New Zealand Acoustics

Volume 24, 2011 / #1

Acoustic Conditions In Sustainable Buildings
"Natural" Noise Mitigation for Surface Transport
Spatial and Temporal Room Impulse Responses

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New Zealand Acoustics

Volume 24, 2011 1st Quarter

Features

Regulars

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Contributions to the Journal are encouraged, and may be sent directly to the Editor either by email, or by post to PO Box 4071, Christchurch.

From the President

I believe I ended my first President's Blurb in the previous Journal for the year by wishing all members a "happy and safe 2011".

Well, it seems wishing has not made it so. Since then, the countries in and around the Pacific have been anything but safe – extreme flooding in south-east Queensland, New South Wales and Victoria in Australia; the second major earthquake (or, rather, series of quakes and aftershocks) in Christchurch; bushfires in Western Australia; cyclone Yasi battering the north eastern coast of Queensland; the devastating earthquake in Japan; the collapse of Japanese nuclear facilities; the subsequent tsunami alerts and fears for dozens of Pacific countries.

The magnitude of damage and loss of property and, unfortunately, life too, beggars belief.

However, it is astonishing to realise that, amongst all the devastation and sorrow, there is something positive.

The corresponding scale of sympathy, empathy, assistance and support is phenomenal. Locally, volunteers in each of the affected areas have come out of the woodwork and communities are banding together to help one another. Nationally, emergency and volunteer services have mobilised with remarkable speed and agility to get to where their presence and efforts will be valuable. Internationally, the pledging and delivering of financial aid and technical expertise to those most stricken has been immediate and widespread.

For me, the most positive element has been the genuine care and concern

that people have displayed for friends, colleagues, neighbours, people in the street, and total strangers that they would otherwise have nothing to do

Publication Dates and Deadlines

New Zealand Acoustics is published quarterly in March, June, September, and December.

The Deadline for material for inclusion in the journal is 1st of each publication month, although long articles should ideally be received at least 2 weeks prior to this.

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Society Membership

Membership in the New Zealand Acoustical Society is open to anybody interested in acoustics. There are no entry requirements. Members receive benefits including;

- Direct notification of upcoming local events
- Regular mailing of Noise News International
- Reduced charges for local and national Society events
- Priority space allocation for trade stands at society events
- Discounted rates on selected acoustic products

To become a member of the society, visit www.acoustics.ac.nz or contact the Secretary.

with. I personally have family in Perth, friends and colleagues in the eastern states of Australia and in Christchurch who were directly affected by the events there.

But in all of those scenarios, the first response from anyone, for myself and for my friends, colleagues and neighbours, was “are you OK?” and “what can I do to help?” and, where nothing could be done, “we are thinking of you”.

I was also in Townsville during Cyclone Yasi – and while it was a terrifying adventure, I suffered no more than the inconvenience of a clean-up and several days without power. In a very short period of time, and for several days afterwards, I had scores of telephone calls from concerned friends, relatives and long-silent acquaintances.

I am proud to say that our Acoustical Society has also been part of the support network in New Zealand. The National Foundation for the Deaf (NFD) approached the Society to join the Earthquake Response Team the NFD had put together. Its primary focus has been to provide support for the Hearing Impaired and Deaf community in Christchurch, in the form of supplying hearing aid batteries, offering repair/replacement of damaged or lost hearing aids, as well as providing general help and support.

The NFD also asked the Society to assist in the preparations for the rebuilding of the city. There will be many buildings refurbishment or replaced, and the NFD asked the Society to assist in stressing the importance of acoustics to the hearing impaired (as well as normally hearing) people - particularly in schools.

To this end, two letters have been prepared, issued via the NFD, to the Ministry of Education and to the Institute of Architects, essentially reminding these entities of the Ministry of Education acoustic guidelines, and underlining the opportunity of new and improved schools in Christchurch.

Our thanks go particularly to James Whitlock for being the spokesperson for the Society, and author of that advice.

So, I say again to all Members – have a safe and happy 2011.

Rachel Foster

(eds. note: the letter to the Institute of Architects is reproduced later in this issue)

NZAS Lunchtime Meetings

The Acoustics Centre at Auckland University has offered to host fortnightly NZAS lunch meetings, to encourage the Auckland NZAS community to get together and discuss interesting topics.

There have been three ad hoc meetings so far in 2011, but any NZAS member is welcome to come along. So far we have been treated to presentations on:-

- Phonak’s new soundfield system-
- Infra-sound and perceived symptoms from wind turbines
- The Holosonic audio spotlight

These meetings are intended to create a framework for the CPD aspect of NZAS Membership (which the council is working on). We encourage other centres around the country to get together in a similar manner also.

As for the Auckland team, there are more exciting talks planned every fortnight so if you’re interested in coming please email: *james.whitlock@marshallday.co.nz* for details.

Editor’s Ramble

I am very pleased present a new issue of the journal for 2011 (and very pleased to have finished typesetting the document; editorship is somewhat less glamorous than I had been led to believe). I would like to express my great appreciation to all those that have helped me in gathering content for the issue, particularly Stuart Camp, Grant Emms, George Dodd, Peter Ibbotson and James Whitlock.

I am also pleased to introduce a new item which I hope will become a ‘Regular’ feature; a cryptic crossword with an acoustic theme!

There is some important information regarding changes to the regulations surrounding membership of the Acoustical Society of NZ on page 10 that I encourage you take a look at.

Wishing you an enjoyable and educational read.

John Cater

Acoustic Conditions In Sustainable Buildings – Results of a Worldwide Survey of Users' Perceptions

George Baird and Clare Dykes

School of Architecture, Victoria University of Wellington, New Zealand

A paper previously presented at ISSA 2010, 29-31 August 2010, Auckland

Abstract

With the trend to sustainability and energy efficiency, buildings are being constructed that are attempting to be as 'green' as possible. One objective in this form of design is to provide a higher level of interior environmental quality than buildings that use conventional practices. Post Occupancy Evaluations have been carried out on 36 sustainable buildings in 11 different countries. This paper describes and analyses the users' overall perceptions of the acoustical conditions and the noise sources (in particular noise from colleagues, from other people, and from both inside and outside sources) in these buildings. The results from these analyses showed that people rate the overall interior environment of these sustainable buildings highly. However, the acoustic aspect tended to score rather less well than some other aspects of the interior environment. A strong correlation was found between the occupants' overall perception of noise and their perception of productivity in the workplace.

Introduction

Over the last decade or so building designers and developers have been producing sustainable buildings for their more environmentally conscious clients. Many of these buildings have been rated highly in terms of relevant Building Sustainability Rating Tools (BSRTs) or have received awards for their low energy design. These ratings and awards are based on the building design and its potential for low energy and sustainable operation, and their focus tends to be on technical aspects of new building designs [1]. Indoor environmental quality is certainly one of these aspects, but the concern is usually with the provision of comfortable temperatures and humidities, adequate air quality, sufficient lighting and appropriate acoustic conditions (all of which are specifiable and measurable).

Our interest has been in how these buildings are performing from the point of view of the building users. While measurements of all the physical factors (inside and outside noise levels, sound transmission and impact characteristics, reverberation times, and so on) would provide insights into the acoustical performance of these buildings, at the end of the day what really matters is whether sustainable buildings are perceived to be acoustically comfortable by their occupants. Buildings that perform poorly from the users' point of view are unlikely to be sustainable in the long term.

It is only very recently that there have been some moves towards developing BSRTs that assess the environmental quality of the building once it is in operation. The groundbreaking Indoor Environmental Quality protocol of the Australian NABERS suite [2] of BSRTs for example, is designed to enable such an assessment. Not only does it specify a range of physical measurements, it also involves conducting a questionnaire survey of the building occupants [3]. Two methods are approved for the survey, one developed by Building Use Studies of York, UK, the other by the Center for the Built Environment, University of California, Berkeley, USA. Our aim here, using the Building Use Studies survey methodology under licence [4], was to determine whether the occupants of a worldwide set of 36 sustainable buildings found them to be acoustically comfortable.

Methodology

For the last five years the performance in practice of a large number of commercial and institutional buildings in 11 countries worldwide has been investigated by Baird [5], to ascertain the users' perception of a range of factors: operational, environmental (including thermal, acoustic and lighting aspects), personal control, and satisfaction.

We are firmly of the belief that people can provide one of the best measures of building performance since "for many aspects of a building the true experts are the people who know most about using it – the users" (refer to Baird et al [6] for more explanation). People know if they are too hot or too cold, have too much or insufficient light, whether it is too noisy, how comfortable they are overall, and in the final analysis, how conditions in the building are affecting their health and productivity.

While many individual quantitative measurements of temperature, lighting, acoustics, etc. are feasible, none of them can readily integrate an individual's sense of comfort overall. In the case of productivity, Leaman and Bordass [7] have noted that

> It is impossible to measure productivity 'objectively' across a building in use; results have to be based on subjective responses of samples of occupants drawn from cross-sections of users. This is not to say that subjectively obtained data are in any way inferior. It just means, as Gary Raw [a lead researcher in the field of Sick Building Syndrome] so aptly said "in buildings, people are the best measuring instruments: they are just harder to calibrate".

Thus the questionnaire simply asks respondents to assess whether they perceive themselves to be more or less comfortable or productive in the building they occupy.

This paper is part of a series [8] [9] [10] describing different aspects of the findings of the authors' research programme. It focuses on the environmental factors relating to the occupants' perception of noise, including that from colleagues and other people, and from sources both inside and outside the building, as appropriate to the building layout and location.

The Buildings

The buildings surveyed were as follows, by country:

- Australia: 40 Albert Street* and 60L*, Melbourne; Red Centre and Institute of Languages*, UNSW, Sydney; Student Centre and General Purposes Building, Newcastle University; Scottsdale Forest Ecocentre, Tasmania.
- Canada: Computer Science and Engineering, York University; Liu Institute, University of British Columbia; Toronto Military Families Resources Centre; National Engineering Yards*, Vancouver.
- Germany: Science Park*, Gelsenkirchen.
- India: Torrent Research Centre, PDEC Buildings and AC Buildings, Ahmedabad.
- Ireland: St Mary's Credit Union*, Navan.
- Japan: Nikken Sekkei HQ*, Tokyo; Tokyo Gas Earthport*, Yokohama.
- Malaysia: MEWC HQ*, Putrajaya.
- New Zealand: AUT Akoranga, Auckland; Landcare Research, Auckland; Erskine Building, University of Canterbury, University of Otago Library*, Dunedin; Nelson Library*; Universal College of Learning*, Palmerston North; Environment House*, Wellington; Conservation House*, Wellington; Paraparaumu Public Library*.
- Singapore: Institute of Technical Education*, Bishan.
- UK: Arup Campus, Solihull; City Hall*, London; Eden Foundation, St Austell; Gifford Studios, Southhampton; Renewable Energy Systems HQ, Kings Langley; ZICER Building, University of East Anglia.
- USA: Natural Resources Defence Council*, California; NRG Systems, Vermont.

These were selected on the basis of their sustainability 'credentials'. Virtually all of them were recipients of national awards for sustainable or low energy design or highly rated in terms of their respective country's building sustainability rating tool (Leed [11], BRAEEM [12], CASBEE [13], Green Star Australia [14] Green Globes [15], etc) or in some way pioneered green architecture. Of course, willingness on the part of the building owner and tenants to be surveyed was also an essential prerequisite, and not all building owners approached felt in a position to accept our invitation.

The 36 buildings were all commercial or institutional in nature. Sixteen of the buildings accommodated office activities predominantly, eleven were tertiary-level academic teaching buildings, four housed laboratories or research organisations, three were libraries, and two contained a combination of light industrial and administrative functions.

2,540 staff responded to the questionnaire, the vast majority scoring every question. Students and library visitors were also surveyed where relevant, using a shorter questionnaire, but these results are not included here as the focus is on the perceptions of the permanent staff. Numbers ranged from a low of 11 responses from the small staff group at the Paraparaumu Public Library to a high of 334 at London City Hall, with a mean of 69 respondents per building. For 97 per cent of the respondents (45.4 per cent female; 54.6 per cent male), the building was their normal place of business – the rest tended to be contractors of one kind or another. They worked 4.74 days per week on average and 7.92 hours per day, of which around 6.34 were spent at their desk or work space and 5.46 at a computer screen. The ratio of under to over 30s was 29.5 to 70.5 per cent and most (75.2 per cent) had worked in the building for more than a year, 61.0 per cent at the same desk or work area. In broad terms, around 30 per cent of respondents either had a single office or shared with more than eight others: while around 13.3 per cent each sharing with either one, two to four, or five to eight colleagues.

Other than those in India, Malaysia and Singapore, all the buildings were in temperate climates of one kind or another (ranging from warm-temperate to cold-temperate). Eighteen (indicated by an asterisk) were located in urban or suburban surroundings, while the remaining eighteen were located in campus settings or in the country. Their systems of ventilation ranged from full air conditioning, through mixed-mode, to natural ventilation.

The Acoustics Questions

The 'Acoustics' questions on the survey form were introduced using the following statement: 'How would you describe noise in your normal work area?'- together with the footnote 'This question refers to conditions all year round'. Respondents were then asked to rate the following five factors on a 7-point scale:

- Noise Overall – is it unsatisfactory or satisfactory?
- Noise from Colleagues – is there too little or too much?
- Noise from Other People – is there too little or too much?
- Other noise from Inside – is there too little or too much?
- Noise from Outside– is there too little or too much?

While a 7-point scale was used throughout, it should be noted that the 'ideal' score differed depending on the question. In the case of Noise Overall the ideal would be '7'; while a '4' would be ideal for all the others.

Results

In this section the results will be presented and analysed, first with an overview of the average scores for each question, followed by a look at the shapes of their distributions over the set of buildings, and then the results of some correlations between Noise Overall and a number of other key performance factors.

The average scores for each of the five questions are presented in Table 1 in terms of their mean and standard deviation (SD) values for the relevant number (N) of buildings. Also listed are the corresponding benchmark (BMK) scores (with the mean and 95% limits based on the average of the previous 50

buildings assessed by this method at the time of each survey).

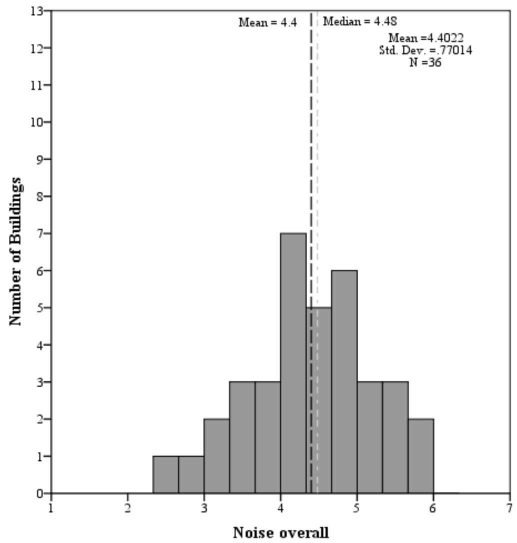
As can be seen, the occupants' perception of Noise Overall has a mean score of 4.40 on a scale where '7' would be the ideal. It is also higher than the benchmark score of 4.17 and greater than the upper limit value of 4.31, indicating a significant difference.

All the other factors (for which a '4' would be the ideal) score very close to their respective benchmarks and are well within the corresponding limits. In the case of noises from *Colleagues*, *Others*, and *Inside*, the mean score is just over 4, indicating a perception of slightly too much noise; while in the case of noise fom *Outside*, the mean is just under 4, indicating slightly too little.

The Standard Deviation (SD) of the scores for each factor is also noted in Table 1 - the distribution of the mean scores over the set of buildings will be examined further in what follows.

