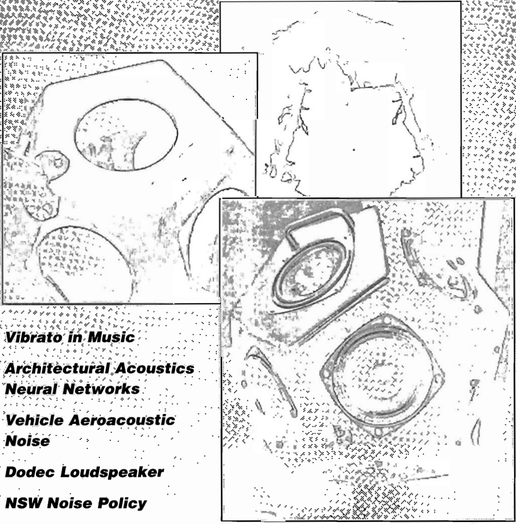
Acoustics Australia



- *Vibrato in Music*
- *Architectural Acoustics Neural Networks*
- *Vehicle Aeroacoustic Noise*
- *Dodec Loudspeaker*
- *NSW Noise Policy*

Australian Acoustical Society **Vol. 29 No. 3 December 2001**

Acoustics Australia
General Business
(subscriptions, extra copies, back issues, advertising, etc.)
Mrs Leigh Wallbank
P O Box 579
CRONULLA NSW 2230
Tel (02) 9528 4362
Fax (02) 9523 9637
wallbank@zipworld.com.au

Acoustics Australia
All Editorial Matters
(articles, reports, news, book reviews, new products, etc)
The Editor, Acoustics Australia
Acoustics & Vibration Unit
Australian Defence Force Academy
CANBERRA ACT 2600
Tel (02) 6268 8241
Fax (02) 6268 8276
email: acoust-aust@adfa.edu.au
www.acoustics.asn.au

Australian Acoustical Society
Enquiries see page 136

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

Responsibility for the contents of articles and advertisements rests upon the contributors and not the Australian Acoustical Society. Articles are copyright, by the Australian Acoustical Society. All articles are sent to referees for peer review before acceptance. Acoustics Australia is abstracted and indexed in Inspec, Ingenta, Compendix and Acoustics Archives databases.

Printed by
Cronulla Printing Co Pty Ltd,
16 Cronulla Plaza,
CRONULLA 2230
Tel (02) 9523 5954,
Fax (02) 9523 9637
email:print@cronullaprint.com.au
ISSN 0814-6039

Vol 29 No 3

CONTENTS

December 2001

Cover Illustration: Making your own dodecahedral speaker. See technical note by Patrick.

AUSTRALIAN ACOUSTICAL SOCIETY - SUSTAINING MEMBERS

ACOUSTIC RESEARCH LABORATORIES
LEVEL 7 BUILDING 2
423 PENNANT HILLS ROAD
PENNANT HILLS 2120

ACRAN
P O BOX 34
RICHLANDS 4077

ADAMSSON ENGINEERING PTY LTD
P O BOX 1294
OSBORNE PARK 6916

ARMSTRONG WORLD INDUSTRIES
P O BOX 109
MORDIALLOC 3195

ASSOCIATION OF AUSTRALIAN ACOUSTICAL CONSULTANTS
PO Box 820
SPRING HILL 4004

BORAL PLASTERBOARD
676 LORIMER STREET
PORT MELBOURNE 3207

BRUEL & KJAER AUSTRALIA
24 TEPKO ROAD
TERREY HILLS 2084

CHADWICK TECHNOLOGY
9 COOK STREET
FORESTVILLE 2087

CSR BRADFORD INSULATION
55 STENNETT ROAD
INGLEBURN 2565

ENCO NOISE CONTROL PTY LTD
50 RIVERSIDE ROAD
CHIPPING NORTON 2170

G P EMBELTON & CO PTY LTD
P O BOX 207
COBURG 3058

INC CORPORATION PTY LTD
22 CLEELAND ROAD
OAKLEIGH SOUTH 3167

KELL & RIGBY
PO Box 888
STRATHFIELD SOUTH 2136

NAL CONSULTING
126 GREVILLE STREET
CHATSWOOD 2067

NOISE CONTROL AUSTRALIA PTY LTD
70 TENNYSON ROAD
MORTLAKE 2137

NSW ENVIRONMENT PROTECTION AUTHORITY
P O BOX A290
SYDNEY SOUTH 1232

NUTEK AUSTRALIA
UNIT 3, 10 SALISBURY ROAD
CASTLE HILL 2154

PEACE ENGINEERING PTY LTD
P O BOX 4160
MILPERRA 1891

PYROTEK SOUNDGUARD
149 MAGOWAR ROAD
GIRRAWEEN 2145

SOUND CONTROL PTY LTD
61 LINKS AVENUE NTH
EAGLE FARM 4009

VIPAC ENGINEERS AND SCIENTISTS LTD
279 NORMANBY ROAD
PORT MELBOURNE 3207

WARSASH SCIENTIFIC PTY LTD
UNIT 7, 1-9 MARIAN STREET
REDFERN 2016

WORKCOVER COMPLIANCE COORDINATION TEAM
LEVEL 3, 400 KENT STREET
SYDNEY 2000

From the President

At the 71st Council meeting in Canberra, I had the honour of being elected President of the Society for yet another year. I took over from Geoff Barnes who, after many years as a Councilor and as National Treasurer, brought his wealth of experience to the task of President. On behalf of all Society members, I would like to thank Geoff for the excellent work he has performed over the past two years as President.

A number of members have commented about the relatively large amount of funds that the Society now possesses. [This buffer is one reason that Council has been able to hold membership subscriptions at their current level for the past three years.] Many members may not realize that the majority of the money is held by the state divisions and is used to run their technical meetings, conferences and other functions. The national body levies the states to obtain the funds to run the general secretariat and to pay subscriptions to national and international bodies, such as FASTS and ICA. A limited amount is also provided to help partially defray the costs involved by members attending, on behalf of the Society, interstate standards meetings and some international acoustics board meetings. In addition, the Society has boosted the profile of acoustics in Australia by providing support for important international acoustics meetings such as ICBEN in Sydney and Wespac8 to be run in Melbourne during April, 2003.

Recently, Council has been alerted to the need in Australian educational institutions for funds to assist in the teaching and promotion of acoustics. As a result, a new education initiative has been launched. Elsewhere in this issue an advertisement asks interested parties in educational establishments to apply for funds to assist them to (i) obtain a piece of equipment necessary for some teaching or research program involving acoustics or (ii) provide a scholarship in an area involving acoustics. At this stage the grant has been limited to a maximum of $5,000, as Council is uncertain about the demand and how to equitably distribute any grants nationwide. While it is part of our charter to promote acoustics education, Council must ensure that any such projects do not become a major burden on Society funds in the future. Grants will be awarded to the best written proposal(s) received by the closing date at the end of June. Successful applicants will be announced at the end of 2002, probably at our next National Conference in Adelaide. Council is excited about the potential of this new venture and seeks responses from members in the form of applications or as comments directly to Council or through Acoustics Australia.

Charles Don.

COUNCIL OF THE AUSTRALIAN ACOUSTICAL SOCIETY 2001-2002

President: Charles Don

Vice-President: Geoff Barnes

Treasurer: Ken Mikl

General Secretary: David Watkins

Federal Registrar: Gillian Adams

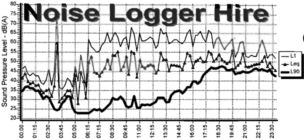
Archivist: David Watkins

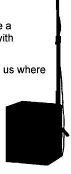
Councillors

(Effective from November 2001)

New South Wales	**Queensland**	**South Australia**	**Victoria**	**Western Australia**
David Eager	Gillian Adams	Byron Martin	Geoff Barnes	Tien Saw
Ken Mikl	Ian Hillock	Peter Teague	Charles Don	Terry McMinn

AUSTRALIAN ACOUSTICAL SOCIETY ON THE WEB:
http://www.acoustics.asn.au


Sound Pressure Level - dB(A)
80
75
70
65
60
55
50
45
40
35
30
25
20
00:00
01:15
02:30
03:45
05:00
06:15
07:15
08:30
09:45
11:00
12:15
13:30
14:45
16:00
17:15
18:30
19:45
21:00
22:15
23:30
L1
Leq
L90



VIBRATO IN MUSIC

Neville H. Fletcher
Research School of Physical Sciences and Engineering
Australian National University, Canberra 0200

ABSTRACT. Vibrato, which is an oscillation in the pitch, loudness or timbre of a musical tone, is a very important aspect of musical performance. This paper discusses the ways in which vibrato can be analysed, and also the ways in which it can be produced by performers on musical instruments and by singers.

1. INTRODUCTION

Transients have an important place in determining the subjective qualities of musical sounds. Most important are the attack and decay transients, without which most sounds lose their individuality – a recording of a piano played backwards sounds like some sort of organ – and these have received considerable attention in the literature. Within a nominally steady musical sound, however, the performer may insert a periodic modulation of some kind with a frequency typically of around 5Hz that is called vibrato. Not all instruments or performances use vibrato, but those that do not, such as pipe organs (mostly by necessity), Renaissance viols (again by necessity), and classical orchestral clarinets (by tradition), gain individuality by this very lack.

Vibrato is in many cases produced by a conscious physical manipulation, such as the regular oscillation of the left hand of a violinist where it stops the string against the fingerboard, but in some situations, such as elderly singers, the vibrato seems to arise naturally through oscillation of abdominal and laryngeal muscles and to be largely uncontrolled. More skilled musicians are able to vary the amplitude, and to some extent the frequency, of the vibrato and do this for musical purpose as the notes of the melody develop. In most cases, however, the frequency is in the range 5 to 8Hz, and it is perhaps significant that this is the typical frequency range of muscular tremors in neurological disorders such as Parkinson's disease and not too far from the resting alpha rhythm of the human brain. This suggests that both the generation and the perception of vibrato are closely related to innate human physiological and psychological characteristics. A classic discussion of psychological aspects has been given by Seashore [1].

It is not the purpose of this paper to investigate these subtle matters, but rather to examine the phenomenon of vibrato from a purely physical and mathematical viewpoint. In the course of this study a careful distinction (acoustical rather than musical) will be made between various types of vibrato, though it is not certain that these can be clearly related to rather vague musical distinctions such as that between 'vibrato' and 'tremolo'. The term 'vibrato' will be used here to encompass all varieties of the effect.

2. ANALYSIS OF VIBRATO

While the steady sound produced by a sustained-tone instrument such as a flute, a violin, or the human voice, is strictly harmonic, the same is not true of impulsive sounds produced by instruments such as harps or guitars, in which all vibrational modes have frequencies close to the nominal mode frequencies of the primary vibrating element (the string in both these cases), and these overtones are not ever in exact harmonic relationship to the fundamental [2]. In both types of instrument, however, the effect of vibrato is to impose a cyclic variation upon some important physical parameter such as string length or blowing pressure and this results in a cyclic variation of acoustic parameters such as the amplitudes and frequencies of the fundamental and overtones constituting the sound. The vibrato may well destroy the exact harmonicity of the overtones of sustained-tone instruments, and this is one of the possibilities to be investigated here.

Consider an infinitely prolonged note with some sort of vibrato. To the ear the sound may vary in three different ways, alone or in combination. The first is a cyclic variation in the loudness, which in music is generally called tremolo; the second is a cyclic variation in the pitch, generally called vibrato, and the third a cyclic variation in tone quality or timbre, to which a musical term has not been assigned. It is helpful to examine the ways in which each of these possibilities can be measured and specified.

TIME-DOMAIN ANALYSIS

This is the most straightforward but least informative way in which to describe the acoustic signal. At some specified location in the sound field the acoustic pressure $p(t)$ is measured at a sampling rate at least twice that of the highest frequency component of interest, ideally after passing the signal through a band-pass filter at that cut-off frequency in order to eliminate aliasing effects. This signal contains all the necessary information about the sound, but is of little use except for further analysis.

FOURIER ANALYSIS

In Fourier analysis the signal $p(t)$ is converted into the frequency domain by performing a Fourier transform, ideally upon an infinite length of signal but in practice on a length containing an integral number of vibrato cycles. This yields a complex frequency spectrum $p(\omega)$ that also contains all the signal information. Generally this complex spectrum is converted for display to a power spectrum $P(\omega) = |p(\omega)|^2/2$ which discards the phase information.

A simple sinusoidal amplitude modulation of a signal of frequency ω and amplitude a by a vibrato frequency Ω and amplitude Δa gives rise to two side-bands at frequencies

$\omega \pm \Omega$ along with the original signal at frequency ω, as shown in Fig. 1(a). The relative amplitudes of the three frequency components depend upon the modulation index $\Delta a/a$, and if this becomes much greater than unity then the component at frequency ω vanishes.

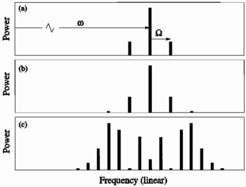


Figure 1. (a) Fourier power spectrum of an amplitude modulated signal with $\Delta a/a=1$. (b) Power spectrum of a frequency modulated signal with $\Delta\omega/\Omega=1$. (c) Power spectrum of a frequency modulated signal with $\Delta\omega/\Omega=5$.

A simple sinusoidal frequency modulation by an amount $\Delta\omega$ at a frequency Ω gives rise to multiple sidebands at frequencies $\omega \pm n\Delta\omega$ with amplitudes proportional to $J_n(\Delta\omega/\Omega$, where J_n is a Bessel function of order n. If $\Omega \ll \omega$ and $\Delta\omega \ll \omega$ as is the case in musical vibrato, then only the carrier frequency ω and the first two sidebands at $\omega \pm \Delta\omega$ are prominent, as shown in Fig. 1(b), so that it may be difficult to distinguish frequency modulation from amplitude modulation simply by examining the power spectrum. At the particular modulation index for which $\Delta\omega = 2.4\Omega$ the component at frequency ω vanishes. If the vibrato is very slow, so that $\Omega \ll \Delta\omega$, then the spectrum spreads over a band of width about $2\Delta\omega$, as shown in Fig. 1(c).

Fourier analysis, it should be noted, does away with the time element entirely, since it deals only with an infinitely long signal (or the same signal endlessly repeated) and yields a frequency spectrum that is time-independent. It is therefore of limited assistance in the study of musical vibrato.

GALERKIN ANALYSIS

Since it is known on general grounds that the sound signal from a musical instrument is based upon a superposition of overtones $a_n(\omega_n)$ at frequencies ω_n that may or may not be in harmonic relation to the fundamental frequency ω_1, it is often more useful to maintain this view and regard the vibrato tone as a superposition of these modes so that

$$p(t) = \Sigma_n\, a_n(t)\cos[\omega_n t + \phi_n(t)]$$

but the amplitudes a_n and phases (n are now relatively slowly varying functions of time. The apparent frequency of mode n is then

$$\omega_n' = \omega_n + d\phi_n/dt.$$

This modal decomposition of the signal, known as the Galerkin approximation, has the great advantage that it yields an 'instantaneous amplitude' and 'instantaneous frequency' that both correspond closely with psychophysical perception, though the terms themselves are not analytically respectable. It is possible to use this approximation to calculate the behaviour of many nonlinear systems of the kind found in musical instruments [3]. The approach gives a readily interpreted picture of the amplitude and frequency of all components of the sound without the complication of sidebands.

One possible problem with this approach is that, if the phase ϕ_n jumps suddenly, then this appears as an infinity in the frequency. An example of this is the case of amplitude modulation or beating with $\Delta a \gg a$. Here the signal has the form $a\sin\omega t\cos\Omega t$ and, if the amplitude a is taken as always positive, then there is a phase jump of π twice in each period, with consequent frequency infinities.

FAST FOURIER TRANSFORM ANALYSIS

While a fast Fourier transform (FFT) is simply a rapid and convenient numerical algorithm for performing a Fourier transform, it differs practically in that this transform is generally performed repetitively on successive small sections of signal and displayed as a time-resolved power spectrum. The frequency resolution $\Delta\omega$ is related to the length Δt of the transformed sample by the condition $\Delta\omega\Delta t \approx 2\pi$, while the Nyquist cut-off frequency is $\omega^* = \pi N/\Delta t$ where N is the number of data points in the transform. Since N is normally fixed by the software used for the computation, the result is a simple trade-off between frequency resolution and time resolution.

If time resolution is sacrificed in favour of frequency resolution so that the sample length is greater than twice the vibrato period, then the FFT approach behaves like the normal Fourier transform and shows a 'carrier frequency' and two sidebands for each mode. If, on the other hand, time resolution is made significantly less than the vibrato period, the FFT will display a set of modes that vary cyclically in frequency and amplitude, following the Galerkin approximation. Because the FFT approach effectively averages the Galerkin approximation over the sample time, if this is short, the possible infinities in frequency are reduced to simply large jumps, but these jumps need to be carefully interpreted.

SONAGRAPH ANALYSIS

The most useful analysis tool derives from the Sonagraph, which in its early forms rotated a sensitive paper on a drum bearing the recorded track to be analysed. The rotation slowly swept an analysing filter through a frequency range from zero to about 5 kHz, and the stylus imprinted the signal level on the paper, giving a time-resolved spectrum of selected bandwidth. Modern signal analysis programs perform the same operation digitally. The figures in the present paper are derived from one such program [4].

HUMAN AUDITORY PERCEPTION

Since the object of this analysis is to relate perceived vibrato effects to physical parameters of the performance, it is important than a method of analysis is chosen that adequately approximates human auditory perception. Numerous psychophysical studies [5] show that human auditory resolution is rather less fine than 50ms and that, while a frequency resolution of about 3 cents, or about 0.2%, is possible near the mid-range of the frequency spectrum though such resolution requires sounds that are steady for several seconds. (One semitone is a change in frequency by a factor $2^{1/12}$ or about 6% and is divided logarithmically into 100 cents.) When the tone duration is 1s or less, the frequency resolution declines rapidly. Similarly, changes in sound level of 1dB are perceptible when they occur at intervals of a second or more, but become progressively less obvious when they occur more rapidly.

These considerations suggest that an method of analysis with a time resolution of about 100ms and a corresponding frequency resolution of about 10Hz, which corresponds to about 2% or 30 cents near the middle of the treble stave (about 400Hz) is probably about optimal for analysing vibrato. An FFT analyser with 1024 data points adjusted to meet these criteria will have an upper cut-off frequency of about 5kHz, which is adequate for the analysis of most musical sounds, though of course the audible components of these sounds extend to much higher frequencies.

3. VARIETIES OF VIBRATO

The most musically and acoustically revealing method of analysis of musical vibrato is an appropriate form of FFT analysis, with the sample length of about 100ms, so that the frequency resolutions is about 10Hz, as discussed above. Applied to a typical musical vibrato, this analysis generally indicates a combination of frequency and amplitude modulation of the sound, which is indeed what the listener hears, though it is possible to concentrate perceptive attention on one or other characteristic. A musical note, however, is not generally a simple sinusoid with a single frequency, but rather consists of a fundamental accompanied by an array of overtones. The effect of vibrato may differ from one overtone to another, so that a third form of vibrato can be identified that might be termed 'timbre' vibrato, where the musical word 'timbre' refers to tone colour.

When considering vibrato, we can identify two basically different classes of musical systems. In the first class, exemplified by plucked or bowed string instruments and by the human voice, it is the frequency of the primary oscillator (the string or the vocal folds) that is varied; associated resonators (the instrument body or the vocal tract) serve simply as shaped filters that modify the spectral envelope of the sound. In the second class, exemplified by woodwind and brass instruments, the primary resonator (the air column) actually determines the frequency of the sound, and what is modified in vibrato is the behaviour of a subsidiary negative-resistance oscillator (the air jet, the reed, or the player's lips) that is slaved to the primary resonator. Frequency deviations are thus much easier to produce in the first class of instruments than in the second, as we see in the examples that follow.

Impulsive stringed instruments

A piano has an inherent amplitude-modulation, though not really a vibrato, for each overtone of the sound by virtue of the fact that most notes are sounded by several strings vibrating in unison. The interaction between the strings is complicated [6] and arises because the bridge is necessarily not completely rigid, since it must transmit the string vibrations to the soundboard. The player, however, has no control over this effect, so it will not be considered further here, despite the fact that it is important to the quality of piano sound.

Something similar happens in the harpsichord and the harp but has a different origin because these instruments have only one string per note (although large harpsichords may have additional strings at octave or sub-octave pitches). Since the string is not generally plucked exactly at right angles to the bridge, it has a tendency to oscillate in an elliptical path, and this ellipse precesses slowly, because of both nonlinear effects and also the direction-dependence of the bridge impedance [2,3]. This precession gives a quasi-periodic amplitude modulation to the normal force on the soundboard. Again the player has no control over this effect, so that it is not a real vibrato.

In a guitar, however, the player uses one finger to 'stop' the string being plucked, and this finger has a position between two of the frets on the neck of the instrument so that the vibrating length is determined by the lower fret position. If, however, the player rocks this finger backwards and forwards, then this has an effect on the tension in the string because of slight variation in the displaced length between the frets. This tension variation in turn varies the vibration frequency of all of the string modes by exactly the same fractional amount, giving a coordinated frequency modulation to the string vibration.

The matter is, however, not as simple as this. The string vibration must be communicated to the instrument body for sound radiation, since the string itself radiates almost no sound because its diameter is so small compared with the sound wavelength involved. The guitar body, however, has many resonances – indeed it is the distribution of these resonances that distinguishes a fine guitar from a poor one. As the frequency of any mode varies under the effect of changing tension, therefore, this alters a little the response of the instrument body as the frequency moves closer to or away from the nearest resonance. There is also an associated change of phase, which adds to the initial frequency modulation. The result is that the simple frequency modulation of the string acquires an amplitude modulation as it is transferred to the body and radiated. When this sound signal is analysed by the FFT method, those parts of the signal with higher amplitude are given higher weight, with the result that there may appear to be a slight shift in the median vibration frequencies of individual modes in addition to the vibrato.

