Acoustics Australia

- Modelling ocean surface scattering
- Measuring hearing protector performance
- Speech recognition with hearing aids
- Dynamic properties of rail pads

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Vol 33 No 2

CONTENTS

August 2005

PAPERS

Cover illustration: "Railway to Nowhere": Heidi Hereth

From the President

Although I only write three of these messages a year, it seems to be only a few weeks after the last message is published that its time to pen a few more paragraphs. I think enthusiasm got the better of me for the first two, so in comparison, this article will be to the point. Acoustic anecdotes will have to wait until the next issue. Just in case you were concerned about embarrassing yourself, if I don't receive a story from each consultant I will resort to making them up and it is highly likely that my "stories" will be more embarrassing than anything you may have done yourself.

Later in the Journal you will read a note from the Editor encouraging us, as an industry, to start ranking the acoustic quality of restaurants we visit. For some time, I have enjoyed reading this section of the New Zealand Acoustics Journal and I hope our members make the effort to submit their own feedback. You never know, perhaps one day more restaurants may realise the importance of good acoustic design. The prize for the person submitting the most reviews is the pleasure of taking my wife and me out to dinner at the restaurant with the highest ranking.

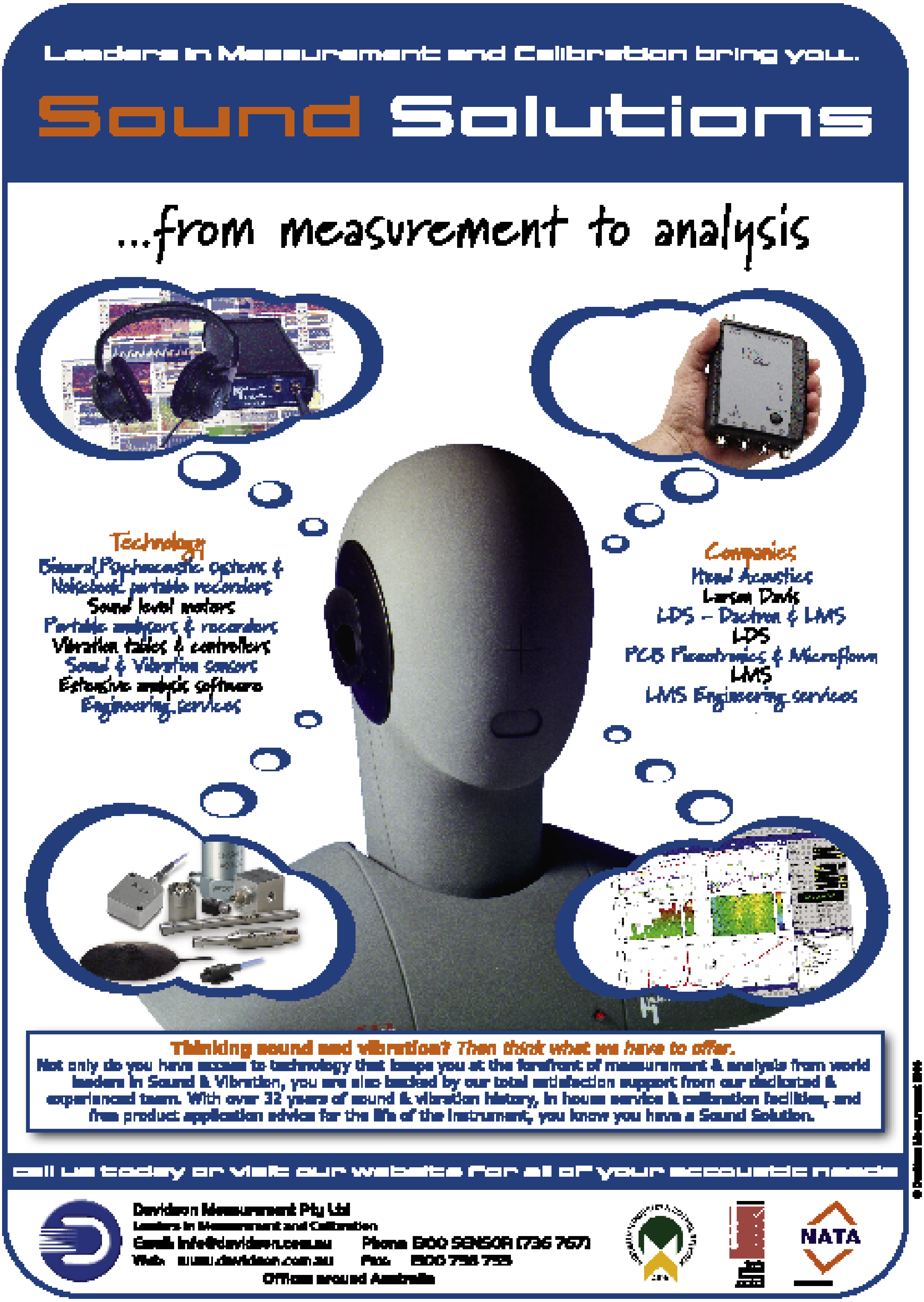
On a more serious note, the annual conference is almost upon us again and the date for early registrations is fast approaching. I believe there has been an excellent response to papers but any members who wish to present should refer to the website (www.acoustics.asn.au) immediately to ensure they can still join in the program. As a learned society whose "articles" rely on sharing knowledge, the annual conference is one of the few chances to tell the acoustics community what you have been doing and also to find out what's been keeping everybody else busy.

One issue which has been raised in recent times has been the overall quality of technical work and reports by consultants (irrespective of whether they are members of the Society or not). Although the debate has been in NSW, I'm sure it is relevant to the rest of Australia. Unfortunately it would appear that a surprisingly high number of reports from a wide range of consultants are not consistently of a high enough quality. I considered this remark related more to the style of reports and possibly confusing presentation. This would make it difficult for the reader to understand the assessment process even though the conclusions were probably accurate. However, it appears that there are too many reports which contain technical inaccuracies or assumptions which are technically unfounded because consultants are providing advice in areas outside their expertise.

In the last year, the Society introduced a register of "areas of competence" which was developed in order to allow organisations such as Councils to find members with experience suitable for certain types of work. Because of the size of our Society, this was designed to be self-regulating and relied on members abiding by our code of ethics.

Whilst not wanting to generate unnecessary conflict, I feel all members are duty bound, when reviewing work by others, to determine whether they consider it is of a suitable standard. I would like to suggest members contact their peers to provide constructive criticism. If done in a professional way, this approach will gradually improve the quality of all acoustics work, and thereby the overall image of the acoustics industry. If we can effectively police ourselves, there should never be a need for the courts to do the policing.

Before you start digging up old reports and phoning other members, I would welcome some suggestions of how to facilitate this improvement in both the technical accuracy and style of our reports (send to: president@acoustics.asn.au).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From the Editors

At nine pm, the restaurant is busy as the waiter passes around the dessert menu. "Cheeses, dessert, coffee, cognac?" You reflect, then someone says "Let's go somewhere we can talk." You emerge onto the footpath and relax: the busy city street is a more pleasant acoustic environment than the one you have just left. Someone in the party complains of a sore throat - it's not a cold, it's just vocal strain from talking loudly enough to be heard.

It seems to me that there is an unmet demand in Australia for restaurants where one can converse comfortably. Of course, conversation is not the primary business of restaurants: the success of fast food chains shows that, for many customers, the aim is to get in, get fed and get out rapidly. Australia follows the US in many trends and this is one.

However, the tradition of the leisurely meal with conversation is a long one and it also has its followers. For the wealthy, as usual, the problem can be avoided: quality restaurants often have good acoustic environments. Customers who are prepared to pay for elaborately prepared food expect comfort and some restaurateurs are prepared to provide an environment that is comfortable acoustically, as well as otherwise.

The problem lies between the two extremes of fast food and haute cuisine. Australia's cities have many restaurants that sell very good, moderately priced food, a fact that is important to and recognised by the tourist industry. But notice that I don't call them very good restaurants. Unfortunately, very many have high background noise and reverberation.

The restaurant trade is highly competitive and a number of pressures encourage poor acoustics. Hard surfaces that can be easily cleaned contribute to long reverberation times. Perhaps alcoves and sound absorbing surfaces are thought expensive. Perhaps they follow the apparent tactics of the fast food chains: an unpleasant environment (whether acoustics or decor) encourages people to eat quickly and to leave early, so that one may serve more diners in an evening.

Could this be what induces restaurateurs to provide muzak in a crowded restaurant? Under the din of voices, often one can hear just the bass line of music, whose higher frequencies are masked by the raised voices. Patrons want their companions to hear what they have to say, rather than the music chosen by the management, so they simply raise their voices. Few are interested in or even notice the bass line. Its presence is possibly vestigial: when the restaurant opened that day it had few patrons and someone put in a CD (on "repeat") in the hope of making the ambience seem busier. Later on, its only effect is to make everyone talk more loudly. In some restaurants, this leads to sound levels well over 80 dBA, with possible occupational health and safety concerns for workers. (Incidentally, many waiters dislike the sound levels and the choice of music, and are more than happy to turn it off. It's a satisfying experience: first the bass line disappears and then, over a minute or two, the sound level gradually falls.)

As you are reading Acoustics Australia, you will know a range of measures that could be taken to improve the acoustic environment, either retrospectively or as part of a competent design. Yet a glance at the interior of most restaurants suggests that it never occurred to the management to consult an acoustician.

If newspaper reviews and restaurant guides carried a separate rating of the acoustic ambience, perhaps more intending restaurateurs would think about acoustics as part of the design. Our sister society across the Tasman encourages members to rate restaurants acoustically and to submit CRAIs (Cafe & Restaurant Acoustic Index). The world has copied many NZ innovations (universal suffrage comes to mind) and this seems to be a good one. That rating form appears below, with permission. You can photocopy it and start rating your favourite restaurants now. We shall place a version of the form on the AAS web site soon.

Camp, S. (2005) "Cafe & Restaurant Acoustic Index", New Zealand Acoustics, 18, 38-39.

Café & Restaurant Acoustic Index Rating Sheet

Name of Café/Restaurant, including City: ....

Date of Visit (Month/Year): ....

Visit by: (Optional) ....

How many people at your table?: ....

Your Age Range:	<25	25-35	35-45	45-60	>60
	A lot				Not at all
1. How much noise do you like in cafés or restaurants?	1	2	3	4	5
2. How much did the level of noise adversely affect your enjoyment of the dining experience?	1	2	3	4	5
3. Did you experience any difficulties conversing with other people as a result of noise?	1	2	3	4	5
4. How much would your experience of noise in this venue adversely affect your decision to return?	1	2	3	4	5
	Almost empty				Full
5. How busy was the café at the time of your visit?	1	2	3	4	5
	Too Loud				None
6. At what level was music playing while you were eating?	1	2	3	4	5

Optional: add comments, including sound level if measured.

Send your completed form to the Editors, Acoustics Australia,
Physics, UNSW, Sydney 2052 Fax: 02 93856060 aaeds@phys.unsw.edu.au

A SIMPLE FUNCTION FOR MODELLING THREE-DIMENSIONAL SCATTERING STRENGTH FROM THE OCEAN SURFACE

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This paper was awarded the **2004 PRESIDENT'S PRIZE.**
This prize established in 1990 by the Australian Acoustical Society, is awarded to the best technical paper presented at the Australian Acoustical Society Conference by a member of the Society.

Both the rough air-sea interface and entrapped air bubbles due to wave breaking scatter sound in all directions and contribute to so-called reverberation in active sonar. There are monostatic sonar systems where the source and receiver are at the same position, bistatic sonar systems where the source and receiver are separated, and multistatic sonar systems involving multiple sources and receivers at different positions. In monostatic situations, reverberation is mainly due to backscattering. In bistatic and multistatic situations, forward and out-of-plane scattering are significant contributors. The empirical Chapman-Harris formula is often used to predict surface backscattering strength in monostatic sonar. To better predict reverberation from the sea surface in bistatic or multistatic sonar, a three-dimensional scattering formula that includes a forward scattering lobe will be desirable. Following earlier work, in this paper the separable form of backscattering models are extended by including an expression of forward scattering lobe obtained under the Kirchhoff approximation, taking into account shadowing effects. Comparison with another more sophisticated model shows that shadowing corrections are important at low grazing angles. The formula obtained here is simple and includes scattering effects from both the roughness of the sea surfaces and the sub-surface bubbles. It may be useful for modelling multistatic surface reverberations.

INTRODUCTION

Wind generates rough sea surfaces. Wave breaking under strong winds also produces entrained air-bubbles below the sea surface. Both roughness of the sea surfaces and the trapped air bubbles scatter sound from sonar and lead to surface reverberation.

Scattering occurs out-of-plane as well as within the vertical plane containing the source and receiver. Modelling active sonar reverberation from the sea surface requires assessment of the surface scattering strength. For monostatic sonar where the transmitter and receiver are co-located, the reverberation is mainly due to backscattering. For multistatic sonar where multiple transmitters and receivers are spatially distributed, there are additional contributions to the received reverberation from forward and out-of-plane scattering.

The empirical Chapman-Harris formula [1] of surface scattering strength is often used for modelling monostatic sonar reverberation. To more accurately predict reverberation in multistatic active sonar systems, formulas for three-dimensional scattering are desirable. Gauss et al (2000, 2002) [2,3] presented a semi-empirical surface scattering strength (SESSS) model that combines incoherent scattering from the rough air-sea interface with scattering from the bubble clouds.

This work follows the approach in Ellis and Crowe (1991) [4] and Caruthers and Novarini (1993) [5] where backscattering models are extended by using the so-called separable approximation, and then combined with a term obtained under the Kirchhoff approximation to obtain a three-dimensional scattering function. In this paper we use the empirical Chapman-Harris formula [1] as our backscattering model. We further modify the expression obtained using the shadowing factor in Torrance and Sparrow (1967) [6] and compare the results with those of Gauss et al (2000,2002) [2,3].

Due to the empirical nature of the Chapman-Harris backscattering model, the expression obtained here includes the effects of both the roughness of the sea surfaces and the sub-surface bubbles. The formula is simple to use in multistatic active sonar performance models.

CHAPMAN-HARRIS BACKSCATTERING MODEL

In underwater acoustics, the ability to scatter sound from extended objects such as the sea surface is often characterized by a scattering strength, which is defined as the ratio in decibels of the intensity of the sound scattered by a unit surface area (normally chosen 1 m^2), referred to a unit distance (normally 1 m), to the incident plane wave intensity. Based on measurements using explosives, Chapman-Harris (1962)[1] give the following empirical fit to measured surface backscattering strength in dB for wind speeds up to 15 m/s and frequencies from 400 to 6400 Hz,

$$S = 3.3\,\beta \log_{10}(\theta/30) - 42.4 \log_{10}\beta + 2.6, \quad \text{dB} \tag{1}$$
$$\text{for} \qquad \beta = 107\,(U f^{1/3})^{-0.58},$$

where θ is grazing angle in degrees, U is wind speed in m/s, and f is frequency in Hz.

For later use, we re-write the Chapman-Harris formula in linear units,

$$b(\theta) = 10^{0.26}\,\beta^{-4.24}(\theta/30)^{0.33\beta}, \tag{2}$$

where b(θ) is referred to as the backscattering coefficient and is related to the surface scattering strength by $S = 10\log_{10}[b(\theta)]$.