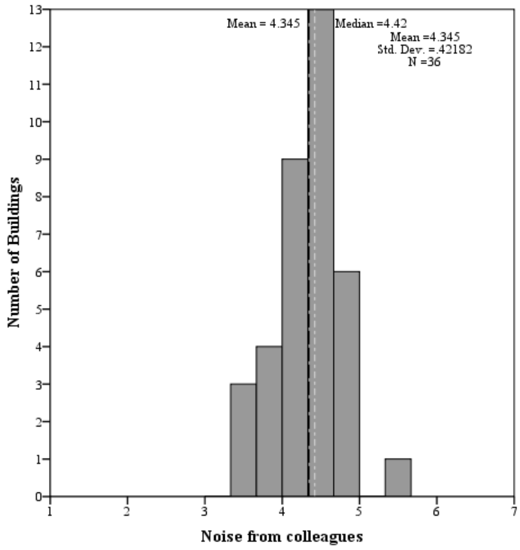
Noise Overall

Figure 1 shows the distribution of the mean *Noise Overall* scores for each of the buildings in the sample. In this context these scores represent the occupants' overall perceptions of the acoustical environmental conditions in the



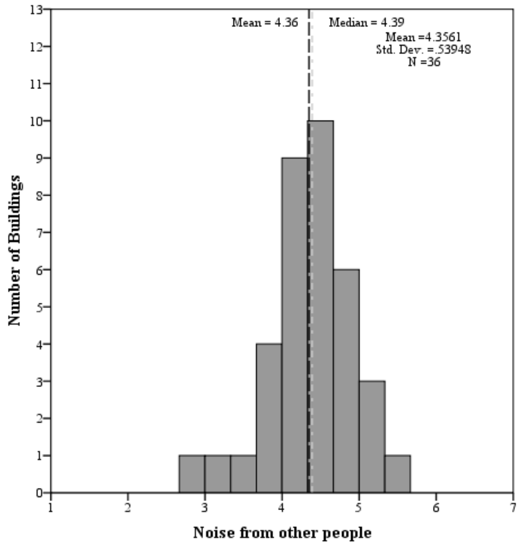
(Satisfactory) (Unsatisfactory)

Figure 1. Distribution of '*Noise Overall*' scores



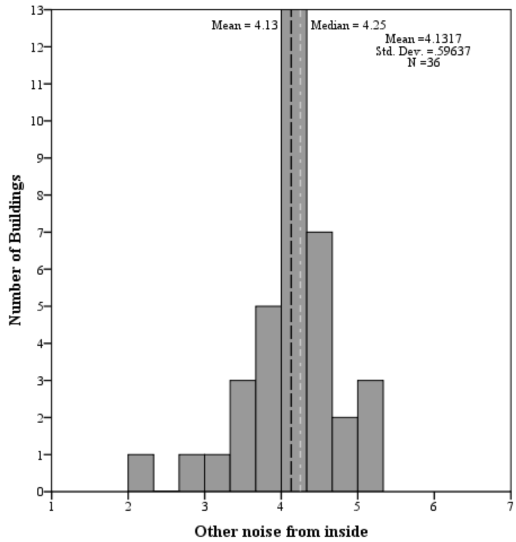
(Too little) (Too much)

Figure 2. Distribution of 'noise from *Colleagues*' scores



(Too little) (Too much)

Figure 3. Distribution of 'noise from *Other People*'



(Too little) (Too much)

Figure 4. Distribution of 'other noise from *Inside*'

building, integrating all relevant factors and based on experience of the building in use over a reasonably long term (over a year in 75 per cent of cases).

The sample mean and median scores (4.40 and 4.48 respectively) are similar and indicated by the vertical dashed lines. With an SD of 0.77 the spread of the scores is relatively wide, with 26 of the 36 buildings (or 72%) scoring above the mid-point of the scale.

Noise from Colleagues

Figure 2 shows the distribution of the mean scores for each of the buildings in the sample, in terms of the users' perceptions about noise from *Colleagues.*

The reference here is to noise emanating from the people in the occupant's work group or team and located in the immediate vicinity of their work area, whether open plan or cellular. While this category of noise can take many forms, occupants are being asked to make a judgement call on a spectrum ranging from too little to too much.

Again, the mean and median (4.35 and 4.42 respectively) for this factor are very similar, but with a smaller SD of 0.42 the mean scores for each building are clustered around the mid-point of the 7-point scale – an encouraging result given a value of '4' is the ideal score in this case. However, most of the buildings (29 out of the 36, or 81%) have mean scores greater than 4 indicating a perception of there being too much noise from Colleagues.

Noise from Other People

Figure 3 shows the distribution of the mean scores for each of the buildings in the sample, in terms of the users' perceptions about noise from *Other People.* Depending on the layout and planning of the building, other people could range from members of nearby work groups (above, below, or in adjacent spaces) to visitors, cleaners and maintenance personnel.

Table 2. Correlation between *Noise Overall* and selected performance factors (R=Pearson Correlation Coefficient)

Strong (R between 0.6 & 0.8) [16]	**R**
Productivity	0.774
Overall Comfort	0.763
Building Design	0.691
Perceived Control over Noise	0.655
Needs	0.625
Moderate (R between 0.4 & 0.6) [16]	
Health	0.573
Space in building	0.568
Facilities	0.556
Image	0.521
Availability of Meeting Rooms	0.497

Once again, the mean and median are similar to each other and to the noise from *Colleagues* scores. While the SD is slightly larger, the same number of buildings (81%) have mean scores greater than 4 indicating a perception of there being *too much* noise from *Others* on average.

Other Noise from Inside

Figure 4 shows the distribution of the mean scores for each of the buildings in the sample, in terms of the users' perceptions of other noise from *Inside*. Examples of this type of noise include that from nearby photocopiers and printers, kitchen areas, footfalls on hard surface walkways, door operation, and the like.

A very similar pattern is evident here too. Interestingly there is one bulding where there it appears the users perceive there to be *too little* other noise from inside. However, in most cases (69% of the buildings have average scores greater than 4) the average perception is that there is *too much*.

Noise from Outside

Figure 5 shows the distribution of the mean scores for each of the buildings in the sample, in terms of the users' perceptions about noise from *Outside.* This category refers to sources of noise external to the building, ranging from nearby traffic and open-air performances, to distant industrial and agricultural operations.

Here too, the mean and median (3.86 and 4.04 respectively) are similar, but in

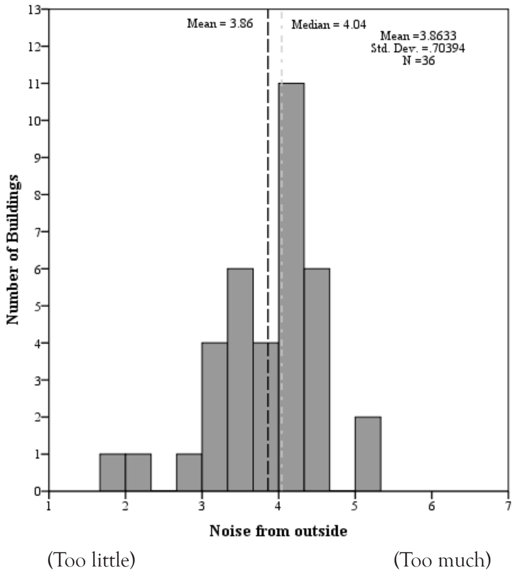


Figure 5. Distribution of 'noise from *Outside*' scores

Table 3. Median scores comparison of Conventional, Green-intent, and Sustainable buildings

Noise Factor	Conventional	Green-intent	Sustainable	Ideal
Overall	4.23	4.22	4.48	7
Colleagues	4.35	4.33	4.42	4
Others	4.35	4.40	4.39	4
Inside	4.10	4.30	4.25	4
Outside	3.75	3.75	4.04	4

Table 4. Mean scores for a range of environmental factors

Environmental Factor	Mean Score
Lighting Overall	5.15
Overall Comfort	4.91
Thermal Conditions in Winter	4.44
Noise Overall	4.40
Thermal Conditions in Summer	4.33

this case the numbers of buildings on each side of the mid-point value of 4 are about the same. While there were a few cases with very low scores, indicating the occupants felt there was too little noise from outside; and a few at the other extreme; most (31 out of 36, or 86%) lay in a central band, between 3 and 5.

Correlation of Noise Overall with other factors

As noted earlier, the survey involved asking respondents to rank their perception of a range of performance factors (some 45 all told) of which the acoustical set comprised the five previously outlined. It was therefore of interest to test for correlations between some of these to gauge the influence of acoustic factors.

Some ten factors were selected for testing against the acoustical factor *Noise Overall*. Of these, five turned out to have strong, and five to have moderate correlations with *Noise Overall* as shown in Table 2.

As can be seen, *Productivity* and *Overall Comfort* had by far the strongest association with *Noise Overall*, with Pearson Correlation Coefficients (R) of 0.774 and 0.763 respectively.

In the case of *Productivity*, the question posed was 'Please estimate how you think your productivity at work is decreased or increased by the environmental conditions in the building?' Occupants indicated their response on a scale ranging from '-40% or less' to '+40% or more' with 10% intervals.

The line of best fit and 95% confidence limits for this relationship are plotted in Figure 7, the R squared linear value of 0.599 (being the square of the correlation coefficient) signifying that it accounts for around 60% of the variance between these two factors.

In the case of *Overall Comfort*, the question posed was 'All things considered, how do you rate the overall comfort of the building environment?' with occupants indicating their responses on a 7-point scale ranging from 'Unsatisfactory' to 'Satisfactory'.

The line of best fit and 95% confidence limits for this relationship are plotted in Figure 8, the R squared linear value of 0.583 (being the square of the correlation coefficient) signifying that it accounts for around 58% of the variance

Continued on page 12

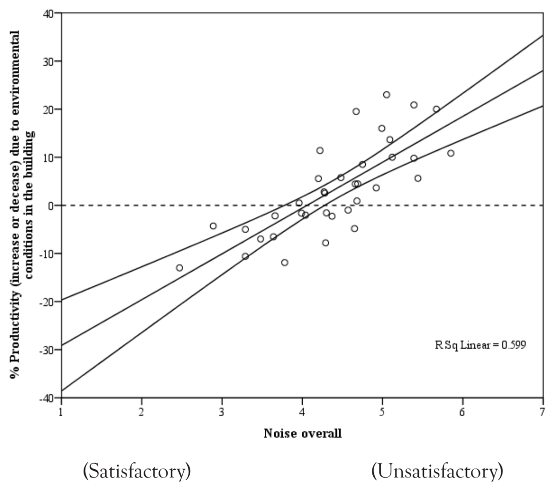


Figure 7. Plot of perceived *Productivity* vs *Noise Overall*

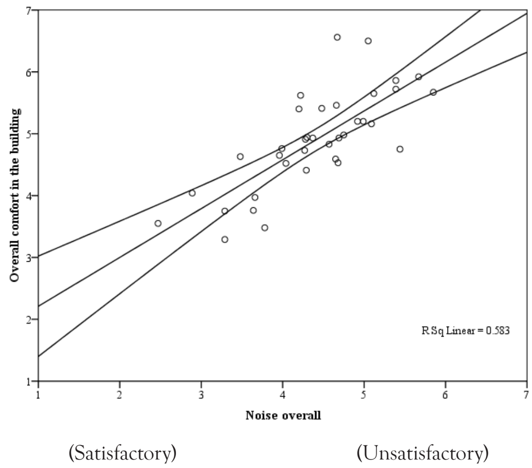


Figure 8. Plot of perceived *Overall Comfort* vs *Noise Overall.*

Membership is GO!

Dear Members,

We are on the verge of entering a new phase in Acoustical Society history. Since Lindsay Hannah and I published our proposal for a new membership regime in the NZAS Journal (Vol 22, #1), we have received and reviewed your comments, held discussion at our 2010 AGM, made changes to our Rules and Rules of Conduct and developed Disciplinary Measures and published them (refer NZAS Journal Vol 23, #3).

In short, the new regime is locked and loaded, and ready to go. The council has agreed on a commencement date of 1 JULY 2011. As of this date, applications for Membership and Affiliation will be accepted.

Application Forms will be available on our website -

www.acoustics.ac.nz/membership

It is also important to note that from this date, we will be the Acoustical Society of New Zealand (ASNZ) (so as to avoid confusion with the NZ Audiological Society).

On behalf of the Council, I warmly encourage you to apply for Membership.

Here is a brief overview of the benefits of joining ASNZ as Member:

- You will be part of the only NZ framework intended to satisfy the common requirement of local authorities for a 'qualified acoustic engineer', or 'suitably qualified person'. The ASNZ will notify relevant authorities of the new membership structure.
- Your qualifications and experience will be registered with the ASNZ
- You will benefit from the proposed Continued Professional Development (CPD) framework being developed by the ASNZ
- You will benefit from peer recognition within NZ and abroad as being a person with sufficient knowledge and experience worthy of achieving the grade of Member. Vocational prospects may also be enhanced for those persons achieving the grade of Member.
- You will be authorised to use the title MASNZ
- You will be eligible for reduced registration fees at ASNZ conferences
- You will receive 4 issues of the acclaimed ASNZ journal per year, free of charge

Note that Affiliates will also receive the last two benefits in this list.

Thank you for your continued help and encouragement in developing this new regime. I look forward a flood of membership applications in July!

James Whitlock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• ACS Linear Look Metal Ceiling Systems
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between these two factors.

Discussion and Conclusions

On the face of it, achieving a mean score of 4.40 for Noise Overall, on a 7-point scale on which a '7' would be the ideal, does not appear to be particularly laudable. Nevertheless, not only is it on the 'better' side of the mid-point of the scale, it is also 'better' than the benchmark score of 4.17 (the average of the previous 50 buildings surveyed). It is also better than the average of a larger set of both conventional and green-intent buildings (see Table 3 later).

As noted on Figure 1, the individual building means cover a wide range of values, but the majority (some 72% of the sample of 36 buildings) score above the mid-point of the range, 18 of them between 4 and 5, and a further 8 between 5 and 6.

A recent analysis by Leaman and Bordass [17] on a larger data set of 165 buildings in the UK, which included both conventional and in their parlance, 'green-intent' buildings reported the median scores for several of these variables. Table 3 compares the median noise scores for these buildings with our set of sustainable buildings.

As can be seen, the 'sustainable' buildings set scores higher than both the 'conventional' and the 'green-intent' buildings for *Noise Overall*, with an average value of 4.48 (cf 4.23 and 4.22). Given this factor is rated on a 7-point scale where a score of 7 would be the ideal, the implication is that the sustainable set is performing better.

In the case of the three factors concerned with internal noise issues, where a score of 4 would be the ideal (ie. noise from *Colleagues, Others*, and *Inside*) the differences are small, though with the suggestion of slightly more noise from colleagues. All of these scores were greater than 4, indicating a perception that on average there is too much noise in these buildings. The average perception score for noise from *Outside* is close to the ideal of 4.

Table 4 ranks the mean scores for a number of 'overall' environmental factors, for all of which a score of '7' would be the ideal, in descending order. As can be seen, by comparison with these other factors, *Noise Overall* lags well behind *Lighting Overall* in the occupants' perceptions but is comparable with thermal conditions in winter and summer. *Overall Comfort* (which can be considered as the integrated perception of all the environmental factors) is towards the higher end of the range with an average score of 4.91. Clearly, some effort will be needed to achieve perception scores for noise that are on a par with those for lighting.

These findings concur with those of Jensen, Arens and Zagreus [18] of the Center for the Built Environment, University of California, Berkeley, who used the alternative approved survey methodology [19] noted in the Introduction. They concluded inter alia, following a survey of 142 buildings, that "Overall, of the nine core satisfaction categories in the IEQ [Indoor Environmental Quality] survey, poor acoustics cause the greatest dissatisfaction".

While the sustainable buildings of the present survey appeared to perform a little better than conventional buildings there is still plenty of room for improvement. Paevere [20] lists several "Opportunities for improving acoustic environment" in a recent review of indoor environmental quality and occupant productivity in office buildings. These should be a high priority for the designers and operators of sustainable buildings. The strong correlations indicated in Figures 7 and 8 indicate that improvements in the users' perceptions of noise could result in significant improvements in overall comfort and productivity.

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Towards "Natural" Noise Mitigation for Surface Transport

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A paper previously presented at ISSA 2010, 29-31 August 2010, Auckland

Abstract

The importance of sustainability in all aspects of procurement is gaining momentum in many countries and recently the EC has awarded a contract (QUIESST) to develop not only improved evaluation techniques for acoustic performance of noise reducing devices but also to examine optimisation and sustainability issues. This paper examines some options for "natural" forms of screening surface transport noise that might on the face of it be considered sustainable but until a number of factors are fully considered it is not clear how they compare with manufactured noise barriers. It also considers the psychological benefits of using natural solutions based on the "tranquillity rating prediction tool" recently developed at the University of Bradford.

Introduction

It is likely that "natural" means of attenuating noise are among the most sustainable options though it is unclear how such options would rank on sustainability criteria. Such criteria will be developed as part of the work recently begun in the WP6 of QUIESST (QUIetening the Environment for a Sustainable Surface Transport - a project co-funded by the European Community's Seventh Framework Programme (FP7/2007-2013) that began on the 1st of November 2009). For example, sustainable design criteria might include not only the carbon footprint of the materials used but a consideration of sustainable design in terms of health and safety issues, effects on biodiversity, severance to communities and habitats but also transport of materials to site, maintenance issues, decommissioning and recyclability. There is a need to develop robust methods and criteria for assessing sustainability in terms of environment, society and economics. It is expected that QUIESST will provide useful practical guidance on assessing overall sustainability.

There is also the question of public acceptability of manufactured products such as noise barriers where anecdotal evidence suggests growing opposition to their use due to a number of factors including ugliness, visual intrusion, personal safety issues and increasingly their use as a "canvas" for graffiti artists. It is important to consider the extent to which more natural options such as belts of trees, earth mounds and "green" barriers are acceptable and this paper provides some insights using research on predicting perceived tranquillity. This paper begins by reviewing and reanalysing the results from some past studies of these natural means of noise control.