Bowed strings

In a bowed string instrument such as the violin, the string vibration is maintained by a stick-slip frictional phenomenon between the moving bow and the string – hence the importance of rosin to enhance the friction. This stick-slip motion is highly nonlinear, with the result that the vibrational motion of the string repeats regularly, giving a precisely harmonic sound for sustained notes. Vibrato is again introduced by rocking the active finger tip against the fingerboard as in the guitar but, because there are no frets, the result is not a change in tension but rather a change in string vibrating length. Analysis of this situation is very difficult, because it constitutes a 'moving boundary problem' but, because the vibrato frequency is very much lower than the fundamental string vibration frequency (5Hz compared with 200–2000Hz for a violin), it is a reasonable approximation to perform a calculation using a quasi-static approximation. The string frequency is then seen to vary approximately sinusoidally at the finger-motion frequency. The fact that the violin body is intimately involved in sound radiation, and that it possesses pronounced resonances of its own, affects the vibrato in the same way as for the guitar, making the final effect one combining frequency, amplitude, and timbre variations. The maximum frequency variation in vibrato is typically about ±3% or about ±50 cents, as shown in Fig. 2. Note that the vibrato extent, when measured in frequency rather than pitch, increases in proportion to the frequency of the overtone involved, thus maintaining a harmonic relationship to the fundamental at all times.

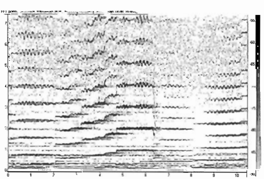


Figure 2. Soundswell analysis of Nigel Kennedy (violin) playing an excerpt from the Meditation from Massenet's Thais. The time span is about 10 seconds and the frequency range 0–7 kHz. Maximum vibrato amplitude is ±3% or about half a semitone in each direction.

Since the violin is a sustained-tone instrument, vibrato is an important feature of its sound quality, and is used almost always. This contrasts with Renaissance bowed-string instruments of the viol family, which have cords tied around the fingerboard to constitute very shallow frets, and are played without any vibrato at all. Adjustment of the frets allows notes to be played consistently in tune, a feat which is much more difficult on the violin.

Violins and other bowed-string instruments are often heard in groups, as in an orchestra, and here the vibrato takes on another role. The string players make no attempt to coordinate their individual vibratos, so that the result is a sound consisting of many superimposed signals with slightly differing frequencies and vibrato rates. When this is considered on the basis of Fourier analysis, the signal is seen to be rather like narrow-band noise. This is called a 'chorus effect' and is particularly pleasant to most listeners.

Flute-like instruments

In instruments of the flute family, a tube resonator with finger holes to adjust its acoustic length is excited by an air jet from the player's lips which blows alternatingly into and out of the instrument mouth-hole. The air jet itself is very complex, and its motion involves the propagation of displacement waves excited upon it by acoustic flow out of the mouth-hole. The interaction of the jet with the sound modes in the tube at the upper lip of the mouth-hole is similarly complex. To sound a given note, the player must control the air-jet length and blowing pressure within fairly narrow limits, or the instrument will either not sound or will sound a higher mode than the one intended.

Vibrato in flute instruments is generally produced by a cyclic variation of about 10% in the blowing pressure. The relative levels of the upper harmonics of the sound depend quite sensitively upon the blowing pressure, while the amplitude and frequency of the fundamental varies by only a very small amount. The result is a vibrato that has been characterised as being a 'timbre vibrato' since there was relatively little change found in either pitch or radiated sound power [7]. Timbre variations do, however, have an effect upon perceived loudness.

A more recent study using FFT techniques [8] has, however, shown periodic variations of about (30 cents in the frequency of the fundamental and rather large and erratic variations in the apparent frequencies of the higher modes, these variations increasing in extent with the mode number. As discussed above, it is possible that these frequency variations are produced by changes in phase, due perhaps to associated variations in the exact blowing angle of the jet in relation to the edge of the mouthpiece [9]. Such phase changes increase in magnitude in proportion to the mode number. The FFT analysis reported in this paper raises some questions about the reality of the frequency fluctuations, however, since the displayed time resolution is about 0.01s and the frequency resolution better than 10Hz rather than the expected 100Hz. The analysis shown in Fig. 3 shows a maximum vibrato shift of about ±25 cents, which confirms the figure given in the referenced publication, but no anomalies are evident in the higher harmonics of the sound.

In the flute, as in other wind instruments that use vibrato, the rate and extent of this vibrato is under the control of the player. Often a sustained note at the beginning of a phrase will start with almost no vibrato, but this will build up in frequency and amplitude during the course of the note and lead on to the next note in the phrase. Conversely, near the end of a phrase this sequence may be reversed. The normal frequency of vibrato, generally in the range 5 to 6Hz, is also often characteristic of the individual player.

Other wind instruments

Reed wind instruments, such as oboes or clarinets, can also produce vibrato, either by oscillation in blowing pressure or, less commonly, by lip pressure on the reed. The vibrato is under the control of the player to the extent that bassoons, for example, may use vibrato when playing duets with oboes but not when playing with clarinets, simply because it is traditional for orchestral clarinets to play without vibrato. There does not appear to have been any detailed acoustic study of this vibrato, but the analysis given in Fig. 4 suggests that the frequency variation is only about ±40 cents and that variations in loudness and timbre may also be important.

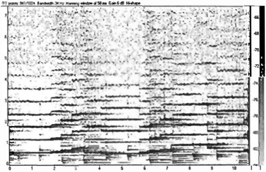


Figure 3. William Bennett (flute) playing part of the Largo from Bach's Concerto for Flute and Strings BWV1056. Maximum vibrato amplitude is ±1.5% or about one-quarter of a semitone. The apparent overlap of notes is due to reverberation.

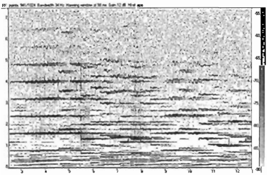


Figure 4. The oboist of the Stuttgart Chamber Orchestra playing the introduction to the Echo Duet of Bach's Christmas Oratorio. Maximum vibrato amplitude is ±2.5% or about 0.4 semitones.

Brass instruments do not use vibrato to any great extent, perhaps partly because of the physical requirements on blowing pressure and lip tension necessary to produce the desired sound and partly because of tradition, which has established that these instruments sound better when played 'straight'.

The singing voice

Vibrato in singing has received a good deal of attention from teachers but less from acousticians. Typically the singing voices of children make no use of vibrato, and this creates the 'pure' or 'simple' sound characteristic of English cathedral choirs. The voices of girls continue to develop smoothly as their age increases, and it is usual for a small amount of vibrato to develop. After the age of 20 or so, the extent of vibrato depends upon artistic choice and physical development. Some professional female singers maintain a voice with very little vibrato for many years, and this style goes very well with the music of composers such as Purcell and with much folk music. Other singers follow a more operatic tradition and use pronounced, and even exaggerated, vibrato in all their singing. After many years of singing in this style, it seems impossible for these singers to revert to simple sounds, and the vibrato intensity generally continues to increase as they grow older. While this is perhaps appropriate in some music with dramatic emotional content, it is felt by many to be an unfortunate defect in singing style. At the other end of the artistic spectrum, singers in some Eastern European traditions eschew vibrato altogether, giving a most striking effect to the music characteristic of that tradition.

Vibrato in male singers, particularly basses, sounds rather different from that of sopranos, probably because the basic sound frequency is typically lower by a factor of nearly four. Certainly, however, some well-known bass singers have developed with age a style with a wide and rapid vibrato, with the result that the pitch of the note being sung is largely obscured in rapidly moving music such as some of that by Handel.

The physiological mechanisms of vibrato generation in singing have been the subject of detailed study [10], but the results vary somewhat from one singer to another. The pitch of a vocal tone is determined almost entirely by tension in the muscles supporting the vocal folds, though this tension is itself influenced to some extent by sub-glottal pressure. The primary origin of vibrato thus lies with the muscles controlling the larynx, though there is evidence of coordinated oscillation in muscle tension in the chest and abdomen, leading to synchronised oscillations in sub-glottal pressure. Because the fundamental frequency of the human voice is not locked to any resonance of the vocal tract, the singer has a great deal of freedom in pitch variation during vibrato.

Quantitative studies of vocal vibrato have been made by several people, and are discussed by Sundberg [10], while a more recent analysis of prominent artists singing Schubert's *Ave Maria* has been reported by Prame [11]. For the quiet mood of the Schubert song, the vibrato rate was 6.0±0.4 Hz and the average vibrato extent 71±9 cents, though this varied from 34 to 123 cents for different notes and different singers. In the wider and more operatic repertoire [10] some well-known sopranos actually use vibrato as large in extent as ±2 semitones! (If the vibrato is larger in extent than this it is called 'trillo'.) For such a large vibrato, particularly if the vibrato rate is rather slow, the perception is of an actual fluctuating pitch, rather than a variation of tone quality on a particular note. For smaller vibratos, however, the pitch perceived by a listener is very close to the average frequency of the sound, so that a wide vibrato does not allow the singer to be significantly out of tune without this fact being evident.

Figure 5 shows a typical example of vocal vibrato for a distinguished soprano (Joan Sutherland) singing a quiet meditative piece of music. Even here the frequency variation is about ±170 cents, or 1.7 semitones in either direction, but the listener senses just the average pitch with quite high precision. Note again that the vibrato extent, when measured in frequency, increases in proportion to the frequency of the overtone involved, thus maintaining a harmonic relationship to the fundamental at all times.

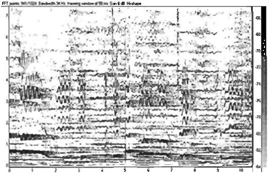


Figure 5. Sound spectrogram of Dame Joan Sutherland singing a tranquil section of Puccini's Suor Angelica. The time span is 10 seconds and the frequency range 0 to 7 kHz. Maximum vibrato amplitude is ±10% or about 1.7 semitones in each direction.

Despite what appears to be the almost autonomous nature of the muscle vibrations responsible for vibrato in singing, the performers do have some measure of control over its amplitude and frequency. The vibrato intensity generally increases with loudness and emotional content of the music, though whether this is conscious or subconscious is not clear. Another level of control is shown in a study of duet singing by pairs of distinguished sopranos, as recently reported by Duncan et al. [12]. They found that in some cases the singers adjusted their singing so that their vibratos were approximately synchronised, sometimes in-phase and sometimes anti-phase.

When, as often happens, mature singers combine to form a choir, their individual vibratos are not synchronised, so that, as for groups of violins, the result is analogous to a narrow-band noise signal. This 'chorus effect' is by no means unpleasant, and indeed adds characteristic beauty to such combined singing. The resulting auditory effect is in sharp contrast to the nearly 'pure-tone' effect produced by groups of boy sopranos in cathedral choirs, where vibrato is not generally used.

4. CONCLUSIONS

Vibrato is an important component of many musical sounds and allows the performer to impose subtle variations upon the quality of notes. It has become so nearly universal, however, that some performances, particularly of early music, gain distinction from the absence of vibrato! In the best performances, the nature and extent of the vibrato are under the close control of the musician and are varied to suit the demands of the item being performed, and indeed help to shape the style of individual phrases within that performance. Unfortunately, many singers appear to develop an uncontrolled and excessive vibrato with increasing age, which detracts from the beauty of their songs.

This brief survey has shown that only some aspects of musical vibrato are understood in detail – there is ample scope for a comprehensive and comparative study. As well as benefiting performers on traditional instruments, a proper understanding can perhaps add life to the otherwise often mechanical sounds of much electronic and computer-generated music.

REFERENCES

1. C.E. Seashore, *Psychology of Music*, McGraw–Hill, New York 1938, reprinted by Dover, New York 1967, Ch. 4.
2. N.H. Fletcher, "The nonlinear physics of musical instruments," *Rep. Prog. Phys.* **62**, 723–764 (1999).
3. N.H. Fletcher and T.D. Rossing, *The Physics of Musical Instruments*, (second edition) Springer-Verlag, New York 1998, Ch. 5.
4. Hightech Development (Sweden), *Soundswell*. (www.hitech.se)
5. E. Zwicker and H. Fastl, *Psycho-Acoustics: Facts and Models*, (second edition) Springer-Verlag, Heidelberg 1999, Ch. 7.
6. G. Weinreich, "Coupled piano strings," *J. Acoust. Soc. Am.* **62**, 1474–1484 (1977).
7. N.H. Fletcher, "Acoustical correlates of flute performance technique," *J. Acoust. Soc. Am.* **57**, 233–237 (1975).
8. A. Nishimura, M. Kato and Y. Ando, "The relationship between the fluctuations of harmonics and the subjective quality of flute tone," *Acoust. Sci. & Tech.* **22**, 227–238 (2001).
9. N.H. Fletcher and L.M. Douglas, "Harmonic generation in organ pipes, recorders and flutes," *J. Acoust. Soc. Am.* **68**, 767–771 (1980).
10. J. Sundberg, *The Science of the Singing Voice*, Northern Illinois University Press 1987, pp. 163–176.
11. E. Prame, "Vibrato extent and intonation in professional Western lyric singing," *J. Acoust. Soc. Am.* **102**, 616–621 (1997).
12. M. Duncan, C. Williams and G. Troup, "Vibrato frequency and phase lock in operatic duet quality," *Acoust. Aust.* **27**, 5–9 (2000).

RECENT DEVELOPMENTS IN THE APPLICATION OF NEURAL NETWORK ANALYSIS TO ARCHITECTURAL AND BUILDING ACOUSTICS

Joseph Nannariello, M. Riduan Osman and Fergus R. Fricke
Department of Architectural and Design Science,
University of Sydney, NSW 2006

Abstract: This paper reviews the work undertaken in the Department of Architectural and Design Science University of Sydney, on the use of neural network analysis in architectural and building acoustics. In auditorium acoustics, developments include the use of neural networks to predict acoustical attributes of concert halls: attributes such as reverberation time, RT_{60}, strength factor, G, clarity factor, C80, and lateral fraction, LF. Investigations have also been undertaken relating the acoustic quality of auditoria, as judged by conductors and musicians, to ten hall 'geometric' parameters and six acoustic parameters. In the area of small rooms, investigations have been carried out to predict the acoustic quality of music practice rooms and music teaching rooms by utilizing a combination of geometric variables as inputs. In rooms used for speech, neural network analyses have been undertaken to predict speech levels in university classrooms. Finally, in the area of noise control in buildings, work has been carried out using neural networks to predict the properties of acoustical materials such as sound transmission loss (wall sound insulation) and absorption coefficients. The results of the work undertaken have shown the potential usefulness of neural networks as design tools and, significantly, that neural network techniques have a role to play in the field of architectural and building acoustics.

1. INTRODUCTION

Sabine (1900) laid the groundwork for architectural acoustics and defined the subject in fairly simple terms. Everything that was simple at the end of Sabine's time appeared to become complicated and, by the 1950s, architectural acoustics had been turned into a complex subject. This is understandable as the field is broad and research activities have been carried out over a large range of topics. Unfortunately, the research has been and is often being directed to work which unavoidably conforms to traditional architectural acoustics precepts. Although the research has been of benefit to the acoustic community, architects and acousticians have continued to fail to come to terms with the concept that acoustically good auditoria cannot be directly scaled up or down to achieve good acoustics in new halls in the same manner in which visual aspects can be. A reason for this is the enormous difficulties that are created by the multiple parameters and multiple criteria aspects of architectural acoustics. These complex situations are not easily recognizable and therefore remain difficult to resolve using conventional methods. This paper summarizes research carried out, using a new approach to help architects and acousticians solve complex architectural and building acoustic design problems.

The new approach being researched at the University of Sydney involves the development of neural networks to investigate the many issues and problems that exist in the multi-disciplinary field of architectural and building acoustics and which are not readily handled by conventional methods. Neural network analysis (*NNA*) can be compared to multiple regression analysis except that with *NNA* assumptions need not be made about the system being modelled. Neural networks already perform successfully where other methods do not; they have been applied in solving a wide variety of problems including those in the area of civil and structural engineering where they have been used extensively [1]. The history and theory of neural networks, and some indications of their future utility, have been described in a plethora of published literature, for example [1–4], therefore, only a very brief overview of how neural networks operate will be covered in this paper. Suffice to say that neural networks obviate the need to use complex wave theory, and computer models, and impractical and costly physical models.

The major part of the work covered in this paper relates to investigations undertaken using neural networks in the area of room acoustics. Also presented is research with neural networks in the area of noise control in buildings, i.e. properties of acoustical materials and constructions.

2. NEURAL NETWORK ANALYSIS

There are many alternative forms of neural networking systems and there are many ways neural networks may be applied to a given problem. The suitability of an appropriate paradigm and strategy for application is very much dependent on the type of problem to be solved. The types of networks applied to many of the problems presented in this paper are the basic multilayer feedforward neural networks (see Figure 1). These networks perform a non-linear transformation of the input data in order to approximate output data. The number of cases (input and output parameter sets) influence the architecture of a multilayer feedforward network. The topology of a network consists of an input layer of neurons (one neuron to each input) a hidden layer or layers of neurons (one layer is usually considered sufficient) and an output layer of one neuron for each output. A neuron, also called a processing element (see Figure 2), is the basic unit of a neural network and executes a summation and activation function to determine the output of that neuron. The number of neurons in the hidden layer is approximately the average number of the inputs and outputs, though this number is also influenced by the number of training cases. For instance, too many neurons in the hidden layer can result in over-training (a lack of generalization which can be overcome by a number of strategies [5]) and lead to large verification errors. On the other hand, too few neurons can result in large training and verification errors.

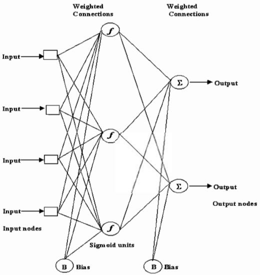


Figure 1: A multilayer feedforward neural network

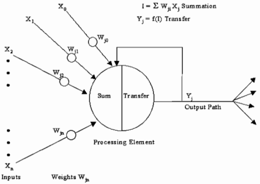


Figure 2: How a processing element (neuron) works. The notation W_{ji} represents the connection weight from the *j*th neuron to the *i*th neuron. (after Nelson, and Illingworth [27])

Inputs to a neural network are presented at the input layer. Starting from an initially randomized weighted network system, input data is propagated through the network to provide an estimate of the output value. The error between the actual output and the predicted value is used to adjust the network weightings (on the connections between neurons) to minimize the error in the predicted outputs. In this iterative procedure, the new weights are accepted if the resulting error is smaller than that recorded using the previous set of weights. Several algorithms [2–4] are commonly used to achieve the minimum error in the shortest time.

Some of the characteristics that support the success of neural networks and distinguish them from the conventional computational techniques are:

- The direct manner in which neural networks acquire information and knowledge about a given problem domain [6–17] (learning interesting and possibly non-linear relationships) through the training phase.
- Neural networks can work with numerical or analogue data that would be difficult to deal with by other means because of the form of the data or because there are so many variables.
- Neural network analysis can be conceived of as a black box approach and the user does not require sophisticated mathematical knowledge.
- The compact form in which the acquired information and knowledge is stored within the trained network and the ease in which it can be accessed and used.
- Neural network solutions can be robust even in the presence of noise in the input data.
- The high degree of accuracy reported when neural networks are used to generalize over a set of previously unseen data (not used in the training process) from the problem domain.

While neural networks can be used to solve complex problems, by what can be simply considered an interpolation process involving multivariate nonlinear mappings (in some cases mapping is acquired automatically and very fast because of the inherent parallel nature of NNA), they do however suffer from a number of shortcomings:

- The data used to train neural networks should contain information which, ideally, is spread evenly throughout the entire envelope of the system.
- There is limited theory to assist in the design of neural networks.
- There is no guarantee of finding an acceptable solution to a problem.
- There are limited opportunities to rationalize the solutions provided.

3. NNA AND ROOM ACOUSTICS

Concert halls: acoustical parameters

Concert hall design, is unique in its complexity. This is mainly because concert hall acoustics, in all its diversity, is a multi-criteria and multi-parameter discipline. Sabine's famous work led to the widespread use of reverberation time. For many years this was the only acoustical parameter used in the design of auditoria. However, uncertainties caused by the audience and performer absorption, together with the many anomalies inherent in the classical equation and other related theoretical formulae, are responsible for the often inaccurate prediction of reverberation times. These predictions are often not within the subjective difference limen of 5%, i.e. $\Delta T/T \approx 0.05$. This reason and because simple and accurate rules of thumb suitable for use at the early conceptual design stage led Nannariello and Fricke [6,7] to investigate an alternative method of predicting reverberation time. It was demonstrated that neural networks can better, more readily and accurately predict low frequency-band $RT_{125\text{-}250}$ and mid frequency-band $RT_{500\text{-}1000}$ reverberation times for auditoria.

Neural networks were trained using constructional and acoustical data of auditoria as input variables. Importantly, the input variables associated with the absorption coefficients were replaced by simple rating coefficients in terms of the absorptivity of materials. The result of this work provided evidence that neural networks 1) can be used to make predictions of reverberation times at low and mid frequencies for auditoria, and 2) that these predictions are as good or better than existing methods. Linear regression analysis of measured versus neural network predicted reverberation times, for low and mid frequency bands, produced R^2s of 0.91, and 0.94 respectively. Furthermore, and more importantly, the results showed excellent strength of association and high percentage agreement (10 out of 12 predictions were greater than 90%) between measured and predicted reverberation times. The results were repeatable and within range of the subjective difference limen of 5%.

Nannariello and Fricke [7] drew from the results obtain previously [6] and extended the idea to using neural networks built with a reduced number of input variables (a network 'dimensionality' reduction) to predict $RT_{125\text{-}250}$ and $RT_{500\text{-}1000}$ for auditoria . The concept was further extended to developing some basic relationships and rules of thumb on how simple geometric parameters affect reverberation time. The results of these investigations are presented in Ref. 7.

