships, a cost-benefit analysis of the impact of ONIHL on performance and productivity, and a model of the impact of selected nationally-strategic ONIHL interventions. These activities will be wholly or partly transferable to other preventable occupational health conditions.

During the course of the project, collaborations with key stakeholders will be built, which will ensure that the outcomes of the research continue to be implemented beyond the life of the Hearing Loss Prevention Program in Australia. The project will provide an opportunity for those with an interest in the control of occupational noise to participate in one or more of the research/prevention activities. For further information please contact the project's principal researcher,
Dr Perri Timmins
(Tel: 02 61213437;
Email: perri.timmins@deewr.gov.au).

*Pam Gunn*

## Railcorp seeks acoustics services.

The Environment Division of Rail Corporation NSW is about to issue a general request for information (RFI) for noise & vibration professional services. A register of professional service providers (PSPs) will be then established to allow RailCorp to seek professional acoustic services for future projects.

Interested parties should check eTendering - RailCorp NSW - https://tenders.nsw.gov.au/railcorp/Home over the period of December 2008 to February 2009. The organisation welcomes responses from any firms that can demonstrate expertise and experience in the area of noise & vibration management and investigation.

## Vacancies on SA Committees

New Society representatives are required for EV10 and AV3/3.

Please apply to the General Secretary - GeneralSecretary@acoustics.asn.au.

## Award for research in reducing traffic noise

Society member Stephen Samuels was recently awarded a Doctor of Engineering (DEng) by the University of Newcastle in recognition of his sustained research contributions. They involved some 39 publications describing investigations of the influences of tyres and road pavements on vehicle traffic and road noise.

In addition to being a Visiting Fellow at the University of New South Wales, Stephen is currently a director of TEF Consulting, a Sydney based firm of Traffic, Environmental and Forensic Engineers.

# New Products

## Ngara sound acquisition system

Acoustic Research Laboratories Pty Ltd (ARL) is pleased to announce the release of Ngara, real time sound acquisition system. Ngara offers class 1 specifications allowing the user to post-process statistical noise measurements from 1/10th of a second stored data files. Ngara provides the option to store calibrated (continual or triggered) 48 kHz raw audio data. Measurements and data are stored to a USB storage device (HDD or memory stick). The unit is powered by 12V DC, using an optional external mains power adaptor or sealed lead acid battery. Two weeks of continual 1/10th of a second data can be achieved under certain configurations whilst using battery power. Ngara is housed within a single durable case for trouble free transportation and equipment security.

Information from Ph: 02 9484 0800 or www.acousticresearch.com.au . ARL - Noise and Vibration Monitoring Equipment for Industry and the Environment.

## Sensear Ear Muff

Australian company Sensear used Safe Work Australia Week to launch the newest product in their range of smart hearing devices that suppress dangerous noise whilst simultaneously elevating speech. Sensear devices allow speech to be heard while protecting users from the dangerous background noise found in industrial environments, noisy restaurants, or the pounding vibes of a nightclub.

The new Sensear Ear Muff uses the patent pending revolutionary SENS(R) (Speech Enhancing Noise Suppression) technology, a world first technology that minimises dangerous industrial noise while allowing face to face, mobile phone and two-way radio communication.

An encouraging response is that after the trials most companies are coming back to place bigger orders as users experience the benefit of clear, safe communications in high noise environments. Sensear has won a number of national and international industry awards.

Information from info@sensear.com, http://www.sensear.com

# Divisional news

## NSW Division Students Awards

As part of its support and encouragement for those studying acoustics. the NSW Division awarded five students a travel scholarship of $1,000 each to participate in the AAS Annual Conference in Geelong. The response from the students to their attendance at the Conference was very enthusiastic – one commented that he found this conference far more interesting and valuable than a recent overseas conference he had attended. The five students supported were:

Mauro Caresta from the School of Mechanical and Manufacturing Engineering UNSW. Mauro's PhD research is in the development of analytical and computational models to predict the structural and acoustic responses of a submerged vessel. This project investigates the vibration and structure-borne sound radiation of a submarine. Mauro presented a paper jointly with Nicole Kessissoglou on "Low frequency structural and acoustics responses of a submarine hull under eccentric axial excitation from the propulsion system".

Jer-Ming Chen from the School of Physics UNSW. Jer-Ming's PhD research investigates the role of the vocal tract in saxophone and clarinet playing by measuring the vocal tract's acoustic impedance during performance. He is currently further investigating the involvement of the vocal tract in other advanced musical effects for the saxophone, clarinet, and subsequently other woodwind instruments. He presented a paper jointly with John Smith and Joe Wolfe on "How to play the first bar of Rhapsody in Blue".

Angus Leslie from the School of Aerospace, Mechanical and Mechatronic Engineering, University of Sydney. Angus is examining a noise control technique for a small UAV (Unmanned Aerial Vehicle) propeller for his Master of Engineering (Research). The technique he is researching focuses on reducing the radiated broadband noise from a small size propeller (10 inch diameter) operating with a small chord length (15~30mm) at low Reynolds numbers. He presented a paper jointly with KC Wong and D Auld on "Broadband noise reduction from a mini-UAV propeller through boundary layer tripping".