Tree Belts

Perhaps the most natural approach is to use belts of trees to screen transportation noise. There has been considerable work on the effects of woodland and forests of various sorts on attenuation of sound [1,2,3,4,5]. However, the most appropriate data for the controlling transport noise are some measurements in belts of English woodland of various types and densities using traffic noise as an effective line source [4]. The attenuation rates were compared with grassland from 5 m to 35 m. At each site the ground was flat and covered by vegetation in full summer foliage that was relatively homogeneous. Grassland was used as a control in order to gauge the benefits of open and dense vegetation. Figure 1 gives the additional attenuation over grassland for 2 different vegetation types i.e. open woodland and

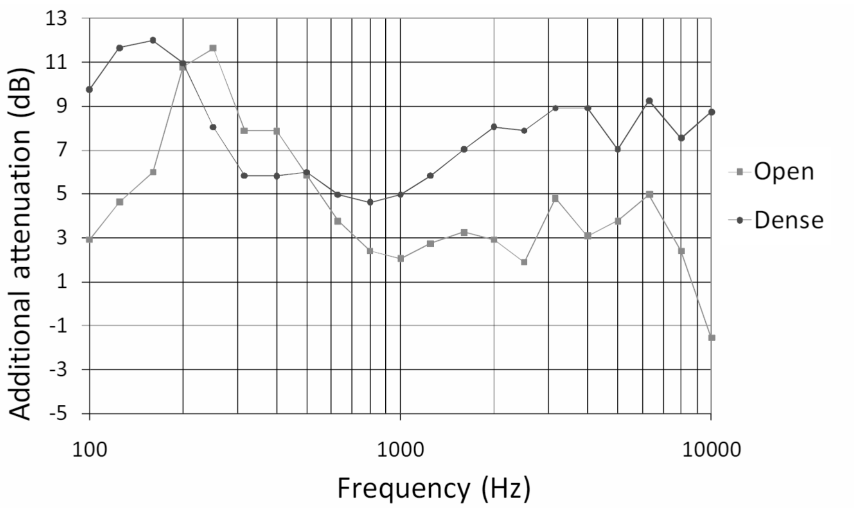

Figure 1: Additional attenuation through 30m belt of woodland compared with grassland.

dense spruce and for a roadside noise barrier. Figure 2 shows views of the two extremes of vegetation.

The efficiency of individual trunks and branches to scatter sound is related to the characteristic diameter of the scatterer. Scattering is significant when the frequency of sound is well above the scattering limit frequency f', given by:

$$f' = \frac{c}{\pi D_{chr}}$$

where D_{chr} is a characteristic cross dimension (in m) of the scattering object [5] and c is the velocity of sound in m/s.

Figure 3 hows the scattering limit frequency as a function of tree trunk/branch diameter. The density of the scattering trunks will be important and clearly the density of small branches is considerably greater than for trunks ensuring significant attenuation at several kHz.

From Figure 1 it is clear that there is a dip in the additional attenuation from approximately 800 Hz to 1.2 kHz where there is a little additional attenuation which perversely corresponds to the A-weighted peak in the traffic and railway noise spectra. To improve attenuation efficiency of vegetation over grassland the focus of attention should therefore be in this band. From Figure 3 a diameter of 0.14 m would equate to a scattering limit frequency of 800 Hz. Therefore introducing a high density of scatterers with a diameter of around 0.14 m should improve attenuation above 800 Hz. An approximation to this situation was found in the spruce forest.

This forest gave the greatest attenuation at mid frequencies and this is because the trunks were approximately 0.12 m diameter (critical scattering frequency 900 Hz) and were thickly planted (just 1 m apart). In addition from Figure 2 it can be seen there was a high density of interlocking branches down to ground level which ensure good high frequency performance as well, although pine needles were largely absent due to the lack of light.

In contrast the deciduous woodland shown in Figure 2 had few branches near ground level and the trunks although thicker (0.2 m) were relatively widely separated (2.5 m) giving poorer overall performance at mid and high frequencies. The attenuation data provided in reference [4] was used to determine the LA10 values expected at a range of distances from 9m from the road edge to over 100m. This was calculated for grassland, open woodland and dense spruce forest.

In addition using CRTN (Calculation of Road Traffic Noise) predicted levels were determine over similar distances with a 3m reflective barrier placed 4m

(a) Open deciduous woodland

(b) Dense spruce forest

Figure 2: Range of vegetation measured.

from the roadside. Figure 4 shows the additional attenuation over grassland for these options.

Close to the barrier it is clear that the barrier provides superior screening but as distance increases the curves converge. At 70m from the source the dense spruce forest is predicted to produce similar screening to the noise barrier while at the largest distance of 110m the open woodland gives similar results to the noise barrier. Clearly where space is available, dense vegetation such as closely planted spruce is a useful alternative to a manufactured noise barrier, especially at the larger distances. However, such a belt does not reach the efficiency of a purpose built noise barrier close to the noise source. Further study is required to optimise the attenuating properties of woodland by careful selection of trees, shrubs and ground cover. Some guidance has been obtained by noting the apparent "pass band" in conventional woodland and forest at around 1 kHz and by a consideration of scattering theory. This would suggest that closely spaced branches and tree trunks of approximately 0.14m should be a guide. Another option is to plant trees in geometric patterns to obtain stop bands at critical frequencies using sonic crystal theory [6]. However, with a distributed broadband noise sources it would be a challenge to obtain meaningful attenuation rates.

Earth Bunds

For the control of highway noise the use of earth bunds, banks or berms have long been used as an attractive option due to their ease of construction where spare soil is available from levelling operations and their natural appearance. In addition they often support a considerable range of flora and fauna.

Developments in more efficient boundary element method (BEM) codes have enabled noise level predictions to be made behind large and complex shaped earth mounds in order to identify acoustically efficient yet practical designs. The effects of detailed modifications to the top surface and slopes of sides can also be examined e.g. the use of multiple edge diffracting edges 0.5m tall placed on the top surface of the bund [7].

It can be seen in Figure 5 that the increasing the side slopes of bunds placed adjacent to the road moves the top diffracting edge closer to the source of noise.

With the standard slope of 20 degree the diffracting edge is 8.2m from the verge edge while for the steep sided bund (80 deg) the diffracting edge is only 0.5m from the verge. This gives additional attenuation compared with the standard bund at 8.2m as can be seen in Figure 6. The greatest gain is for the steep sided bund (80 deg) where insertion loss gain is approximately 3dB(A). A further benefit will be the sound absorptive qualities of the grass covered slopes when compared with standard reflective noise barriers. In addition a much smaller volume of earth is employed in the narrower bund and of course the space required is considerably less. In order to produce such steep-sided bunds some interventions are necessary for soil stability. Various methods can be used, for example the use of woven willow baskets to retain the soil with evergreen creepers growing over the barrier. Once the creepers have been established there should be no requirements to irrigate.

A further method is to use gabions (wire mesh boxes to retain soil and stones).

These can be shaped in various ways or rectangular boxes can be stepped. Figure 7 shows a possible structure for free standing trapezoidal shaped gabions filled with irregular shaped rocks. Such a fill will have the effect of scattering and absorbing sound. However attention has to be given to sound transmission and it may be necessary to carefully grade the stone fill to achieve a satisfactory balance between sound absorption and sound transmission. The challenge for this design is to achieve an acceptable surface finish. The use of evergreen ivy may be an option as a cover or a stepped design may encourage the establishment of grasses and creepers.

A further design which takes even less space is a woven willow fence with ivy growing on the outside (Figure 8). Fibrous sound absorbing panels are incorporated into the panels. The willow is dried so no irrigation is required.

A living willow barrier is shown in Figure 9. This design requires irrigation and is likely to be less robust than the ivy equivalent. Because these barriers are made of natural materials withgrowing creepers or willow the barrier has the potential to enhance the urban environment by providing an attractive

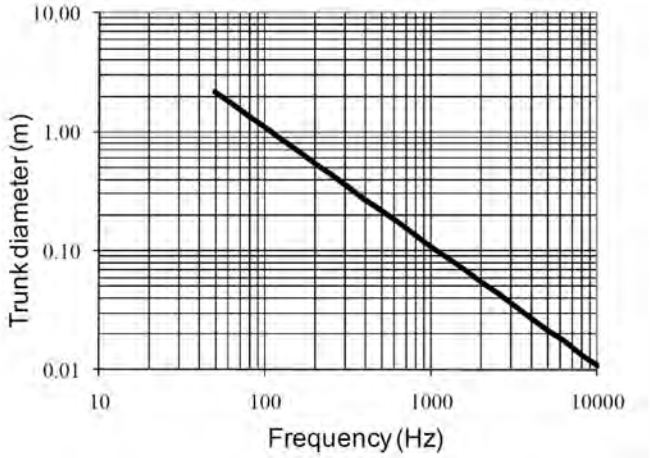

Figure 3: Scattering limit frequency by trunk diameter.

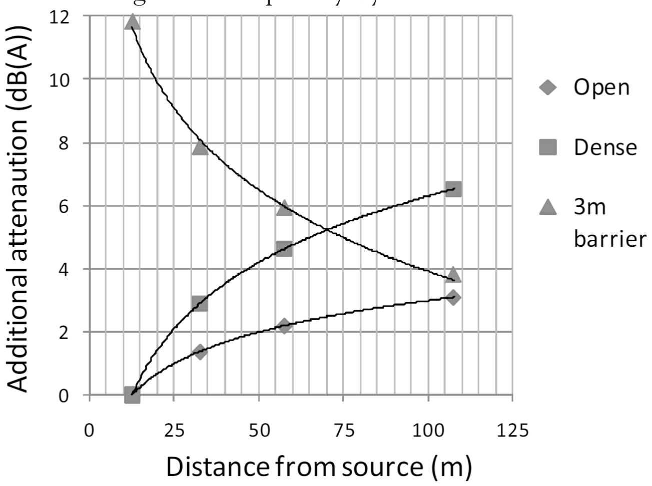

Figure 4: Additional attenuation compared with grassland.

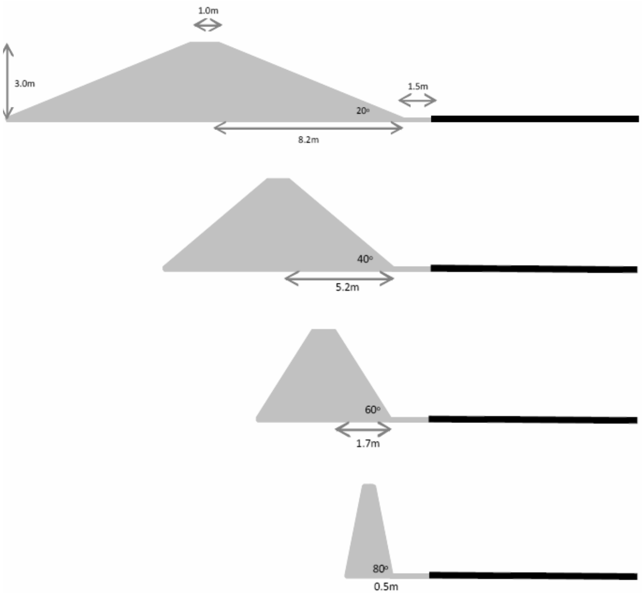

Figure 5: Earth bunds with different side slopes

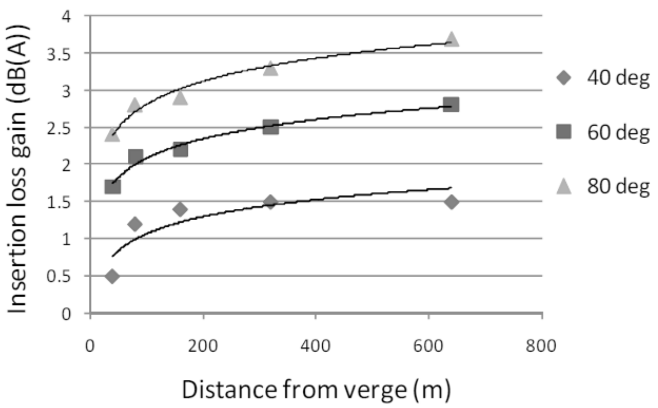

Figure 6(a): Insertion loss gain compared to standard bund with 20 degree slopes.

contrast with hard man-made surfaces such as brick, concrete, glass and steel. They will also be less attractive to graffiti artists. For the barriers using growing willow it will be necessay to irrigate and regular pruning will be essential to maintain a tidy appearance and prevent excessive windloading.

Effects On Human Perception

The human perception system is multisensory and so that auditory perception is influenced by what is seen. Some recent research using functional magnetic resonance imaging (fMRI) has demonstrated that connections in the brain are strengthened when the scene is considered tranquil rather than non-tranquil [8]. In fact this study showed a greater connection between the auditory cortex and medial prefrontal cortex indicating a greater engagement with the tranquil scenes and an apparent rejection of non-tranquil scenes. This was despite the fact that the same audio input (a constant "roar") was replayed at the same level under both conditions. Quiet and natural environments are key feature of such tranquil environments and it is quite likely that for a noise screen to be fully acceptable to residents, both auditory and visual factors should be considered of similar importance to gauge overall perception.

Figure 6(b): Retained soil bank with well established evergreen creeper (Weavewall Ltd).

At the University of Bradford research has been carried out in the laboratory using the playback of video cuts that contained binaural recordings taken with an artificial head in a variety of landscapes from open moors through beach scenes and residential areas to city centres. The background to this research [9] and the final form of the formula relating auditory and visual factors has

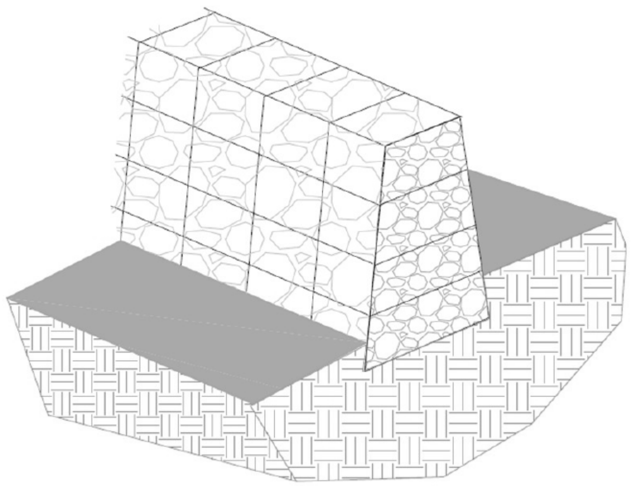

Figure 7: Gabion system for noise control (Enviromesh Ltd).

recently been reported [10].

$$TR = 9.68 + 0.041\ CF - 0.146\ L_{Aeq} + MF$$

Where TR is the tranquillity rating on a 0 to 10 rating scales. CF is the percentage of natural and contextual features in the landscape (average over 360 degrees). Contextual features include listed buildings, religious and historic buildings, landmarks, monuments and elements of the landscape, such as traditional farm buildings, that directly contribute to the visual context of the natural environment. L_{Aeq} is the equivalent constant A-weighted sound pressure level, which for practical application should be the level of man-made noise over the day time period. MF is an adjustment due to moderating factors which are not expected to be large and include the presence of water and associated sounds and litter and graffiti. The following classification of the tranquillity rating is suggested to guide assessments for planning purposes [10]:

<5	unacceptable
5.0 – 5.9	just acceptable
6.0 – 6.9	fairly good
7.0 – 7.9	good
≥ 8.0	excellent

With a constant noise level, increasing CF will improve the rated tranquillity. If this can be applied to noise barriers it will be seen that this may have a relatively large effect. To model the effects it is assumed that a busy road (1300 vehicles/hr with 10% heavy vehicles) is subject to a 50km/hr speed limit and is screened by a 3m high barrier 4m from the kerb. It is also assumed that the barrier subtends essentially 180 degrees in the horizontal plane and that the receiver is surrounded by grassland with uninterrupted views of the barrier.The angle of view at the receiver position in the vertical plane is ±20.4 deg and the area of sky above the barrier is not used in the calculation of CF. Hence the view of the barrier will critically influence the perceived tranquillity at close distances. Further away the barrier subtends a smaller angle and its visual influence will consequently diminish.Noise levels will also reduce with distance due to geometric spreading. If the barrier is perceived as a natural feature then CF=100%. However, if the barrier is not perceived as natural or contextual e.g. an obviously manufactured product such as a concrete or metal barrier, then CF will be lowered depending on the area the barrier subtends when compared with the rest of the scene (which is assumed will be natural grassland).

Figure 10 shows that at 5m distance behind the natural barrier the perceived tranquillity is expected to be 5.0 which is "just acceptable" on the above scale. However for the manufactured barrier the expected rating would reduce to 3.2 which on the scale is clearly unacceptable. The difference is a result of the visual aspect alone as noise levels are identical in these two cases. At greater distances the predicted tranquillity for the two barrier types converge as can be seen in Figure 10. For taller barriers differences will be greater and the convergence will be less rapid due to the larger angles subtended by the screen at the receiver. Further research is required to confirm these predictions but the implications, if correct, are potentially very important for predicting residents' reactions. Note that it should be possible to further refine predictions by a consideration of the moderating factors (MF). For example it has been shown that the presence of litter causes a reduction of one scale point [11] so it is likely that the presence of graffiti on the barrier surface

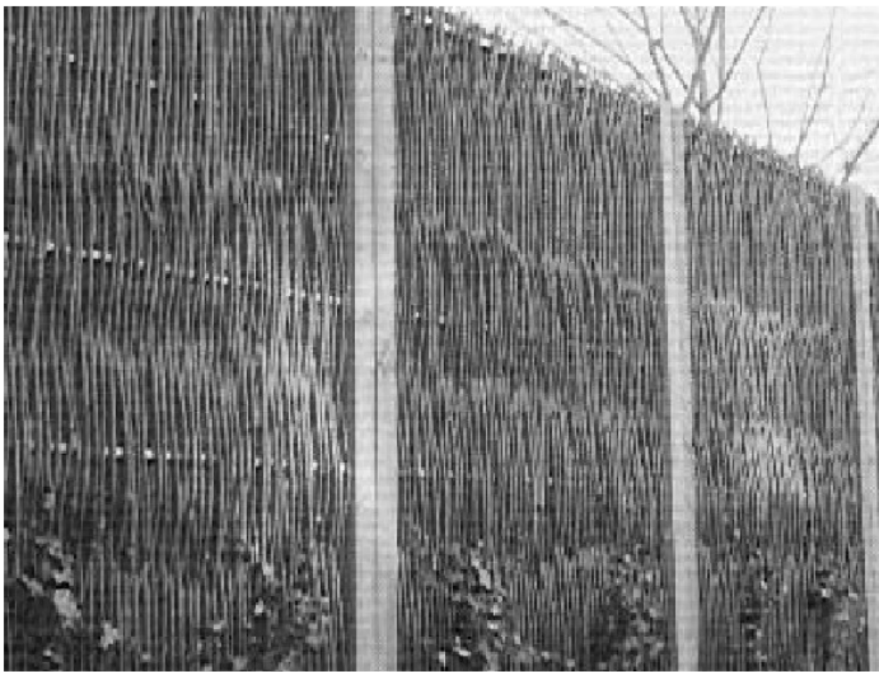

Figure 8: Woven willow panels with recent ivy plantings (ETS Ltd).

would have an even greater deleterious effect due to the fact it will tend to be more obvious and is more permanent. This should be considered a possibility especially for manufactured products that present a suitable surface for spray paints.