It has long been realized that there is more to auditorium acoustics than reverberation time. Over the last 30 years or so, a number of objective acoustical parameters (related to the subjective assessment of the acoustical characteristics of auditoria) have emerged to aid the design of auditoria. Consequently a number of methods have been developed [18-21] to predict parameters such as the strength factor G, the clarity factor C_{80}, lateral energy fraction(LF, and interaural cross-correlation coefficient $IACC$, but these methods have their limitations.

Nannariello and Fricke [9] investigated and developed a method of predicting G, C_{80}, LF, and $1\text{-}IACC_{E3}$ values in auditoria using neural networks. As a trial of this concept, and because well-documented measured data from halls is a rarity, Nannariello and Fricke [8] used neural networks trained using ODEON 3.1 numerical predictions. It was important to determine whether the neural networks could acquire the information and knowledge about the given domain (sound level distribution) and make accurate sound level (strength factor, G) predictions. A number of general conclusions came from this work. Firstly, that a neural network could be trained and tested using numerical predictions. Secondly, that these networks, because they use simple inputs, could be used in the early stage of a design. Thirdly, and most interestingly, that at least for reasonably diffuse shoebox shaped rooms, neural networks could make accurate predictions of G values. And finally, that there was a good basis for carrying out further investigations using noisy and poorly distributed measured data to train neural networks to predict G values and possibly values of other acoustical parameters.

The subsequent work of Nannariello and Fricke [9] provided evidence that non-linear models, such as neural networks trained with geometrical and measured acoustical data, could make predictions of the G, C_{80}, and LF values in concert halls. The predictions were as accurate as those calculated using existing models. The study demonstrated that neural networks could be trained with a handful of simple and available input variables such as the volume, maximum length, total floor area, reverberation time and tube ratio (see below). Between five and eight input variables were used to train networks to predict seat-averaged G, C_{80}, and LF. Six input variables were used to train networks to predict position-dependent G values.

It was demonstrated that the exact positions of seats in a hall were not required to accurately predict the average parameters. For the 126 receiver positions, in the 8 auditoria tested, the neural network analysis produced excellent results. Detailed descriptive analysis of the 8 auditoria in the 1000 Hz octave frequency band produced R^2s between predicted and measured data of between 0.29 and 0.93. More importantly, the absolute average errors and root mean square errors were within the subjective difference limen of G, which is approximately equal to ± 1 dB. Table 1 shows the accuracy of neural network predictions for the seat-averaged parameters G, C_{80}, and LF. The Table shows that, for the auditoria tested, neural network prediction errors for G, C_{80}, and LF were, in most cases, within the subjective limen of ±1 dB, ±0.5 dB, and ±0.05 dB respectively.

Nannariello and Fricke [10] extended the idea of using neural networks to make predictions of auditorium attributes to using neural networks to develop some basic knowledge and rules of thumb on how simple geometric parameters affect the attributes of an auditorium (in this case G). In this work, the use of acoustical parameters, such as reverberation time, as an input variable, was deliberately avoided. The results showed that neural networks trained with 4 simple geometric input variables—the hall volume, V, the maximum length, L_{MX}, maximum width, W_{MX}, the total acoustical floor area, S_T, and the tube ratio [19], $D_{mean}/(W_{mean} \times H_{mean})$,—where D_{mean} is the mean depth of the hall (distance from front of platform to rearmost wall) and W_{mean} and H_{mean} are the mean width and height respectively—gave accurate predictions of G. Table 2 shows the accuracy of the predictions: the high global correlation coefficient (R^2_G = 0.95) and low global errors (RMS_G = 0.37, $StdErr_G$ = 0.39 and $AbAvErr_G$ = 0.30 dB). The prediction errors are well below the subjective difference limen for *G*. The other attendant benefit was that the neural network models produced relationships which, in most cases, agreed with the published literature [19,22,23]. That is, *G* is affected by a number of architectural factors, the most important of which are the distance of the listener from the stage, the presence of reflecting surfaces, the acoustical floor area (the area occupied by the audience), and the volume of the auditorium. Significantly, however, the work also showed that determining the cubic volume and number of seats is not sufficient as a 'rule' in modern auditorium design. The optimization of *G* is dependent on a combination of geometrical factors including the shape of the hall, which is represented by the tube ratio and the maximum dimensions. This is demonstrated in Figure 3. It shows a three-dimensional quadratic smooth response surface plot of *G*, as a function of the tube ratio, $D_{\mathrm{mean}}/W_{\mathrm{mean}}{\times}H_{\mathrm{mean}}$, and the volume, *V*. The response surface plot also shows the non-linearity of the situation i.e. that the preferred value of *G* is dependent on the tube ratio and the volume.

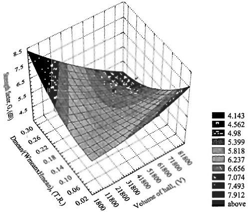


Figure 3: Quadratic smooth surface plot (*V,TR,G*) showing relationship between averaged acoustic parameter *G* (dB), hall volume *V* (m^3) and tube ratio, $D_{mean}/W_{mean}{\times}H_{mean}$ (m^{-1}) [10].

Continuing with the neural network approach, Nannariello and Fricke [26] investigated a neural-computation method for predicting the early interaural cross-correlation coefficient, $IACC_{E3}$, in unoccupied auditoria. Thirty-six auditoriums were used in the neural network analysis. A multilayer perceptron, fully connected, three layer feedforward network architecture, based on the supervised learning procedure was used to build the neural networks. Seven input variables were used in the first layer. The set-up function for the neural network analyses was: $1\text{-}IACC_{E3} = f(V, L_{\mathrm{MX}}, W_{\mathrm{MX}}, D_{\mathrm{mean}}/W_{\mathrm{mean}}{\times}\mathrm{H}_{\mathrm{mean}}, S_{\mathrm{T}}, A_{\mathrm{w}}, RT_{\mathrm{mid}}$, where the symbols specify quantities previously defined and A_{w} is the side wall angle of hall, and RT_{mid} is the mid frequency reverberation time. Results of the investigations showed that the neural network model could predict $IACC_{E3}$ values within the subjective difference limen, which is 0.075 ± 0.008. Five auditoria were used to assess the neural network analysis method and the errors between measured and predicted $1\text{-}IACC_{E3}$ ranged from –0.05 to 0.02. The neural network model used to make $1\text{-}IACC_{E3}$ predictions was imbedded in an Excel spreadsheet so that designers and researchers, without assess to specialized neural network software, could use the results of the work.

Concert halls: acoustical quality

Architects and designers, when designing concert halls, still make use of precedents especially at the sketch design stage. This technique, in most cases, has not guaranteed good acoustics. Fricke and Han [13] undertook a neural network analysis which related the acoustic quality of halls, as judged by conductors and musicians (subjective acoustic quality index, *AQI* [12]), to ten hall parameters; volume, surface area, number of seats, length, width, height, rake angle of seats, a surface diffusion index (visually assessed) [12-14], stage height and extent of stage shell/enclosure. Fricke and Han's work demonstrated that neural networks offered the opportunity to study the non-linear interactions of the many variables involved in the acoustic performance of concert halls and evaluate the acoustics of halls though the standard deviation ratio SDR achieved (≈ 0.90) left a lot to be desired. Further, unpublished work has considerably reduced the uncertainty of predictions.

In other work carried out by Fricke [14–15], the visually assessed surface diffusion index SDI, together with Beranek's [23] other orthogonal variables, the early interaural correlation $IACC_{E3}$, the time delay between the direct and first reflected sound at the centre of the main seating area T_{I}, the early decay time *EDT*, the measure of the average sound level in a hall at mid-frequency G_{mid}, and the bass ratio *BR*, were used as input variables to train neural networks to predict the acoustic quality *AQI*, of halls. The results of the neural network analyses were used firstly to investigate the importance of surface diffusion [14], and secondly they were applied to the Concertgbouw, in Amsterdam, to see how changes in the orthogonal variables might change the acoustic quality *AQI*, of the hall [15].

From the results of the neural network analysis, Fricke [14] concluded that Beranek's approach to the prediction of the acoustic performance of concert halls is valid, however a better way of predicting the acoustic performance may be to use a trained neural network. The neural network results showed that:

- using Beranek's six orthogonal parameters as inputs, better concert halls are achieved with higher *SDI* values
- the importance of *SDI* varies from hall to hall
- in some cases a relatively small error in assessing the *SDI* value could result in a hall being ranked at the opposite end of the quality scale.

Fricke [15] used the Concertgebouw data in a neural network analysis to compare the relatives merits of a number of approaches to predict the *AQI*. Several combinations of Beranek's input variables were used to train a set of neural networks and a second set of neural networks were trained using Beranek's input variables together with the number of seats (*N*), and the volume of the hall. The results of the neural network analyses were presented as standard deviation ratios, *SDR*s, and as *AQI* response surfaces. The *SDR*s values show the degree to which the data had been fitted. *SDR* value of 0.1 is considered an excellent fit, a ratio of 1 means that the predictions are no better than using the mean value. Response surface plot technique was used to show the relationship between parameters and *AQI*. From the results of neural network analyses using many combinations of input parameters Fricke conclude that:

- Ando's four-parameter model (*IACC*, T_I, G_{mid}, and *EDT*) [25] is not as good as Beranek's model [23] (*SDR*s of 0.87 and 0.40 respectively).
- A five-parameter model using (*IACC*, T_I, G_{mid}, *EDT*, and *SDI*) appears to be only marginally worse than the six-parameter model *SDR*s of 0.42 and 0.40 respectively. A four-parameter model using (*IACC*, *EDT*, G_{mid} and *SDI*) is marginally better for predicting *AQI* (*SDR* =0.37) than Beranek's six parameter model.
- There does not appear to be linear relationship between *AQI* and some of Beranek's parameters.
- A Bass Ratio *BR*, of less than 1.0 is preferred and is contrary to accepted wisdom.
- It is possible to obtain better predictions of the acoustic performance of concert halls using *IACC*, T_I, G_{mid}, *EDT*, *SDI* and *N* or *IACC*, G_{mid}, *EDT*, *BR*, *SDI* and *N* than it is using any combination of Beranek's parameters (*SDR*s of 0.25 and 0.33 respectively).

Rooms for speech

It would be very useful at the schematic design stage of a classroom, to have an expeditious and accurate method of predicting the distribution of sound levels (speech levels). Nannariello, Hodgson and Fricke [11] investigated and developed a method of predicting the Sound Propagation *SP*, in university classrooms. The *SP* is the variation of sound pressure level, normalized to the source power level, with distance from an omnidirectional source. Constructional and acoustical data for 34 randomly chosen unoccupied University of British Columbia (UBC) classrooms were used for the neural network analyses. The results of this work showed that neural networks trained with variables that have a causal relationship to the acoustical quality of the UBC classrooms produce reliable and accurate predictions. *RMS* errors for *SP* in each of the frequency bands, were within the subjective difference limen for steady-state sound pressure levels, which is about 1 dB (i.e. $\Delta E/E = 0.26$ where *E* is the energy density). Furthermore, results showed that *SP* predictions for classrooms were in better agreement with measured values than those obtained using Barron's revised theory [18] or the Hopkins-Stryker equation.

The good fit between measured and predicted *SP* values for the four classrooms tested was highlighted by the high correlation ($R^2 = 0.97$). The average error and standard deviation of the variations () between measured and predicted *SP* in the octave bands 125 to 2000 Hz ranged between –0.72 (0.35) and +0.69 (1.05) dB, confirming that in most cases the error was relative small and that predictions of speech levels at listener positions were accurate to within the magnitude of the subjective difference limen. Table 3 highlights, for example, the accuracy of neural network predictions, in the 4 classrooms tested, in the 1000 Hz octave frequency band.

Small music rooms

A large amount of research has been undertaken on acoustics of auditoria for the performance of live music and for speech, but there has been very little research carried out on the acoustics of smaller rooms used as music rooms and music teaching rooms. Osman and Fricke [16] developed a method of predicting the acoustic quality of small music rooms by utilizing a neural network trained with data collected and measured using binaural recordings made in the small music rooms. The 36 rooms used in the investigations were parallelepipedic with volumes ranging from 24 to 427 cubic metres. A combination of simple input variables for four musical instruments (cello, saxophone, trumpet, and guitar) was used to build a number of neural networks. The neural network models were used to predict the *AQI* of six small music rooms. From the results of the investigations Osman and Fricke concluded that neural network models can be used to predict acoustic performance of small music rooms, and that room volume, reverberation time, and room height are the most significant elements that determine *AQI*.

4. NNA AND NOISE CONTROL IN BUILDINGS

Sound transmission loss

Bearing in mind that the method of determining the transmission loss can be both expensive and time consuming Coomes and Fricke [17], using the results from acoustic laboratory tests on known partitions, investigated the application of neural network analysis for predicting the sound transmission class, *STC*, and transmission loss, *TL*, at specific frequencies, for different types of drywall constructions. Basic parameters (stud frame size, mass of wall construction, the inclusion, type and with of any insulation, overall partition width, minimum sheet lining thickness, and the difference in sheet lining from one side to the other), were used as inputs for the neural network analysis. The total number of training cases used in the neural network analyses was 128 (this included walls with isolated or resilient framing systems).

The results obtained were highly encouraging, with neural network designs achieving predictions for *STC* values within a similar range to those determined by a number of acoustic laboratories for comparable wall constructions. For instance, using data from the Canadian NRC on all types of dry wall constructions a neural network was trained to predict *STC* values within a *RMS* error of *STC* 2.01. The training data included partitions with *STC* ratings between 32 and 60. The inputs variables used in this case were type of studs (timber or steel), type of fixing (direct or vibration isolated), mass of wall, overall thickness and absorbent infil type (none, mineral wool, fibreglass, polyester or cellulose). Coomes and Fricke concluded that the modelled neural networks provided a good means of predicting *STC*, and that the significant computational effort required by other simulation methods are considerably improved on by the use of neural networks which provide a less complex prediction technique.

Sound absorption coefficients

Current measurement techniques for absorption coefficients, can give results from different laboratories which are more than 20% different. Such difference can mean the difference between winning and loosing a contract worth million of dollars. As part of the research program at the University of Sydney, attempts were made to develop a method of predicting sound absorption coefficients at specific frequencies, which was more reproducible and less costly and demanding than existing methods, by exploring the possibilities of applying *NNA*. Neural networks were first used to examine the influence of various air gaps on the absorption performance of porous materials. The neural network analysis used 8 input variables, the depth function (the air gap distance), the thickness of the material, and results of absorbent coefficient test at each of the octave frequencies. The analyses used a sample of 14 different ceiling tiles tested over a range of air gaps in order to learn a pattern of influence of air gap distance on the absorption coefficient. The results showed that neural networks were capable of mapping the absorption coefficients. In each of the specific frequency bands the error between known and predicted values of absorption coefficients was 5 to 10%. This work is continuing.

5. CONCLUSIONS

Indications are that concert hall design is ready to develop into a more scientific discipline. While art will always have a role in the design of concert halls, neural-computations present the opportunity of to extend the degree of science in the design process. The results of investigations carried out so often suggest that neural network techniques appear to be particular appropriate for application at the conceptual stage of a design. Neural network analysis approach not only considers the possible non-linearity of the combination of factors pertinent to the acoustic quality of a hall but it makes use of precedents which are intrinsic in the neural network model.

The work presented in this paper as shown that the neural network technique, using limited input variables, has been successfully used to predict the acoustic quality of concert halls and small music rooms. It has also been used to establish and investigate guidelines and rules of thumb for concert hall design. Furthermore, results of work in the area of auditoria for music and auditoria for speech have shown that neural networks—though not without limitations—can be successfully used to make accurate predictions of acoustical parameters, at an early stage of the design.

Testing the acoustic performance of various types of wall constructions and calculating the sound absorption coefficient materials require complex and costly techniques which require excess computer and analysis time. The work presented here has shown that there is potential for the neural networks technique to mitigate some of the costly issues associated with the laboratory testing. In addition, the technique can be used as design tool to complement formal acoustic testing and at the same time provide accurate predictions for *STC* and sound absorption coefficients at specific frequencies.

The most general conclusion to come out all the work undertaken and presented here is that the results of the investigations have shown the potential usefulness of neural networks as design tools. Furthermore and significantly, neural network techniques have a definite role to play in the field of architectural acoustics and in the acoustic community at large. Finally, it is hoped that ongoing research in this field will lead to other applications and the development of more robust [5,24] neural networks to further improve their efficacy in making accurate predictions of acoustical parameters.

Table 1: Descriptive statistics of averaged parameters, *G*, C_{80}, and *LF* predictions for auditoria 'tested' using neural networks (see Ref. 9).

Halls	*G_Meas*	*G_P_NN*	*G_Err*	C_{80}*_Meas*	C_{80}*_P_NN*	C_{80}*_Err*	*LF_Meas*	*LF_P_NN*	*LF_Err*
1	5.58	5.03	-0.55	-1.96	-2.12	-0.17	0.13	0.18	0.04
2	6.54	6.74	0.20	-5.14	-4.13	1.01	0.16	0.18	0.02
3	3.41	3.08	-0.33	-1.51	-1.21	0.30	0.27	0.17	-0.09
4	2.86	3.09	0.22	-1.66	-1.36	0.30	0.16	0.21	0.05
5	1.58	1.30	-0.29	0.67	1.00	0.33	0.18	0.20	0.02
6	5.50	4.56	-0.94	-4.36	-3.81	0.55	0.17	0.18	0.01
7	3.57	3.85	0.28	-2.15	-3.30	-1.15	0.20	0.17	-0.03
8	4.38	5.20	0.81	-	-	-	-	-	-

G_Meas = Measured strength factor, G, (dB)

G_P_NN = Neural network predicted strength factor, G, (dB)

G_Err = Error between measured and predicted strength factor, G, (dB)

C80_Meas = Measured clarity factor, C80, (dB)

C80_P_NN = Neural network predicted clarity factor, C80, (dB)

C80_Err = Error between measured and predicted clarity factor, C80, (dB)

LF_Meas = Measured lateral fraction, LF

LF_P_NN = Neural network predicted lateral fraction, LF

LF_Err = Error between measured and predicted lateral fraction, LF

Table 2: Descriptive statistics of neural network trained with set up function $G = f(V, L_{MX}, \textit{Tube Ratio}, S_T)$ used to predict average G values for the 7 enclosures for which the resulting $R^2Ga = 0.95$, $StdErr_G{}^b = 0.39$, $AbAvErr_G{}^c = 0.30$ and $RMS_G{}^d = 0.37$ (see Ref. 10)

Halls	Measured *G* values (dB)	Neural network Predicted G values (dB)	Error between measured and predicted values (dB)
1	5.58	4.89	-0.69
2	6.54	6.87	0.33
3	3.41	3.46	0.05
4	2.86	3.38	0.52
5	1.58	1.81	0.23
6	5.50	5.61	0.11
7	3.57	3.43	-0.14

[a] R^2_G = Global correlation coefficient between the measured and predicted G

[b] $StdErr_G$ = Standard deviation of errors between the measured and predicted G for the seven halls (dB)

[c] $AbAvErr_G$ = Absolute average error between the measured and predicted G, for the seven halls (dB)

[d] RMS_G = Root mean square error between the measured and predicted G, for the seven halls (dB)

Table 3. Descriptive statistics of a neural network result for Sound Propagation, SP, predictions for 4 classrooms at a total of 20 listener position in the 1000 Hz octave band. SP = sound pressure level minus sound power level (Lp-Lw) at that position (dB) (see Ref. 11)

Classroom	R_{OS} *(m)*[a]	*M_SP*[b]	*P_Nnet*[c]	R^2[d]	*Err_SP*[e]	*NN_RMS*[f]
C3	0.50	-6.16	-4.92		1.24	
	1.00	-9.39	-9.54		-0.15	
	2.00	-15.70	-14.05		1.65	
	5.00	-18.50	-19.19		-0.69	
	10.00	-20.50	-21.50	0.98	-1.00	1.07
C7	0.50	-6.16	-6.25		-0.09	
	1.00	-9.39	-9.53		-0.14	
	2.40	-11.80	-13.12		-1.32	
	5.00	-14.40	-13.63		0.77	
	10.00	-14.90	-14.73		0.17	
	15.00	-16.00	-15.42	0.96	0.58	0.68
C16	0.50	-6.16	-6.18		-0.02	
	1.00	-9.39	-8.84		0.55	
	2.00	-12.10	-11.14		0.96	
	5.00	-13.40	-13.35	0.98	0.05	0.55
C27	0.50	-6.16	-5.95		0.21	
	1.00	-9.39	-10.17		-0.78	
	2.00	-12.60	-13.35		-0.75	
	5.00	-16.60	-16.20		0.40	
	9.00	-19.40	-17.54	0.97	1.86	0.98

[a] R_{OS} = Distance between sound source and listener position (m)

[b] *M_SP* = Measured Sound Propagation, SP, at listener position (dB)

[c] *P_NNet* = Neural network predictions of Sound Propagation, *SP* (dB)

[d] R^2 = Coefficient of determination (correlation coefficient)

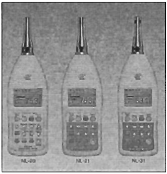
[e] *Err_SP* = Error between measured and predicted Sound Propagation, *SP* (dB)

[f] *NN_RMS* = The root mean square error of measured and predicted Sound Propagation, *SP* (dB)

REFERENCES

1. Nannariello, J., Fricke, F.R., "Introduction of neural network analysis and its application to building services engineering," *Building Services Engineering Research and Technology*, **22**(1), 61–71 (2001)
2. Hertz, J., Krogh, A., and Palmer, R.G., *Introduction to the theory of neural computation*. Addison-Wesley New York (1991).
3. Fausett, L., *Fundamental of Neural Networks*. Prentice Hall, New York (1994).
4. Baillie, D., and Mathew, J., "Diagnosis rolling element bearing faults with artificial neural network," *Acoustics Australia*, **22**(3), 79–84 (1994).
5. Martin, E.B., and Morris, A.J., *Artificial neural Network and Multivariate Statistics. In: Statistics and Neural Networks – Advances at the Interface*, Edited by Kay, J.W., and Titterington, D.M. Oxford University Press (1999).
6. Nannariello, J., and Fricke, F.R., "The prediction of reverberation time using neural network analysis," *Applied Acoustics*, **58**, 305–325 (1999).
7. Nannariello, J., Fricke, F.R., "The prediction of reverberation time using optimal neural networks," *Journal of Building Acoustics* (in press) (2001)