Sascha Merz from the School of Mechanical and Manufacturing Engineering UNSW. In his PhD project, Sascha investigates the harmonic excitation of a submarine hull in the frequency range up to 100 Hz due to interaction of the propeller with the wake. Numerical methods such as the finite element method (FEM) and the boundary element method (BEM) are used for modelling the propeller-shafting system, submarine hull and surrounding fluid medium. He presented a paper jointly with R Kinns and N Kessissoglou on "Structural and acoustic responses of a submarine due to propeller forces transmitted to the hull via the shaft and fluid".

Sebastian Oberst from the School of Aerospace, Civil and Mechanical Engineering, UNSW at the Australian Defence Force Academy. Sebastian's PhD research is in the thorough analysis of car brake squeal noise. Analytical models and more complex structural finite element (FE) models are developed. Nonlinear analysis techniques are used in order to shed light on unknown mechanism in the time domain and to study the chaotic behaviour of a brake system. Further, Sebastian is making use of the boundary element method (BEM) to investigate the radiation efficiency of unstable vibration modes. He presented a paper jointly with J Lai on "New approaches for understanding the mechanisms of brake squeal".

## QLD Division Awards

The Queensland Division conducts an educational awards program to encourage and to support education and research in acoustics in Queensland institutions of learning. Awards are granted on an annual basis in two divisions, a schools division (Division I) and a tertiary division (Division II).

The Division 1 Bursary is awarded as part of the Queensland Science Contest. The 2008 Bursary of $460 was split between two entries. The 1st prize, of $360, was awarded to Seong Mook Choi, a Year 12 student at Southport School for a study entitled "*Rubens' Tube*". This was an investigation of the standing wave flame tube, including construction of a working device for demonstration purposes. The 2nd prize, of $100, was awarded to Andrew Hastie, a Year 1 student at Albany Creek State School for his project, "*Experimenting with sound*".

Division II comprises category 1 and category 2.

The Category I bursaries are intended to encourage final year undergraduate or first year postgraduate research projects in acoustics or vibration. Two $1500 bursaries are available, the Acoustic Bursary and the RJ Hooker Bursary, with the latter intended to encourage projects conducted in the context of a professional placement. The 2008 Acoustic Bursary was awarded to Sam Hames (University of Queensland, Mechanical Engineering) at the Queensland Division Christmas Party on 10 December 2009 for the project "Imaging Laminar Bond Failures in Aircraft Composite Structures using Ultrasonic Guided Waves". The RJ Hooker Bursary was not awarded in 2008.

The Category II bursaries (of $150) are awarded to the most outstanding student in a four undergraduate acoustics course at a Queensland university. The 2008 winners were Justin Thomas (ME3511 Dynamics and Acoustics at James Cook University), Michael Warren (MECH3250 Engineering Acoustics at University of Queensland) and Michelle Nicolls (AUDL 7800 Acoustics and Psychoacoustics in Audiology at University of Queensland). The Category II bursary for MMB413 Industrial Noise and Vibrations at University of Queensland was not awarded in 2008.

Submissions for the 2009 Division 1 Bursaries close: 30 March 2009 and application setails are on the AAS web page www.acoustics.asn.au

# *Meeting Reports*

## Pub Noise

On Tuesday 19th August at NAL, Ray Tumney and Peter Knowland gave a talk about their views of how to deal with low frequency music noise from pubs and clubs and the current suitability of the LAB criteria.

As most of us know this requires an octave band assessment outside a premises of 5dB above background before midnight and 0dB above background after midnight, with the additional requirement for inaudibility inside residences after midnight.

We are all aware of the difficulties of applying the inaudibility criterion due to the subjective nature of the test and impracticalities of obtaining access at inconvenient times, so the intent of the presentation was to promote debate about this aspect.

Ray had the opportunity to obtain internal background noise measurements in "urban" and "suburban" environments and also the transmission loss of typical facades. A common approach to inaudibility is to assume a 10dB below background as a design intent, however in areas of low background this noise level is found to be less than inaudibility curves presented in ISO documents, hence the approach tendered by the presenters was to consider the higher of the ISO curve of background -10 as the design goal.

My judgement of the audience response was that the current ISO curves may represent the inaudibility of the average respondent, but would not account for the proportion of the population who are more sensitive to noise. In addition there were questions raised about hearing relating to maximum or peak levels and not L10 or Leq even over short time periods.

In principle the dual curve approach seems sensible, however the inaudibility curve needs to be the right curve which, in line with other approaches to noise, protects 90% of the population 90% of the time.

*Neil Gross*

## The acoustics of musical wind instruments - and of musicians

The Queensland Division Christmas Party and Technical Meeting was held at The Wisden Room, Queensland Cricketers Club Woolloongabba on Wednesday 10 December 2008. The venue overlooks the "Gabba" (Brisbane Cricket Ground).