Conclusions

The following conclusions can be drawn from this analysis of "natural" means of controlling surface transport noise.

- Both woodland and planted forests produce significantly greater attenuation than grassland. The greatest effect was produced by dense spruce forest. With such a dense forest extending from close to the roadside it was predited that at approximately 70m from the source the attenuating effect on a traffic noise would be similar to that of a 3m high barrier placed near the roadside.
- Earth bunds can achieve significant screening though it has been shown that for the greatest benefit the bund should be placed close to the noise source. This implies a requirement for steep sided bunds and various solutions are described.
- The perceived benefit of noise screening has been examined using a novel tranquillity prediction tool. This indicates that natural barriers have advantages over barriers made from man-made materials if they are perceived as natural features in the landscape.

Figure 9: Growing woven willow fence with absorptive panel cores (ETS Ltd).

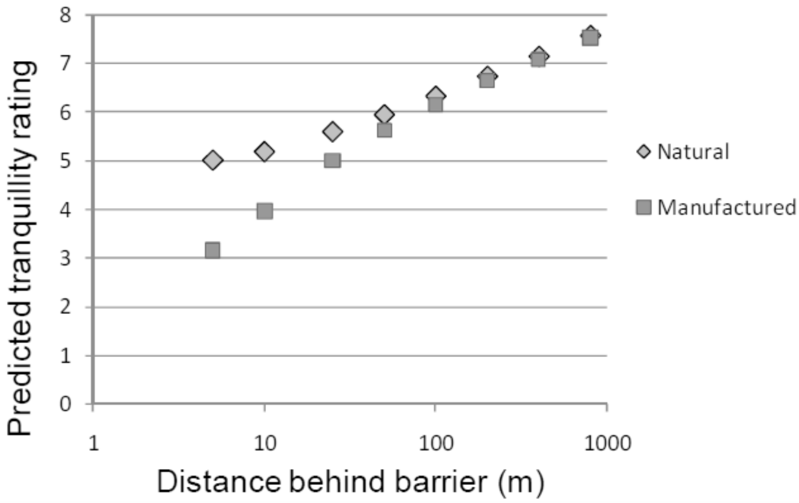

Figure 10: Predicted effects of barrier type on perceived tranquillity.

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New Products (Advertising Feature): Casella Sound Level Meters, DUO Smart Monitors

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Models are available for both environmental and/or occupational noise with the availability of frequency analysis and advance functions such as data markers, timers and logging of time history data. Even with such advanced functionality, the CEL-630 Series remains very simple to use.

The chart opposite shows the range of models available.

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DUO is devoted to classic hand-held sound level meter measurements, either using the built-in keyboard and screen or dBDUO web interface on a wireless commercial remote control, fixed or not to the body of the instrument with the integrated magnet. Short, medium or long-term noise monitoring avoiding presence of the operator in the field

Based on its all-weather design, DUO is devoted to indoor and outdoor noise monitoring. Its operating battery lifetime allows for more than 3 days of measurements without external power supply.

Wireless connections (Wi-Fi and 3G) to DUO allow for remote access to the measurements in progress and selective retrieval of stored data avoiding physical presence of the operator in the field.

DUO's "all in one" unique design allows for extremely easy and fast transport and installation. DUO's on-board periodical self-check of the entire measurement chain guarantees the reliability of the measurement results.

The metrological design of DUO allows for measurement at reference directions of 0°, as well as at 90° , of the source by internal setup.

DUO allows noise measurements for different types of environmental noise: ground transportation, aircrafts, sports and leisure activities, construction sites, quiet areas.

DUO allows for optimised analysis of emergence by simultaneous use of

one DUO as a measurement point and one or several DUO as trigger (coding) points based on perfect GPS time synchronisation. The noise levels difference is applicable with no possible error.

DUO is equipped with an extractible high-capacity SD card allowing for simultaneous storage of time histories (global and spectral data) and audio signals recorded upon trigger on threshold or relying on programmable timer.

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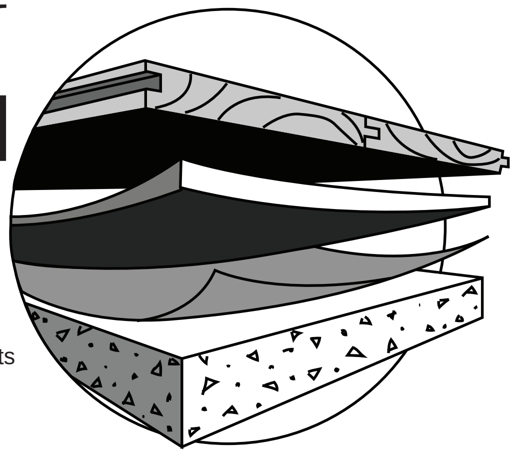
for more information.

Application	Model Number	Storage of Cumulative Data	Data Markers	Run Duration Timers	Automatic On/Off Timers	Logging of Time History	Statistical Parameters (Ln%)
Occupational	CEL-630	✓	✓	✓			
Environmental	CEL-631	✓	✓	✓			✓
Occupational (with logging)	CEL-632	✓	✓	✓	✓	✓	
Environmental (with logging)	CEL-633	✓	✓	✓	✓	✓	✓

EMBELTON
IMPACTAMAT

FLOOR ISOLATION



TYPICAL PERFORMANCE CHARACTERISTICS

The table below gives IIC ratings based on tests of various surface treatments Ref. ASTM E989 using an Impactamat resilient interface on a 100mm thick concrete structural floor.

FLOOR SURFACE TREATMENT (Floating Floor Construction)	Impactamat			Overall IIC Rating	IIC Improvement over bare slab	Ref.fig.
	Construction	Type	Thickness			
Loose lay timber veneer flooring with thin foam bedding layer	full cover	750	5mm	47-50	18-20	1
Direct bond 19mm block parquetry	full cover	900	5mm	45-49	18-20	2
Direct bond 10mm ceramic tiles	full cover	750	5mm	44-46	13-15	2
Particle board or strip timber battens supported at nom. 450 x 450 centres with acoustic absorption	pads 75 x 50mm	750	10mm	52-60	21-30	3
Double layer bonded 12mm ply with bonded parquetry, supported at nom. 300 x 300 centres (sports floor)	pads 75 x 50mm	750	10mm	52-57	21-27	4
50mm reinforced concrete slab or 25 mm slab with 20mm bonded marble/slate/ceramic tile	full cover	750	10mm	58-63	27-32	6
50mm reinforced concrete slab	full cover	750	15mm	59-64	28-33	5
100mm reinforced concrete slab	full cover	750	15mm	60-65	29-34	5

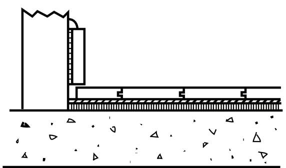


Fig. 1 Timber loose lay floating floor

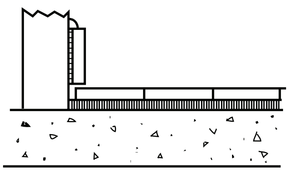


Fig. 2 Direct bond parquetry or ceramic tiles

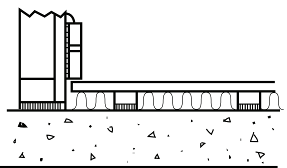


Fig. 3 Timber strip floor on battens with isolated frame wall

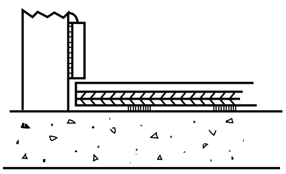


Fig. 4 Sports floor

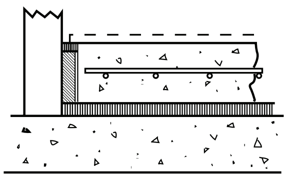


Fig. 5 Concrete slab

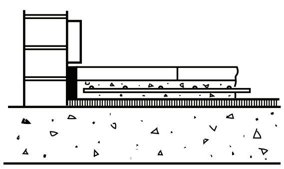


Fig. 6 Marble/slate ceramic tiles with thin reinforced slab

IMPACTAMAT by EMBELTON features two main environmental properties: it is recycled and it reduces noise pollution.
Indeed, it is made from 100% recycled natural rubber recovered from tyres, granulated and reconstituted as a solid mat (various sizes are available upon request).

IMPACTAMAT is a flexible material manufactured as a preformed sheet bound together with a flexible binder.
It is a low cost impact absorbing layer for covering hard earth or concrete in outdoor applications or as an underlay for in-situ cast or pre-cast concrete floors where noise isolation is required (rubber underlay, acoustic insulation, door mats, playground and sports surfaces, industrial floor tiles etc.).

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NFD Letter for Christchurch

The National Foundation for the Deaf (NFD) has been co-ordinating a sector wide response in support of people who are deaf and hearing impaired living the earthquake affected part of Christchurch.

They have asked the NZAS (as a member organisation) to prepare letters to the Institute of Architects, and Ministry of Education, outlining the unique opportunity to consider acoustics when rebuilding Christchurch. The letter below is written to the NZ Institute of Architects.

Acoustic Considerations in Rebuilding Christchurch

I am writing on behalf of the New Zealand Acoustical Society (NZAS). Our organisation represents professionals and non-professionals in the field of acoustics including consultants, researchers, manufacturers and distributors of acoustic products, and environmental health officers.As a group we were, along with all New Zealanders, greatly affected by the earthquake in Canterbury. We have been backing the initiatives of the National Foundation for the Deaf (NFD) in improving the support and resources for hearing impaired residents in Christchurch, and numerous companies whose members are in the NZAS have been strong in their fundraising initiatives.

Our thoughts turn now to rebuilding Christchurch, and in particular the rebuilding of schools, hospitals and other public buildings. New Zealand architects will be playing a keystone role in this process, and I would like to take this opportunity to offer a reminder about acoustics. The field of acoustics is relatively young in New Zealand and historically, the importance of acoustic design in public buildings has not been fully realised until well after their completion.

In Christchurch, because of the widespread damage, we are presented with a unique opportunity to rebuild many important buildings... and this time, we can consider their acoustics from the outset. This is particularly relevant in schools, where good acoustics supports learning – or, more crucially, poor acoustics can destroy the learning environment. We strongly urge, therefore, that all school buildings are rebuilt according to the acoustic guidelines contained in the Ministry of Education/BRANZ "Designing Quality Learning Spaces: Acoustics" document, which can be found online at: http://www.minedu.govt.nz/~/media/MinEdu/Files/EducationSectors/PrimarySecondary/PropertyToolbox/ModernLearning/AcousticsGuide.pdf.

We would also encourage that specialist acoustic advice is sought when designing new halls, performing arts centres, gymnasia, theatres, community centres, town halls etc. to ensure the acoustic design supports their intended use.

Good acoustic design enhances the potential of all public spaces, for both normally hearing people and the hearing impaired. Let's make sure that Christchurch is rebuilt with the acoustic needs of its people in mind.

Please feel free to contact our organisation at info@acoustics.ac.nz if you have any comments, queries or questions.

Yours sincerely,

James Whitlock (NZ Acoustical Society – Council Member)

Acoustics Standards Advisory Group: Request for Input

From around 1997 to 2000 Standards New Zealand (SNZ) had an Acoustics Standards Coordination Group. The role of this committee was to have overall responsibility for the development of all New Zealand national acoustics standards and to:

- Assist working groups in determination of national priorities and setting of target dates,
- Provide co-ordination between technical inputs to international acoustics standards work, and
- Assist in obtaining sufficient funding to meet a desired work programme.

The committee was funded by the Ministry of Health for two years, but after that period the committee ceased. Since that time some of the functions of the committee have been continued by various individuals, but there has been a lack of strategic direction for acoustics standards development and adoption of international standards. For example, we could benefit from standardisation of many aspects of vibration and building acoustics assessments, which could probably largely occur through adoption of existing international Standards. Also, New Zealand Standards require funding but SNZ doesn't necessarily know what the potential standards needed are and who the potential funders might be. A coordination group could provide direction.

I consider that reconstituting a formal committee would be of benefit to acousticians and acoustics in New Zealand. Informal consultation suggests that such a group would be widely supported. SNZ has suggested two possible models for a reformed group:

Option 1

- The NZAS forms its own technical group to monitor and review current NZS and other standards used in New Zealand. The aim would be to assess whether current standards remain fit-for-purpose (e.g. relevant, effective, robust, accepted best practice, etc), what additional areas require standardisation, and what other international standards would be appropriate to adopt or adapt for New Zealand.
- The NZAS group decides how often it should meet, consults with its membership, and prepares recommendations on any technical or other improvements to acoustics standards. This may include recommendations to amend or revise existing standards, develop new, or adopt other national or international standards.
- Where the NZAS standards group considers it appropriate, the group submits recommendations on any changes or developments to SNZ, indicating areas of priority and possible sponsors. Using this advice, SNZ would follow up appropriate steps with potential sponsoring organisations.

Option 2

- Subject to the availability of funding, SNZ initiates and formally constitutes the establishment of an Acoustics Standards Advisory Group (ASAG).
- The ASAG's key role is to provide a strategic overview of acoustics standards, and make recommendations to SNZ on areas of priority for acoustical standardisation.
- SNZ invites national organisations to nominate people on to the ASAG. SNZ will ensure that the ASAG has balanced representation from key stakeholder groups, and the necessary technical expertise.
- Organisations represented on the ASAG provide the necessary support for their nominees to attend and participate in the ASAG.
- Members of the ASAG attend and contribute to the meetings of the ASAG (at least one meeting per year).
- SNZ prepares and consults with the ASAG on its terms of reference.
- SNZ coordinates, facilitates, and records the proceedings of at least one meeting per year of the ASAG.
- ASAG's oversight would include NZS, joint AS/NZS, ISO and IEC acoustics standards, and SNZ would keep the ASAG informed of proposals and developments of such standards.
- Likely cost for SNZ to organise and facilitate the ASAG including one meeting a year would be in the order of $3,000 a year. SNZ would require funding for this cost.

My preference would be for the group to be organised by SNZ (option 2), as I believe it would be more effective being within SNZ and would be professionally organised. Those volunteers who have been involved running conferences or other activities for the NZAS will be aware that it can be a heavy load, which is often hard to juggle in between a paying day job. In many instances the NZAS activities end up slipping as a result. Therefore, in the same way that we used professional conference organisers for recent NZAS conferences, I favour a professional organiser for an ASAG.

I am now seeking views from the NZAS membership on the following points:

- Should there be an Acoustics Standards Advisory Group?
- Should it be an informal group within the NZAS or a formal group in SNZ, or something else?
- If part of SNZ, should the NZAS partly or fully fund SNZ's costs?
- Who else might provide funding?

I would welcome responses to these questions and any other comments on this matter, by email in the next four weeks.

Stephen Chiles

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Determination and Display of Spatial and Temporal Room Impulse Responses

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Department of Electrical and Computer Engineering, The University of Auckland, Auckland, New Zealand

A paper previously presented at ISSA 2010, 29-31 August 2010, Auckland

Abstract

The acoustical characteristics of a room are traditionally determined using directionless impulse response measurements, the directionless nature of which imposes significant limitations on the kinds of information that can be extracted. Obtaining such information in 3D would permit, for instance, a more detailed analysis of sound reflections to be undertaken. This paper overviews a technique for capturing a room's impulse response in 3D using a practical mi-crophone array (A-format) and then transforming this data into a Cartesian coordinate system (B-format) so that it can be visualised as an image or video. This 3D impulse response visualisation carries information about sound reflections in terms of sound intensity, spatial orientation and time. A software package has been developed in MATLAB to implement this technique, preliminary results from which will be presented. Enhancements of this 3D visualisation, together with a thorough understanding of the accuracy and robustness of the technique, are the focus of a current study and will be briefly discussed.

Introduction

The acoustical characteristics of a room are typically measured by recording the room's impulse response at a number of locations. An excitation signal that represents an impulse function, often in the form of a swept sinusoid, is generated at some specified location in a room (e.g., the stage in a concert hall). This signal is then recorded at one of a set of repre-sentative listening positions, and mathematically converted into a set of impulse responses. The impulse response at a specific location describes how the room reflects and absorbs sound waves as observed at that location. It is traditionally recorded using an omnidirectional pressure microphone, with the result that all spatial information is combined into a single audio signal and a directional analysis of the room reflections observed at that location is not possible. Obtaining the impulse response in 3D would permit an acoustician to identify the direction of specific reflections, and relate this information to the physical features of the room under study.