8. Nannariello, J., and Fricke, F.R., "The use of neural network analysis to predict the acoustic performance of large rooms: Part I Predictions of the parameter G utilizing numerical simulations," *Applied Acoustics*, **62**(8), pp.917–950 (2001).
9. Nannariello, J., and Fricke, F.R "The use of neural network analysis to predict the acoustic performance of large rooms: Part II Predictions of the of the acoustical attributes of concert halls utilizing measured data," *Applied Acoustics*, **62**(8), pp.951–977 (2001).
10. Nannariello, J., and Fricke, F.R., "A Neural Network Analysis of the effect of geometric variables on Concert Hall G values," *Applied Acoustics* **62**(12), 1397–1410 (2001).
11. Nannariello, J., Hodgson, M., and Fricke, F.R., "Neural network predictions of speech levels in university classrooms," *Applied Acoustics*, **62**(7), pp.749–767 (2001).
12. Fricke, F.R., and Haan, C.H., "Predicting the Acoustics of Concert Halls Using an Artificial Neural Network," *Acoustics Australia*, **23**(3), 87–95 (1995).
13. Fricke, F.R., and Han, Y.G., "A neural Network Analysis of Concert Hall Acoustics," *Acustica*, **85**, 113–120 (1999).
14. Fricke, F.R., "Visual assessments of the surface diffusion properties of concert halls," *Applied Acoustics*, **60**, 253–261 (2000).
15. Fricke, F.R., "Concert Hall Acoustics: an Alternative Approach," *Journal of Building Acoustics*, **7**(4), 233–246 (2000).
16. Osman, M.R., and Fricke, F.R., "Predicting the acoustical quality of small music rooms," Australian Acoustical Society Conference, Brisbane, Australia, November, 13–15 (1996).
17. Coomes, J., and Fricke, F.R., "The Prediction of Wall Sound Insulation Using Neural Networks," *Journal of Building Acoustics* (in press 2001)
18. Barron M., and Lee, L-J., "Energy Relation in Concert Auditoria. I," *J. Acoust. Soc. Am.*, **84**(2), 618–628 (1998).
19. Gade, A.C., "Prediction of Room Acoustical Parameters," A paper presented on the 121st Meeting of the Acoust. Soc. Am., Baltimore, May 1991 (1991).
20. Bradley, J.S., "Comparison of concert hall measurements of spatial quality," *J Acoust. Soc. Am.*, **96**(6), 3525–3535 (1994).
21. Vorlander, Michael, "International Round Robin on Room Acoustical Computer Simulation," 15th International Congress on Acoustics Trondheim, Norway 26–30 June, 689–692 (1995).
22. Gade, A.C., "Room acoustic properties of concert halls: quantifying the influence of size, shape and absorption area," 3rd ASA/ASJ meeting, Honolulu, paper 5aAA1, 1–6 (1996).
23. Beranek, L.L., *Concert and Opera Halls: How They Sound*, Acoust. Soc. Amer., Woodbury, New York (1996).
24. Tickle, A,B., Andrews, R., Golea, M., and Diederich, J., *Rule extraction from trained artificial neural networks,* In: *Neural Network Analysis, Architecture and Applications*, Ed. Browne, A., Inst. of Physics Publishing, Bristol and Philadelphia (1997).
25. Ando, Y., *Concert Hall Acoustics*, Springer-Verlag, Berlin, (1985).
26. Nannariello, J., and F.R., Fricke, "A neural computation method of predicting the interaural cross-correlation coefficient. IACCE3, for auditoria," *Applied Acoustics*, (in press 2001).
27. Nelson, M.M., and Illingworth, W.T., *A Practical guide to neural nets*. Addison-Wesley, New York, (1991).



AEROACOUSTIC NOISE AND THE MOTOR VEHICLE: RESEARCH AT RMIT UNIVERSITY

Simon Watkins, Peter D. Mousley,
Juliette Milbank and Firoz Alam
Dept. of Mechanical and Manufacturing Engineering
RMIT University, Melbourne, Australia

ABSTRACT: With every new model of car, customers expect reductions in noise and increases in refinement. Aeroacoustic noise plays a significant role in reducing the perception of quality of a vehicle and thus vehicle manufacturers now place a high priority on reducing this noise. In this paper, an overview of the common aeroacoustic noise sources in vehicles, and the research being conducted at RMIT University to better understand and reduce aeroacoustic noise, is discussed.

1. INTRODUCTION

The automotive consumer now has a wide choice of potential vehicles and the sound "quality" of the vehicle plays an increasingly important role in vehicle selection. Because of this, vehicle manufacturers now place considerable emphasis on the customer perception of quality. In car companies, the majority of work is performed for in-cabin sound quality and whilst this can extend to the opening and closing noises of components such as switches and doors, the overall sound quality under typical driving conditions is also important. Due to the efforts of the passenger vehicle manufacturers, levels of noise, vibration and harshness (NVH) have been reduced for car mechanical components (engines, drivetrains and exhausts for example), such that aerodynamically generated noise and vibration is now very significant. A good overview can be found in George and Callister [1].

In Australia, car manufacturers have dedicated noise-and-vibration groups and there are considerable experimental and analytical strengths in Universities. The purpose of this paper is to give a broad overview of aerodynamically generated noise relevant to cars, detailing some of the mechanisms that generate noise, and to give insight into the work that is ongoing at RMIT University.

2. MECHANISMS THAT GENERATE WIND NOISE

Aerodynamically generated noise can be produced by a range of different mechanisms. For the relatively low speed, incompressible flows around road vehicles the main mechanisms are:

- Aspiration noise, caused by the leakage of air in or out of the cabin
- Separated flows that impinge on surfaces, examples of which include the reattaching flow around the A-Pillars and the wakes of mirrors
- Cavity-induced noise, with coupling between the cavity fluid or structure and the exterior flow (Helmholtz resonance for example)
- Vortex shedding from bluff bodies, attached to the (relatively streamlined) body of the vehicle

The resulting noises depend not only on the mechanisms, but are also very dependent on the relative air velocity, which can include the effect of yaw angle (the angle between the apparent wind, as perceived by the moving vehicle, and the vehicle centreline). Since the relative velocity experienced by a moving vehicle is the vector difference of the wind speed (relative to the ground surface) and the road speed of the vehicle, the gusts in the atmosphere help generate wind noises that sound intermittent (for details, see Watkins [2]).

2.1 Aspiration Noise

Aspiration noise is usually insignificant for a well-sealed car. However, due to the pressure differences that exist around the moving vehicle (which, in strong crosswinds, can vary considerably with time) and dynamic body flex (due to road inputs), movement of door seals can still occur and in some cases can permit a leakage through a seal. When this occurs, significant, short-term noise can be generated. Car companies now place considerable emphasis on maintaining effective sealing of the body under the wide spectrum of operating conditions.

2.2 Separated Flow Noise

Much of the aerodynamically generated noise that reaches the ears of vehicle occupants comes from the surface pressure fluctuations arising from a separated vortical flow that originates from either side of the base of the A-pillars (note: the A-pillars are the inclined joining members between the edges of the windscreen and the side windows). For many car shapes, the local flow breaks away from the surface as it tries to turn around the A-pillars and the intermittency and reattachment of the flow to the side window can generate a broadband wind noise. For a given relative velocity, the strength of these vortices (and hence the noise) depends on the yaw angle, which in itself depends on the strength and orientation of the atmospheric wind (see Figure 1 for sample noise spectra, from within a car, at positive and negative yaw angles). When yawed, the leeward side vortex is of greater size and strength than the windward side vortex and therefore, the noise on the leeside is generally greater than the windward side because of this effect. Many studies of the A-pillar flow have been made (Watanabe *et al* [3] for example) and much commercial work is carried out in the early development stages of new car models. Figures 2 and 3 show the difference in flows for yaw angles of ±15 degrees. For the windward side (+15 degrees) the vortex has disappeared and thus the flow is attached and steady, whereas for the leeward side (-15 degrees) the flow is separated and very unsteady, as shown by the somewhat random direction of the wool tufts.

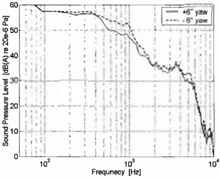


Figure 1: Sample noise spectra at 100 km/h, ±6° yaw

Figure 2: Flow on the side window at +15° yaw (from Watkins and Oswald [8])

Figure 3: Flow on the side window at -15° yaw (from Watkins and Oswald [8])

2.3 Cavity Noise

Cavities come in many shapes and sizes and exist in many areas of a production vehicle. Examples include door and panel gaps, open sunroofs, open windows and wheel arches. For applications that are specific to vehicles, George [1] has identified two general types of noise associated with cavities: a broadband noise that results from both the leading and trailing edges of the cavity; and tonal noise. The types of tonal cavity noise produced by different configurations and the variation in frequency of the noise have been discussed in a review by Rockwell and Naudascher [4]. Tones can be due to a number of feedback mechanisms. These mechanisms can be confined to the cavity shear layer while others involve the cavity volume and/or structure to generate tonal noises. Tonal noise mechanisms confined to the shear layer have a resonance frequency that is a function of freestream velocity over the cavity, while their amplitude depends on cavity edge geometry and shear layer properties. Feedback resonance and shear layer tones are an example of this type of mechanism. Mechanisms that involve the cavity volume or structure have resonance frequencies that are independent of freestream velocity but dependent on cavity geometry. The amplitude of these mechanisms is dependent on the shear layer properties, freestream velocity and cavity geometry. A good example of this type of mechanism is Helmholtz resonance.

Much research has been published on aspects of tonal noise production mechanisms but most studies have been focused on cavity and flow scales pertinent to aircraft; there is a shortage of published data relevant to automotive cavity and flow scales. Experimental and theoretical research is continuing into the parameters that affect some types of cavity noise (Ahuja and Mendoza [5], Milbank *et al* [6] and Howe [7]), with a view to better understanding the mechanisms and ways of reducing tonal noise.

2.4 Vortex Noise

Two and three-dimensional bluff bodies tend to periodically shed vortices. Hence, the vehicle itself sheds vortices; vortices are shed from the rear end of the vehicle, where the flow separates, and from around the A-pillars. Vortices are also shed from protuberances on the vehicle. These include aerials, roof-rack bars, and external rear-view mirrors and a consideration of these and the associated flow field has been given in Watkins and Oswald [8].

Vortex shedding gives rise to fluctuating forces on the bodies in both along and crosswind directions, and thus generates aerodynamically induced noise. The primary frequency of the noise generated is at the vortex shedding frequency, with some minor harmonics. For very low frequencies, the vortices tend to modulate higher frequency noise that may be present. The Strouhal number, S, defines the frequency of vortex shedding and hence noise; $S = fD/U$ where f is the vortex shedding frequency (Hz), U is the freestream velocity (m/s) and D is the body diameter (m). For the range of flows encountered by add ons to the car (both circular and prismatic, such as aerials and roof racks respectively), the Strouhal number can be considered essentially constant with velocity—typical values are from 0.20 to 0.28, depending on the body shape. Further details can be found in texts dedicated to flow-induced noise and vibration, such as Blake [9] and Blevins [10]. Vortex shedding from a vehicle body is more complex and not completely understood. However, researchers have tended to use the vehicle width as the characteristic diameter, as this typically produces Strouhal numbers in the same range as quoted above (see Nguyen [11] for further details).

An example of vortex shedding noise is that emanating from circular, telescopic aerials. Shown in Figure 4 is a standard telescopic aerial, adjacent to an aerial that has been manufactured from a tapered stainless steel blank into which has been ground an optimised spiral grind. Changing the circular sections into a shape that suppresses coherent vortex shedding along the axis leads to a large reduction in the radiated noise. Figures 5 and 6 depict the resulting noise spectrum and the reduction in the peaks in the spectrum can be clearly seen.

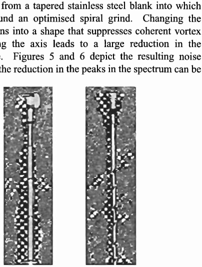


Figure 4: Standard telescopic aerial and optimised spiral ground aerial (both from Czydel [12])

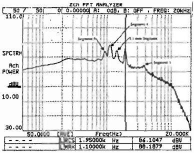


Figure 5: Noise spectrum from a standard telescopic aerial (from Czydel [12])

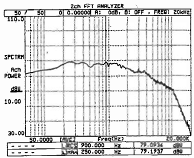


Figure 6: Noise spectrum from a spiral ground aerial (from Czydel [12])

3. CURRENT RESEARCH PROGRAMS AND FACILITIES AT RMIT UNIVERSITY

Despite producing less than 1% of the world's vehicles, Australia is well served in respect of facilities and undertakes research that is of international significance. Australia's largest vehicle aerodynamics and aeroacoustics research group is located at RMIT. An overview of the major infrastructure and research programs at RMIT is given here.

3.1 Experimental Facilities

There are two relatively quiet tunnels in Australia that can accept full-size cars—the Monash University 1 MW tunnel and the RMIT University Tunnel. The Monash Tunnel is an open-jet tunnel (i.e. it does not have solid boundaries close to the vehicle, instead the vehicle is immersed in a jet that issues into a plenum chamber). In contrast, the RMIT Tunnel is of the traditional type, where the test section is enclosed by walls and a roof. As part of a recent refurbishment, acoustically treated turning vanes were installed. A plan view of the RMIT tunnel is shown in Figure 7. Car and component companies use both of these wind tunnels for commercial and research work, often in conjunction with postgraduate research students.

In addition to the major infrastructure, instrumentation includes: a Head Acoustics Aachen binaural head system (which can be seen in the car in Figures 3 and 8); SPL meters; multi-channel DAT recorders; and an ellipsoidal, dish-type, highly directional microphone of 1m diameter.

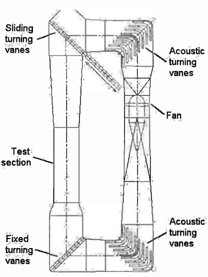


Figure 7: Plan view of the RMIT University Wind Tunnel

3.2 Current Research Programs

As well as commercial development programs that are undertaken by the car and component companies, there are several basic research programs sponsored by the car companies and by the Australian Government (via the Australian Research Council), including an investigation of the intermittency of in-cabin wind noise. As vehicle occupants notice noise sources that fluctuate in amplitude more than noises of constant amplitude, it is important that sources of fluctuating noise be investigated during a vehicle development program. However, aeroacoustic noise sources often fluctuate in amplitude because of fluctuations in the atmospheric wind, but the wind tunnels used to evaluate wind noise generally feature very smooth airflow. Hence, noise fluctuations generally do not occur and cannot be evaluated in these wind tunnels. To address this, a program to better understand the noise fluctuations is being undertaken, with the hope that results from this program can be used to develop a system that allows fluctuations to be 'added' to noise measured in a wind tunnel. The main aim is to be able to synthesise on-road noise from noise measured in a wind tunnel so that it includes some of the fluctuations that are experienced on-road. It is also expected that tyre noise and mechanical noise could be added to the wind noise measured in a wind tunnel, giving engineers a more realistic prediction of the noises that will be present when a new vehicle is driven on the road through "real" atmospheric winds.

To investigate the links between fluctuations in the atmospheric wind and modulation of sounds heard within the vehicle cabin, velocities around the passenger-side A-pillar were measured simultaneously with the noise inside the cabin during a comprehensive series of tests performed on-road and in the wind tunnel. Velocity measurements were performed with 4-hole, 'Cobra' pressure probes that allow determination of the velocity in 3-components, and fluctuations of velocity of up to 1500 Hz to be measured (which is well in excess of the frequency of the major fluctuations in the atmosphere, which are typically less than 10Hz). The noise measurements were performed with an Aachen binaural head system, which is shown in Figure 8 along with two Cobra probes (one upstream of the A-pillar and one next to the side window).

Figure 9 shows a sample section of data that illustrates a link between wind velocity fluctuations and interior noise fluctuations. The top time trace shows the wind velocity, with the mean removed, while the centre time trace shows the local yaw angle, also with the mean removed. The bottom time trace shows a representation of interior noise fluctuation, which has undergone signal processing to emphasise the fluctuations. Strong correlation between the velocity and noise signals is observed, and the coherence for low frequency (less than 8 Hz) fluctuations is found to be above 0.8. This, and other similar, data have been used to synthesise noise in windy conditions from wind tunnel data with encouraging results.

Data from on-road testing are also being processed to separate and provide information about wind noise, mechanical (mainly transmission) noise and tyre noise — in practice this proves difficult, as all three noise sources overlap in terms of frequency content and while the mechanical noise is relatively constant, both the wind noise and the tyre noise fluctuate with time.

Figure 8: Set-up for wind tunnel and on-road testing, showing two Cobra probes and an Aachen head

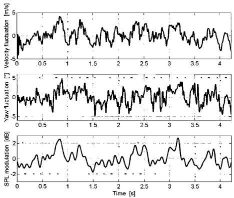


Figure 9: Sample link between velocity and yaw angle fluctuations and modulation of the sound pressure level

In addition to the programs that involve direct measurement of sound and velocity, work is ongoing on the reduction of surface pressure fluctuations near the A-pillar. Whilst the hydrodynamic pressure fluctuations can be a direct cause of noise, another way that sound is generated in the car cabin is by the surface pressure fluctuations exciting the car structure, particularly the side window glass. In order to reduce this, an increase of the A-pillar radius is required. To assess the influence of size and shape of curvature, and to ascertain how useful scale models are in the very early stage of car development, a comprehensive program of tests measuring the surface pressure fluctuations in the A-pillar region are being carried out (Alam [13]). In Figure 10, two very different geometries of A-pillar can be seen and the influence on the surface flow is depicted using wool tufts. Additionally, microphones have been flush-mounted at various locations on the surface in order to measure fluctuations in surface pressure. These pressure fluctuations are non-dimensionalised by the reference dynamic pressure, to give Cp_{rms}. The variation in Cp_{rms} for various radii of A-pillar can be seen in Figure 11. It is seen that radii tighter than 0.3m lead to a significant increase in the surface pressure fluctuations, particularly on the leeward (negative yaw) side. All of these measurements are also compared with similar work carried out on production cars, in both the wind tunnels described above and on-road, with a view to determining scaling laws for aerodynamic noise between model scale and full-scale testing.

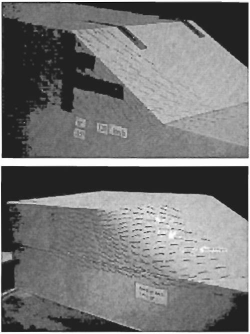


Figure 10: Comparing the influence of A-Pillar radius on the flow and pressure fluctuations (both from Alam [13])

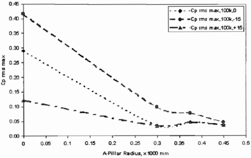


Figure 11: Fluctuating Cp rms Variation with Local A-Pillar Radii, Yaw = -15°, 0° and +15°

FUTURE DIRECTIONS

The preceding discussion has given an overview of automotive aeroacoustic noise sources and the recent research work conducted at RMIT to better understand these noise sources. Work is ongoing in all of the areas discussed and new areas are starting to be investigated, with the aim of providing vehicle manufacturers with more powerful design and analysis tools for the prototype and development stages of a new motor vehicle.

ACKNOWLEDGEMENTS

The authors would like to thank Rod Czydel for his contributions and the continuing support of the Mechanical Engineering Departments of RMIT and Monash Universities. The financial support of the Australian Research Council, Holden Ltd and the Ford Motor Company (Australia) is also gratefully acknowledged.

REFERENCES

1. A.R. George and J. Callister, "Aerodynamic Noise of Ground Vehicles", Society of Automotive Engineers (SAE) International, Technical Paper 911027
2. S. Watkins, "Gusts and Transients" in *Automobile Wind Noise and Its Measurement part 2,* SAE Special Publication SP-1457, ISBN 0-7680-0389-X
3. M. Watanabe, M. Harita and E. Hayashi, "The Effect of Body Shapes on Wind Noise", Society of Automotive Engineers (SAE) International, Technical Paper 780266
4. D. Rockwell and Naudascher, "Review – Self-Sustaining Oscillations of Flow Past Cavities", *Transactions of the ASME,* **100**, 152-165 (1978)
5. K.K. Ahuja and J.M. Mendoza, "Effects of Cavity Dimensions, Boundary Layer, and Temperature on Cavity Noise with Emphasis on Benchmark Data to Validate Computational Aeroacoustic Codes", *NASA CR 4653*, NASA Langley Research Centre, Hampton, VA (1995)
6. J. Milbank, S. Watkins and R. Kelso, "Tonal Noises From Small Cavities on Motor Vehicles and a Case Study of a Whistling Mirror", Seventh International Congress on Sound and Vibration, 4–7 July, Garmisch-Partenkirchen, Germany, 1315-1322 (2000)
7. M.S. Howe, "Edge, Cavity and Aperture Tones at very Low Mach Numbers" *J. Fluid Mechanics*, **330**, 61–84 (1997)
8. S. Watkins and G. Oswald, "The Flow Field of Automobile Add-Ons – with Particular Reference to the Vibration of External Mirrors", *J. Wind Engineering and Industrial Aerodynamics*, **83**, 541-554 (1999)
9. W. K. Blake, *Mechanics of Flow-Induced Sound & Vibration,* Volumes I & II, Academic Press Inc. (1986)
10. R. D. Blevins, *Flow-Induced Vibration*, 2nd Edition, Van Nostrand Reinhold (1990)
11. T.M. Nguyen, *The Sideways Dynamic Response of Passenger Cars in Turbulent Winds*, PhD Thesis, Dept of Mechanical and Manufacturing Engineering, RMIT University (2001)
12. R. Czydel, *The Mechanism of Wind-Generated Noise of Circular Motor Vehicle Antennae*, Final Year Project Thesis, Dept of Mechanical and Manufacturing Engineering, RMIT University (1996)
13. F. Alam, *The Effects of Car A-Pillar and Windshield Geometry and Yaw Angles on Local Flow and Noise*, PhD Thesis, Dept of Mechanical and Manufacturing Engineering, RMIT University (2001)

Erratum

Virtual sensors in active noise control

Kestell, Hansen and Cazzolato
August 2001 issue Vol. 29, p.57

A technical problem made the four equations hard to read and a legible version is given below.