The event was attended by 32 members and guests who were entertained by our guest speaker for the evening, Prof. Joe Wolfe from the School of Physics, The University of New South Wales.

Joe's presentation *"The acoustics of musical wind instruments - and of musicians"* was very well received. Joe enthusiastically presented an interesting and informative technical presentation, interspersed with practical demonstrations. The presentation gave some insight into the influence of the vocal tract in clarinet or saxophone playing and how it could be measured experimentally.

Guests were entertained by the recent winner of the Artemis orchestra competition, Robot Clarinet, a clarinet playing robot built by a team from NICTA (National Information and Communications Technology Australia) and UNSW Music Acoustics Group. A video of the robot playing a duet with eminent clarinet soloist Deborah de Graaff was a highlight of the presentation. The duet is available at www.phys.unsw.edu.au/jw/clarinetrobot.html

Following Joe's presentation, the 2008 Acoustic Bursary was awarded to Sam Hames (University of Queensland, Mechanical Engineering) for the project "Imaging Laminar Bond Failures in Aircraft Composite Structures using Ultrasonic Guided Waves". Michael Warren (MECH3250 Engineering Acoustics), one the recipients of the Category II bursaries for 2008 was also presented with his award.

The event, a great opportunity to socialise and connect with fellow members, was enjoyed by all. *Colin Speakman*

## Directivity of Panels and Openings

The Victoria Division's third technical meeting for 2008 was held on April 22 in the RMIT University City Campus Building # 12 (Physics) with 22 present. After light refreshments, those present were taken on a tour of the acoustical laboratories and the adjacent three reverberation rooms. This was followed by a technical talk by John Davy on the subject of "The Directivity of Panels and Openings", ending with questions and discussion.

Of the three reverberation rooms, the largest (200 m$^3$) is a single room mounted on five neoprene blocks, each providing a deflection of around 75 mm. This room needs several diffusion panels to randomise sound diffusion at frequencies above 630 Hz. Its maximum reverberation time, when empty, is 9 seconds. The other rooms form a pair connected by an opening for placing specimen partitions whose transmission loss is to be determined. The volumes of the transmitting and receiving rooms are, respectively, 115 and 114 m$^3$. Flanking transmission around the test specimen limited the attenuation available to 70 dB until the cork insulation between these rooms was removed.

Following this inspection, John Davy spoke on "The Directivity of Panels and Openings". His research into developing a method for calculating the forced radiation of sound from panels and panel openings (such as occurs from the external wall of a room or at the end of a duct) was prompted by the original question of how to predict the directivity of sound radiated from a large flat factory roof, due to machine noise inside the factory.

The theoretical derivation of the equations for predicting the directivity and levels of the radiated sound, and the comparisons of predicted and measured directivity and levels were described in detail in 32 PowerPoint slides shown at the meeting. They have since been described in papers to the 2008 international acoustics conference, Paris *(The directivity of the forced radiation of sound from panels and openings including the shadow zone)*, and the 2008 AAS national conference, Geelong, Vic *(Comparison of theoretical and experimental results for the directivity of panels and openings).*

The main equations derived in the theoretical approach (described in detail in the two papers cited above) were the total mean square sound pressure,

$$\left|p_{Trms}(\theta)\right|^2 \propto \int_{-\pi/2}^{\pi/2} \frac{w(\phi)}{\left|2\rho c\sigma(\phi)+Z_{wp}(\phi)\right|^2} \left\{ \frac{\sin\left[ka(\sin\theta-\sin\phi)\right]}{ka(\sin\theta-\sin\phi)} \right\}^2 d\phi$$

and the predicted observed relative sound pressure level (in dB),

$$L_O(\theta) = 10\log_{10}\{10^{L(\theta)/10} + 10^{(L_{max} - L_s)/10}\}$$

where

$\phi$ = the angle of the incident sound from the normal to a panel or opening (of specific value for direct incident sound or from $\pi/2$ to $-\pi/2$ for reverberant incident sound),

$\theta$ = the angle of the transmitted sound from the normal, of values from $\pi/2$ to $-\pi/2$,

p = the rms sound pressure,

a = the half length of the panel or opening,

k = the wave number of the sound,

$w(\phi)$ = a weighting function depending on the sound absorption coefficient of the walls of the room containing the sound source,

$\rho$ = the density of the fluid,

c = the speed of sound in the fluid,

$\sigma(\phi)$ = the radiation efficiency into the fluid of one side of the finite panel in an infinite baffle, whose vibration is due to a plane sound wave incident at an angle $\phi$ to the normal of the panel,

$Z_{wp}(\phi)$ = the wave impedance of the finite panel in an infinite baffle to a plane sound wave incident at an angle $\phi$ to the normal of the panel, ignoring fluid loading,

$L_{max}$ is the maximum value of $L(\theta)$(in dB), and

$L_s$ = the level of the scattered sound (in dB), less than $L_{max}$.