In this current work, a special microphone array is used to record a set of impulse responses. A software application is then used to extract information from these recordings and display it as an image.

An example of such an image, generated from a 3D impulse response, is shown in Figure 1. This image is made up of a number of lines, where each line corresponds to energy re-corded at the measurement location as a function of magnitude, orientation and time of arrival. The length of a line represents magnitude, the orientation of a line corresponds to the angle of incidence, and the colour of a line represents time of arrival. The scale is represented in Decibels, and the axes convey spatial direction.

As part of the current study alternative ways of representing the acoustical data are being explored, together with the ro-bustness and accuracy of the analysis routines used to extract it.

The next section explains some concepts which are funda-mental to the techniques discussed in this paper. Subsequently a system for determining and visualising 3D room impulse responses is described. This is in terms of a brief overview followed by an in

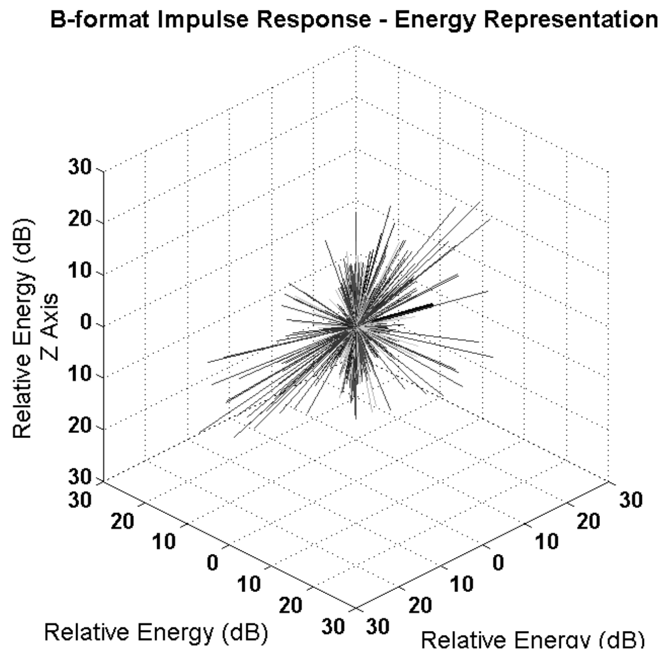

Figure 1: Example of a 3D impulse response image. Source: [1]

depth discussion of each part of the system. Currently the system is being experimentally validated in a controlled environment in order to assess its accuracy and robustness. An example of one such validation experiment is presented, followed by a discussion of planned future experimental work. Enhancements to the visualisation of the room impulse response are also discussed, followed by some concluding statements.

Background Fundamentals

The concepts of sound field, sound intensity, active and reactive sound fields, and B-format and A-format representations of a sound field are discussed in this section, as they underpin the techniques to be described later in this paper.

Sound Field Properties

A vibrating object, such as a loudspeaker, will cause mechanical disturbances in the surrounding medium. Similar to the effect of dropping a rock into a pond, the disturbances will propagate as sound waves outwards from the vibrating object, called the source, into a physical region in which sound waves exist, called the sound field.

A sound source causes the disturbance from steady state of several physical quantities of a medium. In the context of this paper, the medium of the sound field is air and the steady state refers to the time-invariant, ambient air conditions. Disturbance of this medium refers to the perturbation of the scalar quantities of pressure and density, as well as the oscillatory motion of the air particles which can be described by vector quantities such as displacement, velocity or acceleration. For a complete objective description of a sound field at a particular position, it is necessary to know both the scalar and vector aspects of these quantities. In this context the most useful and commonly used quantities are pressure and particle velocity. Of these, the fluctuating pressure (called the sound wave pressure), over the frequency range between 20 Hz and 20 kHz, is the most important for a subjective analysis, as this is the quantity that the human hearing system responds to.

Sound Intensity

From the standpoint of propagation of energy, a sound source radiates mechanical energy and the resulting propagating waves are a transmission of that energy through the sound field. Sound intensity (W/m2) is a quantity that describes the rate of energy flow through a unit area in the sound field. It is a vector quantity because it carries information about direction and is therefore one parameter used in the directional analysis of a sound field.

Instantaneous sound intensity, I(t), as distinct from sound intensity, I, at a position in the sound field, is defined as the product of the instantaneous sound wave pressure p(t) and the instantaneous particle velocity vector u(t) [2]:

$$I = p(t)u(t) \qquad (1)$$

The particle velocity vector, and thus the intensity vector, at a position in a sound field are inherently 3D quantities.

Sound intensity is then a time averaged rate of energy flow and is defined as:

$$\overline{I(t)=p(t)u(t)} \qquad (2)$$

where the bar indicates a suitable length time average [2]. At a position in a sound field where energy is flowing back and forth, the net flow or net intensity will be zero.

Active and Reactive Sound Fields

A purely active sound field is one in which there is a net energy flow, an example being a plane wave propagating in a free field (i.e., a sound field with no reflections). Conversely, in a completely reactive sound field, all the energy is travelling back and forth and the net energy flow is zero. For most sound fields, there will be both active and reactive components [3].

The active sound intensity, measured at a position in a sound field, is the time averaged sound intensity mentioned previ-ously. The reactive sound intensity gives an indication of the back and forth flow of energy through that position [4].

B-Format and A-Format Representations of a Sound Field

One way of representing a sound field at a position in terms of magnitude and direction is in the so called B-format. This is described in terms of sound wave pressure and 3D particle velocity. Sound wave pressure is a scalar quantity. Particle velocity is measured in a Cartesian coordinate system (broken down into its orthogonal X, Y and Z components), as shown in Figure 2(a). The positive directions in respect to this X, Y and Z coordinate system are forward, left and upwards, respectively. In terms of B-format, the pressure signal is referred to as the W channel, and the X, Y and Z components of the particle velocity are referred to as the X, Y and Z channels, respectively [5] [6].

One approach to determining the particle velocity experimen-tally would be to use an appropriately configured set of ve-locity microphones aligned in the X, Y and Z directions. Each of these microphones would need to have a directional response that resembled a figure-of-eight, as shown in Figure 3. The W channel, corresponding to sound wave pressure, would be determined by an omnidirectional microphone placed at that same location, as also shown in Figure 3.

In practice, however, it is very difficult to position and align microphones in the way that has been described. An alternative approach to solving this problem, developed by Michael Gerzon in 1975 [8], is based upon the A-format representation of a sound field. The coordinate system associated with A-format can be visualised in terms of the four vertices of a cube surrounding the measurement position. These four vertices are referred to as FLU, FRD, BLD and BRU, corresponding to front-left-up, front-right-down, etc., as shown in Figure 2(b). Unlike B-format, obtaining experimentally the A-format representation of a sound field at a location is relatively straightforward through the use of an A-format microphone array. Four directional cardioid microphones, which are partially sensitive to sound wave pressure, and partially sensitive to particle velocity, are aligned in the four A-format directions, facing outwards from the measurement position. One such microphone array is the Core Sound TetraMic [9], shown in Figure 4.

The signals produced by the A-format microphone array may be combined and filtered in such a way as to obtain the equivalent B-format representation, as will be discussed in the next section.

System Overview

This section briefly outlines the system used in this study to transform from a measured impulse response (IR), determined using an A-format microphone array, into a 3D visualisation of this response. The functional blocks of this system are shown in Figure 5.

Firstly, the impulse response is recorded in terms of the A-format representation of a sound field by means of an A-format microphone array. The resulting set of signals is then converted into B-format. Once in this form, the sound intensity impulse response signals are calculated, these carrying information about both direct and reflected sound energy at the measurement location. This information is characterised in terms of magnitude, direction and time, and can then be visualised in terms of vectors on a 3D Cartesian coordinate system.

The following sections discuss each part of this system in greater detail. (Note: the details concerning the generation of impulse signals and the recording of impulse responses are not discussed in this paper).

A-Format To B-Format Conversion

In this section, a method is described to convert from A-format to B-format signal recordings. The theoretical framework underpinning this conversion process was initially formulated by Michael Gerzon [8]. Improvements to this process intended to enhance the accuracy and robustness of the technique have subsequently been presented by Angelo Farina [5].

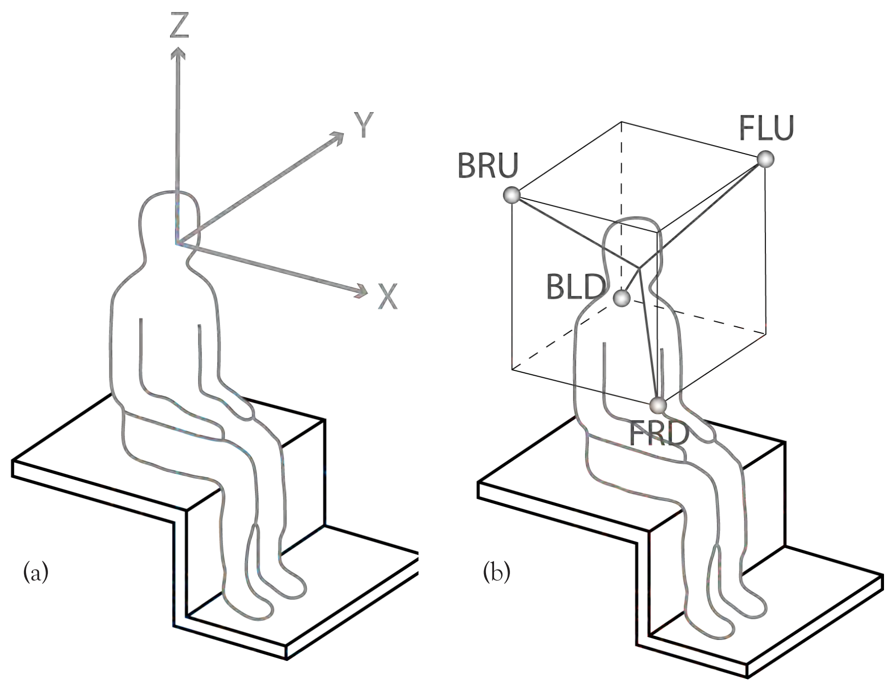

Figure 2: (a) B-format Cartesian coordinate system (b) A-format coordinate system. Adapted from [5].

A block diagram of Gerzon's theoretical framework is pre-sented in Figure 6.

The fundamental part of this conversion process is a matrix operation on the four A-format signals, as defined in Equation 3:

$$W' = FLU + FRD + BLD + BRU$$
$$X' = FLU + FRD - BLD - BRU$$
$$Y' = FLU - FRD + BLD - BRU$$
$$Z' = FLU - FRD - BLD + BRU \qquad (3)$$

The four signals at the output of this matrix operation are essentially in B-format but still require some post-filtering. Thus they are denoted with a prime signal. Post-filtering is required as a result of the non-coincident effects associated with the placement of the microphones which causes the signals, after the matrix operation, to have directivity patterns that deviate from the ideal [6] [10]. (Note: The ideal patterns were shown in Figure 3.) Gerzon derived theoretical post-filters to account for these issues, but it has subsequently been shown that these filters do not provide a realistic correction [5] [6]. A major reason for this is due to the fact that Gerzon's theoretical filters assumed a perfectly ideal microphone array. In reality, however, each microphone will exhibit non-ideal frequency response and directional characteristics.

Farina proposed an enhancement of Gerzon's approach, in the form of a set of pre-filters, as shown in Figure 7, in order to overcome the limitations just described.

These pre-filters equalise the frequency

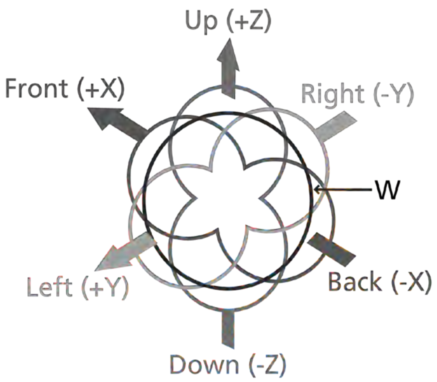

Figure 3: B-format directivity patterns, centred at the measurement point. Source: Adapted from [7].

response of each A-format microphone capsule, thereby ensuring that each capsule responds identically to the others. The filters are determined using an empirical method based on impulse response measurements as described by Farina [5].

Sound Intensity Analysis

Once the impulse response

Figure 4: Core Sound TetraMic A-format microphone array Source: [9].

measurements have been converted from A-format to B-format, a sound intensity analysis can be undertaken, providing information on direct and reflected sound energy in terms of magnitude, direction and time of arrival.

The B-format signals represent the sound wave pressure and 3D particle velocity at a position in a sound field. Therefore, computing the 3D sound intensity is straightforward, as defined in Equation 2. The result is three signals: the sound intensities in the X, Y and Z directions. For example, the sound intensity calculation for the X direction is shown in Equation 4. The intensity and particle velocity in the X direction are I_X (t), and u_X(t), respectively. The bar indicates a suitable length time average, as will be discussed further below.

$$I_X(t) = \overline{p(t)u_X(t)} \qquad (4)$$

In undertaking this sound intensity analysis, in order to get information about sound reflections from objects in the room, it is necessary to distinguish between energy flow related to direct sound, early reflections and subsequent reverberation, as shown in Figure 8.

The rationale underpinning the classification of recorded sound intensity into these three classes will now be discussed.

In a typical room, the sound field will be composed of time varying active and reactive components, and knowledge of these properties will determine what directional information can be obtained from the sound intensity impulse responses. Firstly, it is assumed that for room measurements the microphone is located in the far field of the source (i.e., not immediately close to the source) and thus reactive near-field effects do not exist.

When only the direct sound is propagating in the sound field, as far as any particular location is concerned, there will be a net energy flow in one direction with respect to the source and thus the intensity at that location will be entirely active.

As soon as sound waves are reflected by objects in the room, multiple sound propagation paths of varying directions will result within the room. However, at any position in the far field, the early reflections at that position should be spaced relatively far apart in time, and hence the individual reflections should be clearly identifiable within the impulse response as shown in Figure 8. For the duration of the direct sound and each early reflection, there is energy flow in generally one direction and thus the intensity is mostly active. As far as the time average associated with determining I_X(t), I_Y(t) and I_Z(t) is concerned (see for example Equation 4), this is chosen so that it does not overlap multiple reflections.

If two early reflections of different directions occur at a similar time (i.e., within this sound intensity time average) in some location, the measured intensity will be partially active and partially reactive, depending on the direction of the sound waves. The resulting analysis will then be an error.

As time progresses, the reflection paths will become more complicated, and the observed reflections at a position will merge together in time (see reverberation section in Figure 8). Eventually there will be reflections in many different and opposing directions at the same time, or within the same sound intensity time average. The active intensity will become zero, as the sound field is now mostly reactive (called a diffuse field).

The process of firstly distinguishing between early reflections as compared to reverberations and then subsequently deciding upon the temporal positions over which individual time averages will be performed is one that is largely guided by a careful examination of the overall impulse response. In many cases, the reverberation section will be largely

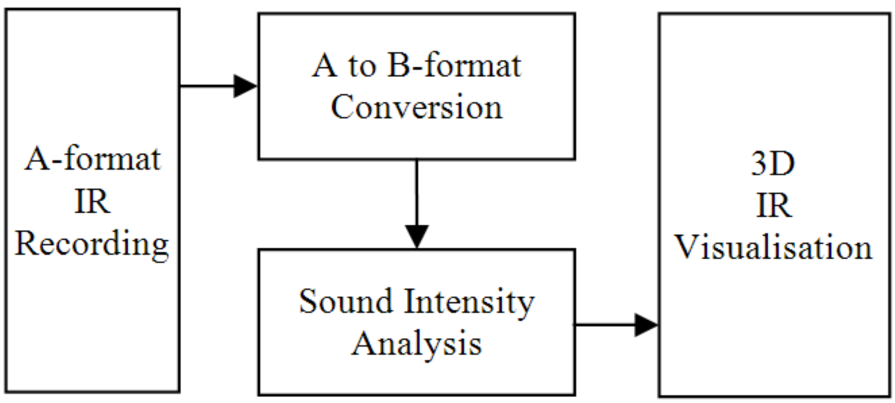

Figure 5: System Overview.

characterised by magnitudes that are smaller on average than those in the early reflection period. As far as the early reflection period is concerned, this will need to get segmented into subintervals over which individual time averages will be performed. Identifying these subintervals is largely done by identifying individual peaks in the early reflection period, the rationale being that each one of these peaks will correspond to an individual reflection. It should be clear from this explanation that the process of determining where individual time averages will be performed is not one that can be automated easily.

The X, Y and Z values for each time average will produce the magnitude and direction information for a single vector on the 3D impulse response image, as shown, for example, in Figure 1. The time information for a particular vector on the 3D impulse response image is governed by where in time the time average has been taken.

Visualisation Of 3D Impulse Response

The idea of visualising the 3D impulse response of a sound field is not new [11] [12].