2. THEORY

With reference to figure 1, four *forward difference prediction virtual sensors* algorithms are summarised as follows:

1. Two microphone, first-order virtual microphone:

$$p_v = \frac{(p_2 - p_1)}{2h} x + p_2$$

2. Three microphone, second-order virtual microphone:

$$p_x = \frac{x(x+h)}{2h^2} p_1 + \frac{x(x+2h)}{h^2} p_2 + \frac{(x+2h)(x+h)}{2h^2} p_3$$

3. Two microphone, first-order virtual energy density sensor:

$$\begin{aligned}\bar{E}_{D_x} = \frac{1}{4\rho c^2}\Bigg[&\left(1+\frac{x}{2h}\right)^2 p_2^2 - \frac{x}{h}\left(1+\frac{x}{2h}\right) p_1 p_2 \\ &+ \left(\frac{x}{2h}\right)^2 p_1^2 - \frac{1}{(2hk)^2}\left(p_2^2 - 2p_1p_2 + p_1^2\right)\Bigg]\end{aligned}$$

4. Three microphone second-order virtual energy density sensor

$$\begin{aligned}\bar{E}_{D_x} &= \frac{1}{4\rho c^2}\Bigg[\Bigg(\frac{x(x+h)}{2h^2} p_1 + \frac{x(x+2h)}{h^2} p_2 \\ &+ \frac{(x+2h)(x+h)}{2h^2} p_3\Bigg)^2 \\ &- \frac{1}{k^2}\left(\frac{2x+h}{2h^2} p_1 - \frac{2x+2h}{h^2} p_2 + \frac{2x+3h}{2h^2} p_3\right)\end{aligned}$$

Where x is the distance between the observer and the nearest sensor, h (25mm) is the transducer separation distance, p_1, p_2 and p_3 are the measured pressures, p_x is the pressure at the observer location and E_{Dx} is the time averaged energy density at the observer location.

www.acoustics.asn.au

Australian Acoustical Society

For Proceedings of
ACOUSTICS 2001

For Information on
ACOUSTICS 2002

See with your ears

Notice something unusual in your report – a peak perhaps, or changes in frequency? No need to guess – just select any part of the graph to hear the actual sound. Want to email the graph, complete with sound and even video attachments? Easy, with the **Larson Davis 824**, a sound level meter and real time analyser in one small rugged package, and DNA software installed on your PC. It's all available at the click of a mouse.

Davidson Measurement offers an extensive range of acoustic equipment, supported by specialised engineering expertise and a thorough understanding of the nature of sound.

Packed with features and capable of downloading and translating binary data to ASC11 text. ***Larson Davis Model 824 with 824 Util software.***

For measurements in acoustic and vibration applications plus modal analysis and vibration diagnosis. Multiple channel operation, PC integration. ***OROS PC-Pack.***

Larson Davis and OROS... two sound reasons to talk to Davidson Measurement

Davidson Measurement

www.davidson.com.au

Leaders in the field of measurement technology ...since [illegible]

Davidson Measurement
Pty Ltd
Head office, Victoria:
1-3 Lakewood
Boulevard
Braeside Victoria 3195
Ph (03) 9580 4366
Fax (03) 9580 6499
E-mail:
info@davidson.com.au
Web:
www.davidson.com.au

New South Wales/ACT
Pl (02) 9748 0544

Queensland
Pl (07) 3853 5300

Western Australia/NT
Pl (08) 9301 0923

Tasmania
FreeCall 1800 816 687

South Australia
FreeCall 1800 816 687

Technical Note

"DODEC" SPEAKER CONSTRUCTION

Peter Patrick
Scientific Acoustics
10 Harth St. Toowoomba 4350

If you have occasional need for a dodecahedral loudspeaker, and would build one yourself but for the compound mitre joints involved, this process could be for you.

The "stitch 'n glue" process is well known to plywood boat builders. The outcome is definitely more certain to be successful from the outset than a compound mitre affair and it will definitely be stronger by several orders of magnitude. Strength and Beauty in the final product as with any project, are a fair measure of your input. In this case however, the skill levels demanded by compound mitre joints are not required.

Ingredients are: (a) hardwood plywood 9mm – 1 small sheet, (b) epoxy resin – 1litre at the most, (c) 50mm Fibre Glass tape – 1 roll, (d) micro-sphere filler – 55gm, (e) soft copper wire approx 1mm diameter, (f) very low cost paint brushes for applying epoxy (each will only be used once).

9mm plywood can be obtained at most hardware stores. System West have a comprehensive display at www.sterndrives.com. I suggest 403 Micro-spheres, 105 Resin and 206 Hardener. The slow hardener gives time for the liquid epoxy to be absorbed into the surface of the plywood and form a strong bond. Polyester resin is not recommended. Most boat builder supply the hardware, and ships chandler shops can supply the glass tape, the epoxy resin and micro-spheres in small quantities.

The loudspeakers will be "front mounted" or secured to the exterior of the completed enclosure. It is therefore necessary to purchase the loudspeakers and measure the back of the mounting flange to ascertain the size of clearance hole required – the hole diameter must clear the tapered frame but support the flat portion of the flange.

Mark out a pattern pentagon from scrap 9mm or 12mm plywood. Start by scribing the circle for the speaker mounting hole with a compass. (In my case this was exactly 100mm). Using the same centre scribe a larger circle within which to construct your pentagon. Make sure there is a nice solid patch of "land" around the speaker hole and cut the pentagon out from the scrap ply. Drill a pilot hole (1/8in or 3mm) in the centre of the pattern. Do not cut the speaker hole out.

Use the pattern to mark out twelve pentagons on the 9mm sheet. Cut the pentagon faces to size and use the pattern as an overlay to pilot drill the centres of all twelve faces. Use a metal-cutting blade in a jig saw for this to obtain splinter free edges. Note that rebating the exterior edges is optional. I did this with a router set to about 1mm depth to a width of approximately 25mm. Drill two small holes (approximately 1.5 to 2 mm) along each edge of each pentagon.

Cut the copper wire into 100mm lengths and "stitch" the pentagons together through the 1.5mm holes near the edges. Assemble all but one face into the familiar ball shape. Keep the faces aligned at the inside edge and maintain an even gap or "V" in the exterior joints. A few gaps in the joinery are no problem at this stage.

Next mix a batch of about 10 table-spoons of epoxy and 2 of hardener (or whatever proportions are specified by the manufacturer), and add micro-spheres a little at a time until a wet putty consistency is obtained. Note that it is counter productive to mix a large batch of epoxy and hardener. The chemical reaction generates heat, which initiates premature curing of the epoxy. Please note the manufacturers material safety data sheets and apply whatever precautions are recommended for the sake of your health. Some people might contract dermatitis from epoxy and breathing the vapours might not be good for ones health.

Now plaster the "putty" into the gaps. I recommend both inside and outside for maximum strength. Fibreglass tape is weakened by sharp bends or kinks. Filling the inside of the joints in a smooth radius is recommended. Ensure the exterior gap is full. A photograph of an enclosure at this stage of construction is shown in Figure 1. Once the putty has set, cut out the copper stitches and sandpaper the interior and exterior joints to a smooth finish.

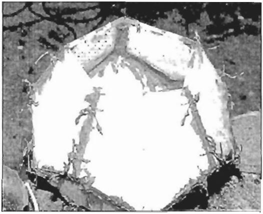


Figure 1. The speaker box, "stitched" with copper wire and "puttied" with epoxy resin. One face of the dodecahedron still has to be attached.

Cut about 30 fibreglass tape strips to the length of an inside edge of the DODEC and paint the inside joins with epoxy/hardener mix. The fibreglass strips are then applied length-wise along each join. Paint epoxy over the strips to ensure they are well filled with epoxy. Any left-over resin should be mixed with micro-spheres and used to fill remaining holes and irregularities. It is preferable, in the opinion of this writer, to discard the brush once the epoxy has hardened it to a useless slab, rather than purchase epoxy thinner chemicals and clean the brush after use. Note: cut the fibreglass strips well before mixing the epoxy and hardener to avoid contaminating scissor blades with epoxy. Trim the final plywood pentagon to fit the last hole with a hand plane or sandpaper and putty it in place.

Once the epoxy has set in the last pentagon, sand the exterior joins to a smooth finish in readiness for the fibreglass tape process. Radius all edges with sandpaper and apply the epoxy and fibreglass tape along the joins, overlapping at the corner points. It is good practice to fill the tape with plenty of clear epoxy. Suspend the enclosure on a hook through a pilot hole to avoid permanent adhesion to any surface in contact with it.

Next use the pilot centres to cut the holes for the speakers. I obtained excellent results using a 100mm fixed diameter hole saw. A skilled operator with a power jig saw might obtain a similar outcome. Reach in through the speaker holes to putty the inside of the untaped joins of the last pentagon face to be glued in place. Sandpaper this last set of five joins to a smooth radius and apply epoxy and tape as elsewhere. If you have rebated the exterior edges of the faces plaster the rebated area with epoxy and micro-sphere putty to provide a smooth exterior. Sand the exterior edges to a smooth radius and finish with fine paper (approx 240 wet-and-dry paper).

Automotive exhaust pipe can be used as a mounting point. Speaker stands (35mm) are an odd size (for automotive exhaust installers) so I had a piece of exhaust pipe stretched at one end to make a snug fit on a speaker stand. Cut three slots with a hacksaw at approximately 120° intervals in the unstretched end of the pipe. Bend the tabs to fit one point of the box. A photograph of an enclosure at this stage of construction is shown in Figure 2. A socket fitting for an acoustic guitar should have appropriate mounting thread or flange to mount properly on the 9mm plywood enclosure.

All that is needed is a coat of paint and a set of speakers. I connected four series-connected sets each of three 8 ohm speakers (24 ohms) in parallel to form a 6 ohm load. Take care to ensure all loudspeakers are connected in the same polarity. I also added a switch to permit operation with just one loudspeaker, thus approximating, in rather vague terms, the acoustic behaviour of the human head. A completed loudspeaker is shown in Figure 3.

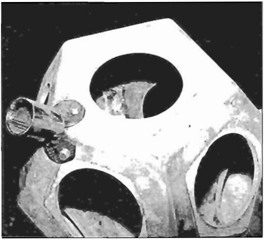


Figure 2. The completed raw speaker box, showing the taped joints and the fixing bracket.

Figure 3. The completed dodecahedral speaker box with speakers mounted.

Technical Note

IMPLEMENTATION OF NSW NOISE POLICY—AN UPDATE

Geoff Mellor and Vicki Labban
NSW Environment Protection Authority
PO Box A290, Sydney South, NSW 1232

This is an edited version of the presentation at the NSW Divisional Meeting in August 2001.

BACKGROUND TO THE NEW NOISE POLICIES

Over the past 3 to 4 years the EPA has been building an improved policy platform for dealing with noise pollution in NSW. Thorough research, comprehensive consultation and economic analyses of changes has resulted in more robust policies that have a wider ownership by stakeholders. Both the NSW Industrial Noise Policy (INP) and the road traffic noise policy underwent extensive public consultation that involved issuing a draft policy, advertising in the media the opportunity to comment, conducting seminars and addressing the issues raised in producing a final policy. An important part of the process of developing these policies was that they should represent a "whole-of-government" position. Accordingly the policies were discussed with interested government agencies and have received government endorsement. The road traffic policy was published in May 1999 and the INP published in January 2000. Both of these policies are available from www.epa.nsw.gov.au

There were a number of objectives we wanted the INP to achieve:

- The policy needed to be sufficiently *flexible* to be able to accommodate the range of different circumstances that occur in the real world and allow for the best solution to be developed. This meant that the process should allow for innovation in assessment and control techniques and include an ability to negotiate agreed outcomes.
- The approach needed to provide the framework for a *consistent outcome* in assessing noise impacts, so that different people would come to the same conclusions for a given set of circumstances. To do this the policy gives details on how an assessment of noise should be conducted.
- We wanted to ensure that as far as possible assessments of noise impacts would result in predicting *what would actually occur in practic*e. This meant including influences such as wind and temperature inversions which increase noise levels.
- In the past a large amount of effort was sometimes expended on debating what noise criteria were appropriate to apply to assess whether an impact occurred. We wanted to move this debate away from the numbers that should apply and *focus much more on the best ways to mitigate* the noise.
- The concept of applying all *feasible and reasonable means of mitigation* needed to be articulated so that interested parties could see what level of control was expected.
- We wanted to *highlight the role of land-use planning* as a means of avoiding noise problems. And develop an understanding that, in some cases, there was likely to be a limit to the degree of noise control from engineering and management practices. And that in this situation it is necessary to look to additional means of minimising noise impacts such as in the design and construction of sensitive developments that are predicted to be affected by noise.

TRAINING

Perhaps an equally important part of introducing a new policy is to follow-up its introduction with training in its use. We decided at an early stage to make a major commitment to training and extensive programs were offered following the release of each policy. In total 47 separate one day courses were offered (24 for road traffic and 23 for industrial noise). To give good access to training courses they were held at various metropolitan and country locations across the State. Interest was high and almost nine hundred people were trained.

IMPLEMENTING THE POLICIES

After INP was published in January 2000 there was a six months transition period where we would accept assessments done using either the old policy or the INP. The approach appears to have worked well and all assessments are now being done using the INP. To date we have received around 30 to 40 assessments using INP and one Commission of Inquiry was held only recently and involved an extension to a coalmine in the Hunter Valley.

During the application of the policy a relatively small number of issues have come up that needed clarification. In some instances the issues were limited to the particular development but in others their application is broader. For example there is sometimes a question on what land use category should apply to an area, what wind speed to assign where winds are found to significantly increase noise and how private haul roads and rail lines should be assessed. We are working towards providing some explanatory notes on common issues.

Assessing and managing noise from industry encompasses both technical and policy issues. Because of the breadth of the subject the policy needed to draw a careful balance between being concise and understandable, and including sufficient detail to cover typical situations. Clearly a policy document, even one with a large technical component should not attempt to cover in detail all of the range of scenarios that may occur in practice. To do so would be likely to create a large and complex document whose usefulness would be greatly diminished.

What is important is that the policy clearly establishes the principles or intent on how it should be applied. Applying the policy to any new set of circumstances then becomes a matter of referring to the principles established in the policy.

IMPORTANT PRINCIPLES

Four important principles established in the policy and that must be considered where questions in interpretation arise are:

1. That the noise assessment needs to address the noise levels that are expected to occur in practice. This means that the effects of weather need to be considered.
2. That all feasible and reasonable controls be applied to limit emission of noise. This recognises the mitigation of noise as the central concern but that there is a limit to what can be achieved.
3. Where noise levels exceed the criteria after applying all feasible and reasonable controls the expected impact from the exceedance needs to be quantified and the proponent needs to clearly explain other relevant factors such as:
   * economic and social benefits,
   * complaint history and views of other stakeholders such as council, and
   * whether the project results in a net reduction in noise

   This information can greatly assist a broader understanding of the context of the project and assist making balanced and well-informed decisions. What we at the EPA are looking for is a demonstration that the range of mitigation measures have been carefully assessed and applied and a good sense of the implication of any remaining level of noise and relevant economic or social factors.
4. That the application of the policy must result in clear and enforceable conditions. This benefits both the licensee and the public by clearly defining the boundaries for noise.

LAND USE CONFLICTS

Land use conflicts happen where noise sensitive and noise producing developments are co-located. Once the location of a noise producing activity is decided it's important not to create situations where unachievable expectations on reducing noise will lead to conflicts. This type of pressure occurs where noise has not been properly considered when developing adjacent land for noise sensitive activities. This isn't to say that a noise producing industry can ignore its noise impact. The primary obligation to control external noise lies with the noisemaker. However where all feasible and reasonable noise control measures are already applied any further reduction depends on future noise control technology and new work practices and is only possible over time.

In situations where land is relatively scarce it makes sense to take all reasonable steps to maximise the use of available land. This implies that a balanced approach is needed that as well as requiring noise producers to apply all feasible and reasonable measures to reduce noise, looks to incorporating noise mitigation in noise sensitive developments to control noise.

CASE STUDIES

1. Extension to existing industrial development

The first case involves a plant that is located in a country town. An extension to the existing plant was being sought. The plant is the only sizeable industrial development in the town and this was likely to remain the case for the foreseeable future. Noise from the existing plant was relatively high, exceeding the relevant noise criteria.

The issues here were how the INP handled the noise from the existing plant and noise from the new extension and how local factors were able to be considered in deciding the best outcome. The INP notes that for existing premises one reason for setting noise limits and developing a noise reduction program is a proposed upgrade or expansion of the development. The emissions from both the existing and proposed plant need to be addressed in any assessment to ensure the cumulative emissions from the plant are accounted for. Once this is done the expansion and the existing plant can be dealt with separately.

In this case the expansion was being designed with low noise emissions and to significantly reduce noise from trucks servicing the plant. There was some early discussion and debate between the proponent and the EPA on what the approval of the new extension needed to cover. The result was that the company and the EPA agreed that a Pollution Reduction Program for noise from the existing plant was needed and this would be negotiated outside of the approval process for the new extension. This resulted in the approval for the extension proceeding and allowed more time to properly consider what needed to be addressed for the existing plant in a Pollution Reduction Program.

The noise assessment identified local circumstances such as the length of time the plant had been at that location, its economic and social importance to the town, the low possibility that additional large industrial development would occur in the area and the reduction in truck noise from the new extension. The INP notes that such local factors are relevant to a balanced and well-informed assessment of impacts and they were considered in assessing the noise impacts from the whole plant. This case demonstrated how the INP was able to handle new and existing premises and to include local circumstances to tailor an appropriate outcome.

2. New industrial development

In this next case a new coalmine was proposed in an area near Muswellbrook in the Hunter Valley. A number of other coalmines are located in the same area, some operating and other approved but not yet working. Weather effects, in particular wind and temperature inversions, can significantly increase noise levels. This is typically a problem where the distances between noise sources and residents is large. In the Hunter Valley it has become increasingly apparent that weather effects are playing a significant role in creating noise impacts.

The main issues here were how to address noise increases due to weather effects, cumulative noise impacts and providing clear and enforceable conditions for noise. The INP clearly requires that weather effects need to be assessed where they are likely to result in a significant increase in noise levels. The policy provides guidance on how this should be done but is not prescriptive. Cumulative noise is directly related to the policy's amenity criteria for different land uses. The policy also supplies guidance (S2.2.4) on how the cumulative noise from multiple developments should be handled.

The noise assessment for the mine recognised that weather effects were significant and put forward a new method of assessing increases in noise due to weather. The approach was based on modelling all the weather conditions that had been monitored for the site and identifying the noise levels that would be met for 90 percent of the time. The proponent used these noise levels to compare to the noise criteria.

While the method is not in-line with the process described in the policy it does meet the intent of the policy to assess weather effects and in fact provides a more comprehensive assessment of weather effects than is required. The advantages of the method used for weather effects are:

- that the noise levels for all the measured weather conditions have been assessed, and
- that a noise limit can be assigned that is independent of weather, for example that the noise will not exceed a set level of say 40 dBA for at least 90 percent of the time regardless of weather conditions.

The disadvantages can be:

- that the assessment can be more complex and costly as the noise levels for all the measured weather conditions need to be modelled for all affected residents, and
- that monitoring compliance can be costly because attended monitoring needs to be done over a period (in this case 9 days) and the data analysed to show that the measured noise levels met the noise limits for 90 percent of that time.

For such a large project occurring in an area that is sensitive to noise impacts this type of approach may be justified. This case study demonstrates that the policy is flexible and can accommodate innovative approaches to assessments (in this case weather effects) provided the intent of the policy is met.

3. New residential development

In this case a new residential subdivision is being developed alongside a hard rock quarry. The quarry has existed for a long period and is concerned that using the adjacent land to build houses may lead to conflicts due to the noise from quarrying and ultimately could restrict their operation.

The INP contains guidance on mitigating noise impacts that can occur where industrial and residential land uses are to be co-located. The land-use planning options mentioned cover the initial planning stage, the residential subdivision stage and the house design stage. Because of their concerns that noise should be properly accounted for in the adjacent residential development the company placed a caveat on the title deed for land within 300 metres of the quarry and its access road. Negotiations with the developer and local council followed. The company retained an acoustical consultant who provided an assessment of noise based on the INP. Following more negotiations the company and the developer agreed that a reasonable means of mitigating noise would be for two zones to be defined.

One zone where houses could not be built and a second where houses could be built provided they incorporated noise mitigation measures in their design and construction. The zones were defined based on noise from operations of trucks on the access road as this ran alongside the boundary for the residential area and was the main noise source. Where noise during the night was more than 45 dBA then housing was to be prohibited. This level of 45 dBA equates to the background noise level plus 10 dB. Where noise at night was in the range 40-45 dBA then housing needed to be designed and constructed to mitigate noise. Both the company and developer agreed that this approach was reasonable.

4. New industrial & residential developments

This case involves a large development that has both an industrial component and a residential one. The are a number of advantages to co-locating employment generating and residential land use. The advantages can include reduced travel times, reduced air emissions and lower infrastructure costs from less demand on the road system. However, there is also a risk to the amenity of the residential areas in being located close to industrial activities. Noise is one of the main amenity issues and the means to minimise noise impacts needs to carefully considered during the planning process.

A particular problem for noise can be where separate industrial developments occur in a gradual manner over time. There is the potential here for pressure from later developments to exceed amenity noise levels. This occurs because early individual developments are typically assessed in isolation, without considering what the cumulative level of impact would be when the whole area has been developed.