When measured directivity and levels of the sound radiated from a panel or opening were compared with corresponding values derived from this theoretical procedure, it was concluded that

a) the directivity of panels and openings excited by sound incident from the other side can be predicted by the theoretical simulation procedure described,

b) this two dimensional theoretical procedure agrees well with experimental measurements with both panels and openings, and

c) the simple diffraction, and angular weighting procedures work well.

At the close of the meeting, Charles Don (acting chairman) thanked John for opening the RMIT acoustics laboratories for this AAS visit, and for his exposition of the complexities of the directivity of the sound radiated from panels and openings, the thanks being carried by applause from all present. *Louis Fouvy*

## Risk of Vibration Damage

AAS members of the NSW Division were treated to a talk by Ray Tumney (Hunter Acoustics) regarding the risk of damage to buildings from vibration levels/strain from construction and blasting activities. The talk was held at NAL and there was good attendance from members, but always plenty of room for more.

The talk presented two case studies (one on a pipe line and the other a building) where vibration levels, strain and temperature were measured by Hunter Acoustics. There were plenty of graphs and photos to talk about. It would be fair to say that the presentation quite convincingly showed that vibration levels significantly higher than stipulated in any of the usual referenced Standards resulted in low levels of strain. Furthermore, the measured strain due to temperature changes were significantly higher than those caused by ground vibration from construction and blasting activities. This translates to negligible risks of building damage from typical construction and blasting activities. Also the measurement of strain is a better indicate of the risk of building damage.

It is important to note that the Standards are extremely conservative. Comments from the floor revealed that some of our members that worked in England recall that the Authorities in England at the time of writing BS7385 asked Consultants "at what measured vibration levels did they witness damage to buildings?". There were no responses, hence the extremely conservative levels.

Finally, congratulations to the caterers - I wonder what will be served next time?

*Sam Demasi*

## Acoustical aspects of current building regulations

The Victoria division's fourth technical meeting for 2008, which 18 attended, was held on Oct-07 in the SKM theatrette, Armadale. The subject for discussion was "Acoustical aspects of current building regulations", led by Michael Madeira, a building surveyor of the GC Performance Based Group Four building consultants. Registered Building surveyors may now be employed by consulting firms as well as by municipalities.

At this meeting the discussions were concerned primarily with the occasions on which building surveyors are required to grant approval for works to proceed, or for occupancy of the finished building. Inspections are required of

1. the soil, as suitable for the building foundations,
2. the base for any *in situ* pouring of concrete,
3. the completed building framework, whether of timber or steel, and
4. the building, upon completion of all works.

Upon completion of the building works a 'Certificate of Final Inspection' is issued, signifying that the building is now 'fit for habitation'. This allows occupancy of the building, and determines liability periods concerning the works. This Certificate is issued after the Building Surveyor is satisfied that

a) all accounts have been paid,

b) the application for occupancy has been completed,

c) the registered builder's statement of completion has been received,

d) the registered plumber has completed the Plumbing Compliance Certificate covering roof, sanitary, and cold and hot water plumbing, the below ground sewer and storm water drainage, gas fitting, mechanical services, and approved solar hot water and rain water tank systems,

e) the House Energy Rating compliance report has been prepared, and

f) the registered electrician has prepared an Electrical Compliance Certificate (including smoke alarms hard wired in accordance with AS3786).

That is, building quality can be policed.

It is at this final inspection that, when noise and vibration issues have been raised (eg, through residential or industrial Noise Regulations), approval of the adequacy of noise and vibration reduction measures may be granted upon production of a certificate stating the expected degree of noise or vibration reduction, or upon evidence that standard reduction procedures have been followed. This points to the need for noise and vibration reduction treatments to be deliberately taken into account at the original design stage, and incorporated in the plans for the new building, not adopted at a later stage when problems are encountered after the building work has been completed and the building occupied. Noise or vibration reduction treatments are invariably more costly if adopted at the 'add-on' or 'retrofit' stage instead of in the original design.

At present, there is in Victoria no organized regulatory acoustical certification process, and no mandatory requirement that acoustical performance of a building be checked. However, compliance checks are possible, and are done, at the architectural stage of a building design. Acoustical problems and questions are normally determined at the 'Permit to build' stage, not later.

The acoustical properties of ceilings, floors and partitions are represented by a corresponding number, which describes the attenuation or absorption of an acoustical treatment. Such treatments are deemed to comply with the Building Code of Australia (BCA) if supported by test results (preferably from a NATA registered laboratory). Expert opinions are not necessarily accepted. That is, treatments are accepted according to their performance. Builders are responsible when they have used a recognised acoustical or anti-vibration treatment.

Several problems were highlighted. Residential apartments near car-parks are a regular source of noise complaint. Buildings in aircraft noise zones cause considerable difficulty. Problems with noisy garage roller doors are alleviated when the door mechanism is isolated from the rest of the building structure. The BCA also contains anomalies. Why, for example, with a car-park directly below a dwelling, need that apartment floor have to comply with an impact code?