THE THREE DIMENSIONAL SURFACE SCATTERING FUNCTION

The Model

Following Ellis and Crowe (1991) [4] and Caruthers and Novarini (1993) [5], we extend the Chapman-Harris backscattering formula b(θ) of Eq. (2) to a three-dimensional scattering function by the following formula,

$$m(\theta_i,\theta_s,\phi)=[b(\theta_i)b(\theta_s)]^{1/2}+D(\theta_i,\theta_s)F(\Omega) \tag{3}$$

and

$$F(\Omega)=(8\pi\delta^2)^{-1}(1+\Omega)^2\exp\left(-\frac{\Omega}{2\delta^2}\right), \tag{4}$$

where $m(\theta_i, \theta_s, \phi)$ is the three-dimensional scattering coefficient, and θ_i,θ_s, are the incident and scattered grazing angles.

The parameter δ is the root-mean-squared slope of the rough sea surface, which can be approximated by the empirical expression of Cox and Munk (1954) [7],

$$\delta^2=0.003+5.12\times10^{-3}U\pm0.004. \tag{5}$$

The parameter Ω is a measure of the deflection of the scattering angle from the specular angle,

$$\Omega=\frac{\cos^2\theta_i+\cos^2\theta_s-2\cos\theta_i\cos\theta_s\cos\phi}{(\sin\theta_i+\sin\theta_s)^2} \tag{6}$$

where ϕ is the scattered azimuthal angle relative to the incident plane.

The first term in Eq. (3) represents so-called separable approximation to the backscattering model $b(\theta)$, the term $F(\Omega)$ represents a forward scattering lobe in the high frequency limit from Gaussian-distributed facets under Kirchhoff approximation (also called the tangent plane approximation)[8,9], and the function $D(\theta_i, \theta_s)$ accounts for shadowing effects on the forward scattering lobe and is discussed below.

The Shadowing Factor

Adjacent facets may obstruct sound incident upon a given facet or the sound reflected by it. This masking and shadowing effect is especially important at low grazing angles. To account for this effect, we adopt the approximate shadowing factor in Torrance and Sparrow (1967) [6],

$$D(\theta_i,\theta_s)=\min\left(1,\frac{2\cos\alpha\sin\theta_s}{\cos\theta_i^{'}},\frac{2\cos\alpha\sin\theta_i}{\cos\theta_i^{'}}\right), \tag{7}$$

where

$$\theta_i^{'}=(1/2)\cos^{-1}(\sin\theta_i\sin\theta_s-\cos\theta_i\cos\theta_s\cos\phi), \tag{8}$$

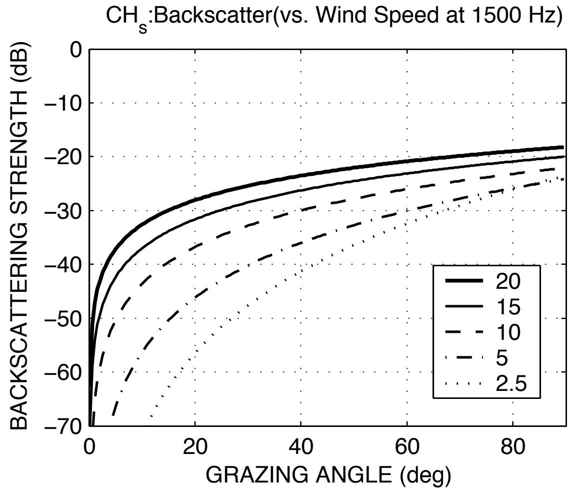
and

$$\cos\alpha=\sin\theta_i\cos\theta_i^{'}+\cos\theta_i\sin\theta_i^{'}\cos\gamma,$$
$$\gamma=(\sin^{-1}(\cos\theta_s\sin\phi/\sin2\theta_i^{'})). \tag{9}$$

The shadowing factor in Eq. (7) is derived using the assumption that each facet is one side of a V-groove cavity, and sound rays only reflect once (i.e. multiple scattering is ignored).

For backscattering, $\theta_s = \theta_i$, $\phi = \pi$, and the shadowing factor becomes unity.

It is worth pointing out that the empirical nature of the



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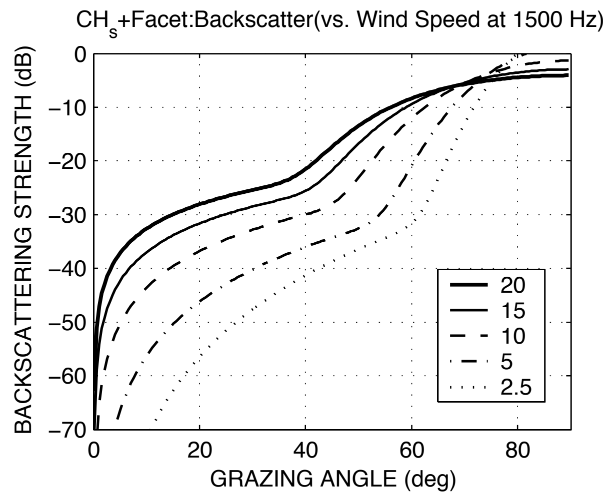

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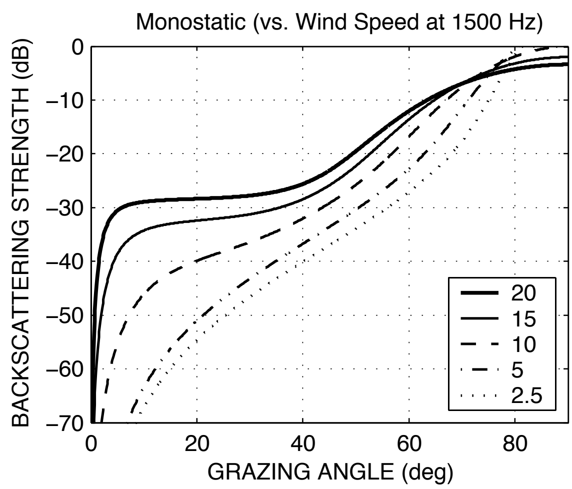
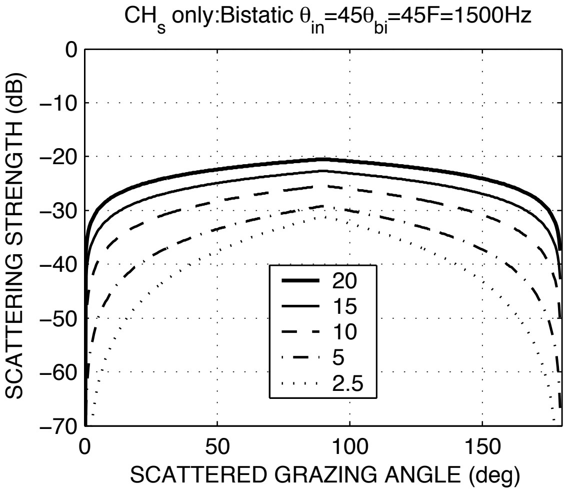


(c)

Fig. 1. Surface backscattering strength at 1500 Hz for wind speeds from 2.5 m/s to 20 m/s. (a) Chapman-Harris model (b) Chapman-Harris model plus Kirchhoff facet scattering, (c) SESSS model of Gauss et al [2,3].



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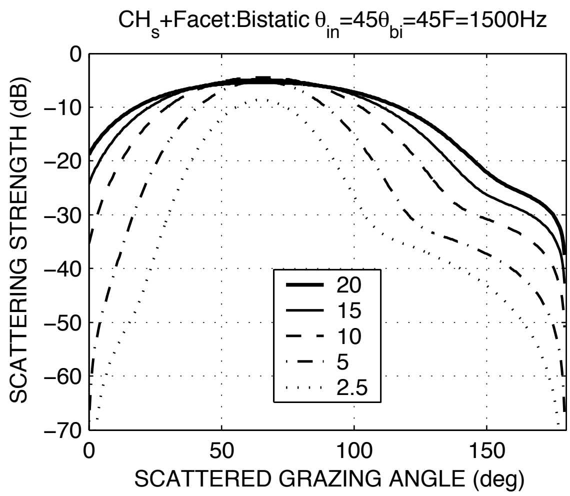

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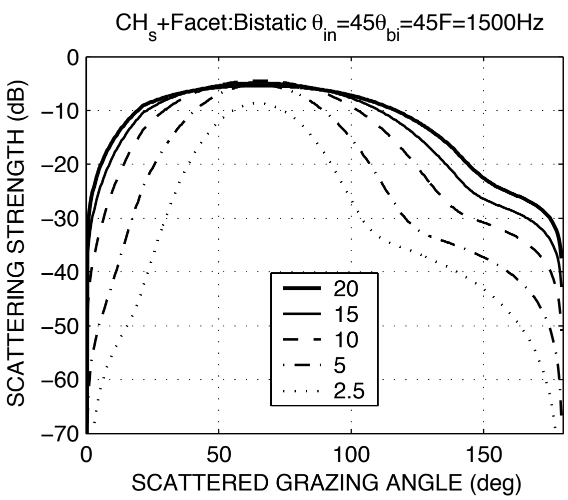

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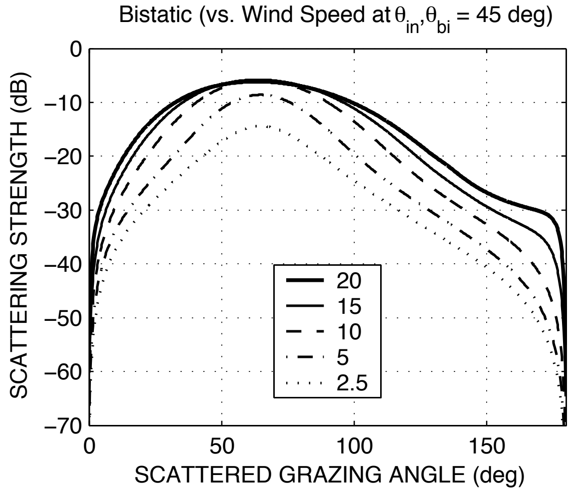

(d)

Fig. 2. Bistatic surface scattering strength versus scattered grazing angle. (a) Separable approximations of Chapman-Harris model (b) Separable approximations of Chapman-Harris model plus Kirchhoff facet scattering; (c) Separable approximations of Chapman-Harris model plus Kirchhoff facet scattering with shadowing effects; (d) SESSS model of Gauss et al [2,3].

Chapman-Harris backscattering model means that the first term in Eq.(3) contains scattering contributions from both the roughness of the sea surface and the sub-surface air bubbles, with azimuthally independent out-of-plane scattering. The second term in Eq.(3) represents scattering contributions from the roughness of the sea surface near the specular forward direction with azimuthally dependent out-of-plane scattering. The overall model in Eq.(3) is a simple function for modelling three-dimensional scattering strength due to roughness of the sea surface and sub-surface air bubbles.

RESULTS

To assess the accuracy of the present model, we compare its results with those from the Semi-Empirical Surface Scattering Strength (SESSS) model [2,3] for two representative cases. The first case is for backscattering and the second case is for a particular configuration of three-dimensional scattering.

Backscattering strength

Figure 1 shows results of comparison of the surface backscattering strength for wind speeds from 2.5 m/s to 20 m/s at an acoustic frequency of 1500 Hz. Gauss et al [2,3] show that at low grazing angles, scattering from sub-surface bubble-clouds dominates when wave breaking is significant. At high grazing angles, scattering is mainly due to ocean surface roughness.

We can see that the Chapman-Harris model plus the diffuse scattering lobe is closer to the results from the SESSS model. However, there are appreciable differences between the two.

We note that the parameters in the semi-empirical SESSS model and the original Chapman-Harris model are fitted using different data sets. It may be possible to obtain better agreements between the present model and the SESSS model if the empirical parameters of the original Chapman-Harris model were re-fitted using the same data set as that used for the SESSS model.

Bistatic scattering strength

Figure 2 shows an example of comparison of the bistatic surface scattering strength for wind speeds from 2.5 m/s to 20 m/s at an acoustic frequency of 1500 Hz. The particular case shown here is for an incident grazing angle of 45 degrees and an azimuthal angle of also 45 degrees. We can see that the shadowing factor improved the agreement at low grazing angles between the present model and the SESSS model.

It is of interest to note that, similar to the present model, the SESSS model is a summation of scattering strengths of azimuthally independent scattering due to air bubbles and azimuthally dependent scattering due to roughness of the sea surface.

SUMMARY

Following earlier work by Ellis and Crowe (1991) [4] and Caruthers and Novarini (1993) [5], a simple expression for modelling three dimensional scattering strength from ocean surfaces was given and compared with another semi-empirical model. The expression combines separable forms of the Chapman-Harris backscattering model with a forward scattering lobe given by a high frequency Kirchhoff approximation. Geometrical shadowing effects of the facets are accounted for by using a separate loss factor.

Three-dimensional scattering data from carefully controlled measurements are needed to ascertain the accuracy of the expression.

The simple expression includes the effects of both the rough air-sea interface and sub-surface bubbles. It may be useful as a sub-model for modelling reverberation in multistatic sonar.

Future work may include improving the shadowing factor [10] and considering other backscattering models such as those in Ogden and Erskine [11,12,13].

ACKNOWLEDGEMENTS

Dr. Roger Gauss and his colleagues at Naval Research Laboratory, Washington DC provided the code of the SESSS model, which was used for producing the results shown in Fig.1(c) and Fig.2(d) in this paper.

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A VARIATION TO THE SOUND LEVEL CONVERSION MEASURE OF HEARING PROTECTOR PERFORMANCE

Warwick Williams

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Abstract This work looks at a variation in the method of calculating the single number rating of hearing protector attenuation performance, the SLC_{80}. The resulting figure has a slight variation from the current method of calculation but comparison with 111 devices that had recently been tested shows that in practice this difference is minimal. The advantage of the variation in the method is that the uncertainty in attenuation performance is reduced to one standard deviation replacing the conventional seven standard deviations. This makes for easier error analysis and future statistical analysis of the relative performance of different devices.

1. INTRODUCTION

For many years in both Australia and New Zealand the Sound Level Conversion (SLC) method (Botsford: 1973) and in particular the SLC_{80} method (Waugh: 1973, 1976) has been used to estimate the effective at ear noise level of individuals who are wearing hearing protectors in noisy situations. Currently the SLC_{80} figure is also the basis of the simplified classification system (Williams: 1999) for the specification of hearing protectors as detailed in combined *Australian/New Zealand Standard AS/NZS 1269.3: 2005 Occupational noise management Part 3 – Hearing protector program*.

The SLC_{80} is more closely defined in *AS/NZS 1270: 2002* and represents the minimum attenuation provided to approximately 80% (strictly 84%) of the users of a hearing protector when wearing the protector appropriately. The intention of the SLC_{80} is to provide a realistic figure for the attenuation of a hearing protector when used in a real life situation. It is intended to provide neither an overestimate nor under estimate of attenuation performance.

The SLC_{80} is one of a number of single number rating systems currently in use around the world for specifying the attenuation of a hearing protector. It is very similar in character to the North American NRR (Berger: 1986, p 329) and European SNR (EN 458: 1993). Being single number rating systems based on the work by Botsford (1973) the discussions that are presented in this paper in relation to the SLC_{80} can apply to both NRR and SNR.

2. METHOD

The method of calculating SLC_{80} is based on the experimental procedure detailed in *AS/NZS 1270: 2002*. This involves a subject-fit test whereby the occluded and un-occluded hearing thresholds of the volunteer test subjects are measured. This is done at seven octave band centre frequencies by exposure to one-third octave band width, filtered pink noise. The attenuation is calculated from the occluded – un-occluded difference in hearing threshold level. In the case of ear muffs there are a minimum of 16 test subjects required while for ear plugs the number is 20. For the SLC_{80} calculation at each octave band a mean attenuation and standard deviation is determined. *(Note: For the requirements of AS/NZS 1270: 2002 a calculation of the SLC of a hearing protector is not necessary)*

From a predefined reference spectrum[1], the mean attenuation of the device at each octave band is subtracted in order to get the attenuated spectrum under the device. The difference between the overall value of the reference spectrum and the attenuated spectrum provides the single figure performance or SLC of the device. This is summarised in the formula:-

$$SLC = 100 - 10 \log_{10} \left(\textstyle\sum_{fj} 10^{0.1(Rfj - Mfj)}\right), \qquad (1)$$

where R_{fj} = reference octave band spectral levels; (71, 81, 89, 93, 95, 93 & 86 dB)
M_{fj} = mean attenuated level at f_j Hz; and
f_j = octave band centre frequencies (*125, 250, 500, 1k, 2k, 4k & 8k Hz)*.