The visualisation method presented in this paper generates an image in a similar style to the 3D impulse response visualisations by Alban Bassuet [12]. Firstly, the time-averaged sound intensity vectors for the direct sound and individual reflections are determined, as discussed in the previous section. The length of each vector (i.e., the magnitude of each reflection) is represented on a Decibel scale, termed the Relative Sound Intensity Level. The vectors are then plotted as lines on 3D axes, in a similar style to Figure 1. The time information associated with each vector is represented in terms of colour. With the current system the resulting 3D image plot can be rotated and viewed from any angle; an invaluable feature for room analysis. Alternative ways of looking at this information are currently being investigated as discussed in a later section.

Experimental Validation

This section outlines the experimental

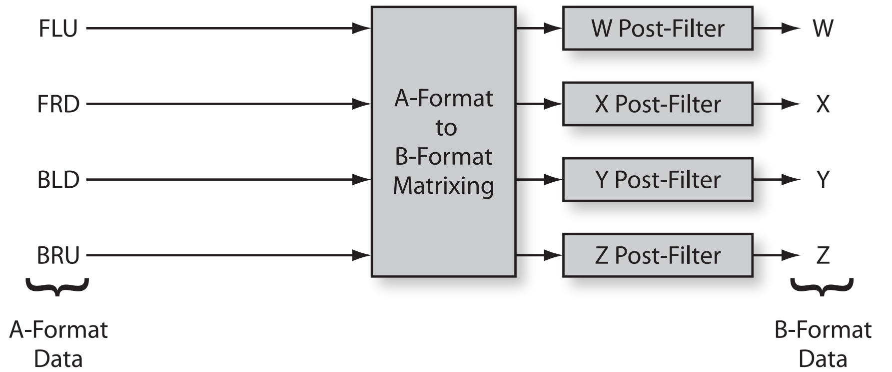

Figure 6: Gerzon's method for converting from A-format to B-format Adapted from [8].

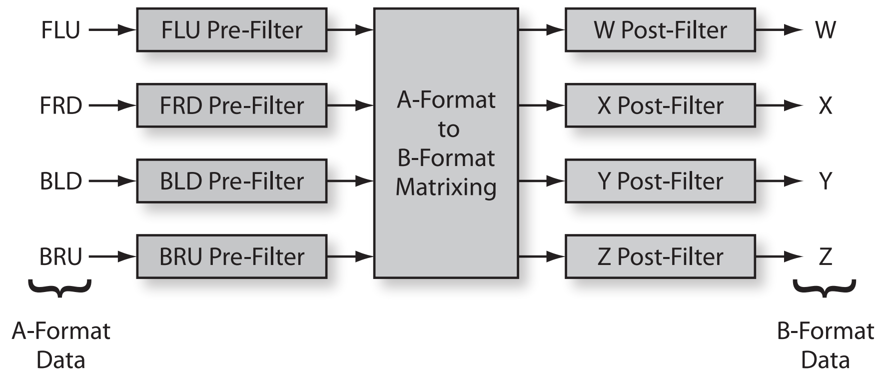

Figure 7: Farina's method for converting from A-format to B-format Adapted from [5].

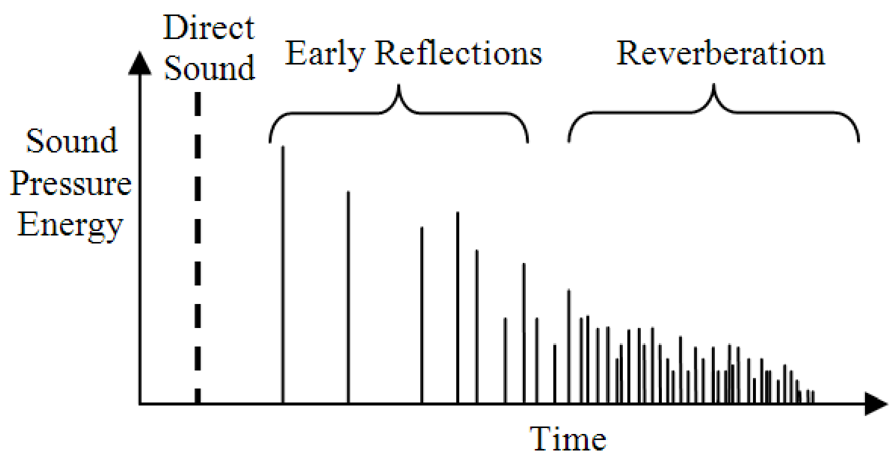

Figure 8: Illustration of simple omnidirectional energy impulse response at a position within a room.

environment which is currently being used to investigate the accuracy and robustness of the analysis process described in this paper. For practitioners, it is very important that these aspects are thoroughly understood before the technique is employed in a more realistic, and thus complicated, environment. The facilities used in this study to investigate these aspects of accuracy and robustness are described next. The results from one such experiment will be presented, followed by a discussion of the kinds of experimental validation that is planned.

Facilities and Equipment

As part of this study, experiments are being undertaken in an anechoic room with internal dimensions of "5m"×"5m"×"5m" . This facility exists within the Acoustics Research Centre of The University of Auckland. Figure 9 shows a photograph of an experimental setup inside this anechoic room. This figure shows an A-format microphone array (Core Sound TetraMic) together with a sound source (Tapco S5 loudspeaker).

An Apple Macbook Pro computer, connected to a Metric Halo ULN8 multichannel audio interface is used to play back the excitation signals, and also record the four channels from the A-format microphone array. This equipment is located in a control room, adjacent to the anechoic room. The software FuzzMeasure Pro is used to generate a swept sinusoid excitation signal to be played back through the loudspeaker. This software also converts the recorded microphone signals into impulse response signals. Included with the TetraMic micro-phone array is software called VVMic which implements the A-format to B-format conversion process. Having obtained a set of B-format impulse responses, these are then plotted in MATLAB in order to identify the early reflection period as distinct from reverberation, as well as the temporal locations of the individual time averages within the early reflection period. MATLAB is then again used to compute the time-averaged sound intensity vectors for the individual reflections, as well as to visualise this data interactively on Cartesian axes in the form shown in Figure 1.

Example of a Typical Experiment

Figure 10 shows a typical experiment conducted to assess the accuracy and robustness of the techniques described in this paper.

With this experiment, there was only one reflector placed some distance away from both the loudspeaker and A-format microphone array. The TetraMic A-format microphone array provides an indication of the positive X direction in terms of the B-format coordinate system. This positive X direction was then made to point directly to the loudspeaker, as shown in Figure 10. The positive Y direction follows automatically from this, as also indicated in Figure 10, with the positive Z direction pointing out of the page. As far as the vertical placement of the reflector is concerned, it is located in the negative Z direction with respect to the microphone position. The blue arrows in Figure 10 are the expected paths of sound propagation from the loudspeaker, and the red arrow represents the expected reflection that should be recorded by the microphone array. The angle ϑ (Figure 10) was physically determined using a laser measuring device to be approximately 112°.

Figure 9: Anechoic room with a TetraMic A-format micro-phone array and Tapco loudspeakerresponse at a position within a room.

The impulse response associated with the W channel for this experiment is shown in Figure 11. In this figure the direct sound and reflected sound are clearly obvious as there are no other reflection sources or noise present in the room.

The X-Y plane associated with the resulting 3D plot for this experiment is shown in Figure 12. The origin of this plot represents the location of the microphone. The vector coloured blue, in the near horizontal direction, is the direct sound intensity vector, and the reflected sound intensity is shown as the vector in red.

Examination of this plot shows the direct sound vector is offset by an angle of 2° in the X-Y plane. The angle between the direct and reflected sound is approximately 126°. This is an error of 14° from the angle ϑ shown in Figure 10.

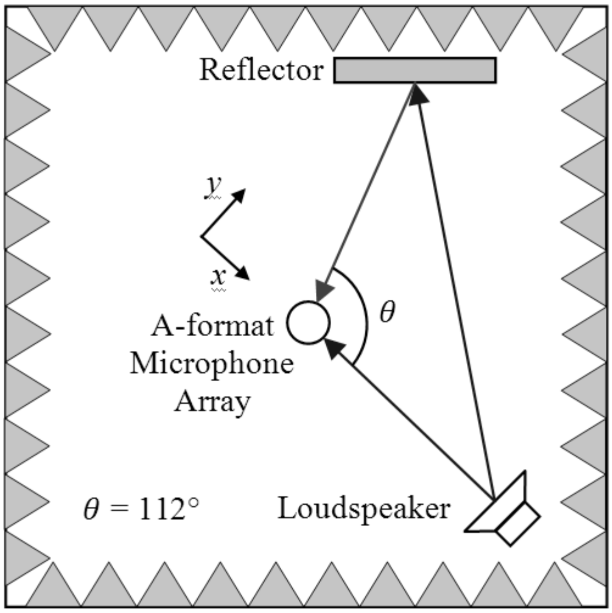

Figure 10: Experimental setup in the anechoic room with a loudspeaker, A-format microphone and reflector.

The angular error associated with the direct sound intensity vector seems very acceptable given the inevitable errors associated with aligning the microphone with the speaker. The angular error in respect to ϑ could possibly be explained in two ways. Firstly, accurate placement of the reflector in respect to the XYZ coordinate system is difficult in practice. Secondly, the nature of the reflection produced by the reflector used in this experiment is not fully understood and will be one of the aspects examined in further investigation. Nonetheless, the results associated with this initial experiment are very promising.

The sound intensity vectors can be visualised in 3D, as illustrated in Figure 13. This represents the same data as Figure 12, but now including the Z dimension. The reflection vector (red), with respect to the origin, is in fact pointing away from the page and downwards, although this is not obvious from the figure. This is consistent with the location of the reflector, which in this case, was slightly lower than the height of the microphone.

This section outlines the methodology of future testing that is planned in order to quantify the accuracy and robustness of the system.

The experiment just described will be extended to include a single reflector placed at a variety of locations in respect to both angle ϑ (Figure 10) and separation distance from both the microphone and loudspeaker. This will then be extended to include a range of experiments involving multiple reflectors.

There are also issues associated with the compensation of the frequency response (i.e., both magnitude and phase response) of the loudspeaker as well as the recording equipment used in these experiments. Though it is expected that the resulting effects on accuracy will be small, it will nonetheless be useful to quantify these in some manner.

Following these experiments, the plan is to test this system in a more complicated environment such as a concert hall. In such a situation, both identifying the early reflections as distinct from reverberations, as well as deciding on the temporal locations for individual time averages associated with this analysis is likely to be non-trivial. The issue of trying to undertake this process in a more automated manner also needs investigation.

Enhancements to 3D Visualisation

In the aforementioned experiment, the sound field was very simple, consisting of only one reflection. In reality the sound fields will involve many reflections, and the resulting visualisation may look confusing, especially in terms of the temporal locations of the reflections. The ability to view only a specific window of time may also help to clarify understanding of the sound field with respect to time. Furthermore, rendering the visualisation as a video will help to show how the sound field changes over time.

The current method of visualising sound reflections as vectors on 3D axes is of some practical value, allowing acousticians to relate reflections to the corresponding physical features of the room. However this will require a manual process of matching the intensity vectors to the room's surfaces. In order to simplify this task, the reflections could be viewed from the point of view of the measurement location. This will require a photograph to be taken from the measurement position in an appropriate direction.

The individual reflections will then be visually indicated in the estimated locations on the photograph, immediately relating the features of the room to the respective reflections. This idea was published in a previous paper, specifically relating to sound intensity measurements in enclosed spaces [13].

The visualisation may also be enhanced in terms of a perceptual analysis. Before calculating the sound intensity vectors, it may be appropriate to filter the signals into certain frequency bands which are of perceptual relevance.

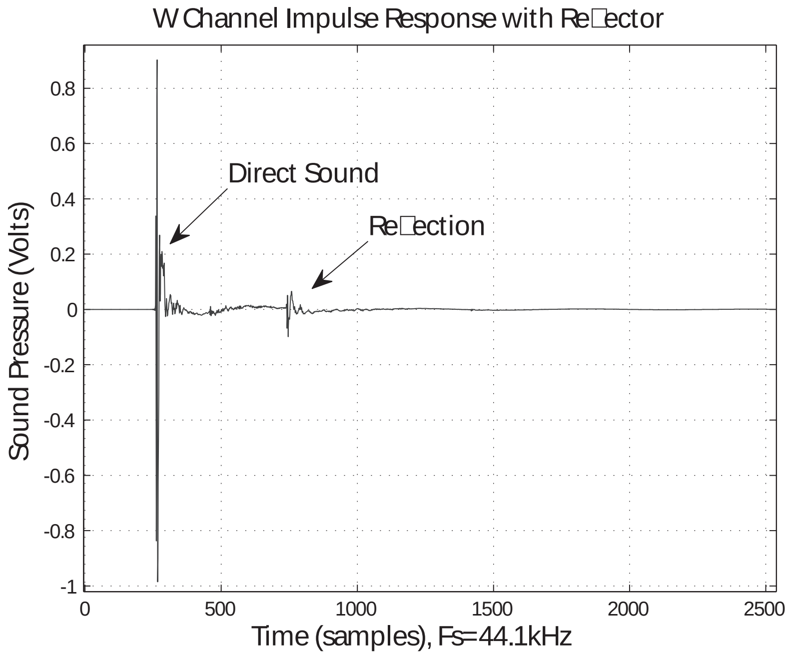

Figure 11: W channel (pressure) impulse response.

Conclusions

This paper has overviewed a technique for determining and displaying 3D impulse responses based upon measurements from an A-format microphone array. The intention with this technique is to be able to identify the magnitude, direction and time of arrival of reflections arising from various reflective surfaces of a room. The purpose of the current study is to ascertain the accuracy and robustness of this technique, as well as to identify the various factors which impact upon these parameters. An experimental setup has been described for undertaking this investigation based upon experiments conducted within an anechoic room. One such experiment has been described, the results of which are certainly promising in terms of the potential usefulness of this system.

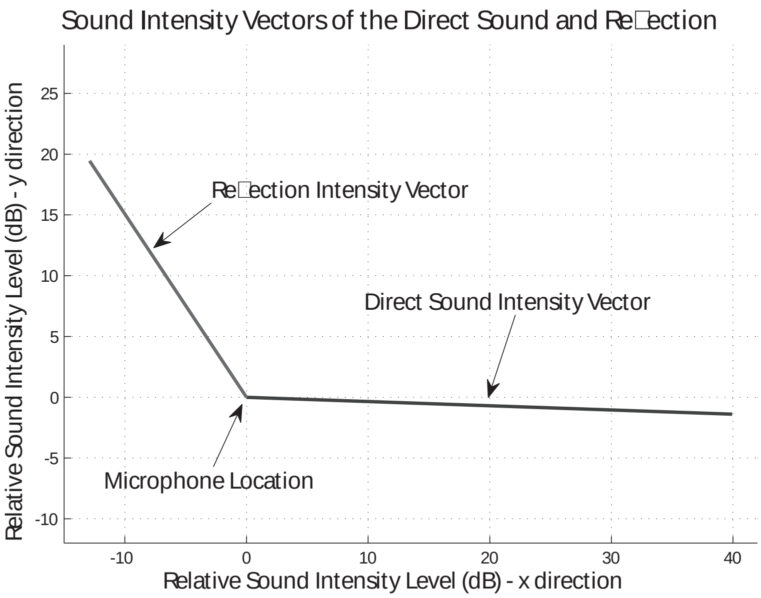

Figure 12: Sound intensity vectors in the X-Y plane of the direct sound and reflection.

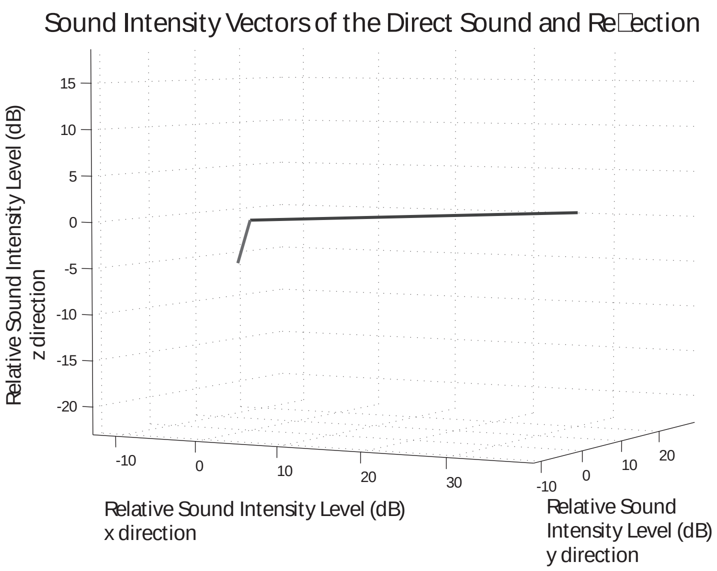

Figure 13: Sound intensity vectors visualised in 3D.

Acknowledgments

The authors would like to thank Keith Ballagh and the staff of Marshall Day Acoustics, Dr. George Dodd and Gian Schmid from the Acoustics Research Centre at the University of Auckland, and Prof. Angelo Farina of the University of Parma in Italy for their invaluable assistance and guidance.

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Sound Snippets: The Sound Under the Ground

A new type of sound sensor system has been developed to predict the likelihood of a landslide.

Thought to be the first system of its kind in the world it, works by measuring and analysing the acoustic behaviour of soil to establish when a landslide is imminent so preventative action can be taken.