Ultimate liability lies with the Building Appeals Board, which is authorised to make determinations in cases of dispute. The Board's current response time is of the order of one month.

At the conclusion of the discussions, the Victoria Division chairman, Norm Broner, moved a vote of thanks to Michael Madeira for sharing his experiences in this field, a vote carried with applause. The Division AGM followed.

*Louis Fouvy*

## New Draft Construction Noise Guidelines

Roger Treagus, Manager of the Noise Strategy Unit of the DECC gave a presentation on the Department of Environment and Climate Change's (DECC) 'Draft Construction Noise Guideline' to the NSW Division at a Technical Meeting on 10th September. The aim of the presentation was to inform acoustic consultants about the guideline and it's applications. Roger went through the two main types of assessment methods – qualitative and quantitative – that would be used and examples of situations where they would be applied. Major changes compared to the existing criteria from Chapter 171 of the old DECC 'Environmental Noise Control Manual' (ENCM) include the change in the noise descriptor used. The criteria from the ENCM referred to the LA10 descriptor, while the new guideline refers to the LAeq descriptor, which is in line with those used internationally and for other assessments such as traffic noise and industrial noise. Another significant change was the assessment of other noise sensitive receivers, instead of just residential type receivers as was the case for the previous assessment method.

One question asked for examples to be included in the guideline illustrating where each assessment method would be applicable.

Overall, I consider the guideline to be a big step in providing a more comprehensive approach to assessing construction noise compared to the ENCM criteria. This is evident in the difference in size of the two documents – Chapter 171 of the ENCM was only one page, while the Draft Construction Noise Guideline is 59 pages.

*Michael Chung*

# Future Meetings

## AAS Annual Conference 2009

The 2009 Annual Conference will be held at the University of Adelaide, which is a central city location, 23-25 November 2009. It will be organised by the SA Division under the Conference Chair Byron Martin. The theme for the conference is "Research to Consulting" and papers on the wide range of topic of acoustics are welcomed and go through a peer review process. Throughout the conference there will be a technical exhibition and also a comprehensive social program. Deadlines are abstract submission 24 April 2009, paper submission 29 May and early bird registration fee closes 23 June. For more information on the conference follow the links from AAS webpage www.acoustics.asn.au.For more information see http://www.aipc2008.com/

## EURONOISE 2009

The international city of Edinburgh in Scotland is the setting, 26-28 October, for the 8th European Conference on Noise Control organised by the UK Institute of Acoustics on behalf of the European Acoustics Association. Edinburgh is an intriguing host city, rich in history and culture. The conference will be held at the Edinburgh International Conference Centre (EICC), which is in the heart of this dynamic city. With world class facilities, this is the perfect environment for a successful event.

The Conference programme will consist of keynote lectures, invited and contributed papers in structured parallel sessions, workshops, and poster presentations. The deadlines are: abstract submissionby 16 February 2009; paper submission by 30 June 2009. Further information on topics and registration from www.euronoise2009.org.uk

## ICSV16

The Sixteenth International Congress on Sound and Vibration (ICSV16), will be held in Krakow, Poland, 5-9 July, 2009, in cooperation with the International Union of Theoretical and Applied Mechanics (IUTAM), the American Society of Mechanical Engineers International (ASME International), and the Institution of Mechanical Engineers (IMechE). The ICSV series of conferences is a major forum for presentation of papers in all branches of acoustics. Abstract submission is available via the ICSV16 website now with the deadline 31 January 2009 and full papers due 31 March 2009 -

There will be seven keynote papers presented:

"Ultrasonic Imaging Using Multitone Nonlinear Coding", Andrzej Nowicki, Janusz Wojcik, Warsaw, Poland

"Transmission and Gearbox Noise and Vibration Prediction and Control", Jiri Tuma, Ostrava, Czech Republic

"State of the Art Beam-forming Software and Hardware for Applications", Samir Gerges, Florianopolis, Brazil, Robert P. Dougherty, Bellevue, USA

"Approaches for Structure-borne Sound Source Characterisation", Bjorn Petersson, Berlin, Germany

"Acoustic and Vibration Exposure and Comfort inside Urban and Extra-urban Transportation Systems", Luigi Maffei, Naples, Italy

"Active Sound Control in Vehicles and in the Inner Ear", Steve Elliott, Southampton, UK

"Machinery Diagnostics and Machinery Health Monitoring", Bob Randall, Sydney, Australia

For more information see www.icsv16.org/

## INTER-NOISE 2009 and ACTIVE 2009

The INTER-NOISE 2009 Congress, sponsored by the International Institute of Noise Control Engineering (I-INCE) and co-organised by the Canadian Acoustical Association (CAA) and the Institute of Noise Control Engineering-USA, will be held in Ottawa Canada, from 23–26 August 2009. The Congress will feature a broad range of high-level research papers from around the world, as well as an extensive exhibition of noise and vibration control and measurement equipment and systems. Distinguished speakers will provide additional stimulation for our technical sessions and discussions with a focus on our theme of "Innovations in Practical Noise Control."