This value is the SLC of the device experienced by the average user and exceeded by 50% of the users. This value could be thought of as the average SLC or the SLC_{50}. In order to calculate the SLC_{80} instead of using the mean attenuated level the mean minus one standard deviation attenuated level is employed. So

$$SLC_{80} = 100 - 10 \log_{10} \left(\textstyle\sum_{fj} 10^{0.1(Rfj - M'fj)}\right), \qquad (2)$$

where M'_{fj} is now the mean attenuated level minus one standard deviation at octave band f_j Hz. Strictly speaking in statistical terms we should refer to this as the SLC_{84}, however, for simplicity SLC_{80} is used.

This method of calculating the SLC_{80} has served well for many years. However, it does suffer from one serious drawback in that it contains seven standard deviations from

1. This spectrum is 'defined' in AS/NZS 1270 as being 100 dB overall with components of 71, 81, 89, 93, 95, 93 and 86 dB at Octave Band centre frequencies of 125, 250, 500, 1k, 2k, 4k and 8k Hz respectively

Table 1 Attenuation test results for a typical set of ear muffs

Subject	125 Hz	250 Hz	500 Hz	1k Hz	2k Hz	4k Hz	8k Hz	*i*SLC	
	Octave Band centre frequency (Hz)								
S1	15	18	35	37	35	45	46	33.9	
S2	2	10	22	35	35	25	31	24.7	
S3	11	25	33	41	39	36	41	35.4	
S4	13	20	28	32	35	37	38	32.3	
S5	8	15	30	34	35	38	32	30.4	
S6	11	23	27	34	35	33	41	32.2	
S7	4	16	22	23	27	30	30	25.0	
S8	20	20	26	27	25	29	36	27.0	
S9	-1	13	18	32	23	33	38	22.8	
S10	8	15	25	38	33	35	32	29.5	
S11	13	18	28	38	31	39	37	31.6	
S12	18	24	31	35	40	37	28	34.8	
S13	8	18	33	33	31	33	38	30.5	
S14	12	13	18	32	33	37	22	25.9	
S15	10	21	31	33	34	34	43	32.2	
S16	2	3	13	23	25	24	21	18.5	
Mean	**9.6**	**17.0**	**26.3**	**32.9**	**32.3**	**34.1**	**34.6**	29.2	***mi*SLC**
SD	**5.8**	**5.6**	**6.2**	**5.0**	**5.0**	**5.3**	**7.1**	4.7	***SD***
Mean - SD	**3.8**	**11.4**	**20.0**	**27.9**	**27.3**	**28.8**	**27.5**	**24.5**	***mi*SLC$_{80}$**

SLC	30.2
SLC$_{80}$	24.6

the seven octave band attenuations and any error analysis of the result must use the seven standard deviations. The seven octave band attenuations are required for the Octave Band method for hearing protector selection.

An alternative procedure is to calculate an individual SLC (*i*SLC) for each test subject using equation (1) by substituting the individual attenuated level at each octave band. An average of the *i*SLCs then produces a mean *i*SLC (*mi*SLC). By subtraction of the standard deviation we have an *mi*SLC$_{80}$. The total error for *mi*SLC$_{80}$ is calculated using the single standard deviation.

Since the introduction of the current method of attenuation testing in *AS/NZS 1270:2002* in 2002 there has been a total of 111 devices (98 ear muffs and 13 ear plugs) tested at NAL that were suitable for inclusion in this analysis. Two methods of analysis were applied to these 111 devices for comparison.

3. RESULTS

Table 1 shows the attenuation results and calculations for SLC$_{80}$ and *mi*SLC$_{80}$ as an example for one particular set of ear muffs.

For the standard SLC$_{80}$ process the results are calculated vertically for mean attenuations and standard deviations followed by a horizontal calculation for the final SLC$_{80}$, while an initial horizontal calculation of an individual SLC (*i*SLC) is carried out followed by a vertical calculation of the *mi*SLC$_{80}$.

By way of example the calculation for the SLC$_{80}$ and miSLC$_{80}$ can be followed from *Table 2*.

Using equation (2) we get,

$$SLC_{80} = 100 - 10\log_{10}(10^{0.1(71-3.8)} + 10^{0.1(81-11.4)} + \ldots + 10^{0.1(93-28.8)} + 10^{0.1(86-27.5)}),$$

$$SLC_{80} = 100 - 10\log_{10}(10^{6.72} + 10^{6.96} + 10^{6.90} + 10^{6.51} + 10^{6.77} + 10^{6.42} + 10^{5.85}),$$

thus $SLC_{80} =$ 24.6 dB.

***Note**: SLC$_{80}$ is normally rounded to the nearest integer. However, in this case it has been left unrounded for analysis and demonstration purposes*

For the *i*SLC value equation (1) is used by substituting the attenuated spectrum level at each octave band for each test subject. For example, for the first subject the *i*SLC calculation would be,

$$iSLC = 100 - 10\log_{10}(10^{0.1(71-15)} + 10^{0.1(81-18)} + 10^{0.1(89-35)} + \ldots + 10^{0.1(93-45)} + 10^{0.1(86-46)}),$$

Table 2 Example of the calculation of SLC$_{80}$ from data supplied from Table 1

Octave band centre frequency (Hz)	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
Reference band level (dB) (equivalent to 100 dB)	71	81	89	93	95	93	86
Mean – SD attenuation of protector (dB)	3.8	11.4	20.0	27.9	27.3	28.8	27.5
Attenuated spectrum level (dB)	67.2	69.6	69.0	65.1	67.7	64.2	58.5

iSLC = 100 – 10 $\log_{10}$ ($10^{5.6} + 10^{6.3} + 10^{5.4} + \ldots$
+ $10^{4.8} + 10^{4.0}$),

or iSLC = 33.9 dB

The mean of the iSLCs are calculated (miSLC = 29.2 dB) and the standard deviation (4.7 dB) subtracted to result in an $mi\text{SLC}_{80}$ of 24.5 dB.

As demonstrated in *Table 1* the SLC_{80} and the $mi\text{SLC}_{80}$ are very close in value and, in general, this does seem to be the case. Mathematically the two processes are not the same and should not necessarily conclude with the same result. When the results of the SLC_{80} and the $mi\text{SLC}_{80}$ for a mixture of the 111 devices (plugs and muffs) tested are compared there is high correlation (r^2 = .99) as shown in *Figure 1*. The two points {(13.8, 16.1) & (14.4, 16.6)} that appear to be well above the possible line of best fit are corded and un-corded versions of a new design of ear plug. This poor performance could be explained through the relatively large standard deviation for both devices of 7.7 and 7.3 dB respectively compared to their $mi\text{SLC}_{80}$ values of 17 and 16 dB.

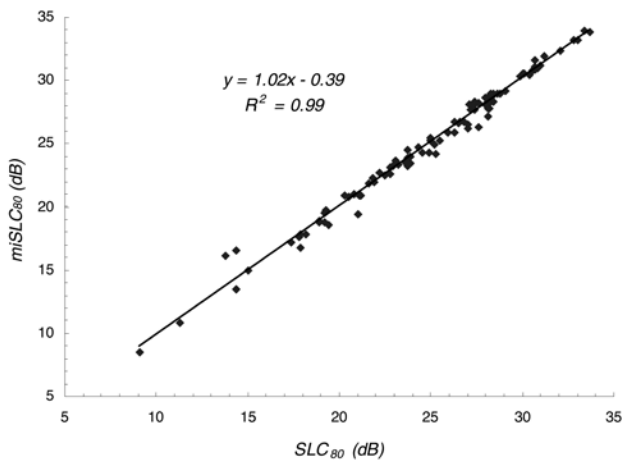

Figure 1: The mean individual SLC_{80} (miSLC_{80}) versus standard SLC_{80} demonstrating the close relationship between the two figures

As a further comparison of results *Figure 2* shows the relation between SLC and the miSLC. The correlation shows that the SLC tends to be, on average, about 1 dB greater than the miSLC.

The summary of results of the overall statistical analysis is presented in *Table 3*. This gives, for the indicated group of devices, the average SLC_{80} as calculated by the *Australian/ New Zealand Standard* method; the average miSLC followed by the average standard deviation of the miSLC for the group; the average $mi\text{SLC}_{80}$, calculated by subtracting the standard deviation from the miSLC.

4. DISCUSSION

The original impetus in the method of calculating the SLC_{80} utilising the mean attenuations arose during a time when computers and calculators had a much more limited capability to carry out complex processes. It was an historical process. With the use of contemporary computing capabilities, calculation

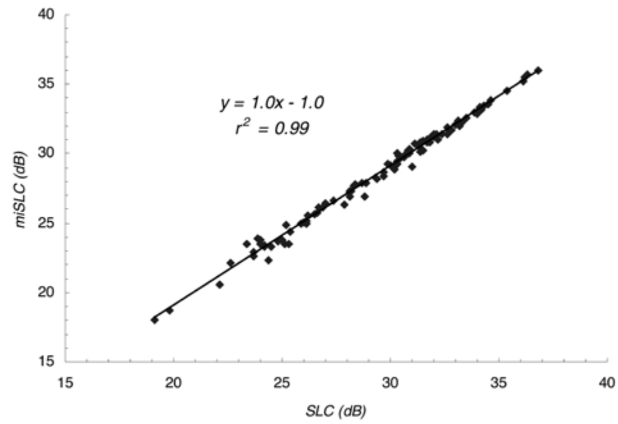

Figure 2: The relationship between miSLC and SCL.
On average SLC is 1 dB greater than miSLC

Table 3
Summary of test results for ear plugs, ear muffs and all devices for the main parameters discussed

Device(s)	*Average SLC_{80} (dB)*	*Average miSLC (dB)*	*Average SD (dB)*	*Average $miSLC_{80}$ (dB)*
ear plugs (N = 13)	18.9	25.2	6.2	19.0
ear muffs (N = 98)	25.9	29.2	3.3	25.9
all devices plugs & muffs (N = 111)	25.0	28.7	3.6	25.1

using the traditional method or the suggested variation is easily achieved. The advantage of the new variation comes with the production of a single standard deviation. For an error analysis and a simple relationship between the miSLC and the $mi\text{SLC}_{80}$ the advantage of the existence of one standard deviation is obvious.

Figure 1 shows a comparison between SLC_{80} and $mi\text{SLC}_{80}$ and presents an argument that the two values are comparable on a practical basis. *Figure 2* shows the consistent relationship between miSLC and SLC with the latter usually being a little larger than the former, in the order of one decibel.

It is now time to look at reasons why it may be of advantage to use this method of $mi\text{SLC}_{80}$ calculation in preference to the traditional method. Using the same 111 hearing protectors from above that demonstrated the correlation between old and new methods of calculation of the performance parameter, it is constructive to plot the standard deviation of the hearing protector against the attenuation performance. This is displayed in *Figure 3*.

From *Figure 3* we can see that there is a strong negative correlation displayed between hearing protector performance and standard deviation, something that with the current method of calculation would be difficult to display quite so clearly. The relation between the two values can be expressed as,

$$mi\text{SLC} = 33.30 - 1.26\ \text{SD},\ (r^2 = 0.36).$$

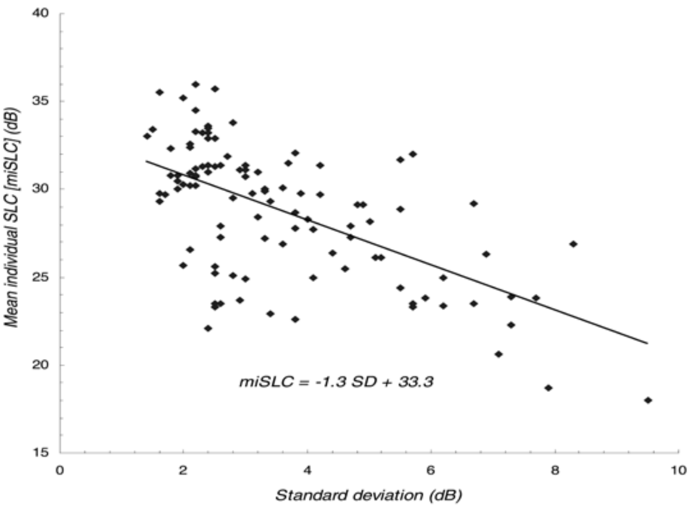

Figure 3: A plot of hearing protector performance calculated by the suggested variation in the method, the mean individual SLC (miSLC), versus the standard deviation for all tested hearing protectors showing a strong negative correlation

This indicates that there is a close correlation between the attenuation performance of the device and the standard deviation. Ideally the standard deviation should be independent of the device attenuation and vice-versa.

Previously the presentation of such data would have been difficult as in the case of SLC_{80} for example there would be seven standard deviations involved from each of the seven octave bands. One way could be to use an average of the individual octave band standard deviations but the relation between this average and the standard deviation of the overall attenuation performance parameter is not as regular as would be desired. The relation between the average octave band standard deviation and the single standard deviation is illustrated in *Figure 4*.

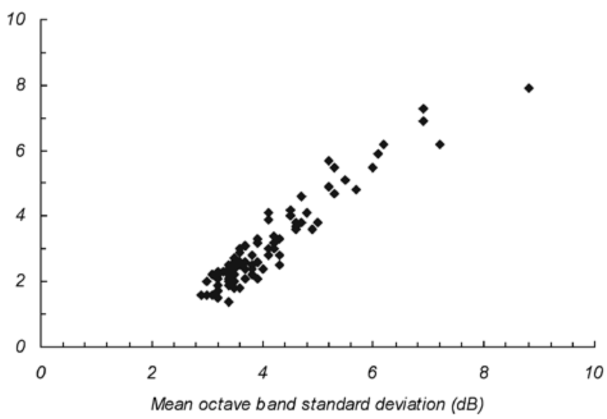

Figure 4: The relationship between the mean of the individual octave band standard deviations and the standard deviation of the overall attenuation performance.

The presentation of test results as per *Figure 3* can allow us to look at hearing protectors and hearing protector use in a different light. For example, it is clear that as the value of the rating of the hearing protector decreases there is a corresponding increase in its standard deviation. This means that for users of hearing protectors with low attenuation there is a much broader spread in performance compared to users of high attenuation devices. Hence those individuals who use hearing protectors in low noise areas, where less attenuation is required, will experience a wider range of attenuation. Users who experience too much attenuation may find this over-protection annoying and decrease their hearing protector use. This is an undesirable outcome.

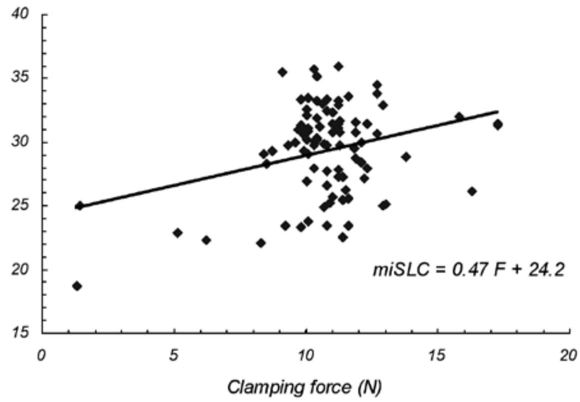

Figure 5: The relationship between clamping force and attenuation

A further relationship that can be displayed is that between the clamping force and attenuation (excludes ear plug data). These results (*Figure 5*) show a general tendency toward an increase in attenuation with increasing clamping force. Intuitively this would seem to be a reasonable result. However, there is a large cluster of devices that have a clamping force in the range of 10 to 13 Newtons with a spread of attenuation values from 22 to 31 dB, indicating an influence of factors other than clamping force alone.