Initially the issue of noise effects on the proposed residential area was limited to assessing an existing quarrying operation. However, the EPA highlighted that the greater noise issue was likely to be from development of the new industrial area and that addressing this issue at the planning stage provided a good chance to avoid or at least minimise potential conflicts over noise.

The land developer retained consultants who conducted noise modelling of various development options. The final proposal consisted of splitting the industrial area into 5 zones and assigning overall noise limits to each of the 5 zones. The noise limits applied were based on achieving the INP's noise criteria for amenity at the adjoining proposed residential area. Predictive modelling, that placed 3 heavy industrial sites in each of the 5 zones was done by the land developer. This showed that the noise limits were reasonable and could be expected to be met in practice.

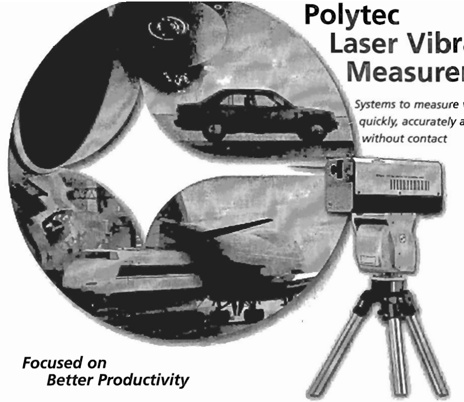
It appears that the developer, the council, the State planning authority and the EPA are satisfied with the outcome and that it will be incorporated into the Precinct Plan for the area. This case demonstrates how it is possible to incorporate noise requirements into land use planning. The result has been:

- an equitable distribution of noise requirements amongst the employment zones,
- avoiding uncontrolled cumulative noise impacts
- providing some flexibility in how noise is managed within each employment zone, and
- protection of the future amenity of adjacent residential areas.

◆

Polytec
Laser Vibration Measurement

Systems to measure vibration quickly, accurately and without contact



Focused on Better Productivity

Whatever the application, from bridge testing to micro-sensors, Polytec has a solution for all your vibration measurement needs. See our comprehensive list of non-contact laser Doppler vibrometer systems. Call us for straightforward answers to your measurement problems.

VibraScan™ PSV-300 automated, scanning systems. Now with APS professional scan geometry, high resolution live full-field video, SE Signal Enhancement with speckle tracking, DC to 1 MHz and up to 4 data acquisition channels.

- Model OFV-303 and OFV-353 standard vibrometers for point measurements
- Fiber optic OFV-511 tests small parts in hard-to-reach areas
- Dual beam fiber optic OFV-512 measures relative vibration between two points
- Dual beam fiber optic OFV-518 for two independent sensor channels
- Low cost CLV compact production vibrometers for on-line quality control
- Series 4000 system for torsional/rotational studies
- OVD-30 ultrasonic module for signals up to 20 MHz
- Controller modules for amplitudes up to +/- 20 m/s, resolutions down to <0.1 µm/s/√Hz and DC response
- OFV-3310 or OFV-3320 for in-plane vibration measurements

NEW • VDD-650 and VDD-660 digital vibrometers

NEW • 3D-LV three dimensional measurement system

Thousands of Polytec systems are in the field solving customer problems. Call us today for more information on your specific applications. Polytec vibrometers - for performance, accuracy and reliability you can count on.

Applications include:

- Engine components
- Automobile body panels
- Rotating shafts
- Household appliances and power tools
- Lightweight and small parts
- Paper and steel mill bearings
- Micro-sensors and actuators
- High frequency piezo devices

Polytec PI

WARSASH Scientific
Advanced Instruments for Research & Industry

tel: +61 (0)2 9319 0122
e-mail: sales@warsash.com.au
fax: +61 (0)2 9318 2192
Internet: www.warsash.com.au

Book Reviews

Hear Today Gone Tomorrow Noise Management and Protection of Hearing at Work

Comet Training, 1999, pp 120, hard cover, Distributor Southfork Enterprises Pty Ltd tel 03 9849 1061, fax 03 9849 1062, southfork@optusnet.com.au. Price, including postage, video only $220 +GST, full package $340+GST.

This training package is one of a series of four which has been commissioned by Comet training to raise awareness of OHS Issues and to support safety induction and training in the NSW Construction Industry. It focuses on the application, for the construction industry, of the NSW Code for Noise Management and the Protection of Hearing at Work - essentially the same as the National Code of Practice.

The presentation of the full training package takes 8 hours and is in two parts. One is designed as a 4 hours face to face, tutor directed, off the job training session. The second part is 4 hours on the job component comprising a 2 hour site visit, 1 hour for the production of a Job Safety Analysis by each participant and 1 hour for discussion. The complete package comprises the 20 minute video plus training notes, code of practice, overhead transparencies and course documentation. The video is an important part of the package, not just an added bonus. The seven parts in the video cover noise and hearing, risk management cycle, noise controls, case study, audiometric testing and training and these are referred to in the training notes.

The requirements for the person delivering the course are experience in training and "at least 2 years industry experience in the relevant course content". This latter requirement is essential as there are only 5 A4 pages of course notes, a handful of overhead transparencies and a 20 min video for the 4 hour face to face part of the course. The notes only list discussion points so the presenter certainly needs considerable background knowledge to lead the discussion and keep the participants interested.

The video, which can be purchased alone, is an excellent concept. Although it refers to the NSW Code, the content is directly applicable to all other parts of Australia. Filmed on Australian building sites and planned to cover each aspect of the code of practice, it can be used as a stand alone training/motivational video. It starts by demonstrating the effect of hearing loss on social interaction and how the hearing mechanism is damaged. It has examples of managing noise including substitution with another process, moving people away from the noisy areas, building enclosures around particularly noisy items etc. It is acknowledged that personal hearing protection is likely to be needed and shows proper use, care and maintenance.

While not many in the building industry are likely to be put through an 8 hour training course on noise, they should all see the 20 min video as a part of their safety training. In particular it would be good for those in trade schools to encourage them to protect their hearing from the first day on the sites.

Marion Burgess

Marion Burgess is a Research Officer at the Australian Defence Force Academy in Canberra and has undertaken a study on noise management on building sites.

Active Noise Control Primer

Scott Snyder

Springer, New York 2001, 159 pp, ISBN 0 387 98951 X (hard cover). Distributor DA Information Services, 648 Whitehorse Rd, Mitcham 3132, Australia, tel 03 9210 7777, fax 03 9210 7788, Price A$129.28

Scott Snyder's primer gives a fresh and qualitative description of a very complex topic that has many potential applications in the years to come. Although this book is aimed at non-specialists who would like to learn about active noise control, the author also provides valuable advice to those who are working at the frontline of active noise control, based on his extensive experience in consulting and controller development.

The book is divided into three major parts. Chapters 2 and 3 are the fundamentals of noise and its control. The technical terms, important concepts and noise control techniques are well explained using simple examples. Side notes and footnotes are effectively used to add practical and historical flavors. The attractive feature of this book is its dialogue style. Starting with the most commonly asked questions, the author kept making the reader wonder what is next to be told.

Chapters 4, 5 and 6 cover the most popular areas in passive and active noise control. Once the passive noise control and its limits are understood, the importance of active noise control in practical applications becomes clear. Chapter 4 starts with the physical requirements for possible active control of noise. The interference, time delay, volume velocity, energy flows and global reduction are conveniently explained by the simple picture of sound waves in free field. Within an enclosure, the sound field becomes complicated due to multiple reflections from the boundaries and consequent interference. Chapter 5 uses modal and modal density concepts to explain why active noise control only has the potential to provide global sound attenuation at low frequencies. The side stories about potential applications of active noise control in domestic dwellings, passenger vehicles and jet aircraft have enriched this chapter. Chapter 6 summaries several important factors in the effective control of noise using air handling ducts as an example. The sections on the use of anti-turbulence microphone probe to improve the signal-to-noise ratio, causality in relation to the distance between reference sensor and control source, and duct splitter in dealing with high order modes in the duct are valuable technical tips for practical application of active noise control.

The rest of the book (Chapters 7 and 8) concentrates on the development of active noise controllers, which are the heart of an active noise control system. This part is most relevant to those who are currently using adaptive feedforward control. Chapter 7 brings us into the "digital world" by introducing analog-to-digital conversion, digital representation of signals and transfer functions of physical components. The adaptive algorithm in this chapter is explained in a most interesting way. The periscope/wind analogy has effectively been used to explain the effect of cancellation path and quantization process on the error. Caution is to be taken when the algorithm is used to design a digital filter (controller) in order to minimize the error. Chapter 8 brings us further into the digital world. It contains the author's valuable experience including selecting appropriate digital filters for specific applications, suitable filter length, convergence coefficient, adaptation rate, sample rate, and identification of cancellation path.

I enjoyed reading this book. It is certainly a "starter's" book on active noise control. Even the experienced users of active noise control systems may find useful tips there.

Jie Pan

Jie Pan is an Associate Professor of acoustics, control and mechatronics in the Department of Mechanical and Materials Engineering, the University of Western Australia.

Sound Therapy

Patricia Joundry and Rafaele Joundry

Sound Therapy Australia, 2001 reprint, 205 pp, ISBN 10876315 24 5, Distributor Sound Therapy Australia, PO Box A 2237, Sydney South NSW 1235, tel 02 9665 1777, fax 02 9664 9777, www.soundtherapyinternatinal.com
Price A$27.45 + p&h $5.50

"The best thing about this [therapy] is that you don't have to understand it for it to work." (p 17) "It sounds like magic and it is ..." (p 18).

The "therapy" in question, based on sounds of high and low pitch, claimed as offering cures for everything, from fatigue to insomnia, from impaired hearing and tinnitus to autism, attention deficit disorder, vertigo (and Ménière's disease), memory loss, dyslexia, and so on and on.

The procedure involves lengthy listening to music or voices reproduced under high-fidelity conditions and low- or high-pass filtering so as to "respectively, energise the cortex and stimulate the middle ear." The original manifestation of this procedure involves studio-standard tape recorders and filter banks; the do-it-yourself version involves a portable sound system and pre-filtered cassette recordings (credulous readers might be induced to spend between about $500 and $670 on a set of four cassettes and a player).

The arguments throughout the book are untenable. For example, it is asserted that the foetus is selectively exposed to very high frequencies in utero (the opposite is true), or that following birth young children neglect high frequencies. Dyslexia is said to result from some speech sounds reaching the brain ahead of others. Stuttering is cured if speakers monitor their utterances with the right ear only. Children make themselves deaf by tuning out to what parents and teachers tell them. All this, along with some very strange anatomy and physiology of the auditory system, is asserted with no evidence, but with the sort of straight-faced conviction that might persuade the innocent.

It is the foregoing point that made me bother to write the present review. I have no idea how much pseudo-scientific rubbish the average citizen is exposed to in the course of an ordinary week; I expect it is not zero. Confident but baseless claims made in book form, and enlisting the identities of (by this reviewer, unheard of) "experts", may seduce the unwary. I fear that people who themselves or whose partners have this or that disability, or parents whose children display signs of hearing or learning difficulties, in well-meaning hope, may fall for the claims put out by this and other similar books. My advice is that it will remain more prudent to consult the genuine expertise to be found in properly accredited quarters such as our Universities, clinics and hospitals, in order to determine what steps may or may not be feasible in response to whatever hearing, learning or language problems are being experienced.

Yehudi Menuhin is credited with writing a little foreword to this volume and he reports having read the book in a single sitting. To any potential reader, I would recommend doing it in less than that.

William Noble

William Noble holds a Professorship in Psychology at the University of New England. His research is primarily in the area of hearing and its impairment.

Future Meetings

International Tinnitus Seminar

This special event occurs every three years and for the first time will be held in Australia in Fremantle, Western Australia 5-9 March 2002.

The Scientific Program promises to be one of exceptional quality and diversity. An outstanding array of international and national speakers will present the latest research, treatment and developments in tinnitus and related health conditions.

The Invited Lectures will be:

Dr Robert Dobie, Director of Research at the National Institute on Deafness and other Communication Disorders, USA on "A Review of Clinical Trials for Treatment of Tinnitus" and "Medico-Legal Aspects of Tinnitus"; and Dr Dennis Turk, currently Professor of Anaesthesiology and Pain Research at the University of Washington School of Medicine, Seattle, on "Mysteries of Chronic Pain (&Tinnitus): Sherlock Holmes, Inspector Clouseau & Sgt Friday meet Lt Colombo" and "The Three Most Important Words in Health Care: Outcomes, Outcomes, Outcomes"

The Guest Lectures will be:

Dr Jonathan Hazell, Director of the Tinnitus and Hyperacusis Centre, London on "Tinnitus - Recent Historical Aspects";

Dr Pawel Jastreboff, Professor and Director of the Tinnitus & Hyperacusis Center at Emory University, Atlanta, Georgia, USA on "Tinnitus and Sound Tolerance: From Stimulus to Reaction"; and

Dr Robert Patuzzi , The Auditory Laboratory, University of Western Australia on "The Role of Cochlear Regulation in Tinnitus".

There will also be a panel discussion on "Future Directions in Tinnitus Research & Management" and extensive free paper sessions. A vast number of Abstracts have been received and to accommodate as many as possible, two concurrent sessions will be on Epidemiology and Demographics, Treatment/Medical and Surgical, Treatment - TRT, Psychology, Mechanisms and Models, Pharmacology, Methods of Detection, Treatment - Devices, Children and special cases, Psychoacoustics, Occupational Health Issues - Noise and Tinnitus.

Registration and other information is available from Janie Binet PO Box 581, Cottesloe, Western Australia 6011,
Tel. & fax: +61 8 9384 1249,
jcsbinet@hotlinks.net.au,
www.tinnitus.com.au

ACOUSTICS 2002

The AAS Annual Conference will be held in Adelaide during November 13-15. The Theme for Acoustics 2002 is Innovation in Acoustics and Vibration. It will provide a forum for the presentation of a wide range of papers in all aspects of fundamental and applied Acoustics and Vibrations. A special stream on underwater acoustics is planned as a strong representation is expected in that field. All submitted papers will be peer reviewed under the coordination of a scientific advisory panel.

The Conference will be held at the elegant Hyatt Regency, next to the City Centre on the banks of the River Torrens and adjacent to a promenade of cafes. It is within walking distance of a wide range of accommodation and entertainment/dining choices. Pre and post conference activities will focus on the nearby Adelaide hills and wine growing areas.

Key dates in 2002:

1 April -	submission of paper abstract
1 May -	notification of acceptance of abstract
15 August -	submission of full paper
15 Sept.-	notification of acceptance of paper with reviewer comments
15 October -	submission of final version of paper

Information

Acoustics 2002, Department of Mechanical Engineering, Adelaide University, SA 5005, AUSTRALIA. Tel: +61-8-8303 5469;
Fax: +61-8-8303 4367;
aas2002@mecheng.adelaide.edu.au,
www.acoustics.asn.au

WESPAC8, 7 - 9 April, 2003.

A taste of Australia may be had by attending WESPAC8 in Melbourne, Victoria, during 7-9 April, 2003. "Acoustics on the move" is the theme of this international conference being organised by the Victoria Division of the Australian Acoustical Society. The conference will cover a broad mix of conventional and rapidly developing topics in acoustics. Technical sessions will include a series of distinguished lectures and it is anticipated that there will be an extensive trade display associated with the conference. Provision has been made for authors to have their papers fully reviewed, if they wish.

Centrally located, the venue will be the Carlton Crest Hotel, directly opposite Albert Park which has a lake, golf course and other sporting facilities. Only a 15 minute tram ride away is the city of Melbourne, with its excellent shopping facilities and world class museums and art galleries. Bayside beaches, the Botanic Gardens and the Melbourne Cricket Ground and Tennis Centre are nearby. A major conference event will be a bush barbecue at "Emu Bottom", an historic Australian Homestead, where delegates can meet in an informal atmosphere while sampling "bush tucker" and test themselves at boomerang throwing and the traditional Australian game, "Two-Up". For delegates with additional time, visits to the famous Penguin Parade, Ayers Rock or the Great Barrier Reef, are highly recommended.

Abstracts are sought by 2 August, 2002. For more details about the conference program, content, timetable and registration procedures, please refer to our website: http://www.wespac8.com

ICSV9

The Ninth Congress of the International Institute of Acoustics and Vibration, IIAV is sponsored by the National Aeronautics and Space Administration, the University of Central Florida, the American Society of Mechanical Engineers, the Society of Experimental Mechanics and the American Society of Civil Engineers (Aerospace Division).

It will be held 8-11 July 2002, in Orlando at the University of Central Florida, UCF. A list of the abstracts received so far is available from the web page along with the details of the location and the program. Further information from icsv9@mail.ucf.edu, http://www.iiav.org

Transport Noise-02

The East-European Acoustical Association (EEAA) is organising the 6th International Symposium on Transport Noise and Vibration, Transport Noise-02, to be held on June 4-6, 2002 in St. Petersburg (Russia). Papers will cover all aspects of transportation noise cars, lorries, ships, aeroplanes, trams, trains etc. Plenary and invited papers will be presented by experts from Russia, France, Austria, Norway and Belgium. More information from http://webcenter.ru/~eeaa/tn/eng/tn2002 or fax: +7 812 127 9323

Coordinated with the Symposium will be the International AES Conference on Architectural Acoustics & Sound Reinforcement on June 1-3, 2002 in St. Petersburg (Fax: +7.812.3161559; st_petersburg@aes.org) and the 6th International Conference on Applied Technologies of Hydroacoustics and Hydrophysics on June 5-8, 2002 in St. Petersburg (Fax: +7.812.3208052; mfp@mail.wplus.net)

MATRIX
INDUSTRIES

VIBRATION
ISOLATION

Matrix Industries Pty. Ltd patented wall ties provide structural support while reducing transmission of structure borne vibrations. Resilient mounting systems are available for all masonry and plasterboard walls and lightweight floating floors.

Matrix Industries products are reducing noise in studios and theatres throughout Australia.

NOW IN STAINLESS STEEL

Enquiries and Sales:

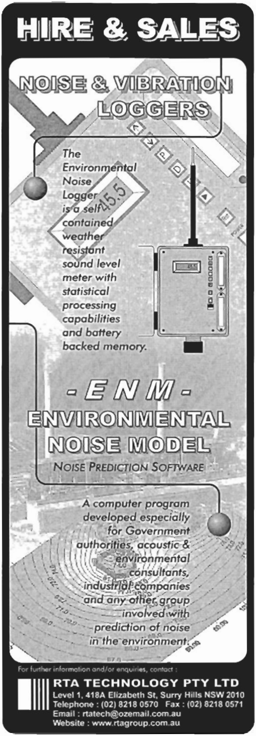
MATRIX INDUSTRIES PTY LTD
144 OXLEY ISLAND ROAD, OXLEY ISLAND NSW 2430
PH: (02) 6553 2577
FAX: (02) 6553 2585

Noise Control-
your solution is here.

We have been designing, manufacturing and installing noise control equipment since 1970.
We help you control noise in your plant from initial on-site evaluation to confirmation of performance on completion.
Our off the shelf and custom built solutions include: enclosures, control rooms, acoustic panel systems, silencers, acoustic louvres, doors, audiometric booths and so on.
Noise control is all we do. Call NOW for details.

Peace Engineering Pty. Ltd.
2-20 Marigold Street, Revesby. NSW 2212
PO Box 4160, Milperra, NSW 1891
Phone: (02) 9772 4857 Fax: (02) 9771 5444
www.peaceng.com.au

Peace
NOISE & VIBRATION CONTROL



HIRE & SALES

NOISE & VIBRATION LOGGERS

The Environmental Noise Logger is a self contained weather resistant sound level meter with statistical processing capabilities and battery backed memory.

- ENM -
ENVIRONMENTAL NOISE MODEL
NOISE PREDICTION SOFTWARE

A computer program developed especially for Government authorities, acoustic & environmental consultants, industrial companies and any other group involved with prediction of noise in the environment.

For further information and/or enquiries, contact :

RTA TECHNOLOGY PTY LTD
Level 1, 418A Elizabeth St, Surry Hills NSW 2010
Telephone : (02) 8218 0570 Fax : (02) 8218 0571
Email : rtatech@ozemail.com.au
Website : www.rtagroup.com.au

INTER-NOISE 02

The 31st International Congress and Exposition on Noise Control Engineering, will be held at the Hyatt Regency Dearborn hotel in Michigan, USA from August 19 to 21, 2001. It will be sponsored by the International Institute of Noise Control Engineering, and will be organized by the Institute of Noise Control Engineering of the USA (INCE/USA) and the Ohio State University's Center for Automotive Research (CAR) in cooperation with SAE International and the Canadian Acoustical Association.

The theme of INTER-NOISE 02 is Transportation Noise as it relates to automobiles, trucks, motorcycles, off-road vehicles, trains, subways, aircraft, helicopters, ships, and recreational vehicles. However, technical papers in all areas of noise control engineering will be presented. A major technical exposition will be held at INTER-NOISE 02.

Other INCE seminars and symposia are also being planned for just before and after INTER-NOISE 02. A Sound Quality Symposium (SQS 02) will be held on the day after INTER-NOISE 2002 ends. The SQS 02 secretariat will be at the Ray W. Herrick Laboratory, Purdue University, West Lafayette, Indiana, USA.

Further information: INTER-NOISE 2002 Congress Secretariat, Department of Mechanical Engineering, the Ohio State University, 206 West 18th Avenue, Columbus, OH 43210-1107, USA.
hp@internoise2002.org,
http://www.internoise2002.org

ACTIVE 2002

Active 2002, International Symposium on Active Control of Sound and Vibration, will be held at Southampton University, United Kingdom, on 15-17 July 2002. The aims of ACTIVE 2002 are to review the current research and application areas in the active control of sound and vibration and to highlight future directions for this technology. Papers are invited in any area of active sound or vibration control. There will be five plenary keynote lectures, which will review the current state-of-the-art in active control and describe exciting new extensions.

Further information: Professor Stephen J. Elliott, ISVR, Southampton University, SO17 1BJ, United Kingdom,
fax: +44 23 8059 3190, sje@isvr.soton.ac.uk,
http://www.isvr.soton.ac.uk/Active2002

Meeting Reports

Acoustics 2001

The national conference of the Australian Acoustical Society was held in Canberra over 21 to 23 November. The theme for this conference was Noise and Vibration Policy - the way forward? More than 140 were involved in the conference.