The 2009 International Symposium on Active Control of Sound and Vibration (ACTIVE2009) will be held 20-22 August, immediately before the INTER-NOISE 2009 congress. The ACTIVE symposia gather together international experts in active control of sound and vibration and are held every 2 or 3 years. ACTIVE 2009 will feature five plenary speakers and three parallel technical sessions following the plenaries.

INTER-NOISE 2009, and ACTIVE2009, will be held at the Westin Ottawa Hotel, which is located in the heart of Canada's Nation's capital close to all major attractions, Parliament Buildings, National Gallery, Royal Mint, and more than 12 national museums, etc.

For both Internoise 2009 and Active 2009, abstracts are due 23 January 2009, full papers 22 May 2009 and early bird registration closes 1 June 2009. For information on both conferences see www.internoise2009.com

## WESPAC X

WESPAC X, the 10th Western Pacific Acoustics Conference, will be held in Beijing, China on 23-25 September 2009. The Congress is co-organised by the Acoustical Society of China (ASC), the Institute of Acoustics, Chinese Academy of Sciences (IACAS), and

*This is the eleventh in a series of regular items in the lead up to ICA in Sydney in August 2010.*

The planning for ICA 2010 is progressing well. The committee welcomes Michael Holmes who has taken up the role of web and email publicity. This complements the role of promotion and presentations at conferences and events and will become increasingly important in the coming year to ensure that the information gets the widest distribution. In parallel with the electronic distribution of information, presentations at related events are important. At the recent Internoise in Shanghai the ICA 2010 was given a booth and the scenes of Australian landscapes and animals were a draw as usual. This, coupled with the opportunity to make a short presentation in the closing ceremony, meant that the information about ICA2010 received a good coverage. If anyone knows of an opportunity for promotion of ICA 2010 either using electronic distribution or for posters and flyers etc at a conference or meeting please let me know (m.burgess@adfa,edu.au) and we will follow it up.

While we are concerned about the effect of the international crises will have on travel to conferences in 2010 we are buoyed by the good attendance and the high standard of papers at the 2008 AAS conference. The ICA 2010 will incorporate the AAS 2010 annual conference and provides the opportunity to showcase the work that is being undertaken in Australia on such a wide range of acoustics and vibration topics. We encourage all AAS members to put ICA 2010 in their calendar for 23-27 August as well as recommending attendance to national and international colleagues.

More information on the conference will soon be added to the web page: **www.ica2010sydney.org**

*Marion Burgess, Chair ICA 2010*

# AAS2009

## Australian Acoustics Society National Conference

'Research to Consulting' to be held at The University of Adelaide.

**23 – 25 November 2009**

**Abstracts (approx 150 words) are due by 24 April, 2009; See http://www.Acoustics2009.com**

the National Laboratory of Acoustics Chinese Academy of Sciences.

The Congress will feature a broad range of high-level technical papers from around the world. The distinguished lecturers will present brilliant stimulations for our technical sessions and some discussions with a focus on the Congress theme. Meanwhile, extensive exhibitions of acoustics technology, measurement instrumentation and equipments, various social activities will be provided.

Beijing is a world-renowned cultural city with a long history of over 3000 years as well as China's most important center for international trade and communications. The Congress will give a unique opportunity to visit and appreciate the historical relics and scenic spots within and outside the city.

Information www.wespacx.org

# FASTS

## FASTS AGM and Workshop

On behalf of the AAS, Neville Fletcher attended the FASTS Workshop, AGM and Board Meetings held 24-25 November 2008. and the following is extracted from his report

**Workshop** The Workshop was nominally on the Governance of Science but also included discussions on the future role of FASTS. The workshop was run by a "facilitator" who will now prepare a report on proceedings and conclusions. Matters raised included the increasing demands of bureaucracy on the time of senior researchers and the time wasted on unsuccessful ARC applications. FASTS was seen as having a continuing important role, but it was suggested the it might concentrate a little more on the relation of FASTS to individual scientific societies and to individual researchers. It was also noted with concern that the membership of many Australian scientific societies was declining, and there was discussion on their long-term future.

**Elections** As a result of a series of secret ballots, the following people were elected as FASTS office bearers: president-elect, Cathy Foley (to take over from Ken Baldwin after the 2009 AGM); Secretary, Peter Adams; policy Co-ordinator, Ruth Foxwell; and Early-career scientist representative, Ben McNeil

**FASTS Performance Indicators** The AGM papers contained a summary of the performance of FASTS during the year as measured by "indicators" such as attendance at the Science-Meets-Parliament occasion, media exposure through press releases, submissions to Parliamentary inquiries, and so on. The performance during the year on all these measures was very impressive. The AGM made some small alterations to the wording of the "indicators".

**Science Education** There were two special presentations at the AGM. The first was by the CEO of the NHMRC. This was informative but did not provoke much discussion.