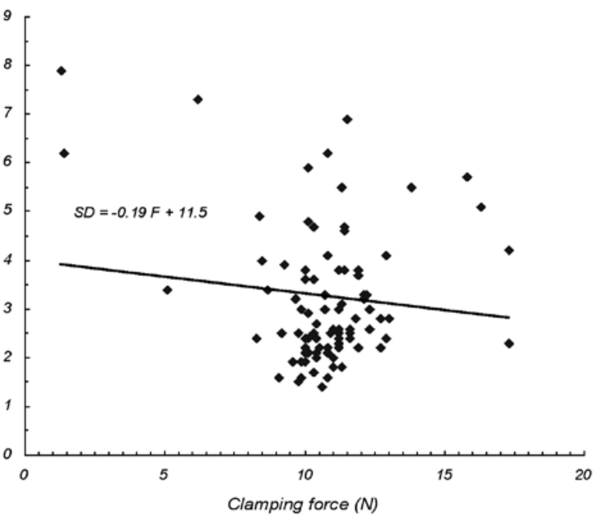

Figure 6: The relation between clamping force and the overall standard deviation of the attenuation of the device

Another relationship is that between clamping force and the standard deviation for the overall attenuation figure (*Figure 6*). This shows that there is an overall trend for the standard deviation to decrease as the clamping force increases, again a reasonably intuitive result, but the wide scatter of results shows that there is obviously a dependency on other factors.

5. CONCLUSION

The suggested variation in the analysis of hearing protector test data provides a significant advantage when examining the general performance of hearing protectors and when comparing individual performance. The use of a single standard deviation also simplifies any error calculation process that may be required for the presentation of the reliability and validity of attenuation test data.

Some examples of the advantage of using the suggested variation in analysis have been illustrated with brief discussions. Detailed discussion of these points is a topic for further research.

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RELATIONSHIP BETWEEN SPEECH RECOGNITION AND SELF-REPORT MEASURES

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ABSTRACT The performance of a prototype digital high-power hearing instrument was evaluated using tests of speech understanding in quiet and a questionnaire. The subjects were 26 adults with moderate-to-profound sensorineural hearing loss, most of whom were experienced hearing aid users. There was no significant difference between the group mean scores on monosyllabic word tests conducted in quiet for the prototype device versus the subjects' own hearing aids. However, responses to the questionnaire showed that 85% of the subjects preferred the prototype device to their own hearing aid(s). Although there was a positive correlation between the questionnaire results and the speech recognition score differences, overall there was a stronger tendency for subjects to prefer the prototype device than could be explained by their speech test results alone.

I. INTRODUCTION

Within the last decade, a range of fully digital hearing aids has become available on the commercial marketplace for clinical use. Digital technology has the advantage over its analog counterpart by being able to perform complex operations while consuming little power [4]. These instruments are capable of implementing a range of signal processing algorithms designed to improve speech intelligibility, listening comfort, and sound quality for people with a hearing impairment.

There are a wide variety of digital hearing aid products for the clinician to choose from. There is some evidence to suggest that despite implementing different processing techniques, digital hearing aids provide similar performance outcomes. For example, a study carried out by Harnack Knebel and Bentler [6] compared real and perceived benefit for two commercial digital hearing-aids. In that study, no significant differences were found between the hearing aids with objective testing of speech recognition.

In addition, clinicians should be aware of a general tendency for new devices to be preferred over existing technology for reasons other than objectively measurable performance improvements. Bentler et al. [1] compared users' preferences for identical hearing-aids after they had been labelled 'analog' or 'digital' at random, and described accordingly to the subjects. Strong preferences were observed for the devices labelled 'digital,' even when they were, in fact, analog hearing-aids.

The aim of the experiments reported below was to examine the relationship between objective measures of speech intelligibility in quiet listening conditions, and subjective measures obtained by means of a questionnaire when evaluating a prototype digital hearing-aid that was designed specifically for use by people with a moderately severe-to-profound hearing loss.

II. METHODS

A. The Prototype BTE Device

The test instrument evaluated in the trial was a prototype behind-the-ear (BTE) digital power instrument claimed to be suitable for people with hearing threshold levels that exceed 50 dB HL at all frequencies. It was omnidirectional and specified to have a maximum output and a maximum gain of approximately 140 dB SPL and 80 dB, respectively (measured in an ear simulator). The gain could be adjusted separately in five partially-overlapping frequency bands and covered a frequency range of 100-4800 Hz. Three main signal processing schemes could be selected during programming to suit the hearing characteristics of the user. These included a programmable amplitude compression scheme and two alternative schemes that provided essentially linear amplification but had slightly different output limiting techniques. The prototype aid did not have any unique signal processing features when compared to other digital aids. In appearance the test hearing aid resembled the patients' own aids. Subjects were provided with some information about the prototype aid as well as being told it was a test instrument.

It was possible to program several different sets of signal processing parameters into the test instrument when it was fitted to each user. These programs could be selected manually by the user to suit the ambient listening conditions. In the experiments described below, the impact on the users' perceptual performance of using only one of these programs was evaluated. Program 1 was selected as it was intended to provide appropriate amplification for most listening situations based on measurements of the hearing characteristics of the aid user.

B. Subjects

Twenty-six adults, comprising 11 women and 15 men, volunteered to participate in the trial. Relevant information about them is provided in Table 1. Their hearing threshold levels, measured conventionally under headphones, are listed in Table 2. The majority of subjects had moderate to severe hearing losses suitable for aiding by the test instrument. However, some subjects who had relatively good low-frequency hearing thresholds were included in the study because their losses were severe or profound from 1 kHz upwards.

For all subjects, hearing losses were assumed to have primarily a sensorineural origin, based on the results of hearing thresholds measured by bone conduction. In one subject (S9), an earlier assessment had indicated a retrocochlear lesion. Seven of the subjects had one unaidable ear where hearing

Table 1. Relevant information about the subjects who participated in the study, and their hearing-aids

Subject	*Age*	*Sex*	*Probable etiology of hearing loss*	*Type of own hearing-aids*	*Features of own hearing-aids*	*Ears fitted with own hearing-aids*	*Processing strategy of test instrument*	*Ears fitted with test instruments*
S1	26	F	Congenital	Widex L8	Digitally programmable	Binaural	Linear	Binaural
S2	72	F	Unknown	Bernafon RB15	Digitally programmable	Left	Linear	Left
S3	48	F	Congenital	Phonak PPCLC	Analog	Binaural	Linear	Binaural
S5	27	M	Congenital	Phonak Novaforte E4	Digitally programmable	Binaural	Linear	Binaural
S6	82	M	Industrial noise exposure	Widex Diva	Fully automatic digital aid with adaptive beamformer and compression	Binaural	Compression	Binaural
S7	42	M	Otosclerosis	Phonak PPSC	Analog	Left	Linear	Left
S8	79	M	Industrial noise exposure	Bernafon RB15	Digitally programmable	Binaural	Linear	Binaural
S9	68	F	Bilateral acoustic neuromas	Oticon 380P	Analog	Left	Linear	Left
S10	47	F	Unknown	Canal Aid Dynamic Equalizer II	Fully automatic digital aid	Binaural	Linear	Binaural
S11	54	F	Premature presbyacusis	Phonak PICS	Digitally programmable	Binaural	Linear	Binaural
S12	59	F	Otosclerosis	Starkey A-13	Analog	Right	Linear	Right
S13	69	M	Industrial noise exposure	Phonak PICS	Digitally programmable	Binaural	Linear	Binaural
S14	71	M	Industrial noise exposure, Cholesteatoma	Bernafon RB15	Digitally programmable	Left	Compression	Left
S15	69	M	Unknown	Widex Senso CX+	Fully automatic digital aid with adaptive directional microphone and compression	Binaural	Compression	Binaural
S16	54	F	Ototoxic drugs, family History	Resound Canta 7	Fully automatic digital aid with adaptive directional microphone and compression	Binaural	Linear	Binaural
S17	63	M	Industrial noise exposure	Widex Senso CX+	Fully automatic digital aid with adaptive directional microphone and compression	Left	Compression	Binaural
S18	74	M	Industrial noise exposure	Bernafon AA310	Digitally programmable	Binaural	Compression	Binaural
S19	61	F	Viral infection	Phonak Claro 21 daz	Fully automatic digital aid with adaptive directional microphone and compression	Right	Linear	Right
S20	60	F	Unknown	Oticon E39P	Analog	Binaural	Linear	Binaural
S21	76	M	Industrial noise exposure	Bernafon SB13	Digitally programmable, fixed directional microphone	Right	Compression	Right
S22	78	F	Miniere's disease	Bernafon SB13	Digitally programmable, fixed directional microphone	Binaural	Linear	Binaural
S23	80	M	Industrial noise exposure	Starkey Sequel	Analog	Binaural	Compression	Binaural
S24	69	M	Industrial noise exposure	Bernafon AA310	Digitally programmable	Binaural	Compression	Binaural
S25	74	M	Unknown	Bernafon LS16D	Digital hearing-aid with adaptive directional microphone and compression	Binaural	Linear	Binaural
S26	64	M	Industrial noise exposure	Phonak PPCLC	Analog	Binaural	Linear	Binaural
S27	46	M	Unknown	Phonak PPSC	Analog	Binaural	Linear	Binaural

thresholds at all frequencies where measured at 90 dB HL or greater, or were wearing only one hearing aid at the time of assessment. In these cases the fitting and evaluation of the hearing aids was carried out on only the single aided ear. One subject (S17) had aidable thresholds in both ears, but had been wearing a hearing aid in the left ear only. This subject was fitted binaurally for this trial. All subjects were experienced hearing aid users. Subjects were not paid for their participation in the experiments, although expenses such as travel costs were reimbursed.

C. Speech test materials

Consonant-vowel Nucleus-Consonant (CNC) word lists were presented from audio recordings [7]. There were 50 words per list, spoken by a female with an average Australian accent. Each word was a monosyllable such as "church". Each word consisted of three phonemes, making a total of 150 phonemes per list. No lists of words (other than practice lists) were repeated for any subject during the trial. The order in which lists were presented to subjects across sessions was randomized. The average level of the words, when measured at the subject's listening position (about 1 m from the loudspeaker), was 55 – 60 dBA. These levels, which are similar to the levels of speech in normal conversation, were generally perceived to be comfortably loud when heard by the subjects through their hearing-aids.

D. Procedure

Aid fitting

The hearing aid usage and medical history of each subject was documented during the first test session. A pure-tone audiogram, including both air and bone conduction, was obtained, and the electro-acoustic characteristics of each subject's own hearing aid(s) were measured and recorded. Most of the subjects' own hearing aid(s) had been fitted using NAL-RP fitting guidelines [2]. The NAL-RP formula aims to maximize speech intelligibility for the listener in both quiet and noise using linear amplification. Table 1 includes relevant details of each subject's own aids. Gain and output measurements with signal levels of 60 and 90 dB SPL were carried out using a standard 2-cm^3 coupler (Madsen Aurical) with both hearing instruments.

The test instruments were fitted to each subject using appropriate fitting software, with which user-selectable normal and noise-reduction programs were created. The software programmed the test instruments to provide target gains at each frequency as well as other signal processing parameters. In general, linear amplification was selected when the average hearing loss at 0.5, 1, 2, and 3 kHz was equal to or greater than 70 dB HL, whereas amplitude compression was selected in cases where the average hearing thresholds were lower (better). Table 1 provides relevant details of the final programs selected for each subject. The subjects' pure-tone thresholds were entered into the fitting software to derive an initial fitting suggestion. These settings were altered at the first follow-up session based on subject feedback. No changes were made to the fitting if the subject was happy with the sound quality of the device. If required, the programming of the test instruments was adjusted to approximate the amplification characteristics of the subject's own hearing aids, based on 2-cm^3 coupler measurements. Such an adjustment was performed for 14 of the subjects (S1, S2, S3, S5, S6, S7, S8, S9, S11, S14, S16, S17, S20, and S22), and resulted in only small differences between the gain these subjects received with the test instruments and with their own aids.

Word recognition in quiet

For all evaluations of speech intelligibility, each subject was tested individually in a medium sized sound-attenuating booth. Initially, the volume controls on each subject's own hearing aids were set for comfortable listening of speech at a conversational level in quiet conditions. For most subjects, this was the default volume control setting. This setting was noted and fixed for all following test sessions involving those aids. A practice CNC word list was then presented to familiarize subjects with the testing procedure and materials. Subjects were instructed to repeat each word immediately after hearing it, and to guess if unsure. After the practice list, two lists were used to test subjects in each of two conditions: (1) using their own hearing aids, and (2) using the test instruments with Program 1 enabled. Subjects' responses were analyzed to determine the number of phonemes correctly recognized out of a total of 150 phonemes per list. Responses from the practice list were excluded from the data analysis.

A counterbalanced sequence of testing was applied in an attempt to minimize the confounding effects of acclimatization over time (Gatehouse, 1992). Initially, subjects were tested with one list using their own hearing-aids. They were then asked to take the test instruments home, and use them in place of their own hearing-aids as much as possible. Each subject wore the test instruments for a total period of 10 – 14 weeks. The CNC word tests were carried out during the final two sessions of this period with the test instrument on Program 1. At the end of the trial period, subjects reverted to wearing their own hearing-aids. After a further two weeks, a final test was carried out to obtain a score for a second CNC word list using the subjects' own aids.

Self-assessment

At the conclusion of the trial, each subject was asked to complete a questionnaire which was designed to elicit responses comparing the test instruments with their own hearing-aids. The questionnaire, which was adapted from the Shortened Hearing Aid Performance Inventory for the Elderly, or SHAPIE (Dillon, 1994), comprised 23 questions. Subjects completed the questionnaire in the laboratory. Responses were indicated by marking a horizontal line printed immediately after each question. Half of the line was marked "Own hearing-aid," and the other half "Experimental hearing-aid." The position of the label "Own hearing-aid" on either the right or left half of each line varied randomly. Each half of the line carried marks labelled with the words "slightly better," "better," and "much better," spaced regularly and symmetrically about the midpoint. Thus, the midpoint of the line corresponded to a response indicating that the subject judged the two types of hearing-aid to be indistinguishable. Subjects were able to respond "Not applicable" to any question. In the analysis of

Table 2. Hearing threshold levels (dB HL) for the subjects who participated in the study

Note: Asterisks indicate levels that were limited by the maximum possible output of the audiometer.