Over 50 papers were presented in two parallel sessions during 22 and 23 November. A high standard was achieved in the papers and in particular those in the special sessions on environmental noise, transportation noise, aircraft noise, occupational noise, building acoustics and vibration. An extensive technical exhibition was open for the duration of the conference.

The opening occurred during the buffet on the Wednesday night when the past president of FASTS, Prof Peter Cullen gave a short talk on policies and politics. A presentation by Robyn Williams, from the ABC Science Show during the Conference Dinner was well received. His entertaining talk wove an interesting link between acoustics and noise and policies and politics. During the closing session, the President's Prize for the best paper at the conference was awarded to Bruce Meldrum from CSIRO, and this paper will be included in a forthcoming issue of Acoustics Australia. Also during this ceremony, the award of Fellow of the Society was made posthumously to Graeme Yates who died in October 2000. The formal presentation was made to his wife during the end of year function of the WA Division.

The accompanying member program included a day tour around the local sights. The mini bus and driver provided a short orientation tour and then offered a flexible tour based on individual interests. The mini bus was available for the remainder of the conference on a self drive arrangement.

A number of innovations were implemented during the planning for this conference. These included the special sessions where the chair of the session invited people working in the topic area to present papers. This provided a core for the technical content of the conference which was supplemented by contributed papers. For the first time, the contributors were given the option of having their paper peer reviewed. This is an important feature for those from Academic Institutions to enable participation but was also taken up by many other conference contributors. Only a handful of the papers needed to be returned to the authors for revision, which indicates the overall high standard of the contributions. The proceedings were only provided as a CD. In fact the papers were never printed out - all were received and processed in the electronic format. The only hard copy was a booklet including the program and the abstracts which was provided to all registrants.

The hard work of the conference organising committee on behalf of the NSW Division, was rewarded with a most successful conference.

Marion Burgess

Acoustics 2001 Proceedings

The proceedings of the recent Australian Acoustical Society Conference, Acoustics 2001, are available for purchase. The CD contains all the papers which were provided in time for the conference – abstracts are included on the CD for the few others.

Over 50 papers on the theme 'Noise and Vibration Policy - the way forward?' are included in the Proceedings. Most of these papers fit into the areas of Environmental noise, Transportation noise, Aircraft noise, Occupational noise, Building acoustics and Vibration. The full list of paper titles can be seen from www.acoustics.asn.au

These proceedings will provide a valuable resource for those who were unable to participate in the conference. An order form (tax invoice) can be downloaded via the link from www.acoustics.asn.au. The cost of $50 plus $5 GST includes postage and packing. Additional information:
m.burgess@adfa.edu.au, fax 02 6268 8276.

Geoff Barnes presenting the President's Prize to Bruce Meldrum.

Charles Don, the new President, discussing the conference organisation with Marion Burgess.

Robyn Williams during the conference dinner.

WA Division

A State Conference was held on 20 September 2001 at the tranquil location of Chapel Farm Restaurant in Middle Swan (homeland of the Western Australian Wineries). A Western Australian blend of Air Acoustics and Underwater Acoustics papers were presented on various topics:

* The use of passive acoustics in studies of marine fauna (Rob McCauley);
* A study of shallow water superficial sediment properties with wavelet correlation analysis (Alex Kritski);
* Inverting transmission loss measurements to obtain geoacoustic properties in shallow water (Justin Hoffman);
* Local government noise complaint survey (Michael Cake);
* A review of national and international transportation policies (Daniel Lloyd);
* Theory of the injury mechanism involved with acoustic shock in call centre workers (Rob Patuzzi);
* Protecting call centre workers from acoustic shock with limiting amplifiers (Ray Cole);
* UK project on measuring call centre operators' noise exposures (Keith Broughton); and
* Chicken farming noise (Richard Langford).

The conference participants enjoyed an outdoor lunch served with local wine. This was both relaxing and refreshing, away from the day-to-day hustle and bustle of the corporate world.

Namiko Ranasinghe

VIC Division

Factory Tour The Victoria Division fourth technical meeting for 2001 at which 5 were present, was held on Jul 25 and was a site visit to Smorgon Steel, Laverton North (3026). Geoff Barnes, of Acoustical Design, has been advising on ways of achieving a quieter environment for those employees exposed to the considerable plant noise in the steel shredding process.

The steels produced at Smorgon are manufactured entirely from scrap, so that the processes of handling the raw materials are mostly very noisy, particularly those such as the steel shredding, electric arc melting, and material handling processes. Without noise isolation or hearing protection, employees exposed to considerable noise could be exposed to levels from 90 to 120 dB(A). As an example, the noise level adjacent to the electric arc furnace would begin at around 120 dB(A), decreasing to about 95 dB(A) after several minutes.

Where possible, noise reduction has been achieved by providing quietened control- and refuge-rooms adjacent to highly noisy processes, by shielding noisy machinery, and elsewhere by providing employees with hearing protection. By these means, employees are now exposed to noise levels not generally exceeding 80 dB(A) at their work places.

After this interesting tour of the factory site, those present thanked the (Safety Officer), Ken Fuhrmeister of Smorgon, who had acted as tour guide.

AGM The Victoria Division AGM was held on Oct 15, in a meeting area at the Melbourne Aquarium, with 23 present. With the relatively high speech interference level of the background aqueous noises, a small public address unit was needed so that those addressing the meeting could be readily heard.

Louis Fouvy

Fan Noise

The end of year function was a bit different this year. It was a 'combined' meeting in that it was a technical and social meeting and also in the sense that the AAS Victoria Division combined with AIRAH (Australian Institute of Refrigeration Air-conditioning and Heating) and the Institution of Engineers. About 75 people attended in all of which 20 or so were AAS members. The location was the Institution of Engineers building in North Melbourne, which proved to be an excellent venue both for the talks and for supper afterwards.

Charles Rossiter and Graeme Harding gave well illustrated talks. Charles turned up with an assistant and seven props ranging from an axial fan to a bass electric guitar. He gave us a good lesson on beating and proceeded to tell us how two similar fans operating under different conditions had produced an annoying beating effect in a 43-storey building. Other culprits in the installation were found to be guide vanes and the motor supports, which generated tonal noise. This effect was convincingly illustrated by placing wooden battens across the fan inlet duct. An extra finding of this work had been that a tip clearance of less than 0.25% of the diameter of the blades was required to limit the fan noise.

Graeme Harding wove his own professional history into the history of silencers. Huge silencers for turbo prop engines had been developed by Bolt, Beranek and Newman, 'BBN' to many of us. They were 24 foot by 24 foot and 16, 24 or 32 foot in length and consisted of layers of porous material with sinusoidal profiles. There was no clear line of sight through the silencers and they could give insertion losses of 48 dB. After the war, the building industry tried to scale down the BBN silencers. "They did stop the noise and some air did get through!"

Graeme himself, then with INSULWOOL, flattened the sinusoidal profiles somewhat obtaining eg 9dB insertion loss in the old 53 1/1 octave band with a 2 foot long silencer. However there was a push to have straight air channels through the silencers, which reduced the high and low frequency attenuation. Moreover the manufacturers performance data were typically 7 to 9 dB higher than results of measurements made in Australia! According the Graeme, we have been left with this legacy. Silencers are not sold with the correct insertion loss figures.

In 1969 Graeme Harding started his own business and manufactured parallel baffle splitters. Wind tunnel tests were conducted in order to find the best shape. The result was silencers with multiple fold edges on the inlet and tapered splitters at the exit producing expanding air channels on the outlet. Graeme concluded his talk with four case histories, ranging from the Saba Radio studios to the Melbourne City Link tunnel, for which the engineer had required him to put a 10 foot square duct into a ten foot diameter round shaft.

Elizabeth Lindqvist

NSW Division

Industrial Noise Policy

The NSW Division Annual AGM and technical meeting was held in the auditorium at the National Acoustics Laboratories, Chatswood on Thursday evening 9 August 2001. Over 65 members were present to hear Geoff Mellor - the Director of the Noise Policy of the NSW Environment Protection Authority (EPA) give a presentation. The theme was an update of the Industrial Noise Policy (January 2000). Geoff was capably assisted by the EPA noise team - Roger Treagus, John Wassermann and Derek Langgons.

A summary of this presentation is included in this issue as a Technical Note.

After a short series of questions and thanks to Geoff and the EPA, the meeting and AGM was concluded with food, drink and the ubiquitous deliberations between old and young acousticians alike.

Ken Scannell

Conservatorium

On Monday 27 August 2001, many members of the NSW division of the AAS attended a lecture by the Conservatorium Redevelopment Project design team at the new Recital Hall West of the Sydney Conservatorium of Music.

The talk opened with Conservatorium's Principal and Dean Professor Sharman Pretty who covered the history of the Conservatorium with some interesting slides dating back to the early 1900's. The State Government Architect Chris Johnson followed the theme and showed some of the many different concepts of the redevelopment project. Barry McGregor, the Design Architect, illustrated how the use of light was a major consideration despite much of the new building being below ground level. Ed McCue, from Kirkegaard Associates explained the room acoustic concepts with an emphasis on the increase on reverberation time for the Verbrugghen Hall from about 1 second to approximately 2.5 seconds. Ed also covered the restoration of the magnificent pipe organ and described the major redevelopment of the Verbrugghen Hall roof. Last but not least was a talk by Barry (Springs) Murray on the huge task of vibration isolating the whole of the building from the nearby (20 metres) railway line.

All the speakers were given a well deserved round of applause and the audience made their way out into a cold and wet Sydney evening.

Ken Scannell

Council News

President's Prize Rules

The President's Prize is an award made at the Annual Conference of the Society for the best paper presented at the Conference. In the past it has only been open to members of the Society. The Council of the Australian Acoustical Society has decided that the President's Prize should be awarded to both members and non-members of the Society. It is hoped that this change will encourage people presenting papers at the Annual Conference to join the Society. The following rules now apply:

That the President's Prize will be open to everyone presenting a paper at the annual conference (including non-members of the Society). The prize will be awarded to the principal author of the paper who, in the case of more than one author, shall be the name that comes first on the paper. The prize shall consist of a medallion and one year's free membership of the Society. In the case of a non-member winning the prize, the free membership will be made at the grade of Subscriber member.

Educational Grant

The Australian Acoustical Society proudly announces the inaugural Annual Educational Grant. The aim of the grant is to promote research and education in Acoustics and is only open to Australian Educational Institutions.

Educational Institutions are invited to apply for funds to assist in providing:-

(a) scholarship(s)

(b) funding of research projects

(c) equipment for educational purposes

(d) other worthwhile use in the area of acoustics.

The grant is limited to a maximum of $5000.00 and must meet the objectives of promoting education or research in acoustics. Submissions must be in writing and provide details of how the grant will be used. The grant will be awarded to the best proposal and will be announced at the Society's Annual Conference in Adelaide during November 2002.

Submissions should be forwarded to the General Secretary, Mr David Watkins, PO Box 903, Castlemaine Victoria 3450 and must be received by the 30 June 2002.

International Representation

Charles Don has been re-elected to the board of International Commission on Acoustics to represent Australia until 2004. This important role continues to allow the AAS to have input directly to the international acoustics community.

Marion Burgess has been elected as the representative from the South East Asian area on the conference selection committee for future Internoise conferences. The representative must be present at the meeting, prior to the Internoise conference, when the competing bids for the future conferences are presented. (Unfortunately the voting process does not include site visits to the short list countries by the selection committee!)

Anita Lawrence deserves acknowledgement for the effort she has made on behalf of international acoustics organisations. One such task has been the job as the Asia Pacific Editor for Noise News International (NNI), a quarterly magazine published by INCE. This has required communication with the various organisations in the area and the preparation of relevant material which is of interest to the international readership of the magazine. She has also produced an editorial on an annual basis. **Marion Burgess** has now been nominated by INCE to take on the task as the Asian Pacific editor for NNI.

AAS web page

During 2001 the new web page for the AAS was established. A major advantage has been the simplification of the web address to **www.acoustics.asn.au**. Full statistical data on the access to this web page shows that there are around 3,000 hits per month, ie over 100 per day. Around 70% of these hits are from domain names outside Australia. Most the hits are during the weekdays with a clear drop off towards the end of the week. The busiest times are around 9am and around 2 pm. It is rewarding to note that there are so many accessing this useful resource maintained by the Society.

Standards Australia

AV3/3 COMMITTEE

The Australian Acoustical Society is represented on a number of Standards Australia Committees by members working in fields of acoustics related to the committee's work. It is important that the Society continues to be represented on Standards Committees by members and that they provide feed-back to the Society on the activities of the Committees.

A vacancy has arisen in the AV3/3 Committee Audiology. Any member who would like to nominate for this committee is invited to provide a brief description of their experience in this field and return it by the 28 February 2002 to the General Secretary, Australian Acoustical Society, PO Box 903, Castlemaine Victoria 3450, or watkinsd@melbpc.org.au

FASTS

Professor Chris Fell has taken over from Peter Cullen as the President of FASTS. He has nominated as his first task to establish an agenda with a new Federal Government and a new Minister. Chris Fell has commented that twelve months ago the tide was running our way. The Government was moving to respond to reports from the Chief Scientist and the Innovation Summit, and the Opposition was talking up its intention to re-energise science, research and higher education. The present situation offers interesting challenges. The new Government's agenda does not appear to be crowded, and Chris Fell believes they will be receptive to new ideas.

Australian scientists and technologists have two priceless contributions to make to politicians in Australia - ideas and solutions. Both these qualities are in short supply, and add to the importance of our regular contacts with Parliamentarians at national and regional level. The university sector remains one of the great unresolved issues in Australian public life. A decline which began 15 years ago is continuing. The pressure on academics to perform more tasks is increasing, as their salary levels are steadily sliding down the ladder on international competitiveness. The quality of infrastructure declines as funding pressures increase. Neither major party seems willing to tackle the issue.

FASTS Council Meeting this year was an opportunity to have a wide-ranging discussion on strategy and issues to take up at Parliamentary and bureaucratic levels. Members will be invited to support three major activities this year: a forum at the National Press Club in mid-year; "Science meets Parliament" Day at the end of the year; and to comment and contribute ideas to the new edition of the FASTS' policy document.

News Items

Eureka Prizes

The $10,000 Michael Daley Eureka Prize is awarded to an Australian journalist(s) or communicator(s) whose work is assessed as having most effectively communicated scientific and/or technological issues to the public. These issues include the natural, physical or applied sciences (including agricultural sciences), IT, technological innovation, design and development, health science issues, as well as work that presents the social and/or economic consequence of science and technology. The deadline for submission is 17/05/2002

The Institution of Engineers Australia Eureka Prize for Engineering Innovation is awarded to an individual, business, company or corporation for outstanding innovation in the conception, design, implementation or redevelopment phases of a piece of engineering work. Entries must contain a major emphasis on the process of innovation, and contribute to the concept of sustainability. The prize is valued at $10,000 and the deadline is 17/05/2002 More information on both these prizes from http://www.amonline.net.au/eureka/

Nova on Noise

'Nova: Science in the news' is a web based educational tool initiated and maintained by the Australian Academy of Science. It aims to provides accurate and up-to-date information on scientific, mathematical, health and environmental issues in the news for senior high school students. The papers are grouped into general topic areas of health, environment, biology, physical sciences, technology and mathematics. The papers have some key text with lots of links to other web pages for detailed information. Early in 2002 a new paper will appear on this series entitled 'Quiet Please! Fighting Noise Pollution' and you can check it out on http://www.science.org.au/nova/index.htm.

NoiseWorks

NoiseWorks is an acoustic calculation spreadsheet program produced by SoundScience@WM - part of Wilkinson Murray Pty Ltd. It allows for quick and easy-to-follow calculations using octave and third-octave band spectra. The calculations are performed in worksheets, which can contain any number of spectra, and are saved in worksheet files which can contain any number of worksheets. Datasheets provide access to databases of stored sound power levels, transmission loss values, etc. Spectra can be graphed and printed in a variety of formats.

And it's FREE. The program can be downloaded by going to Wilkinson Murray's web site at www.wmpl.com.au and following the links to SoundScience@WM.

Social Survey Catalogue

A catalogue of residential community noise response surveys has been posted on web. This document will be invaluable to anyone undertaking social surveys on environmental noise issues. The full citation is "James M. Fields, 2001: An Updated Catalog of 521 Social Surveys of Residents' Reactions to Environmental Noise (1943-2000). NASA/CR-2001-211257. Washington, D.C.: National Aeronautics and Space Administration." It can be downloaded from the NASA Langley Research Center web site http://techreports.larc.nasa.gov/ltrs/ and search using the report number (2001-211257).

Proceedings on Acoustic Shock Seminar

Proceedings from the Seminar on Risking Acoustics Shock held in Fremantle in September 2001 are now available. This seminar covered a broad spectrum of information from research studies in Denmark, UK and Austrlia. As well as case studies from an otolaryngolost, occupational physician, audiologists and a psychologist, the legal ramifications of acoustic shock injury was discussed. The CD ROM of the proceedings is now available at a cost of A$339 plus 10% GST and postage of $27 per CD. This CD is available from A&K Corporate Concepts, tel 03 9532 7656, akcc@optusnet.com.au, www.inboundaus.akcc.com.au

Proceedings of Noise-Con 2001

Proceedings from Noise-Con 2001 held in October in Portland Maine are now available. The theme of this conference was Noise and Planning and comprised papers in three main streams: National and International Noise Policy; Transportation Noise; and Community and Industrial Noise.

Also on the CD are the proceedings of the Noise-Con conferences 1996, 1997, 1998, 2000 plus the proceedings for the 1998 Sound Quality Symposium. Three technical reports prepared for IINCE are included: Noise Emissions of Road Vehicles (2001), Assessment of noise walls (1999) and Upper limits on noise in the workplace (1997).

The CD-NC01 is available for US$70 including postage from order@bookmaster.com fax 1 419 281 6883.

InsuLink

Bradford Insulation has recently launched a technical insulation bulletin designed to provide technical information on issues that affect the insulation industry including regulations and standards, case studies, new products, systems and design concepts as well as international news. For your copy contact Bradford Insulation on 1800 354 044 or www.bradfordinsulation.com.au

Innovation In Acoustics Award

At the recent Australian Acoustical Society Conference dinner in Canberra, Michael Coates, Managing Director of I.N.C. Engineered Materials, presented awards for I.N.C.'s Innovations in Acoustics Competition, for innovative applications of I.N.C.'s DECI-TEX™ acoustic textiles.

Renhurst Ceilings was awarded first prize of a holiday for two in Port Douglas, for their Rippletone and Rippletex Acoustic Ceiling Systems. The Renhurst innovation was selected on the basis of teamwork, technical merit, novelty and export success.

Second prize of five days accommodation in Hilton Hotels, was awarded to Holyoake Industries, of New Zealand, for their novel use of self-adhesive DECI-TEX™ 3D in air handling units.

Third prize of one dozen bottles of Wynn's Coonawarra Shiraz was awarded to Marshall Day Acoustics for specifying DECI-TEX™ wall linings in the high profile Federation Square cinemas project.

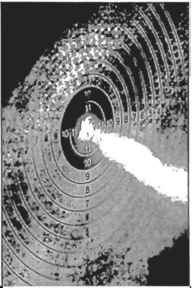
Achieve the ultimate with Brüel & Kjær service

Brüel & Kjær offers faster and better service than any other lab in Australia - at very competitive prices!

For more information on how your business can save on repairs and calibration costs ...

NATA
Accredited
Lab No 1301

Call Brüel & Kjær's Service Centre today on 02-9450 2066



SERVICE AND CALIBRATION

HEAD OFFICE, SERVICE AND CALIBRATION CENTRE
24 Tepko Road * PO Box 177 * Terrey Hills * NSW 2084
Telephone 02-9450 2066 * Fax 02-9450 2379
e-mail: bk@spectris.com.au * www.bksv.com.au

Brüel & Kjær

Welcome to the quiet world of

SOUND BARRIER SYSTEMS

DOUBLE GLAZE and HEAR the difference

HERE IS WHY:

- ★ Up to 46 STC
- ★ Custom Designed to suit all applications
- ★ Afforcable and cost effective solutions
- ★ Existing external appearance of the building remains unaltered
- ★ Specially selected safety glass offers security
- ★ Extremely durable
- ★ Easy to clean and maintain
- ★ Powder coated aluminium frames in a variety of colours
- ★ suited to homes, schools, units, offices, hospitals and other buildings
- ★ Easy access to opening and closing
- ★ Simple and time effective application
- ★ Stay warmer in winter and cooler in summer
- ★ 20 years of experience
- ★ Award winning designs
- ★ Conditional 7 year warranty

SOUND BARRIER SYSTEMS
ACN 002 359 855

SHOWROOM
72 Parramatta Road, Lewisham NSW 2049
Telephone: 02 9540 4333
Facsimile 02 9540 4355 Mobile 0412 478 275

Letters to the Editor

Conference Proceedings

From its inception in 1964 as the NSW and Victoria Divisions, and its incorporation in 1971, there have been around 63 AAS and AAS-related Conferences and Symposiums held in Australia. For those among us such as myself who are interested in chronicling our acousticians' activity, the printed Proceedings are a valuable record of some of their work and researches. I would be interested to hear from all who have copies of any of these Proceedings which they no longer wish to keep, in order that we might arrive at a mutually agreeable arrangement for their transfer. Please contact me at 241 Cotham Rd, Kew, Vic, 3101, by phone on (03) 9817 1881, or by email on fouvyp@pacific. net.au.

Louis Fouvy

The Expert Witness and Payments

Many lawyers accept claims for workers compensation on a 'no-win no-pay' payment basis. As advocates, it is their job to do the upmost to win the case for their client. This is of course provided that the case is genuine.

With hearing loss compensation claims, members of the Australian Acoustical Society (AAS) are often engaged to provide 'expert' opinion for use as evidence of noise exposure and likely effects of hearing damage to the applicant. Members of the AAS are also often engaged to provide an opinion for use as evidence in environmental noise disputes.