The second presentation was by Prof Denis Goodrum and concerned the just-released *National Science Curriculum: Framing Paper.* This document may be downloaded from the web site www.ncb.org.au/default.asp and contains an Appendix with Feedback Questions. Public consultation is open from now until 28 February 2009. Members at the AGM had many criticisms of the paper, such as the fact that the Board Committee dealing with it contains only one scientist, all other members being "educators". The draft was also criticised as concentrating too much on social issues and failing to include adequate science.

**Board Meeting** The Board meeting was held on Monday afternoon and consisted of Cluster Representatives and Officers of FASTS. Matters raised in the Workshop and at the AGM were considered and certain actions indicated for the Executive. FASTS will negotiate with Societies to include a FASTS Newspage in each issue of the Society's journal, a payment to be made for this.

## Bradley Review of Higher Education

This important review of Higher Education has been released and the Government has indicated that it will respond to the Review and its recommendations in February 2009. The review makes 46 recommendations – some of which will make a real impact on higher education if implemented (and will also require significant injections of new money from the Commonwealth). At its core is an intent to expand the sector significantly. This is driven by the already existing COAG target to halve the proportion of Australians aged 20- to 64-years without a certificate level III and ensure 40 per cent of 25- to 34-year-olds will have attained at least a bachelor-level qualification by 2020. The current attainment is 29 per cent.

The Bradley review argues "Australia faces a critical moment in the history of higher education. There is an international consensus that the reach, quality and performance of a nation's higher education system will be key determinants of its economic and social progress." Yet Australia is falling behind, it argues. For example, Australia is 9th out of 30 OECD nations with the proportion of 25 – 34 year olds with higher education qualifications down from 7th a decade ago. It identifies many problems within the current system ranging from declining participation of equity groups, inefficiencies from micromanagement; problems of cross subsidisation of research from teaching particularly international students, and inadequate student income support.

The key elements of their recommendations are:

- Set targets for attainment of higher education degrees
- Set targets of 20% for low SES participation (it is currently around 15.5% and has been since 1991), with significant funding attached
- Introduction of vouchers to enable an expanded, demand driven sector (funding follows students)
- Institutions to enrol as many students as they wish
- Increase funding for teaching by 10% (and note that the word is explicitly for teaching not a general increase for unis to divert to other functions)
- Better indexation of grants to universities
- Increase funding for regional and rural institutions
- Some funds to unis to be allocated on performance
- Tighten the criteria for title of university and right to offer research degrees
- Increase research funds for research to better reflect costs and thus halt cross subsidies from teaching and learning
- States to hand over authority for regulation to the commonwealth
- Government to establish an independent national tertiary education regulatory body to mediate between Govt and institutions

The report is 300 pages long and there is a lot of detail to assimilate. It can be downloaded from http://www.deewr.gov.au/highereducation/Pages/default.aspx

## Infrastructure Grants

The government has announced 11 Research infrastructure projects totalling $600m over 4 years which will be bought forward (the funding for this coming from the Education Innovation Fund – EIF) and includes an investment of $1.6 billion in University and TAFE infrastructure. Included in the list of 11 projects is the Macquarie Uni hearing hub to be awarded $40m over 3 years.

## Business expenditure on R&D

Business expenditure on R&D increased for the eighth consecutive year in 2006/07, to a total of $12,036 million, according to figures released by the Australian Bureau of Statistics (ABS). R&D expenditure in 2006/07 was up 16% in current prices and 11% in real terms on 2005/6. As a % of GDP, this expenditure on R&D increased to 1.15% - a record high although it remains below the OECD average of 1.56%.

The largest contributors to business R&D by Industry sector were Manufacturing ($3,780 million or 31% of BERD), Mining ($2,541 million or 21%) and Professional, scientific and technical services ($2,012 million or 17%).

Further details from www.abs.gov.au/

# Book Review


## Springer Handbook of Acoustics

**T.D. Rossing, editor**

Springer, 2007, 1182 pp

Includes a CD-ROM

ISBN: 978-0-387-30446-5

eISBN: 0-387-30425

€200 ~ A$380

Acoustics is a broad field: the combined meeting of the American and European acoustical societies this year ran for five days, often with 24 parallel sessions. This handbook is necessarily broad. The editor, Tom Rossing, and many of the authors of its 28 chapters will be known by reputation to many professionals throughout acoustics.

It is well planned and logically organised: the fine introduction is followed by 4 chapters on history, linear acoustics and propagation in air and water. Then follow three chapters on physical and nonlinear acoustics, three on architectural, three on hearing and signal processing, five on music, speech and electroacoustics, three on biological and medical, two on structural and voice and five grouped as engineering acoustics.

The editing has been good: I noticed no inconsistencies in notation (though an index of symbols would have been helpful), the chapter styles and the figures are surprisingly consistent. Overall, the figures are excellent and I congratulate the authors, the editor and those whose job it was to obtain permissions from other authors and publishers.