		Frequency (kHz)								
Subject	Ear	0.25	0.5	0.75	1	1.5	2	3	4	8
S1	L	55	70		80	85	85	90	110	110*
	R	55	65		75	85	95	105	105	110*
S2	L	35	50	70	85	85	85	95	120	110*
S3	L	90	95	115	120*	120*	120*	110	120*	110*
	R	80	95	105	115		120*	120*	120*	110*
S5	L	60	65	85	85		80	80	85	90
	R	40	65	65	85		85	70	70	95
S6	L	45	55		70		75	65	75	95
	R	35	45		65		65	75	80	85
S7	L	55	70	80	90		85	75	90	110*
S8	L	50	65	80	85	120*	120*	120*	120*	110*
	R	45	65	80	90	115	120	115	115	110*
S9	L	65	65	70	90	95	100	120	105	110*
S10	L	45	65		80	90	90	100	120	110*
	R	40	60		80	95	90	95	100	110*
S11	L	50	60	80	90	90	90	85	90	75
	R	50	55		70	75	80	105	95	110*
S12	R	70	65		55	70	85	95	95	110*
S13	L	50	35		60	80	90	90	100	90
	R	30	35		60	65	70	85	90	75
S14	L	40	40		45	35	50	105	100	110*
S15	L	50	75	75	85	95	85	90	110	110*
	R	40	50	60	75	75	70	65	75	75
S16	L	60	75	90	105	115	120	120*	120*	110*
	R	70	95	95	105	115	120	120*	120*	110*
S17	L	55	50		55	65	70	80	85	110*
	R	55	50		60	70	75	85	110	110*
S18	L	40	55		65	80	80	70	80	70
	R	30	45		55	65	90	85	80	70
S19	R	55	60		65	70	80	80	85	110*
S20	L	60	60	70	80	90	100	95	110	110*
S21	R	50	50		50	60	70	80	90	110*
S22	L	90	85		85	85	80	80	85	100
	R	35	45	60	70	100	110	95	95	110*
S23	L	40	50		55	60	70	85	105	110*
	R	35	45		55	55	65	80	100	110*
S24	L	20	35	45	60	60	65	80	75	100
	R	30	45	50	60	75	80	105	85	100
S25	L	55	60		70	75	90	120	120	110*
	R	55	60		65	75	70	80	95	110*
S26	L	55	70	65	65	75	75	100	120	110*
	R	55	70	70	70	70	75	90	110	110*
S27	L	10	50	60	70	115	115	120	115	110*
	R	10	35	60	70	115	115	115	115	110*

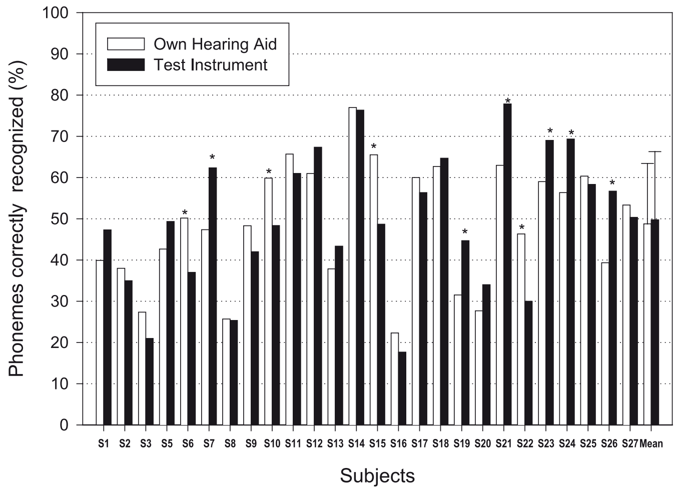

Figure 1. Mean phoneme scores recorded for the 26 hearing-impaired subjects when listening to monosyllabic words in quiet. Filled columns show scores obtained using the test instruments (with Program 1), and unfilled columns show scores obtained using the subjects' own hearing-aids. Scores averaged across subjects are shown in the pair of rightmost columns, with error bars indicating one standard deviation. Asterisk symbols indicate statistical significance ($p < 0.05$).

each subject's data, questions answered with such a response were omitted. Otherwise, each subject's response to each question was assigned an integer value ranging from –5 (for the response "Own hearing-aid much better") to +5 (for the response "Experimental hearing-aid much better").

IV. RESULTS

A. Word recognition in quiet

For the CNC word test in quiet, mean phoneme scores for each subject with their own hearing-aids and with the test instruments on Program 1 are shown in Fig. 1. Although there was some variability among subjects, the group mean scores (rightmost columns) showed almost no difference in phoneme scores between these two conditions. A paired t-test on these data confirmed that the scores were not significantly different ($t = -0.506$, $df = 25$, $p = 0.62$). Further analysis was carried out on subjects' individual scores using a Chi-squared test. As shown, 6 of the subjects (S7, S19, S21, S23, S24, S26) obtained significantly higher scores ($p < 0.05$), and 4 subjects (S6, S10, S15, S22) obtained significantly lower scores ($p < 0.05$) with the test instruments than with their own aids on this test. The remaining subjects' scores were not significantly different between the two test conditions.

B. Self-assessment

To analyse the results from the comparative questionnaire, the numbers assigned by each subject as responses were averaged across the 23 questions. The mean response values are shown for each subject in Fig. 2. Positive values, plotted on the right of the graph, indicate preference for the test instruments, whereas negative values, plotted on the left, indicate preference for the subject's own aids. Although preference ratings varied considerably, all but 4 of the subjects indicated that they preferred the test instrument to their own hearing-aids. The exceptions, subjects S6, S11, S15, and S16, indicated that they had only a relatively small preference for their own hearing-aids. It is noteworthy that three of these subjects (S6, S15, and S16) owned hearing-aids that employed relatively sophisticated signal processing schemes (see Table 1).

V. DISCUSSION

For the subjects who participated in the study, the test instrument provided perceptual performance approximately equal, on average, to the performance of the subjects' own hearing aids when listening to words presented at a moderate level in quiet conditions. This outcome was not unexpected, particularly because the test instruments were specifically adjusted for

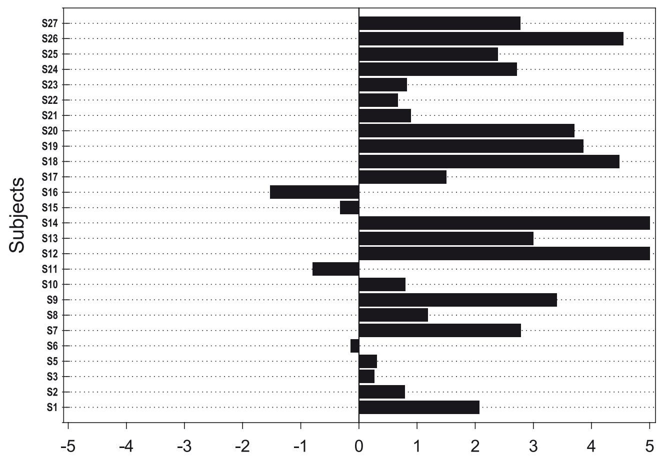

Figure 2. Mean scores from the questionnaire provided to the subjects. Each horizontal bar shows, for each subject, the average across all questions of numerical values assigned to that subject's responses. As shown on the horizontal axis, the possible values range from –5 (own hearing-aid preferred) to +5 (test instrument hearing-aid preferred).

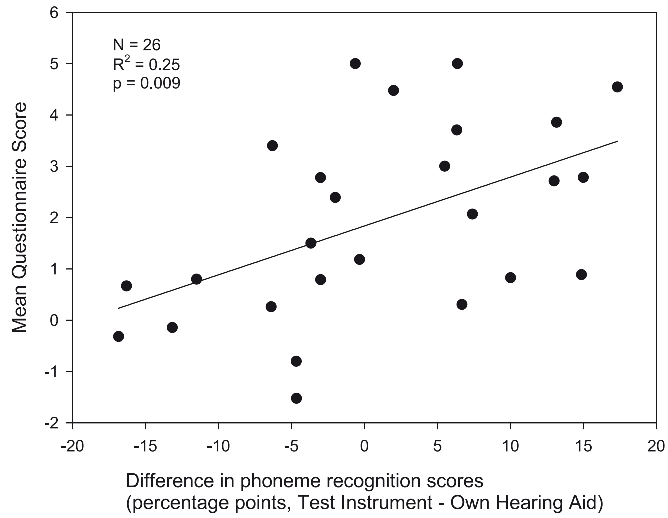

Figure 3. The relationship between the mean questionnaire score for each subject (vertical axis) and the difference in phoneme recognition scores obtained by the same subjects for the two types of hearing-aid evaluated in the study (horizontal axis). The score difference was calculated by subtracting the phoneme recognition score for the monosyllabic words test in quiet using the subject's own aids from the corresponding score obtained with the test instruments (on Program 1). The straight line shown fitted to the data indicates that about 25% of the variance in the questionnaire scores is accounted for by the variance in the phoneme score differences.

about half the subjects at the first follow-up session after initial fitting to provide a gain and frequency response similar to that of their own hearing aids. Interestingly, the large majority of subjects who showed no significant differences in scores between the two devices had this adjustment made to the test device. For many of the remaining subjects, it is probable that the initial programming of the test instruments also provided electro-acoustic parameters similar to those of their own aids. These speech perception results are consistent with the findings reported by Harnack Knebel and Bentler [6].

However, the results of the questionnaire administered in the present study showed that 22 of the subjects preferred using the test instrument rather than their own aids in many everyday situations. During the trial, each subject was aware of which aid they were using, and therefore it is possible that the positive results from the questionnaires reflect a general tendency for the new devices to be preferred over their existing hearing aids. Could this bias have affected the results (shown in Fig. 2) from the questionnaire used in the present study?

To investigate this issue, the questionnaire results were plotted as a function of the difference in phoneme recognition scores (in quiet) for each subject when using the test instruments compared with their own hearing-aids. These data, and a fitted straight line, are shown in Fig. 3. A statistical analysis revealed that the questionnaire scores were moderately correlated with the difference in phoneme scores ($r = 0.5$). The fitted line has a positive slope that was confirmed to be significantly different from zero ($p = 0.009$). The straight line shown fitted to the data indicates that about 25% of the variance in the questionnaire scores is accounted for by the variance in the phoneme score differences. The remaining 75% of the variance may be accounted for by a variety of factors, including test-retest variance.

As shown in Fig. 3, subjects who obtained a larger improvement in speech understanding when using the test instruments compared with their own aids were more likely to have provided positive responses to the questionnaire. Consequently, it seems likely that the preferences for the test instruments were related to the subjects' personal judgments of its perceptual performance (relative to that of their own hearing-aids), rather than reflecting only a bias associated with their involvement in the trial. However, the observation that the phoneme score differences are approximately evenly distributed around zero, whereas the mean questionnaire scores are mostly positive, suggests that, on average, subjects had a stronger tendency to prefer the test instruments overall than can be explained by differences in their objectively-measured ability to understand speech. In general, this outcome is consistent with that reported by Bentler et al. [1] where subjects showed a preference for new technology.

Speech perception in quiet is only one aspect in which a hearing aid can provide benefit for the listener. There are many additional listening environments which would affect how a listener would judge sound quality. These other environments include listening in noise, music, and environmental sounds. It is possible that the test instrument may have provided perceptual benefits for the subjects in ways that were not measured in the current study. This may also account for the majority of subjects' preference for the test instrument rather than their own hearing aids.

VI. CONCLUSIONS

The results of these evaluations of a prototype digital high-powered hearing instrument can be summarized as follows.

1. Recognition of words presented in quiet did not differ

significantly, on average, between the test instruments and the subjects' own hearing-aids.

2. Based on responses to the questionnaire, 22 of the 26 subjects preferred the test instruments to their own hearing-aids overall.
3. Across subjects, a moderate positive correlation was found between the questionnaire responses and the difference in objectively measured speech intelligibility for the test instruments in comparison with the subjects' own hearing-aids.
4. It is important to examine speech intelligibility as well as subjective measures when assessing the performance of hearing instruments.

ACKNOWLEDGEMENTS

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DETERMINATION OF DYNAMIC PROPERTIES OF RAIL PADS USING AN INSTRUMENTED HAMMER IMPACT TECHNIQUE

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Abstract. The repeated impact of train wheels over sleepers can reduce the lifetime of a sleeper and degrade ballast. In more extreme cases it can lead to the breakdown of the concrete sleeper. Concrete sleepers are rigid compared to steel and wooden sleepers and therefore it is necessary to provide impact attenuation to prevent premature breakdown of the concrete. One of the measures employed to attenuate the effect of the impact loads on concrete sleepers has been the use of the resilient rail seat pads. Numerous analytical and numerical models have been formulated to investigate the dynamic behaviour of railway track substructures. All models require careful selection of the track component properties to satisfactorily represent track vibration response. However, there is currently no standard method available that can be used to evaluate the dynamic properties of the rail pads. At the University of Wollongong, an instrumented hammer was used to excite an equivalent single degree-of-freedom system (SDOF), incorporating a rail pad as a resilient element, to determine the dynamic properties using methods of modal analysis. The analytical SDOF dynamic model was applied to best fit the experimental modal measurements that were performed in a frequency range of 0–500 Hz. The curve fitting gives such dynamic parameters as the effective mass, dynamic stiffness, and dynamic damping constant, all of which are required for numerical modelling of a railway track.

INTRODUCTION

Railways have played an important role in spreading population over large areas of Australia. The traditional ballasted track system, consisting of rail tracks, pads, and sleepers laid on ballast and subgrade, is used throughout this country. In this system, rail pads, usually made from polymeric compound materials, are mounted on rail seats and tend to attenuate the dynamic stress from axle loads and wheel impact from both regular and irregular train movements. These pads are crucial as they act as a softening medium between rail track and sleepers. Previous problems arising from improper or inadequate utilization of pads include cracking of sleepers at rail seats, high settlements of global and local tracks, and ballast/subgrade breakage from heavy tamping. These problems result in lower load capacity and deficient structural adequacy of track substructures, requiring a costly maintenance and rehabilitation budget. Thus, in addition to minimizing unpredictable maintenance and repairs, rail pads have been of interest to rail engineers as they reduce the dynamic stresses and impact loads on sleepers.

To gain a better insight into the dynamic characteristics of rail pads, it is important to carry out laboratory tests on their dynamic properties. These are also used in the numerical simulation of track dynamics. The numerical solution confirms the reliability and integrity of the railway substructures. It comes after the determination of dynamic properties of each track component, i.e. concrete sleepers, rail pads, and the ballast support. At present, there are many types of rail pads, such as high density polyethylene (HDPE) pads, resilient rubber pads, and resilient elastomer pads, all of which have different surface profiles. Examples of plain and studded profiles are illustrated in Figure 1. Until recently, the investigation of the dynamic characteristics of resilient pads had been limited, even though resilient rail pads are used extensively on all major Australian railway networks. The dynamics of the resilient type have been studied mostly based on a two-degree-of-freedom (2DOF) model [1–4]. In this paper, a SDOF-based method was developed to help railway track engineers to evaluate the realistic values of the dynamic properties of rail pads required for the design and maintenance of railway tracks. Figure 2 displays typical ballasted track construction and a typical railway track model used for numerical simulations. Figure 3 demonstrates a test setup of a SDOF system. An analytical solution was used to best fit the vibration responses. Vibration response recordings were obtained by impacting the rail with an instrumented hammer. Bovey [5] was one of the first researchers to use an impact method to determine the dynamic characteristics of railway installations. In this paper, the curve fitting method was applied to the frequency response functions (FRFs) obtained from modal testing measurements to extract the effective mass, dynamic stiffness and damping of resilient-type rail pads.