Where lawyers carry out the case on the 'no-win no-pay' payment basis it is in their interest to try to persuade the expert witness to accept the same terms or similar terms (i.e. a higher hourly rate for a 'win' result).

However the expert witness is, or should be, bound by a procedure or code of conduct laid down by the Courts. For example the District Court Procedure, NSW, states that the expert witness has a general duty to the Court rather that to the person retaining the expert. This includes "...an overriding duty to assist the Court impartially on matters relevant to the expert's area of expertise". The Court's code of practice specifically states that the expert witness is NOT an advocate for either party. Should the expert witness be persuaded to accept the advocate's 'no-win no-pay' payment basis, or even a higher fee for a winning result, this would place the expert in an almost impossible position to maintain the impartially that the Court insists on.

In my view, expert witnesses should be paid before they carry out any work - either report writing or Court appearances. This is to ensure that they are not influenced or tempted to provide evidence that they believe the person retaining them wants to hear rather than the total impartially which we all seek. Where the time to be spent is unknown, a retaining fee should be paid, in advance, to either the expert witness or a third party.

Perhaps the AAS should have a code of practice for payments to expert witnesses. I would welcome others views

Ken Scannell MAAS

New Members

Qld	
Member	Keith Allison, Richard Devereux
Associate	Peter Patrick
Vic	
Graduate	Sylvia Jones, Dianne Williams
Member	Michael Sullivan
NSW	
Associate	Tony Wellbourne
Member	Stephen Gauld
Subscriber	Steve Marlor

New Products

Gib® Sound Barrier (GSB)

Timber floors in domestic situations present particular noise problems, both between different spaces within the same house or between different occupancies in multi-unit dwellings. Conventional framing, flooring and lining systems provide inadequate protection from airborne sound (insulation measured by STC ratings), and also from impact sounds (measured by IIC ratings). A need has been identified to improve the options available for simple, effective and practical sound control through timber floors, and to complement the existing range of products that make up light frame floor systems.

Gib® Sound Barrier (GSB) is a high-density gypsum fibreboard sheet material intended to be used as a sound control underlay to most common floor finishes. While its development was initially aimed at the new timber-frame construction market, in particular multi-unit development, the material will also be useful in concrete construction and in retrofitting existing buildings.

Information contact: Steve Marlor, Duroid Pty Ltd, Private Bag 800, Wetherill Park. Sydney, NSW 2164. Tel: (02) 9757 3088, 0408 278 606, Fax: (02) 9725 5992, smarlor@fletcher.com.au

Warsash Scientific

Industrial Vibration Sensor for QC

Warsash Scientific has announced the availability of the new, non-contact Industrial Vibration Sensor from Polytec of Germany, the IVS-200. Designed specifically to replace accelerometers for on-line production vibration testing, this low cost ruggedized laser Doppler vibrometer uses an eye-safe visible laser that is aimed and focused onto the part being measured. The primary application of the IVS-200 is to monitor, with the goal of reducing, any defects or noise and vibration in manufactured parts, enabling faster non-contact 100% quality control, improving time-to-market and turnover. As the measurement is quantitative, the defects can be characterised and yield improved dramatically. Simple to install and operate, the IVS-200 has a variable focus lens system for working distances ranging from about 70 mm to 2000 mm. The focus can be locked for tamper-resistant permanent installations. The unit is housed in an IP64 industrial casing. Applications include quality control of AC & DC motors, vibration measurements on any products using electric motors, pumps, noise control on gearboxes, transmission, steering devices and other automotive components.

Information contact Derek Huxley at Warsash Scientific on (02) 9319 0122, or at d.huxley@warsash.com.au.

DAVIDSON

Sound Level Meter

Larson Davis System 824 Sound Level Meter combines sound level meter and real time analyser capabilities in one small, rugged package. The instrument is user friendly, flexible and easy to use, versatile and has large data storage. It measures slow, fast, impulse, peak and Leq for A, C and flat weightings simultaneously. The optional accessories give the unit the capability to do full and 1/3 octave measurements, environmental logging, high seed real time analysis for RT calculations and FFT analysis

Information from Davidson,
tel 03 9580 4366, info@davidson.com.au, www.davidson.com.au

ARL

Rion NC-74 Sound Calibrator

Acoustic Research Laboratories announce the release of the Rion NC-74 sound calibrator in Australia. This new calibrator is compliant with IEC 60942:1997, Class 1 and can be used to calibrate Type 1 sound level meters with 1/2" and 1" microphones. The NC-74 is small and light weight - 200 g including batteries - making it easy to carry and use anywhere. Sophisticated design means that the NC-74 automatically compensates for atmospheric pressure fluctuations so that manual compensation is not required.

The NC-74 complements but does not replace the well known Rion NC-73 calibrator which will continue to be available for applications not requiring a Class 1 calibrator.

Information: Acoustic Research Laboratories. Tel 02 9484 0800, your local branch of ARL or
www.acoustic research.com.au.

BRUEL & KJAER

PULSE 6.1

With Version 6.1 of PULSE™, Brüel & Kjær's sound and vibration measurement platform, we can now offer: Spatial Transformation of Sound Fields - Nearfield acoustical holography on data generated by acoustic test consultant for near field analysis and source location; steady state response analysis and arbitrary waveforms on PULSE, improved modal solutions - twice the number of supported channels, multiple-input Multiple-output (MIMO) analysis (supported by Modal Test Consultant(tm)); and a new version of operational modal analysis, envelope analysis - analysis using amplitude demodulation, e.g., for the diagnosis of roller bearing elements and the identification of gear box faults, PULSE Interface to Sony® SIR-1000 Software - allows data to be read directly into PULSE on your PC from a Sony® tape streamer via a standard SCSI interface

Sony® AIT SIR-1000

With any of the Sony® SIR-1000 series you have a state-of-the-art AIT (Advanced Intelligent Tape) recorder providing a non-compressed storage capacity of 25GB per cartridge and a data transfer rate of up to 24Mbps. Designed for a wide range of measurement applications, the SIR-1000 series includes: SIR-1000i - 16 channels of analogue data to 20kHz (can be expanded up to 128 channels) and SIR-100W - wideband analogue and digital signals (e.g., 4 channels up to 160kHz, 16 channels to 40kHz)

And to make the series even more attractive, the PULSE Interface to Sony® SIR-1000 Type 7774 software allows data to be read directly into PULSE without using a front-end from a Sony® tape streamer via a standard SCSI interface. Type 7774 provides the user-interface for controlling the tape streamer allowing you to control playback and playback speed. PULSE treats the data as if it was coming directly from a data acquisition front-end and analyses the data directly as it is being streamed from the tape streamer.

Impact Hammers

Brüel & Kjær has launched a new line of impact hammers with integral DeltaTron®/ISOTRON® line drive for excitation of everything from small disk drives to large civil engineering structures.

Experimental modal analysis has evolved over the last two decades as one of the most popular tools for investigating the root cause of excessive sound and vibration. The reason behind this development has much to do with the advent of the PC, the availability of inexpensive modal parameter extraction software packages, and the instrumented impact hammer. In less critical applications, the impact hammer has made simple modal testing possible with tremendous savings in costs and test times.

For scaled modal models requiring an input force measurement, test engineers can choose either an attached method, such as an electrodynamic exciter, or a hammer fitted with a high quality piezoelectric (PE) force transducer. In applications where a high crest factor and a limited ability to shape the input force spectrum is of no concern, impact hammer testing is an ideal source of excitation. Impact hammer testing is quick and doesn't require elaborate modal exciter fixtures and cumbersome stinger attachments. Portable and highly suitable for field work, impact hammers are relatively inexpensive and provide no undesirable mass loading of the structure under test.

DeltaTron/ISOTRON outputs are provided on all hammers except for miniature Impact Hammer Type 8203. Practical and fitted with ergonomic rubber grips, all ENDEVCO impact hammers feature a high-quality PE force transducer with acceleration compensation. A variety of tips and extender masses is also available for easier shaping of the input force spectrum.

Accelerometer Family

Brüel & Kjær has launched ENDEVCO's new VALULINE(tm) accelerometer family with the variable capacitance (VC) Model 7596.

Economical and rugged, Model 7596 offers a low-cost solution for low-level, low-frequency applications. Applications include laboratory measurements where the accelerometer will be subjected to high shock levels up to 10,000 g. It is also suitable for modal studies on large structures. Four models are available offering ± 2, ± 10, ± 30 and ± 100g measurement ranges. Specifications include sensitivity of 1000 ± 20mV/g, 66 ± 4mV/g, and 20 ±1mV/g respectively, frequency response from 0 to 15Hz, 0 to 500Hz, 0 to 800Hz and 0 to 2000Hz respectively and mounted resonance frequency of 1300, 3000 and 5500Hz respectively. Operating temperature range is -55 to 121°C for all models. Gas damping and internal over range stops enable the anisotropically etched silicon microsensors to withstand very high shocks and acceleration loads.

Laser Doppler Vibrometers

In cooperation with Ometron, Low-range Laser Doppler Vibrometer Type 8333 and High-frequency Laser Doppler Vibrometer Type 8334 have been released. Both of these single-point Laser Doppler Vibrometers (LDVs) are easy-to-use (point-and-shoot) yet extremely powerful instruments, suitable for field, laboratory and industrial use. Weighing only 7kg in a unique and all-encompassing one-box design, Types 8333 and 8334 are easy to transport and set up.

The Low-range Laser Doppler Vibrometer Type 8333 has been especially developed for demanding, low-velocity range applications where the highest-quality, non-contact measurement data at very low vibration levels are required. Type 8334 is targeted at high-frequency, non-contact vibration measurement applications where vibration frequencies up to more than 400kHz are encountered.

Both instruments are of rugged design and feature an unsurpassed, high optical sensitivity providing for trouble-free, non-contact measurements of up to 200m on targets without any surface treatment. Despite this, the laser source in both instruments is an eye-safe, Class II HeNe laser. The uniquely high optical sensitivity also facilitates accurate and precise vibration measurements of targets submerged in a liquid. Type 8333 can be equipped with an optional fiber optical cable for applications where access to the target might be difficult.

Information: Bruel & Kjaer Australia
Syd 02-9450 2066 Melb 03-9370 7666
Bris 07-3252 5700 Perth 08-9381 2705
bk@spectris.com.au www.bksv.com.au

FANTECH

WhisperJet

The WhisperJet Fan kit is based on Fantech's popular Powerjet series fan renowned for powerful and reliable exhaust capabilities. The kit consists of a Powerjet fan, two CC silencers and a two speed switch in a size range of 150, 200, 250 and 315mm. It provides ventilation solutions for office tenancy fitouts such as utility rooms, conference rooms, canteens or computer rooms.

Information: Fantech, tel 03 9560 2599, info@fantech.com.au

CSR BRADFORD INSULATION

Ultraphon

Bradford Ultraphon is a black woven glass fabric acoustic lining offering excellent broad band sound absorption. It has good dimensional stability and remarkable maximum service temperature of 550 deg. It is non combustible, fire resistant and highly resistant to attack by most chemicals. It is durable being unaffected by sunlight, fungus or bacteria and is easily cleaned by wiping down with a damp cloth.

Information: CSR Bradford insulation on 1800 354 044 or
www.bradfordinsulation.com.au

ANNUAL INDEX
Vol 29 2001

Diary...

2002

5-9 March 2002 FREMANTLE
International Tinnitus Seminar
Mrs Janie Binet, PO Box 581, Cottesloe, Western Australia 6011, Tel. & fax: +61 8 9384 1249, jcsbinet@hotlinks.net.au, www.tinnitus.com.au

3-7 June, PITTSBURGH,
143rd Meeting of the Acoustical Society of America.
http://asa.aip.org, fax: +1 516 576 2377

4-6 June, ST. PETERSBURG,
6th Int Symp on Transport Noise & Vibration.
http://webcenter.ru/~eeaa/tn/eng/tn2002,
fax: +7 812 127 9323

27-29 June, PATRAS
4th In Cong Computational Mechanics
http://gracm2002.upatras.gr/, fax +30-61-996344,
gracm2002@upatras.gr

7-12 July, ORLANDO
ICSV 9
http://www.iiav.org/, fax 407-823-6334,
icsv9@mail.ucf.edu

15-17 July, *SOUTHAMPTON*
Active 2002
http://www.isvr.soton.ac.uk/Active2002 or Prof S Elliott, ISVR, Southampton University, SO17 1BJ, fax +44 23 8059 3190, sje@isvr.soton.ac.uk

19-21 August, MICHIGAN
Internoise *2002*
http://www.internoise2002.org or Congress Secretariat, Dept Mech Eng, Ohio State Univ, West 18 th Ave Columbus OH 43210-1107 USA, peersen.1@osu.edu
hp@internoise2002.org

22 August, MICHIGAN,
Sound Quality Symposium
http://www.SQS2002.org

19 - 23 August, MOSCOW
16th International Symposium on
Nonlinear Acoustics (ISNA16).
O. Rudenko, Physics Department, Moscow State University, 119899 Moscow, Russia,
isna@acs366b.phys.msu.su

16 - 21 September, SEVİLLA
Forum Acusticum 2002 (Joint EAA-SEA-ASJ Symposium) http:/www.cica.es/aliens/forum2002,
fax: +34 91 411 76 51

16-18 September, LEUVEN
Int Conf Noise and Vibration Engineering
http://www.isma-isaac.be ,
lieve.notre@mech.kuleuven.ac.be fax: (+32) 16 32 29 87

17-20 September, DENVER
Int Conf on Spoken Language Processing
http://cslr.colorado.edu/icslp2002

*** 13-15 November, ADELAIDE**
Acoustics 2002
Department of Mechanical Engineering, Adelaide University, SA 5005, AUSTRALIA. Tel: +61-8-8303 5469; Fax: +61-8-8303 4367; aas2002@mecheng.adelaide.edu. au, www. mecheng.adelaide.edu.au/aasconf

21-22 Nov, AUCKLAND
New Zealand Society Conference
mmv@hitz.co.nz
www.acoustics.org.nz

30 Nov–8 Dec, MEXICO
1st joint meeting of ASA, Iberian Fed. Acoustics, Mexican Inst Acoustics
http://asa.aip.org/cancun.html

2003

7 - 9 April, MELBOURNE.
WESPAC8
Acoustics on the Move
http://www.wespac8.com

7-10 July, STOCKHOLM
ICSV 10
Fax:+46 8 661 91 25, icsv10@congrex.se, www.congrex.com/icsv10

24-27 August, KOREA
Internoise 2003
Fax +82 42 868 5044, hjeun@kriss.re.kr

2004

04 - 09 April, KYOTO,
18th International Congress on Acoustics (ICA2004).
http://ica2004.or.jp

WWW Listing
The ICA meetings Calendar is available on
http://www.icacommission.org/calendar.html

Research Position Musical Acoustics

This 2-3 year position, at post-doctoral or senior research assistant level, is part of an ARC collaboration to investigate the acoustics of the didjeridu, including the interaction of the bore, lips, vocal tract and vocal folds. The candidate should have skills in some of: acoustics, experimental physics, signal analysis and modelling.

The candidate will spend most time at UNSW in Sydney, and some time at the University of Melbourne.

For more information:

www.phys.unsw.edu.au/~jw/Ad.html

or

A/Prof Joe Wolfe

J.Wolfe@unsw.edu.au

or A/Prof Lloyd Hollenberg

L.Hollenberg@physics.unimelb.edu.au

ACOUSTICS 2002

Innovation in Acoustics and Vibration

13 to 15 November 2001
Adelaide, SA
Hyatt Regency Hotel

Papers on all aspects of fundamental and applied acoustics
AND special sessions on Underwater Acoustics
PLUS Technical Exhibition
PLUS Technical Tours: Whispering Wall and Winery
PLUS Social Activities: welcome function, conference dinner, breakfast, lunch and tea breaks included in the registration.

Call for Abstracts now available

Information via **www.acoustics.asn.au**
Or contact: Acoustics 2002, Dept Mech Eng,
Adelaide University, SA 5005
Tel: 08 8303 5469 Fax: 08 8303 4367
aas2002@mecheng.adelaide.edu.au

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) 9887 9400
email: watkinsd@melbpc.org.au
www.acoustics.asn.au

SOCIETY SUBSCRIPTION RATES

For 2001/2002 Financial Year:

Fellow and Member	$103.40
Associate and Subscriber	$82.50
Retired	$34.10
Student	$23.10

Including GST

DIVISIONAL MATTERS

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

AAS - NSW Division
Professional Centre of Australia
Private Bag 1,
DARLINGHURST 2010
Sec: Mr D Eager
Tel (02) 9514 2687
Fax (02) 9514 2665
david.eager@uts.edu.au

AAS - Queensland Division
PO Box 760
Spring Hill Qld 4004
Sec: Rebecca Ireland
Tel: (07) 3367 3131
Fax: (07) 3367 3121
rebecca@ronrumble.com.au

AAS - SA Division
C/–Department of Mech Eng
University of Adelaide
SOUTH AUSTRALIA 5005
Sec: Simon Hill
tel: (08) 8303 5469
Fax: (08) 8303 4367
simon.hill@mecheng.
adelaide.edu.au

AAS - Victoria Division
PO Box 417
Collins St. West
PO MELBOURNE 8007
Sec: Elizabeth Lindqvist
Tel (03) 9925 2144
Fax (03) 9925 5290
elindqvist.gharding@
projectx.com.au

AAS–W A Division
PO Box 1090
WEST PERTH 6872
Sec: Mr J Macpherson
Tel (08) 9222 7119
Fax (08) 9222 7157
john_macpherson[illegible]viron.gov.au

ACOUSTICS AUSTRALIA INFORMATION

GENERAL BUSINESS

Advertising Subscriptions

Mrs Leigh Wallbank
PO Box 579, CRONULLA 2230
Tel (02) 9528 4362
Fax (02) 9523 9637
wallbank@zipworld.com.au

ARTICLES & REPORTS NEWS, BOOK REVIEWS NEW PRODUCTS

The Editor
Acoustics Australia
Acoustics & Vibration Unit, ADFA
CANBERRA ACT 2600
Tel (02) 6268 8241
Fax (02) 6268 8276
email: acoust-aust@adfa.edu.au

PRINTING, ARTWORK

Scott Williams
16 Cronulla Plaza
CRONULLA 2230
Tel (02) 9523 5954 Fax (02) 9523 9637
email: print@cronullaprint.com.au

SUBSCRIPTION RATES

	Aust	Overseas
1 year	A$ 57.20	A$ 64
2 year	A$ 96.80	A$112
3 year	A$137.20	A$161

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

ADVERTISING RATES

B&W	Non-members	Sus Mem
1/1 Page	$605.00	$550.00
1/2 Page	396.00	357.50
1/3 Page	302.50	275.00
1/4 Page	258.50	242.00

Spot colour: $110 per colour
Prepared insert: $275 (additional postage may apply)
Column rate: $19.80 per cm (1/3 p 5.5cm width)
All rates include GST

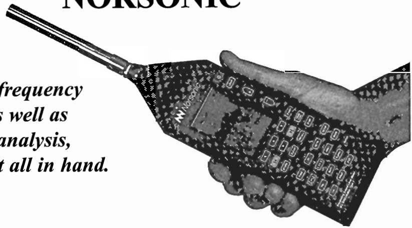
Discounted rates for 3 consecutive ads in advance

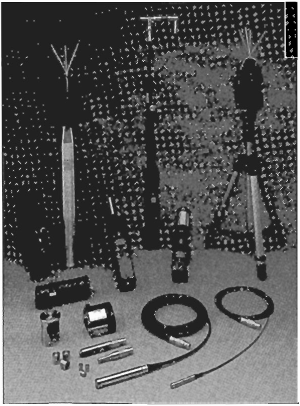
Special rates available for 4-colour printing

All enquiries to: Mrs Leigh Wallbank
Tel (02) 9528 4362 Fax (02) 9523 9637
wallbank@zipworld.com.au

ACOUSTICS AUSTRALIA ADVERTISER INDEX - VOL 29 No 3

Acoustic Research Labs	110
Alliance Constructions	132
Australian Hearing	94
Bruel & Kjaer	131, back cover
Davidson	116
ETMC	Inside back cover
Richard Heggie Associates	96
Infobyte	96
Kingdom	Inside front cover
Matrix	126
Noise Control Australia	94
Noise Measurement Services	132
Nutek Australia	124
Peace	126
RTA Technology	126
Sound Barrier Systems	131
Warsash	122


Norsonic

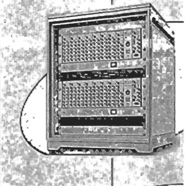


PULSE - A SOLID FOUNDATION

Hans Konstantin-Hansen
Applications Specialist

Jong-Bo Kim
Marketing Manager, PULSE

- FOR BUILDING YOUR FUTURE



OVER 2500 CUSTOMERS A
ALREADY USING PULSE

PULSE™ Analyzer platform is modula
and scalable and forms the basis for
ever-increasing number of sound and
vibration applications. Built on years
Brüel & Kjær knowledge, experience
and innovation, it forms a solid found-
ation from which you can create a
system to suit all your needs.

NEWS IN PULSE VERSION

- 128 Channels
- 100 kHz Frequency Range
- Sony® SIR-1000 Interface
- Envelope Analysis
- Arbitrary Waveforms
- Steady State Response Analysis (S
- MIMO Analysis
- STSF Near-field Acoustic Holography v 1.0

e-mail: bk@spectris.com.au
www.bksv.com.au

Brüel & Kjær

SYDNEY
Tel: 02-9450 2066
Fax: 02-9450 2379

MELBOURNE
Tel: 03-9370 7666
Fax: 03-9370 0332

BRISBANE
Tel: 07-3252 5700
Fax: 07-3257 1370

ADELAIDE
Tel: 02-9450 2066
Fax: 02-9450 2379

PERTH
Tel: 08-9381 2705
Fax: 08-9381 3588

NEW ZEALAND
Tel: 09-489 8100
Fax: 09-489 858