Noise created by movement under the surface builds to a crescendo as the slope becomes unstable and so gauging the increased rate of generated sound enables accurate prediction of a catastrophic soil collapse.

The technique has been developed by researchers at Loughborough University, in collaboration with the British Geological Survey.

The detection system consists of a network of sensors buried across the hillside or embankment that presents a risk of collapse. The sensors, acting as microphones in the subsoil, record the acoustic activity of the soil across the slope and each transmits a signal to a central computer for analysis.

Noise rates, created by inter-particle friction, are proportional to rates of soil movement and so increased acoustic emissions mean a slope is closer to failure. Once a certain noise rate is recorded, the system can send a warning, via a text message, to the authorities responsible for safety in the area. An early warning allows them to evacuate an area, close transport routes that cross the slope or carry out works to stabilise the soil.

Neil Dixon, professor of geotechnical engineering at Loughborough University and principal investigator on the project, explains how the system – thought to be a global first – works. "In just the same way as bending a stick creates cracking noises that build up until it snaps, so the movement of soil before a landslide creates increasing rates of noise," said Professor Dixon.

"This has been known since the 1960s, but what we have been able to do that is new is capture and process this information so as to quantify the link between noise and soil displacement rates as it happens, in real time – and hence provide an early warning," he added.

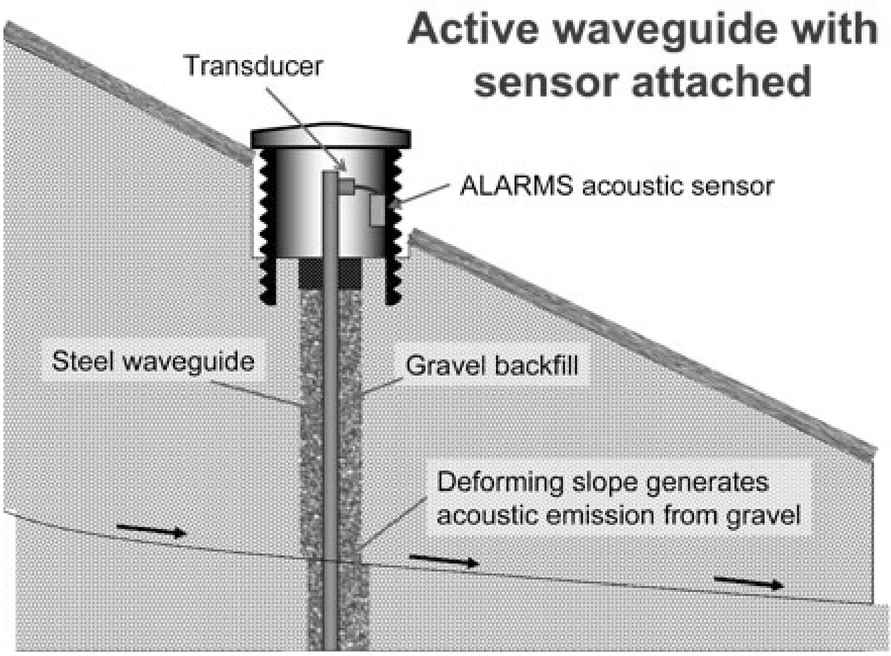


Figure 1. A schematic showing the arrangement of the system.

The system is now being developed further to produce low cost, self-contained sensors that do not require a central computer. This work, which is being carried out under the second project, is focused on manufacture of very low cost sensors with integrated visual and/or audible alarms, for use in developing countries. Ongoing work includes field trials, market research and planning commercial exploitation of the technology.

"The development of low cost independent acoustic slope sensors has only become possible in very recent times due to the availability of microprocessors that are fast, small and cheap enough for this task," says Dixon.

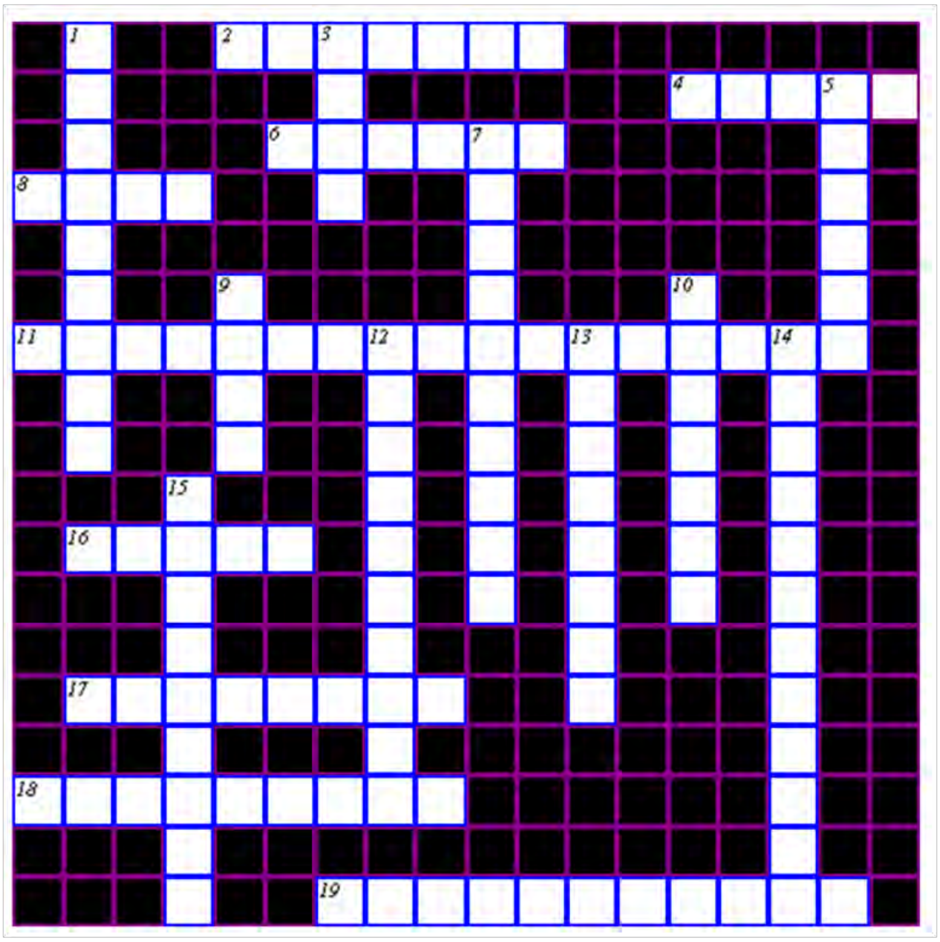
As well as the life-saving implications for countries prone to disastrous landslides, the technique can also be used in monitoring the condition of potentially unstable slopes built to support transport infrastructure, such as rail and road embankments, in developed countries.

Adapted from: EPSRC Press Office,

http://www.epsrc.ac.uk/newsevents/news/

Figure 2. The system installed on a slope

Acoustic Crossword #1



CLUES ACROSS

2. Can be heard when Australian dollar gets holy book without first boy (7)
4. Something unwanted when two nostrils surround one (5)
6. Blaise for pressure? (7)
8. Type of noise from a baby girl? (4)
11. Answer to how often? (9, 8)
16. Personal identification number not applicable initially for hearing component (5)
17. A sound presentation therefore no small weight (8)
18. Puss includes star sign or device for checking sensitivity (10)
19.One not articulating softly? (11)

Crossword solution in the next issue.

Crossword submitted by:

Dogged Doer.

CLUES DOWN

1. A small mass of sound for recording hearing acuity? (9)
3. Unable to hear it is non-caffeinated not a hundred (4)
5. She got raped and he fathered decay theory (6)
7. Rugby players take an option round right for soaking up (10)
9. Sounds like bobbed down for pipe (4)
10. Company goes to small church by grassy meadow for hearing organ (7)
12. Ask social worker for someone to advise (10)
13. Southern guitar pick loses fifty in sound plot (8)
14. On one's feet giving the departing gesture? (8, 4)
15. Ninety sit arranged for sound concentration (9)

Young New Zealander of the Year 2011: Jamie Fenton

The teenage student from Taranaki that invented a device to reduce excessive noise exposure at child care centres has been awarded Young New Zealander of the year.

Jamie Fenton, 17, came up with the noise level meter when she was only 10 and it's now being produced commercially by the National Foundation for the Deaf.

The preschool noise issue came to light in 2009 when figures released by the foundation showed at least one in five children are being exposed to excessive noise levels while they play.

The commercial version of Jamie's noise meter is kown as a Safe Sound Indicator (SSI). The device lights up to let children and staff know when noise levels are at a dangerous high. The amber light comes on at 85 decibels, the level where hearing loss becomes a threat.

Jamie built the electronic traffic-light noise-meter system with the help of her dad, as an entry in a school science fair. The first model used an old tool box with coloured cellophane to represent the lights. It won a merit in the science fair, was posted on a local science website then banished to the garage for "years".

The Safe Sound Indicator is currently being produced by the National Foundation for the Deaf and is used to prevent hearing damage in children at early childhood centres across New Zealand.

As the lead student in the Ministry for the Environment Energy Conservation and Renewable Energy pilot project at Inglewood High School, Jamie also wrote a compelling nomination document that won the school a regional conservation award.

Adapted from: http://www.nzawards.org.nz

Photo: Chris Hillock

Sonar device inspired by dolphins

Scientists at the University of Southampton have developed a new kind of underwater sonar device that can detect objects through bubble clouds that would effectively blind standard sonar.

Just as ultrasound is used in medical imaging, conventional sonar 'sees' with sound. It uses differences between emitted sound pulses and their echoes to detect and identify targets. These include submerged structures such as reefs and wrecks, and objects, including submarines and fish shoals. However, standard sonar does not cope well with bubble clouds resulting from breaking waves or other causes, which scatter sound and clutter the sonar image.

Professor Timothy Leighton of the University's Institute of Sound and Vibration Research (ISVR), who led the research, says: "Cold War sonar was developed mainly for use in deep water where bubbles are not much of a problem, but many of today's applications involve shallow waters. Better detection and classification of targets in bubbly waters are key goals of shallow water sonar."

Professor Leighton and his colleagues have developed a new sonar concept called twin inverted pulse sonar (TWIPS). TWIPS exploits the way that bubbles pulsate in sound fields, which affects the characteristics of sonar echoes. "To catch prey, some dolphins make bubble nets in which the best manmade sonar would not work," he says.

"It occurred to me that either dolphins were blinding their sonar when making such nets, or else they have a better sonar system. There were no recordings of the type of sonar that dolphins use in bubble nets, so instead of producing a bio inspired sonar by copying dolphin signals, I sat down and worked out what pulse I would use if I were a dolphin."

TWIPS uses trains of twinned pairs of sound pulses. The first pulse of each pair has a waveform that is an inverted replica of that of its twin. The first pulse is emitted a fraction of a second before its inverted twin.

Professor Leighton's team first showed theoretically that TWIPS might be able to enhance scatter from the target while simultaneously suppressing clutter from bubbles. In principle, it could therefore be used to distinguish echoes from bubble clouds and objects that would otherwise remain hidden.

In their latest study, the researchers set out to see whether TWIPS would work in practice. "TWIPS outperformed standard sonar in the wake of large vessels such as passenger ferries," says coauthor Dr Justin Dix of the University's School of Ocean and Earth Science (SOES) based at the National Oceanography Centre, Southampton.

Possible future marine applications for TWIPS include harbour protection and the detection of bubbles in marine sediments and manufacturing. Technologies based on the same basic principles could be used in medical ultrasound imaging, which was already using pairs of inverted pulses to enhance (rather than suppress) contrast agents injected into the body.

The TWIPS principle would work with other sensors such as in Magnetic resonance imaging (MRI). Professor Leighton has proposed TWIPR (Twin Inverted Pulse Radar) for the detection of improvised explosive devices or covert circuitry. But what about the original inspiration for the research do dolphins and other echolocating animals use TWIPS?

"Key ingredients of a TWIPS system appear in separate species but they have never been found all together in a single species," says Professor Leighton.

"There is currently no evidence that dolphins use TWIPS processing, although noone has yet taken recordings of the signals from animals hunting with bubble nets in the wild. How they successfully detect prey in bubbly water remains a mystery that we are working to solve"

Adapted From: News Release, University of Southampton, Nov. 2010.

Detecting Divers By The Sound Of Their Breath

At Stevens Institute of Technology, Dr. Alexander Sutin is developing a non-lethal weapon for protecting ports from underwater divers with malicious intentions ~ an acoustic device that overwhelms them with the amplified sound of their own breath.

The technique may offer Homeland Security and the Navy a kinder, gentler method of non-lethal diver deterrent, an alternative to deadly underwater explosive charges or loud underwater sirens, which may impact marine life.

The idea is to detect the diver's breathing passively instead of using an active acoustic technology like a sonar ping. Dr. Sutin, a Research Professor at Stevens Center for Maritime Systems, has recently returned from Holland, where he and a team of Stevens and Dutch scientists investigated passive acoustic methods of diver detection.

"Many fish can produce similar signals to divers on active sonar, but fish do not breathe like humans," says Sutin. "Passive methods based on the breathing of a diver are such simpler and offer a much better detection rate."

The next step will be to develop a method to isolate a narrow band of the breathing sound and radiate it back to the diver. Using a technique called Time Reversal Acoustics (TRA), the scientists hope to produce an amplified beam of sound loud enough to overwhelm an intruder but focused enough to spare the surrounding wildlife. TRA has been successfully used to amplify acoustic signals to the level enough to destroy kidney stones.

Source:Stevens Institute of Technology Press Release.

CRAI Ratings

Editors Note: As a result of the February 22nd Earthquake, a number of the rated Christchurch Restaurants no longer exist. As soon as the cordon is lifted, we will check details and update the list.

Auckland

215, Dominion Rd	(1)	★★★★½
Andrea (form. Positano), Mission Bay	(1)	★★★
Aubergine's, Albany	(1)	★★★★½
Backyard, Northcote	(1)	★★
Bask, Browns Bay	(1)	★★★
Bay (The), Waiake, North Shore	(1)	★★★★★
Bolero, Albany	(1)	★★★★
Bouchon, Kingsland	(1)	★★
Bowman, Mt Eden	(1)	★★★★½
Bracs, Albany	(1)	★★★★
Brazil, Karangahape Rd	(1)	★★★
Buoy, Mission Bay	(2)	★★★★½
Byzantium, Ponsonby	(1)	★★★
Café Jazz, Remuera	(1)	★★★★½
Carriages Café, Kumeu	(1)	★★★★
Charlees, Howick	(1)	★★★★★
Cibo	(1)	★★★★★
Circus Circus, Mt Eden	(1)	★★
Cube, Devenport	(1)	★★
Del Fontaine, Mission Bay	(1)	★★★★★
Deli (The), Remuera	(1)	★★★★
Delicious, Grey Lynn	(1)	★★★★★
De Post, Mt Eden	(1)	★★
Dizengoff, Ponsonby Rd	(1)	★★
Drake, Freemans Bay (Function Room)	(1)	★★
Eiffel on Eden, Mt Eden	(1)	★★
Eve's Cafe, Westfield Albany	(1)	★★★½
Formosa Country Club Restaurant	(1)	★★★★★
Garrison Public House, Sylvia Park	(1)	★★★★½
Gee Gee's	(1)	★★★
Gero's, Mt Eden	(9)	★★★
Gina's Pizza & Pasta Bar	(1)	★★★½
Gouemon, Half Moon Bay	(1)	★★
Hardware Café, Titirangi	(1)	★★★★★
Hollywood Café, Westfield St Lukes	(1)	★★½
IL Piccolo	(1)	★★★★
Ima, Fort Street	(1)	★★★★
Jervois Steak House	(1)	★★★
Kashmir	(1)	★★★★
Khun Pun, Albany	(2)	★★★★★
Kings Garden Ctre Café, Western Springs	(1)	★★
La Tropezienne, Browns Bay	(1)	★★
Malaysia Satay Restaurant, Nth Shore	(1)	★★★★★
Mecca, Newmarket	(1)	★★★★★
Mexicali Fresh, Quay St	(1)	★★
Mezze Bar, Little High Street	(16)	★★★★
Monsoon Poon	(1)	★★★★★
Mozaike Café, Albany	(1)	★★
Narrow Table (The), Mairangi Bay	(1)	★★★★½
One Red Dog, Ponsonby	(1)	★★★
One Tree Grill	(1)	★★★
Orbit, Skytower	(2)	★★★★
Patriot, Devonport	(1)	★★★½
Pavia, Pakuranga	(1)	★★★★★
Prego, Ponsonby Rd	(2)	★★
Remuera Rm, Ellerslie Racecourse	(1)	★★★★★
Rhythm, Mairangi Bay	(1)	★★
Rice Queen, Newmarket	(12)	★★★★
Sails, Westhaven Marina	(2)	★★★★★
Scirocco, Browns Bay	(1)	★★★
Seagers, Oxford	(1)	★★★★
Shahi, Remuera	(1)	★★★½
Shamrock Cottage, Howick	(1)	★★
Sidart, Ponsonby	(1)	★★★★½
Sitting Duck, Westhaven	(1)	★★★½
Sorrento	(1)	★★½
Stephan's, Manukau	(1)	★★★★★
Tempters Café, Papakura	(1)	★★★★★
Thai Chef, Albany	(1)	★★★★★
Thai Chilli	(1)	★★★★★
Thai Corner, Rothesay Bay	(1)	★★★★★
Tony's, High St	(1)	★★★
Traffic Bar & Kitchen	(1)	★★
Umbria Café, Newmarket	(1)	★★★★½
Valentines, Wairau Rd	(1)	★★★★★
Vivace, High Street	(2)	★★½
Wagamama, Newmarket	(1)	★★★★½
Watermark, Devonport	(1)	★★
Woolshed, Clevedon	(1)	★★½
Zarbos, Newmarket	(1)	★★
Zavito, Mairangi Bay	(1)	★★ ★

Arthur's Pass

Arthur's Pass Cafe & Store	(1)	★★★½
Ned's Cafe, Springfield	(1)	★★★★

Ashburton

Readers are encouraged to rate eating establishments which they visit by completing a simple form available on-line from www.acoustics.ac.nz, or contact the Editor.
Repeat ratings on listed venues are encouraged.