THEORETICAL REVIEW

Rail pads can be arranged as the elastic and dashpot components of a simple mass-spring-damper SDOF system by placing the pads between a steel rail and a rigid block, as shown in Figure 3. The dynamic characteristics of rail pads in the vertical direction can be described by the well-known equation of motion:

$$m\ddot{x} + c_p\dot{x} + k_p x = f(t) \tag{1}$$

$$\omega_n^2 = {k_p}/{m}, \quad 2\zeta\omega_n = {c_p}/{m}, \text{ or } \quad \zeta = {c_p}/{2\sqrt{k_p m}} \qquad \text{(2a, b, c)}$$

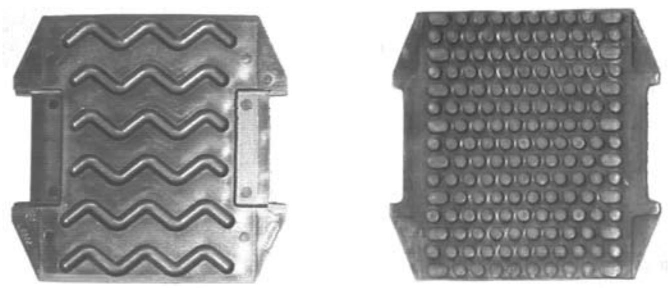
where m, c, and k generally represent the effective rail mass, damping and stiffness of a rail pad, respectively. Taking the Fourier transformation of (1), the frequency response function can be determined. The magnitude of FRF is given by

$$H(\omega) = \frac{1/m}{\sqrt{\left(\omega_n^2 - \omega^2\right)^2 + \left(2\zeta\omega\omega_n\right)^2}} \tag{3}$$

Substituting equations (2) into equation (3) and using $\omega=2\pi f$, the magnitude of the frequency response function $H(f)$ can be represented as follows:

$$H(f)=\frac{1}{m}\frac{4\pi^2\left(\frac{m}{k}\right)f^2}{\sqrt{\left[1-4\pi^2\left(\frac{m}{k}\right)f^2\right]^2+\left[4\pi^2\left(\frac{m}{k}\right)\left(\frac{c^2}{km}\right)f^2\right]}} \tag{4}$$

This expression contains the system parameters m, k and c that will later be used as the curve-fitting parameters.

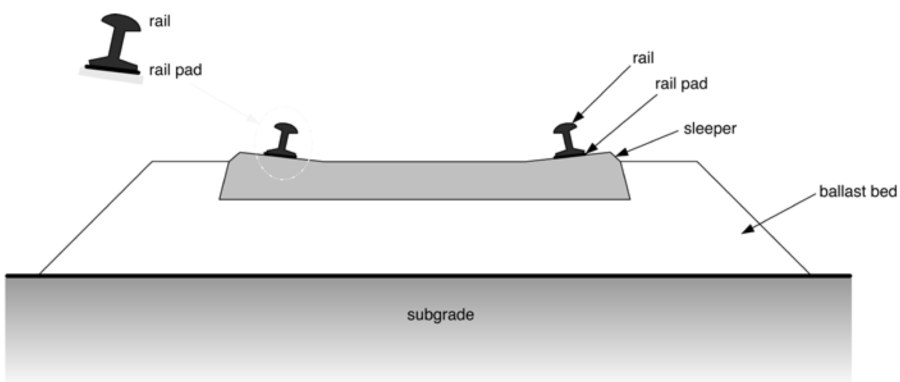


(a) Plane surface (b) Studded surface

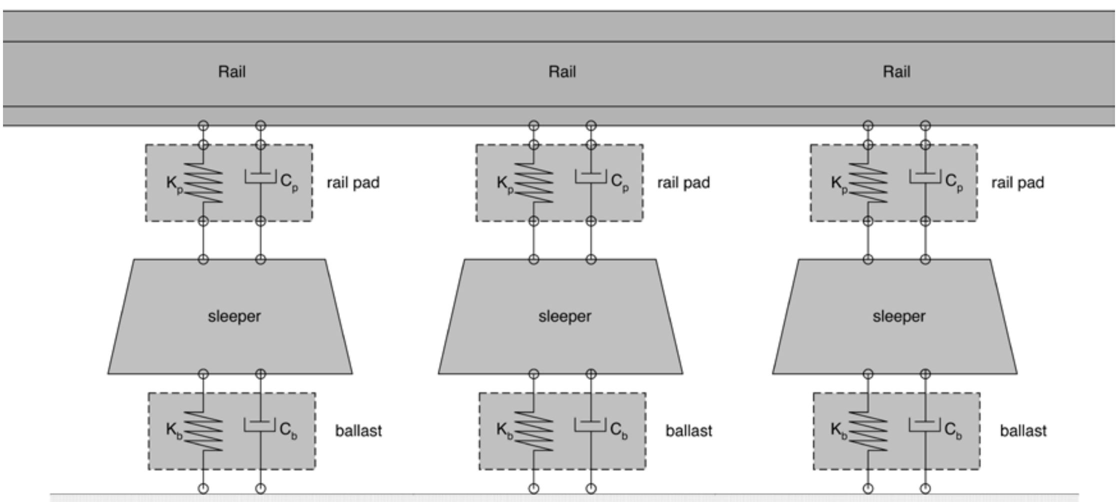
Figure 1 Examples of rail pad profiles

VIBRATION RESPONSE MEASUREMENTS

To measure the vibration response of the rail pads, an accelerometer was attached to the top surface of the railhead, as illustrated in Figure 3. The mass of the rail segment was 21.25kg, and the mass of the e-Clip fastening system was 0.75kg. It should be noted that a test rig was rigidly mounted on a “strong” floor (1.5m deep of heavily reinforced concrete), the fundamental frequency of which was significantly higher than the frequency range of interest for the rail pads. The railhead was impacted vertically with an instrumented hammer and the measurements were taken within a frequency range of 0–500 Hz. The FRF was then measured by the Bruel&Kjaer PULSE modal testing system, which was connected to a computer. Measurement records also included the impact forcing function and the coherence function. It is known that the FRFs describe the modal parameters of the vibrating rail system. The coherence function represents the quality of FRF measurements and should be close to unity. As an example, the properties of the PANDROL resilient rubber pad (studded type, 6.5 mm thick) were determined using the test rig and the results are presented in Figure 4. They included: the transient impact forcing function (Figure 4a); the vibration responses to the impact (Figure 4b); the magnitude FRF (Figure 4c) derived

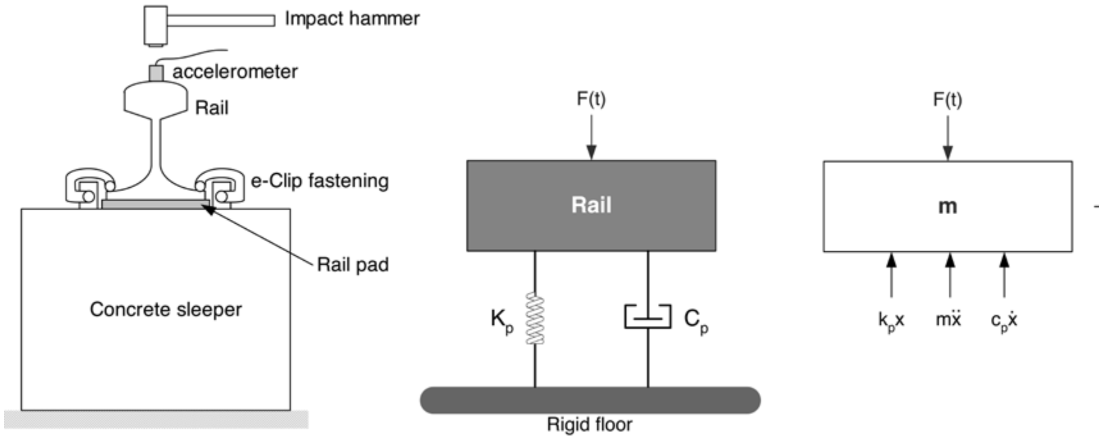


a) Typical ballasted track system



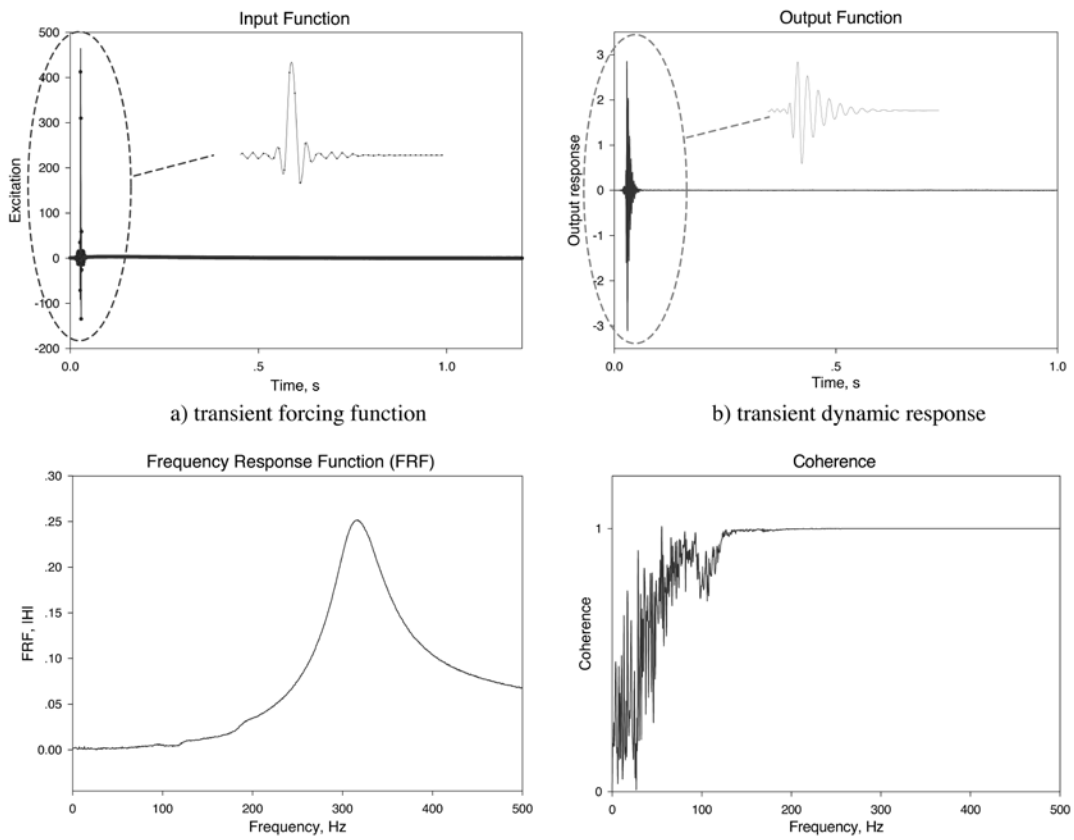
b) Numerical model of track system and dynamic properties of track components

Figure 2 Track Simulation



a) Schematic Test Rig b) Analytical Model c) Free Body Diagram

Figure 3 Experimental rig for testing rail pads



a) transient forcing function b) transient dynamic response

c) FRF d) coherence function

Figure 4 Vibration response measurements using impact instrumented hammer

from the vibration responses and the forcing functions logged; and the coherence function (Figure 4d) that confirmed a high degree of linearity between input and output signals.

BEST FITTING FRF

Parts of FRFs, in particular in the vicinity of the resonant frequencies, supplied detailed information on the properties of the tested component. The extraction of these dynamic properties was achieved using a curve-fitting approach. In this approach, the FRF of the model (4) was tuned to be as close as possible to the recorded FRF in a frequency band around the resonant frequency. Curve-fitting routines can be found in many general mathematical computer packages (e.g. MATLAB, Mathematica, Maple), or using specialized curve-fitting computer codes (e.g. DataFit). Figure 5 demonstrates the curve fitting performed by DataFit and gives the system

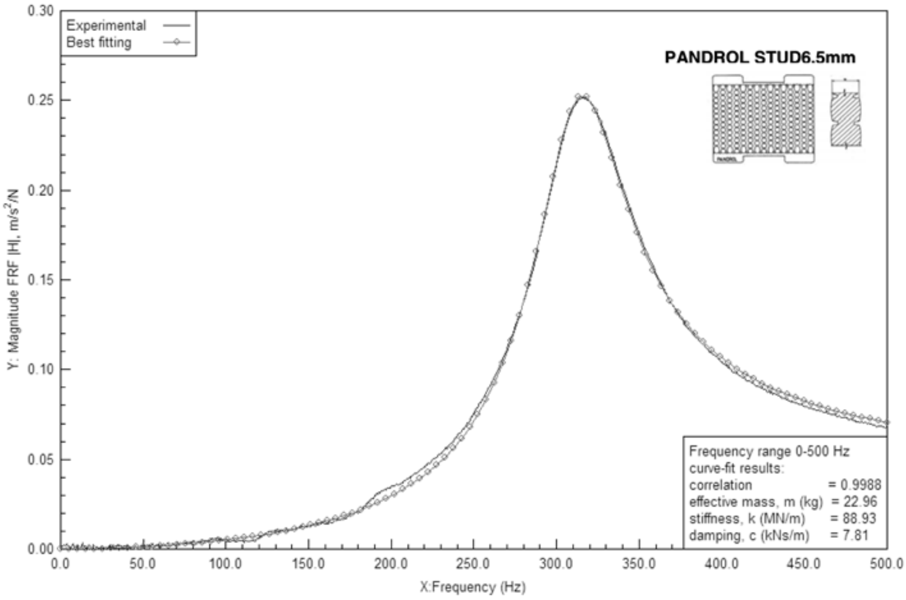


Figure 5 FRF Best Curve Fitting

Table 1 Dynamic properties of new rail pads tested at UoW

Test place	Material	Shape	Area (cm^2)	Thickn. (mm)	Preload (kN)	Temp. (Celsius)	Nr	Dynamic stiffness (MN/m)	Damping constant (kNs/m)
UOW	HDPE	Full material	208	7.5	20	20	3	470	6
	HDPE	Full material	246	10.0	20	20	3	628	4
	Rubber	Studded, double side	225	6.5	20	20	3	89	8
	Rubber	Studded, double side	267	10.0	20	20	3	66	5

parameters that are comparable to the parameters found in the open literature [6, 7] using impact-load testing. The results in Figure 5 show an excellent agreement between the analytical solution and the experimental data, since the correlation coefficient r^2 is equal to 0.9988, or less than 0.12% error. The dynamic properties of HDPE and rubber pads are also tabulated in Table 1. The results in Table 1 are in close agreement with the previous research results [6] given in Table 2. These data were developed by the Track Testing Center (TTC) of Spoomet, South Africa, and by TU Delft (DUT) of the Netherlands.

CONCLUSIONS

An alternative strategy based on the SDOF vibration response measurement for determining the dynamic properties of rail pads was proposed. The strategy was demonstrated to be simple and reliable, and was shown to be a fast and non-destructive test method to assess the dynamic stiffness and damping constant of all kinds of rail pad types available in Australia. The approach enables testing of new types of rail pads as well as evaluation of the influence of age of pads on their dynamic characteristics. The proposed impact method can be generalized to include the modal analysis of more complicated track components. Recently, field investigations were undertaken using the proposed technique on a heavy haul coal line in Central Queensland with the cooperation of Queensland Rail. It was found that the proposed technique yielded reliable and repeatable results in field tests as well as in laboratory conditions. These new results will be presented in future publications by the authors.

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Table 2 Dynamic properties of new rail pads tested at TTC and DUT [6]

Test place	Material	Shape	Area (cm^2)	Thickn. (mm)	Preload (kN)	Temp. (Celsius)	Nr	Dynamic stiffness (MN/m)	Damping constant (kNs/m)
	UK Hyfref 6358	Insert, loaded withour baseplate		8.5	25		3	130	20
	RSA EP2/EP2	Base plate + insert		7.0+8.5	25		3	90	17
	RSA EP2/8358	Pad + insert		5.5+5.5	25		3	110	23
	HDPE (lab)	Full material		12.0	25			375	7
	HDPE (field)	Full material		12.0				1200	50
	Rubber	Studded		10.0	25			75	
	Corkalas (soft)	Rubber bonded cork	196	5.2	20	20	5	970	32
	Corkalas (norm)	Rubber bonded cork	196	4.7	20	20	5	1420	34
	Rubber (hard)	Full material	193	4.9	20	20	5	2990	29
	Lupolan V3510k	Full material	197	5.0	20	18	5	3030	29
	Amilial EM400	Full material	197	5.0	20	18	5	1840	14
	Amilial EM400	Full material	195	9.4	20	25	3	1210	12

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News

Award for Sonomax

Sonomax™ Solution was named the overall winner of the 2005 British Safety Industry Federation (BSIF) Product Innovation Award. The BSIF Product Innovation Awards are the only awards to promote and recognise the importance of innovation and to underline the highest standards of excellence within occupational safety and health. For all entries, the panel of eight judges took into account the following criteria: Is the product unique in concept, design or performance; has the product contributed to improvements in occupational safety and health; has the product assisted reduction of occupational injuries; does it use technology new to the health and safety industry?