In the chapters where I claim a familiarity, this book is a good introduction. In the regrettably many areas of acoustics of which I have only very limited knowledge, it also appears to be a good introduction. The word 'introduction' is not to be taken as a criticism: for the subjects of nearly every chapter, one can find several specialist books for the expert. One criticism is that some of the chapters have relatively few references from the last decade. Against this, one could say that acoustics overall is a mature field and that this is an introduction to the entire field, not a specialist guide to each.

I expect that most readers would, like me, find this to be a good reference book. It would make a very comprehensive and approachable text book at undergraduate or postgraduate level, if cost were no problem.

Twelve hundred 240 x 190 mm pages make this a big book, so a prospective buyer might consider its value on a price per word. Further, the price includes a CD-ROM of all chapters, plus some sound files. So, if you already have a laptop in your bag, you can avoid the weight of this volume and gain the advantage of electronic searches. *Joe Wolfe*

*Joe Wolfe is a professor of physics at the University of New South Wales, where his research interests are music acoustics and biophysics. He is one of the editors of Acoustics Australia.*

Acoustics Australia

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# Diary

## 2009

**4 – 6 January, Cairo**
Advanced Materials for Application in Acoustics and Vibration (AMAAV)
www.amaav.org

**5 – 8 April, Oxford**
NOVEM 2009, Noise and Vibration: Emerging Methods
http://www.isvr.soton.ac.uk/novem2009/index.htm.

**18 – 22 May, Portland**
157th Meeting of the Acoustical Society of America
http://asa.aip.org/meetings.html

**24 – 27 May, Zakopane Portland**
MARDiH 2009: 9th International Conference on Active Noise and Vibration Control Methods,
www.vibrationcontrol.pl

**17 – 19 June, Aalborg**
3rd International Conference on Wind Turbine Noise
http://www.windturbinenoise2009.org

**21 – 25 June, St. Petersburg**
13th International Conference "Speech and Computer."
www.specom.nw.ru

**22 – 26 June, Nafplion**
3rd International Conference on Underwater Acoustic Measurements: Technologies and Results
www.uam2009.gr

**5 – 9 July, Krakow**
ICSV16: 16th International Congress on Sound and Vibration.
http://www.icsv16.org

**20 – 22 August, Ottawa**
ACTIVE2009: The 2009 International Symposium on Active Control of Sound and Vibration
http://www.internoise2009.com

**23 – 28 August, Ottawa**
INTER–NOISE 2009
http://www.internoise2009.com

**6 – 10 September, Brighton**
Interspeech 2009
http://www.interspeech2009.org

**23 – 25 September, Beijing**
WESPAC X: 10th Western Pacific Acoustics Conference
www.wespacx.org

**23 – 25 September, Xi'an**
Pacific Rim Underwater Acoustics Conference (PRUAC)
lfh@mail.ioa.ac.cn

**26 – 28 October, Edinburgh**
EURONOISE 2009
"Action on Noise in Europe"
www.euronoise2009.org.uk

**23 – 25 November, Adelaide**
AAS Annual Conference
'Research to Consulting'
www.acoustics.as.au

## 2010

**15 – 19 March, Dallas**
International Conference on Acoustics, Speech, and Signal Processing.
http://icassp2010.org

**27 June – 1 July, Aalborg**
14th Conference on Low Frequency Noise and Vibration.
http://lf2010.org/

**13 – 16 June, Lisbon**
INTER–NOISE 2010
http://www.internoise2010.org

**23 – 27 August, Sydney**
ICA2010
http://www.ica2010sydney.org

**26 – 30 September, Makuhari**
Interspeech 2010 - ICSLP.
http://www.interspeech2010.org

**11 – 14 October, San Diego**
IEEE 2010 Ultrasonics Symposium.
bpotter@vectron.com

## 2011

**27 June – 1 July, Aalborg**
Forum Acusticum 2011
http://www.fa2011.org

Meeting dates can change so please ensure you check the www pages. Meeting Calendars are available on http://www.icacommission.org/calendar.html

# New Members

**Student**

Alireza Moazen Ahmadi (SA)

Angus Leslie (NSW)

**Graduate**

Kult Heaton (QLD)

Craig O'Sullivan (QLD)

**Member**

Benjamin Brooks (QLD)

Charles Conrad-Wilson (VIC)

Sinisa Djordjevic (WA)

Emma Plint (QLD)

**Subscriber**

Simon Law (VIC)

# AUSTRALIAN ACOUSTICAL SOCIETY ENQUIRIES

### NATIONAL MATTERS

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

General Secretary
AAS– Professional Centre of Australia
Private Bag 1, Darlinghurst 2010
Tel/Fax (03) 5470 6381
email: GeneralSecretary@acoustics.asn.au
www.acoustics.asn.au

### SOCIETY SUBSCRIPTION RATES

For 2005/2006 Financial Year:

| | |
|---|---|
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| Graduate, Associate and Subscriber | $85.00 |
| Retired | $35.00 |
| Student | $25.00 |

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Sydney 2052 Australia
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61-2-93856060 (fax)
aaeds@phys.unsw.edu.au

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