★ Lip-reading would be an advantage. ★★ Take earplugs at the very least. ★★★ Not too bad, particularly mid-week.
★★★★A nice quiet evening. ★★★★★The place to be and be heard. (n) indicates the number of ratings.

Ashburton Club & MSA	(1)	★★★★½
Robbies	(1)	★★★
RSA	(1)	★★★★
Tuscany Café & Bar	(1)	★★★

Bay of Plenty

Alimento, Tauranga	(1)	★½
Imbibe, Mt Maunganui	(1)	★½
Versailles Café, Tauranga	(2)	★★

Blenheim

Raupo Cafe	(1)	★★

Bulls

Mothered Goose Cafe, Deli, Vino	(1)	★★

Cambridge

GPO	(1)	★★★★★

Christchurch

3 Cows, Kaiapoi	(1)	★★★★
Abes Bagel Shop, Mandeville St	(1)	★★★★
Alchemy Café, Art Gallery	(1)	★★★★★
Anna's Café, Tower Junction	(1)	★★★★
Annie's Wine Bar, Arts Centre	(16)	★★★½
Arashi	(1)	★★
Azure	(2)	★★★
The Bog	(1)	★★★★★
Becks Southern Ale House	(11)	★★★★½
Buddha Stix, Riccarton	(1)	★★★★
Bully Haye's, Akaroa	(1)	★★
Café Bleu	(1)	★★★
Cafe Valentino, Colombo St	(1)	★★★½
Caffé Roma	(1)	★★★★★
Cashmere Club	(1)	★★★★★
Chinwag Eathai, High St	(8)	★★
Christchurch Casino	(1)	★★
Christchurch Museum Café	(1)	★★★★
Cobb & Co, Bush Inn	(1)	★★★
Coffee Shop, Montreal Street	(1)	★★
Cookai	(3)	★★½
Costas Taverna, Victoria Street	(1)	★½
Coyote's	(6)	★★★
Decadence Café, Victoria St	(1)	★★★★★
Drexels Breakfast Restaurant, City	(1)	★★★★½
Drexels Breakfast Restaurant, Riccarton	(1)	★★★★
Dux de Lux	(1)	★★★★
Elevate, Cashmere	(1)	★★★
Fava, St Martins	(1)	★★
Foo San, Upper Riccarton	(1)	★★★½
Fox & Ferrett, Riccarton	(1)	★★★★★
Freemans, Lyttleton	(9)	★★★½
Gloria Jean's, Rotheram St	(1)	★★★★
Golden Chimes	(1)	★★★★★
Governors Bay Hotel	(1)	★★★★
Green Turtle	(1)	★★★★
Harpers Café, Bealey Ave	(1)	★★★★★
Hari Krishna Café	(1)	★★★
Holy Smoke, Ferry Rd	(1)	★★
Honey Pot Café	(8)	★★★
Indian Fendalton	(2)	★★
Joe's Garage, Hereford St	(4)	★★½
Joyful Chinese Rest., Colombo St	(1)	★★★★★
Kanniga's Thai	(1)	★★★
Le Café, Arts Centre	(1)	★★★
Little India	(2)	★★★★★
Lone Star, Manchester Street	(15)	★★
Lone Star, Riccarton Road	(6)	★★★
Lotus Heart, Colombo Street	(1)	★★★★
Lyttleton Coffee Co, Lyttleton	(1)	★★★★
Manee Thai	(6)	★★½
Mexican Café	(6)	★★★
Oasis	(1)	★★★★½
Old Vicarage	(2)	★★★½
Petrini, Ferrymead	(3)	★★★★½
Phu Thai, Manchester Street	(1)	★★★
Portofino	(3)	★★★★★
Pukeko Junction, Leithfield	(1)	★★★★
Red, Beckenham Service Centre	(1)	★★★★
Red Elephant	(1)	★★★★
Retour	(1)	★★★
Riccarton Buffet	(2)	★★★★½
Richmond Workingmens' Club	(2)	★★★★
Robbies, Church Corner	(2)	★★★★½
Route 32, Cust	(1)	★★★★
Ruptured Duck, Sumner	(1)	★★★★
Saggio di Vino	(4)	★★★★½
Salt on the Pier, New Brighton	(6)	★★★½
Santorinis Greek Ouzeri	(1)	★★
Scarborough Fare	(1)	★★
Simo's Moroccan	(8)	★★★★
Speights Ale House, Tower Junction	(1)	★★★★
Terrace View, Copthorne Central	(1)	★★★★★
Tap Room	(9)	★★★
The Bridge, Prebbleton	(1)	★★★★★
The Bicycle Thief	(1)	★★★★½
The Flying Burrito Brothers	(1)	★★
The Preservatory	(1)	★★
The Sand Bar, Ferrymead	(2)	★★★½
The Vault, Cashel Mall	(1)	★★★★
Tokyo Samurai	(1)	★★★★★
Tutto Bene, Merivale	(2)	★★
Untouched World Cafe	(1)	★★★★★
Wagamama, Oxford Terrace	(6)	★★★
Waitikiri Golf Club	(1)	★★
Waratah Café, Tai Tapu	(1)	★★★
What Bar, Hotel SO	(1)	★★

Clyde

Old Post Office Cafe	(1)	★★★★★

Dunedin

A Cow Called Berta	(1)	★★★½
Albatross Centre Cafe	(1)	★★★★★
Bennu	(1)	★★★★
Bx Bistro	(1)	★★★★
Chrome	(1)	★★★★½
Conservatory, Corstophine House	(1)	★★★★★
Fitzroy Pub on the Park	(1)	★★★★★
High Tide	(2)	★★
Nova	(1)	★★★★★
St Clair Saltwater Pool Cafe	(1)	★★★★½
Swell	(1)	★★
University of Otago Staff Club	(1)	★★

Gore

Old Post	(1)	★★★
The Moth, Mandeville	(1)	★★★★★

Greymouth

Cafe 124	(1)	★★★

Hamilton

Embargo	(1)	★★★★★
Gengys	(1)	★★
Victoria Chinese Restaurant	(1)	★★★★★

Hanmer Springs

Laurels (The)	(2)	★★★★★
Saints	(1)	★★★★½

Hastings

Café Zigliotto	(1)	★★★

Havelock North

Rose & Shamrock	(1)	★★★½

Levin

Traffic Bar & Bistro	(1)	★★

Masterton

Java	(1)	★★

Matamata

Horse & Jockey	(1)	★★★★★

Methven

Ski Time	(2)	★★★

Napier

Boardwalk Beach Bar	(2)	★★★★★
Brecker's	(1)	★★★★★
Café Affair	(1)	★★
Cobb & Co	(1)	★½
Duke of Gloucester	(1)	★★★★½
East Pier	(1)	★★
Estuary Restaurant	(1)	★★★★★
Founder's Cafe	(1)	★★★★★
Napier RSA	(1)	★★★★★
Sappho & Heath	(1)	★★

Nelson/Marlborough

Allan Scott Winery	(1)	★★★★★
Amansi @ Le Brun	(1)	★★★★★
Baby G's, Nelson	(1)	★★★★★
Boutereys, Richmond	(1)	★★★★
Café Affair, Nelson	(1)	★★
Café on Oxford, Richmond	(1)	★★★
Café Le Cup, Blenheim	(1)	★★★
Crusoe's, Stoke	(1)	★★★
Cruizies, Blenheim	(2)	★★★★½
Grape Escape, Richmond	(1)	★★★★★
Jester House, Tasman	(1)	★★★★★
L'Affaire Cafe, Nelson	(1)	★★
Liquid NZ, Nelson	(1)	★½
Lonestar, Nelson	(1)	★★★★
Marlborough Club, Blenheim	(1)	★★
Morrison St Café, Nelson	(1)	★★½
Oasis, Nelson	(1)	★★★★★
Rutherford Café & Bar, Nelson	(1)	★★★★★
Suter Cafe, Nelson	(1)	★★
Verdict, Nelson	(1)	★★
Waterfront Cafe & Bar, Nelson	(1)	★★★
Wholemeal Trading Co, Takaka	(1)	★★★★★

New Plymouth

Breakers Café & Bar	(1)	★★★
Centre City Food Court	(1)	★★★★
Elixer	(1)	★★★★
Empire Tea Rooms	(1)	★★★★½
Govett Brewster Cafe	(1)	★★
Marbles, Devon Hotel	(1)	★★★
Pankawalla	(1)	★★★★★
Simplicity	(1)	★★★
Stumble Inn, Merrilands	(1)	★★★
Yellow Café, Centre City	(1)	★★★
Zanziba Café & Bar	(1)	★★★

Oamaru

Riverstone Kitchen	(1)	★★★★★
Star & Garter	(1)	★★★
Woolstore Café	(1)	★★★★

CRAI Ratings (cont.)

Palmerston North

Café Esplanade	(2)	★★★★
Chinatown	(1)	★★★★
Coffee on the Terrace	(2)	★★★
Elm	(1)	★★★★½
Fishermans Table	(1)	★★★★★
Gallery	(3)	★★★★
Rendezvous	(1)	★★½
Roma Italian Restaurant	(1)	★★★
Rose & Crown	(1)	★★
Tastee	(1)	★★★
Thai House Express	(1)	★★★★★
Victoria Café	(1)	★★★★

Queenstown

Bunker	(1)	★★★★
The Cow	(1)	★★★
Sombreros	(1)	★
Tatler	(1)	★★★★
Winnies	(1)	★★★★★

Rotorua

Cableway Rest. at Skyline Skyrides	(1)	★★★★★
Lewishams	(1)	★★★
Woolly Bugger, Ngongotaha	(1)	★★★
Valentines	(1)	★★★★★
You and Me	(1)	★★★★★
Zanelli's	(1)	★★

Southland

Lumberjack Café, Owaka	(1)	★★★★★
Pavilion, Colac Bay	(1)	★★
Village Green, Invercargill	(1)	★★★★★

Taihape

Brown Sugar Café	(1)	★★★★½

Taupo

Burbury's Café	(1)	★★★
Thames		
Thames Bakery	(1)	★★★
Waiheke Island		
Cortado Espresso Bar	(1)	★★★★
Cats Tango, Onetangi Beach	(1)	★★★★

Timaru

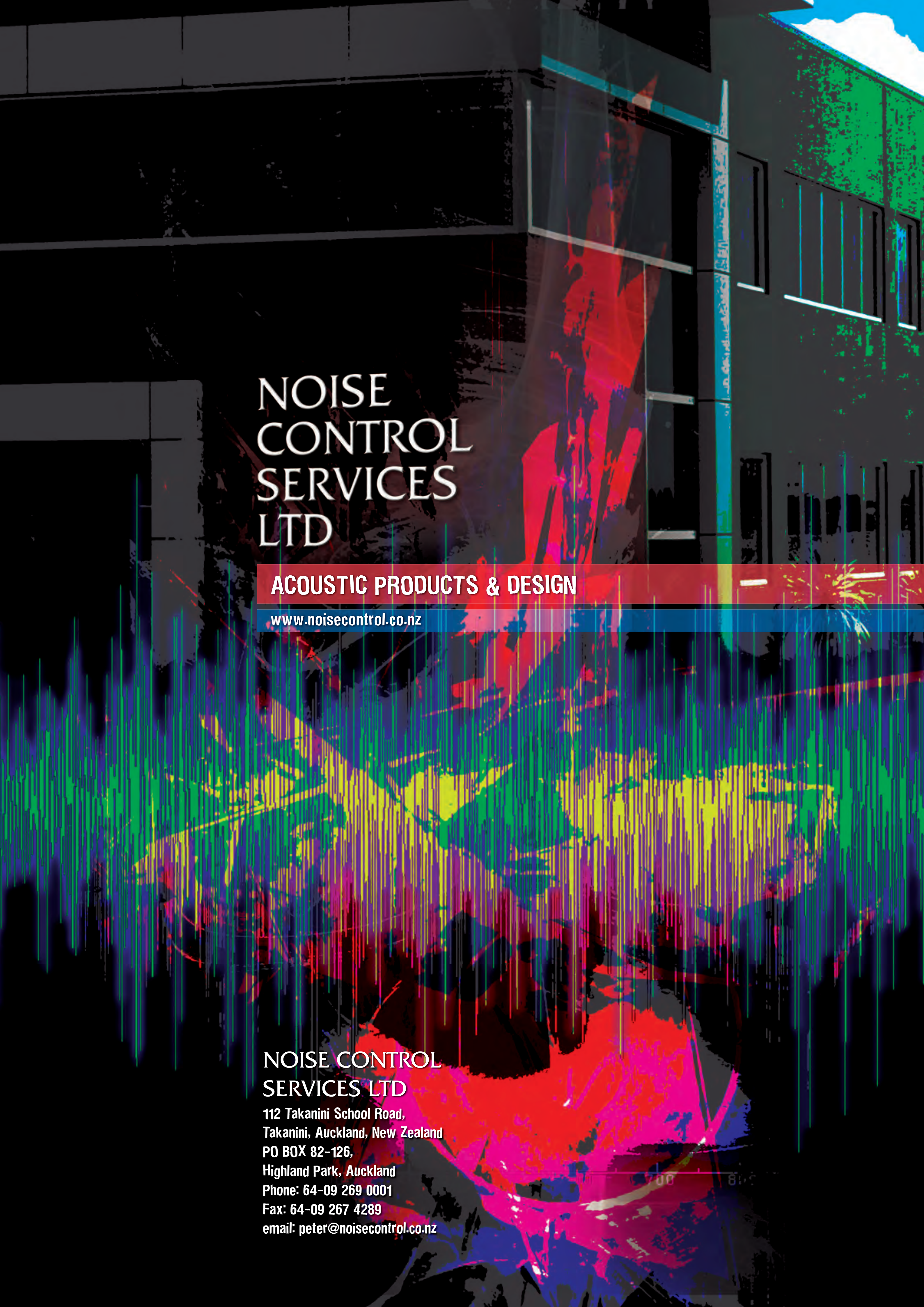
Fusion	(1)	★★★★★

Wanganui

3 Amigos	(1)	★★★½
Bollywood Star	(1)	★★★½
Cosmopolitan Club	(1)	★★★★
Liffiton Castle	(1)	★★½
RSA	(1)	★★★½
Stellar	(1)	★★★★½
Wanganui East Club	(1)	★★★★

Wellington

162 Café, Karori	(1)	★★★★★
180o, Paraparaumu Beach	(1)	★★
88, Tory Street	(35)	★★
Anise, Cuba Street	(1)	★★
Aranya's House	(1)	★★★★★
Arbitrageur	(2)	★★★
Arizona	(1)	★★
Astoria	(2)	★★★
Backbencher, Molesworth Street	(1)	★★★
Bordeaux Bakery, Thorndon Quay	(1)	★★
Buzz, Lower Hutt	(1)	★★½
Brewery Bar & Restaurant	(5)	★★★★
Carvery, Upper Hutt	(1)	★★★★★
Chow	(1)	★½
Cookies, Paraparumu Beach	(1)	★★★½
Cosa Nostra Italian Trattoria, Thorndon	(1)	★★★★
Gotham	(6)	★★★½
Great India, Manners Street	(2)	★★★★★
Habebie	(1)	★★
Harrisons Garden Centre, Peka Peka	(1)	★★★★
Hazel	(1)	★★
Katipo	(1)	★★★★★
Kilim, Petone	(4)	★★★★½
La Casa Pasta	(1)	★★★★½
Lattitude 41	(3)	★★★★
Legato	(1)	★★
Le Metropolitain	(1)	★★★★★
Loaded Hog	(5)	★★★★½
Manhatten, Oriental Bay	(1)	★★★★
Maria Pia's	(1)	★★★
Matterhorn	(1)	★★★
Mungavin Blues, Porirua	(1)	★★★★★
Olive	(1)	★★★★★
Original Thai, Island Bay	(1)	★★★★
Palace Café, Petone	(1)	★★½
Parade Café	(1)	★★
Pasha Café	(1)	★★★★
Penthouse Cinema Café	(2)	★★★½
Pod	(1)	★★½
Rose & Crown	(1)	★★★★★
Shed 5	(1)	★★
Siem Reap	(1)	★★
Speak Easy, Petone	(1)	★★
Speights Ale House	(1)	★★
Sports Bar Café	(1)	★★★★
Stanley Road	(1)	★★★
Stephan's Country Rest., Te Horo	(1)	★★★★★
Windmill Café & Bar, Brooklyn	(1)	★★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