Sonomax information states that it 'has invented a unique earpiece that is the gatekeeper between sounds and eardrums. With its multi-purpose capabilities, it can shut the gate on harmful sounds like workplace noise with unparalleled efficiency, and can also welcome sounds like music and voices with perfect fidelity' . More information from www.sonomax.com and Australian Agent anzinfo@sonomax.com

Company Merger

Heggies Australia Pty Ltd (Heggies) has announced a merger with the NSW-based New Environment Management and Technology Pty Ltd. New Environment is now a wholly owned subsidiary of Heggies but will continue to operate under the present name at its North Ryde and Illawarra Offices. The New Environment management team and all staff members retain their present roles, however opportunities for closer integration of the two firms will be sought over time. New Environment is a leading provider of environmental and occupational health and safety consulting and testing services, including environmental and OHS audits and surveys, environmental and OHS management systems and plans and associated training.

Valley Music Harmony Plan

After more than two years of debate and discussion, Brisbane City Council has formally adopted its Valley Music Harmony Plan (VMHP) in a bid to help ensure the Fortitude Valley live music scene remains "loud and proud". In announcing the move, Brisbane Deputy Mayor David Hinchliffe said the plan represented two years' hard work by residents, the music industry (including Q Music), business people, Council officers and the Liquor Licensing division.

The Valley is a popular and vibrant area, including nightclubs, live music venues, restaurants, cafes, shops and residents. These different land uses have caused conflict between residential and entertainment users. To balance the area's value as an entertainment precinct with the needs of Valley residents and other commercial interests, the Council prepared the *Valley Music Harmony Plan*. Key recommendations in the plan include recognising the Valley as a special entertainment area, requiring all new developments to attenuate noise, and standardising noise limits for music venues.

The key actions to come out of the plan are:

- A special entertainment area will be designated in the Valley and as music noise does not stop at a boundary, a special entertainment area buffer also be designated
- New developments will be required to incorporate a high level of noise insulation
- New Liquor Licensing laws will allow different noise limits to be set within the Valley special entertainment area.
- A project team will assist Valley music venues, businesses and residents by providing advice and information for improving noise management.
- Communication will be improved between government, industry and the community regarding noise issues in the Valley and avoid conflict before it occurs.

However, the designation of an entertainment precinct in the Valley does not provide a "blank cheque" for venues to emit unlimited noise levels. The Valley will remain a mixed use community and therefore a degree of compromise will be required on all sides.

For more information http://www.brisbane.qld.gov.au and do a search on *Valley Music Harmony*

Changes in the Land & Environment Court

The Chief Judge of the NSW Land & Environment, the Hon. Justice Peter McClellan QC, has been making substantial changes to the way his Court is run and the way expert evidence is given. At the Engineers Australia on the Court Users Group meeting held in June, the Chief Judge advised that there has been a 13% reduction in Class 1 appeals in the year to date (end of May) compared with the same period in 2004. These are the "merit" appeals in which most engineering evidence is given. Representatives on the Court Users Group felt that this was partly due to the economy and partly due to the new Court procedures. The Court is also offering what calls "a neutral evaluation". This process provides the opportunity to consult with a Commissioner on the prospects of success for a pending Appeal. The Commissioners do not take notes. They provide a verbal opinion based on the information presented to them. If the matter does proceed to a hearing, this Commissioner has no further involvement. There have only been a handful of such evaluations to date, but results are promising. For more information on the operation of the Court plus details of the judgements handed down, see www.lawlink.nsw.gov.au/lec.

The Court has successfully introduced the practice of appointing Court Experts in Class 1 and 3 Appeals. The Court Expert is briefed by both parties, and both parties are responsible for their fees. This framework allows an expert to bring detailed design deficiencies to the attention of the applicant, to allow their consultants to consider the issues prior to the Appeal being heard, making the process more efficient in resolving the resolvable, and at the same time reduce the costs.

The appointment of a Court Expert does not prevent the parties from having their own independent expert, if they do not agree with the Court Expert's assessment. These experts then will typically confer, produce a joint report on the matters they agree and disagree on, and if appropriate, appear in the witness box together and present concurrent evidence. Concurrent evidence is an innovative approach where experts can often ask each other questions, or at least provide immediate responses to the views expressed by the other(s).

AAS members are welcome to attend an address by Chief Judge to Engineers Australia, on 29th September in Sydney – more information from www.acoustics.asn.au and follow the links from Notices to Divisional notices to NSW.

Extracted from Engineers Australia notice

Aircraft Noise Reduction Award

The American Institute of Aeronautics & Astronautics Program presents an Aeroacoustics Award for an outstanding technical or scientific achievement resulting from an individual's contribution to the field of aircraft community noise reduction. The deadline is 1st October, 2005 but if it's too late for this year look out for it next year http://www.aiaa.org/content.cfm?pageid=290 or carols@aiaa.org

New Products

Onset Computer Corporation

Equipment usage logger

Two new low-cost data loggers have been introduced for monitoring runtimes of a broad range of equipment, such as HVAC/R systems, pumps, and industrial process tools. The new HOBO U9 Motor On/Off and HOBO U9 State loggers provide a simple and convenient way to record up to 43,000 equipment on/off cycle or state changes, and use Windows-based software to convert the recorded data into time- and date- stamped graphs.

Information: OneTemp Pty. Ltd., 136 Richmond Road, Marleston, S.A. 5033, Ph: 1300 768 887 www.onetemp.com.au

Wavecom Instruments

Sound to light unit.

Wavecom Instruments have been appointed as the Australian distributors for the Velleman Group from Belgium. Of particular interest to acousticians will be the Velleman MK103 sound to light unit. In its standard form four high intensity LEDs light up in response to sound. In this form, the unit is useful for the hearing impaired to let them know visually that their telephone is ringing or that a visitor has rung their door bell. The sensitivity is adjustable via a potentiometer.

Acousticians will also be interested in what can be done with the trip current which activates the LEDs. As an example, in an industrial application, the trip current can be used to activate strobe lights – or some other warning device – when the sound level in the workplace exceeds a preset level. There are many other circumstances where a visual warning of sound exceeding a preset level will be useful.

Information: www.wavecom.com.au and follow prompts to the Velleman site.

Kingdom

SignalCalc Analysers.

Data Physics have increased the compliance of their Real Time Octave analysis application. Previously the difference between the centre frequency band and the adjacent band was about 15 dB down which whilst complying with the ISO (or ANSI) filter standard was on the lower end of the range of compliance. Their recent modifications have now increased that difference to 18.5 dB down which is on the higher end of the range of compliance. The modification will apply to all Data Physics Real Time Octave Analysis applications running on SignalCalc analysers including ACE-I PCMCIA, ACE-QUATTRO USB-2, Mobilyzer-I ethernet, Mobilyzer-II ABACUS ethernet and Savant ABACUS ethernet analysers.

Signalcalc analysers provide Synthetic Octave analysis as standard and this analysis method generally satisfies most practical engineering work. Real Time Octave analysis is provided as an option where there is a need to relate the measurements to the international or USA standard for example in some litigation work.

Side band cursors is a new tool to allow users to position a cursor on a carrier frequency and search for amplitude modulation side bands on either side of the carrier. The side band feature lists the frequency and amplitude of the centre and all selected side bands. Also you can now read the power in a frequency band using dual cursors. Another new feature is a Single Degree of Freedom curve fit to quickly identify natural frequency and damping of modes of vibration. Just place the cursor at the magnitude peak and ask for the curve fit. Cepstrum analysis is now included as a global function in all appropriate modules. Cepstrum can be used for the identification of any periodic structure in a power spectrum. For more information contact Kingdom Pty Ltd 02 9975 3272, www.kingdom.com.au

Meetings

Acoustics 2005 -

9-11 November

Acoustics 2005, the Annual Conference of the Australian Acoustical Society, will be held in Busselton, WA, 9-11 November. The Conference will commence with registration and a social function on Wednesday 9th November. Parallel paper sessions will run on Thursday 10th November. The Conference Dinner will be held on the Thursday evening. Further papers session and Workshop will be held on the Friday, and there will be trade displays both days.

There will be two excellent plenary speakers - Joe Rice (USA) on underwater acoustic communications and Neville Fletcher (Australia) on acoustic systems in biology. There is also a possible third plenary speaker from the UK. The response to the Call for Abstracts was outstanding, with some 90 abstracts being submitted, covering a wide range of topics in various areas of acoustics, vibration and underwater acoustics. Most of these have now been received as final papers, so the program is looking great.

There will be a pre-Conference workshops/ short course on Active Noise Control and another on Transport Noise, plus other workshops held during the conference.

Busselton is located in the scenic southwest of Western Australia close to the region's famous wineries, beautiful coastal scenery, and magnificent forests. It is a great place for a holiday if you can spare a little extra time. Transport by coach between Perth and Busselton will be arranged and can be booked at the time of registration.

See the website for all the information on the conference including the Registration Form (early bird rates apply till 30 September) and Abbey Beach Resort Accommodation rates.

www.acoustics.asn.au and follow the link to Conference

WESPAC IX 2006

The 9th Western Pacific Acoustics Conference will be held June 26-28, 2006 in Seoul, Korea, the Land of Morning Calm. If life is all about keeping a balance between two extremes, Seoul is certainly the a place to discuss "Better Life through Acoustics" the proposed theme. The program will include papers on a wide range of acoustics topics along with a technical exhibition and a full social program. Abstracts are due 16 December 2005 so now is the time to plan for your participation in this conference.

Information from http://www.wespac9.org

ICSV13

The13th International Congress on Sound and Vibration will be held July 2-6, 2006 at the Vienna University of Technology which is located in the centre of the city. ICSV13 participants will be able to take part in a Congress with a first rate scientific programme and exhibition and to get acquainted with the history and beauty of Vienna, its magnificent and romantic buildings and its parks and culture. Deadlines:

October 1, 2005 - Proposals for Structured Sessions (200 words)

December 1, 2005 - Submission of Abstracts (300 words)

Further Information http://icsv13.tuwien.ac.at

Note that the next in this series of conferences, ICSV 14, will be held in Cairns Australia in July 2007

FASTS

Report on 1st year student experience.

A DEST report by Craig McInnis et al at Unimelb's Centre for the Study of Higher Education was released yesterday. The report is the third in a series looking at 1st year student experiences at universities and follows reports in 1994 and 1999. The report, "The First Year Experience In Australian Universities: Findings From A Decade Of National Studies" is available at http://www.dest.gov.au/sectors/higher_education/publications_resources/profiles/first_year_experience.htm

Some science specific findings are:

- Enrolments in science declined by 20% - note there has been a 36% increase in 1st year enrolments over the same period and a 70% increase in Management and Commerce enrollments.
- Students in Science feel most strongly that parents have little understanding of what they do at university.
- Science and Engineering students most agree that university subjects build on their school study, while the opposite is true for students in Society/Culture, Creative Arts and Architecture.
- Science students typically use e-mail resources less than other broad fields of study for contacting lecturers and peers but use online resources more than any other broad field of study (82%).

Meeting Reports

Acoustics 2004

As I write this, over seven months have elapsed since ACOUSTICS 2004; the Western Australian Division is now on the home stretch to ACOUSTICS 2005, an exciting prospect. As one who knows the tribulations of ensuring the technical content is in, I wish Alec Duncan and his committee members the very best. How to report on a conference? Given the amount of writing that goes into putting one on this may seem an odd question; however as Congress Chair one is perhaps not as objective as an outside reporter. Nevertheless the Editor of these pages has given the command, so here goes.

ACOUSTICS 2004 was a successful gathering, with 211 delegates and 245 persons at the Dinner; it was by far the largest annual conference of the Australian Society to date. We were blessed with a good venue (the Gold Coast International Hotel), a great location and good subject matter. The subject matter was important; the conference theme was *Transportation Noise and Vibration,* with *Underwater Acoustics* as another major focus. Together these subjects provided three parallel streams. We also had good representation in the architectural acoustics and noise control categories, with the new BCA generating strong interest. The local attractions; in particular the dolphins at Sea World, also helped to get the show up and running and off on the right track.

The technical program comprised 106 presentations, five workshops and the pre-conference technical tour of Seaworld. The technical presentations and workshops were organised in five parallel sessions over the two days of the conference. A short course on aspects of environmental and transportation noise control was conducted on the day prior to the conference. Altogether there were 41 papers on transportation noise and vibration, 26 papers in underwater acoustics (marine platform noise control included) and 12 papers on architectural acoustics. A further 27 papers ranged across a broad field, which for summary purposes, can be called noise and vibration assessment and control. **Table 1** provides a summary of the topics represented.

Some highlights:

- The dolphins at Seaworld; Doug Cato on marine mammal acoustics.
- George Wilson, on transit noise and vibration; how it used to be and how it got a whole lot better.
- Martin Lawrence, on listening to icebergs calve in Antarctica (from Vienna).
- Dave Anderson on wheel-rail noise practicalities and definitions.
- Arthur Hall, on why the "Pacific Highway" is such a good name for a road.
- Michael Noad on arduous field acoustics at Perigian Beach.

On the social side, 57 lucky people attended the Technical Tour of Seaworld. The dolphins always put on a good show, this time they had something to celebrate; it's not always that they get to sample the eating qualities of hydrophones. The Welcoming Function was to be a barbeque by the pool, but due to Queensland weather having other ideas was held indoors with 150 persons in attendance. One item for future conference organisers; we had 75 people confirmed in advance for the Welcoming Function. For this years delegates: if you intend coming to the Welcome Function, please tick the box! Thanks go to Ken Mikl, who in retiring as President opened ACOUSTICS 2004.

245 persons attended Congress Dinner and not another seat in the house! Mel Western and the Big Jazz Band really kept the place jumping – anyone needing musical accompaniment need only ask Steve Pugh (yep that's Askce Impressario!). As has been the case for some years now the presentation of the CSR Bradford's Excellence in Acoustics Award was a highlight.

The Congress Exhibition was a great success and a great meeting place – thanks to all our Sponsors and Exhibitors and to the "booth personnel" for making happen. Thanks also to the UQ Racing Team for coming down and exhibiting their car: 114 dBA @ 1 m (i.e. at the driver's ear) is really something.

Lastly the conference luncheons were attended by over 200 persons – believe me I know, we had to collect tickets and count people in – once again please tick the box!

The Editor of these pages has asked me to explain how we got the consultants interested. Actually as a consultant myself: we are always interested. It is just that those pressing reports one needs to write keep getting in the way! More seriously, transportation noise and vibration is bread and butter acoustics for consultants and also increasingly the major acoustic "issue" for government. With that in mind, it will hopefully not be long before another major transportation noise and vibration conference is held in Australia. If you missed the first one; a new print run of the book and CDROM versions of the Proceedings has been organised, copies of these can be purchased from the Queensland Division.

No conference can be successful without strong support from sponsors and exhibitors and I thank all sponsors and exhibitor organisations for their contribution. Particular thanks go to our major sponsors Queensland Transport and Main Roads, CSR (Gyprock, Bradford and Hebel), Bruel and Kjaer, Heggies Australia, RTA NSW, Davidson Measurements, Embelton and GJames.

In closing this report, I once again, thank our Plenary Speakers: George Wilson, Martin Lawrence and Professor Munjal, Keynote Speakers: John Davy, Mark Simpson, Lex Brown, Steve Brown and Rob McCauley, our invited speakers and all those who contributed technical papers to the conference or who contributed with short presentations at the workshops.

I also thank my fellow members of the Organising Committee and all those who contributed to bringing it together (including the many on in the technical review panel). Particular thanks must go to our interstate committee members; Alec Duncan and Dave Anderson, for their efforts in helping the

Table 1 Technical Presentations: by topic

Theme	Subject Classification	Number of Papers/ Presentations
Transportation Noise and Vibration (41 papers)	Railway noise and vibration	15
	Aircraft noise	7
	Road traffic noise and vibration	14
	Vehicular noise sources and control	5
Underwater acoustics (26 presentations)	Underwater acoustics	14
	Marine mammal bioacoustics	8
	Marine platform noise control	4
Architectural acoustics (12 papers)	Architectural acoustics and the BCA	9
	Sound absorption	3
Noise and vibration assessment and control (27 papers)	Environmental noise modelling	5
	Industrial and community noise and vibration	14
	Noise and vibration control elements and analysis	4
	Speech communication and hearing protection	4

Queensland Division convince the underwater acoustics and rail noise fraternities to attend. I'd also like to make special mention of the contributions of Bob Hooker, David Mee and Colin Speakman, without whose unstinting contributions as Technical Committee Chair, Congress Secretary and Congress Treasurer, respectively, the conference would not have been possible.

Lastly, for those persons still recovering from ACOUSTICS 2004, what better place to do it than Busselton WA *See you in November at ACOUSTICS 2005*

Ian Hillock

Low noise road surface workshop

The workshop on low-noise road surfaces was well-attended, with about 20 participants. Graham Hennessey of Boral Asphalt Technology led off with a brief description of the various road surface types. For each surface type, Graham was able to tell us not only about the typical acoustic performance, but also about the various non-noise-related characteristics of the various types, including cost and durability.

Steven Samuels of TEF Consulting and University of NSW followed with a discussion of work that he has done in Queensland and NSW over the last few years looking at the variation over time of the acoustic performance of some road surface types. With regard to the "low-noise" open-graded asphalt (OGA) surface type, it appeared that the acoustic performance was quite stable and even improved during the first year or so after being laid.

This was consistent with some of the evidence from local and overseas studies presented by Neil Huybregts which showed that, in some cases, the acoustic performance of OGA can improve slightly in the first year. However, these studies also provided evidence that the acoustic performance of open-graded asphalt may disappear (ie be no better than standard dense-graded asphalt) within as little as 5 years. Neil's conclusion, that there was little point in using OGA as a long-term noise control method, was controversial and not well-accepted.

Neil briefly presented an outline of the mechanisms suspected to play a part in the degradation of the acoustic performance of OGA, including the best-known mechanism, clogging of the pores. However, according to work presented by Steven, a study undertaken in Queensland and NSW showed very little, if any, improvement in the acoustic performance of OGA after cleaning with special-purpose OGA cleaning equipment.

Neil Huybregts

Standards Australia

STANDARDS Australia

New Logo

On Tuesday 28 June 2005 CEO John Tucker introduced the "new" Standards Australia. Their new website, logo and marketing collateral were revealed, each reflecting the fresh new and unique image and presence.

Standards Australia July 2005 News states that

"Organizational change has enhanced Standards Australia's capacity to focus on its core business - to facilitate consensus-based solutions that result in the development of Australian and international standards, and related guidance materials; and to promote excellence in Australian design and innovation through the Australian Design Awards. These capabilities are very much in the national interest".

The background to the new logo is explained as:

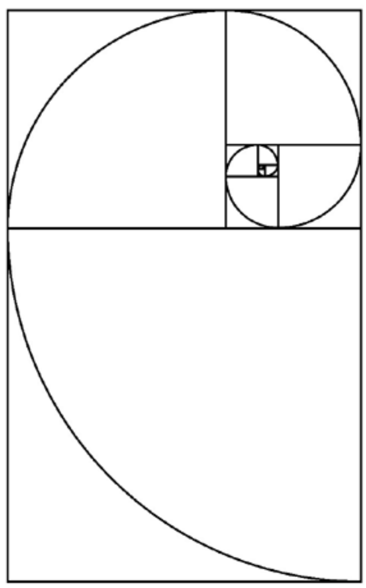
" …created around what could be expressed as nature's perfect standard - a unique number that goes by the names of golden mean, divine proportion or golden ratio. The golden mean is a mathematical expression of proportion that ancient Greek philosophers observed throughout the natural world. They considered the golden mean to be the middle between two extremes, one of excess and the other of deficiency. To the early Greeks it was an attribute of beauty. It has been claimed, though not substantiated, that if you draw a rectangle around the face of Leonardo da Vinci's Mona Lisa, the ratio of the height to width of that rectangle is equal to the golden ratio. This "divine proportion" can be found throughout the universe; from the spirals of galaxies to the spiral of a seashell; from the harmonics of music to the beauty and aesthetics in art. It has been attributed to the growth patterns of flowers and plants, observed in the behaviour of light and atoms, used in architecture and in the construction of human anatomy. Some would say it is nature's perfect standard....... a synergy that could not be missed when creating our branding and logo. We wanted to breathe meaning and life into our new image through our branding and logo. There could be no better way than with nature's own perfect standard - the golden mean. Standards Australia's new logo was born."

Review of Operations

In a letter from John Tucker, Chief Executive Officer, all the stakeholder organizations are invited to comment on the report from governance specialist Cameron Ralph. His 72 page report is a "top-to-toe" review of the comprehensive mechanisms in place to ensure balance, rigour and credibility of the consensus driven, authoritative Australian Standards development process. This report is available for comment at http://www.standards.org.au/downloads/CameronRalphReport.pdf. Although the deadline is August, late submissions may be accepted before the board meeting in November.

New Members

Member	Stephen Barlow (WA)
	Tim Kuschel (NSW)
	Matthew Fishburn (NSW)
	Michael Gange (NSW)
	Oliver Gaussen (NSW)
	Benjamin Lawrence (NSW)
	Michael Plumb (Vic)
	Alan Subkey (NSW)
	Roy Sullivan (NSW)
	Nicholas Tselios (NSW)
	David Watkins (NSW)
Graduate	Jimi Ang (NSW)
Associate	Shony Toma (NSW)
Subscriber	Stephen Lyons (Qld)
	Eliot Palmer (Vic)
	Craig Gleghorn (Vic)
Student	Tom Bamman (SA)



ICA 2010

International Commission for Acoustics

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

The first item in this series [*Acoustics Australia, 33(1), 2005*] outlined the actions by the AAS to win the bid to host the International Congress in Acoustics in Sydney in 2010. This item provides some background information on the International Commission for Acoustics, for which the congress is an important activity.

The International Commission for Acoustics (ICA) was instituted in 1951 as a subcommittee to the International Union of Pure and Applied Physics (IUPAP). By the 1990s it was clear that the ICA had achieved sufficient international support that it should obtain its mandate from the international acoustics community rather than the international physics community. In 1996 the ICA became an IUPAP affiliated commission with new statutes. The new ICA held its first General Assembly 1998 where the statutes and by-laws of the new organization were adopted by the Member Societies.

The purpose of the Commission is to promote international development and collaboration in all fields of acoustics including research, development, education, and standardisation. The means for the Commission to fulfill its mission are:

a) i to maintain close contacts with national and regional acoustical societies and associations as well as other relevant professional organisations and seek consensus in matters of mutual interest;

   ii to provide an information service on societies, congresses, symposia, etc., research and education organisations in the field of acoustics;

   iii to take a pro- active role in co-ordinating the main international meetings within acoustics.

b) to convene the International Congresses on Acoustics in accordance with the Commission's guidelines and to act as the International Advisory Committee for these congresses.

c) to sponsor or co-sponsor other topical and special international conferences normally in close cooperation with national and/or regional organisations and to give financial support (grants or guarantees), as a grant to organising committees for such meetings or as a travel grant to participants.

The Commission is affiliated to the International Union for Pure and Applied Physics (IUPAP) and through IUPAP to the International Council of Scientific Unions (ICSU), and hence to engineering bodies

Currently there are 44 national acoustical societies (or corresponding organisations) as members of the commission. The management of the Commission is by a board comprising fifteen members: President, Past-President, Secretary-General, Treasurer, and eleven other members. The election of the Board is undertaken at the General Assembly, held every three years at the time of the Congress. Currently the President is Philip Nelson (UK), Vice President Suk Wang Yoon (Korea), Secretary-general Sonoko Kuano (Japan), Treasurer Hugo Fastl (Germany) and Past President Gilles Daigle (Canada). In the last decade Australia has been successful in having representation on the board, with Charles Don and, since 2004, with Doug Cato. In addition from 2005 Marion Burgess has been invited as an Associate Member on the board to provide ongoing updates for ICA 2010.

The main activity of the Commission through the years has been to convene the triennial International congresses on acoustics. This has the generic title International Conference on Acoustics. Hence the same acronym, ICA, applies to the Commission and to the Congress. The first congress was held in Delft in 1953. In 1980, Australia was the first country in our region of the world to be given the opportunity to host the Congress and, 30 years on, we again have the honour.

The Commission also considers requests for sponsorship of Specialty Conferences in Acoustics. These are normally limited to a specialized topic with an expected attendance of about 100. Support for regional or national conferences, especially in developing regions, are considered as long as the conference has an international character.

The Commission is particularly keen to foster excellence in acoustics and has instituted an Early Career Award. This is presented at the Triennial Congress to an individual who is relatively early in his/her professional career (about 10-15 years of active career), and who has been active in the affairs of Acoustics through his/her National Society, other National Society(ies), Regional or International organisations and has contributed substantially, through published papers, to the advancement of theoretical or applied acoustics or both. In addition, the Commission provides between fifteen and twenty-five grants for young scientists to attend Congresses. The commission also maintains a listing of international conferences and meetings.

Information on all these activities is available from www.icacommission.org [*from which much of the content of this item has been extracted.*]

Marion Burgess

Diary

2005

4-8 September, Lisbon
Interspeech 2005 - ICSLP.
www.interspeech2005.org

05 - 09 September, Bath
Boundary Influences in High Frequency, Shallow Water Acoustics.
http://acoustics2005.bath.ac.uk

11 - 15 September, Beijing
6th World Cong Ultrasonics (WCU 2005).
www.ioa.ac.cn/wcu2005

19-22 September Charleston
6th Int Symposium on Cable Dynamics
www.conf-aim.skynet.be/cable

20 - 22 September, Okayama
Int Symp on Environmental Vibrations.
http://isev2005.civil.okayana-u.ac.jp

9 - 11 November, Busselton
Acoustics 2005
Acoustics in a Changing Environment
www.acoustics.asn.au

10 - 11 November, Stockholm
Active Control of Aircraft Noise Concept to Reality
http://www.ave.kth.se/CEAS-ASC

2006

15 - 19 May, Toulouse
IEEE International Conference on Acoustics, Speech, and Signal Processing (IEEE ICASSP 2006).
http://icassp2006.org

5-7June, Morgantown, WV
1st American Conference on Human Vibration
RKD6@cdc.gov

26-28 June, Seoul
WESPAC9
www.wespac9.org

03 - 07 July, Vienna
13th International Congress on Sound and Vibration (ICSV13)
http://icsv13.tuwien.ac.at

17 -19 July, Southampton.
9th Int Conf on Recent Advances in Structural Dynamics
www.isvr.soton.ac.uk/sd2006/index.htm

18 - 20 September, Adelaide
ACTIVE 2006
http://www.active2006.com

18 - 21 September, Pittsburgh
INTERSPEECH 2006 - ICSLP.
www.interspeech2006.org

20 – 22 November Christchurch
1st Joint Australian/New Zealand Acoustical Societies Conference
"Noise of Progress"
www.acoustics.org.nz

28 November - 02 December, Honolulu
Acoustical Soc of America & Acoustical Soc of Japan Fourth Joint Meeting.
http://asa.aip.org

3-6 December, Honolulu
Inter-Noise 2006.
www.i-ince.org

2007

9-12 July, Cairns
ICSV14
n.kessissoglou@unsw.edu.au

27 - 31 August, Antwerp
INTERSPEECH 2007.
conf@isca-speech.org

2-7 September, Madrid
ICA2007
www.ica2007madrid.org

9 - 12 September, Barcelona.
Symposium on Musical Acoustics (ISMA2007)
www.ica2007madrid.org

2008

28 July - 1 August, Mashantucket
ICBEN 9 Int Cong Noise as a Public Health Problem.
www.icben.org

2010

23-27 August, Sydney
ICA2010
www.acoustics.asn.au

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

Obituary

MAURICE ALBERT JEFFERIES

Morry Jefferies, a pioneer of the Australian Acoustics Industry, died recently in Sanctuary Cove, Queensland, after suffering motor neurone disease (MND) for some years.

Morry was born in Hounslow, near Heathrow Airport, London in 1932 attended local public schools and trained as a fitter and turner. The main incentive for him to come to Australia was to avoid call-up as a national serviceman to serve for the British Forces in Malaysia in the early '50s. Morry was supremely interested in self preservation. Morry did not like working the tools and subsequently became an architectural draftsman, which is ironic, given Morry's written scrawl; an almost childlike print and his undecipherable signature, rejected countless times after presenting his credit card at restaurants and hotels around the world.

Working as a draftsman at AGL (Australian Gypsum), Morry founded the original Australian acoustics company, Nonoys, with Graeme Harding in 1963, but running a small engineering business in the 1960's was difficult, particularly after the credit squeeze of 1969. The business they founded was purchased by D Richardson & Sons in 1974 and was reformed as Sound Attenuators Australia (SAA), the Australian licensee of SAL of the United Kingdom.

Following his arrival in Australia, he met his future wife, Patricia (Pat), and they subsequently had two children, Suzanne and Kent. To those who knew him well, Morry was a larrikin, a practical joker with a great sense of fun, a fine dancer and very musical, playing the piano competently. There are many Morry stories - some of which cannot be told.

Morry pioneered an Australian business because he had experienced the absurdly optimistic and unsustainable American based products on the market at that time. His derivation and creation of product names such as "Dingo" (red) "Devil" and "Dynadoor", all created as jokes to highlight their Australian character, became trade names respected in Australia and overseas.

Since 1992, after moving from Langwarrin Victoria, he led an active life at Sanctuary Cove, until being struck with MND in 2000. Those who knew Morry will never forget him and the indelible impression he made. His booming laugh, easy manner, unique character and style (unconventional to some), won him a wide circle of friends and admirers.

Timm Marks

AUSTRALIAN ACOUSTICAL SOCIETY ENQUIRIES

NATIONAL MATTERS

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

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

SOCIETY SUBSCRIPTION RATES

For 2004/2005 Financial Year:

Fellow and Member	$110.00
Graduate, Associate and Subscriber	$85.00
Retired	$35.00
Student	$25.00

Including GST

DIVISIONAL MATTERS

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

AAS - NSW Division
Noise and Sound Services
Spectrum House
1 Elegans Avenue
ST IVES NSW 2075
Sec: Ken Scannell
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GRAS SPECIAL MICROPHONES

WINDOW MICROPHONE TYPE 41AW:

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Microphone: ½” Free Field 50mV/Pa Type 40AF
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