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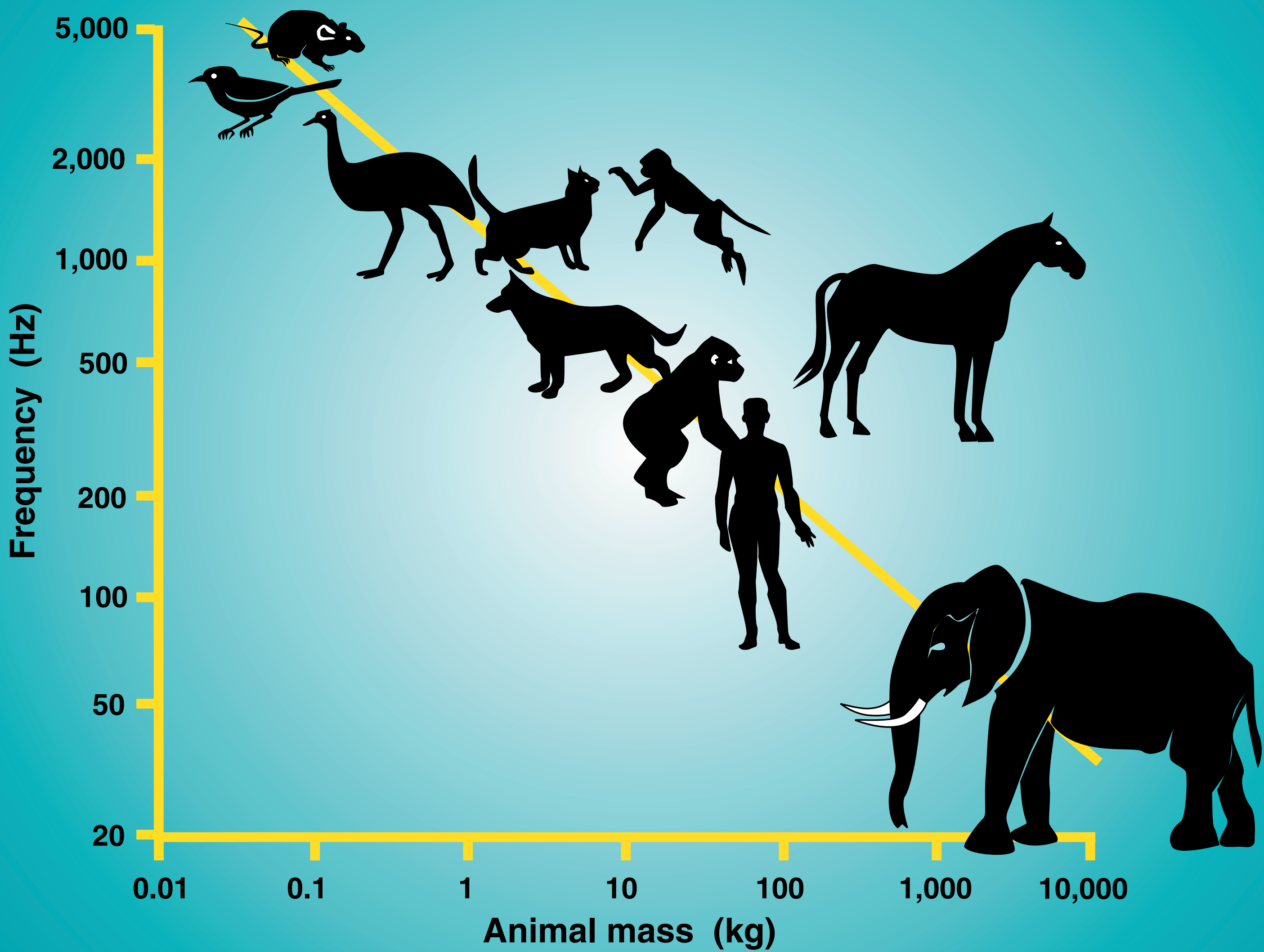

SPECIAL ISSUE: AAS CONFERENCE

- *Animal sounds: from insects to elephants*
- *The boundary element method*
- *The sound of non-existent machines vibrating*

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PAPERS

FORUM

Cover illustration: 'The bigger the lower', see Fletcher page 83

From the President

I have just returned from the annual conference in Busselton, Western Australia and have mixed feelings. My first thought is that the acoustics industry mostly comprises enthusiastic and passionate engineers / scientists who genuinely enjoy what they do and achieve. I know there is a thriving community out there. However, on the reflection, it is clear there is a general demise in the availability of good education in acoustics (although some states may be an exception). So why the dichotomy?

The "universities" suggest that the lack of acoustics students results in courses eventually being closed. However, if people who work in acoustics enjoy their career so much, why is this feeling or message not getting through to students or potential students? I guess the simple answer is that nobody tells them. But whose job or role is it to tell them? The Society definitely has a role to play, but I am not sure it is the pivotal role. I believe that ultimately it is a combination of those organisations who need the skills of acousticians (Government in its many guises and acoustical consulting firms) and the "universities" who presumably need to fill places that have the more immediate need who should be those mainly responsible for encouraging school aged children or undergraduates to consider acoustics as a viable career. The enthusiasm of lecturers about acoustics is therefore paramount if courses are to succeed

So what can be done about the current situation? There has been some suggestion that the adoption of the UK Institute of Acoustics post graduate Diploma in Acoustics through distance learning may be a useful way of encouraging more people in Australia to undertake some study in a course that is particularly relevant to either work as an acoustic consultant or in an Environmental Health Officer style role. I got the feeling that many Australian acousticians felt that we are quite capable of providing this sort of distance learning diploma ourselves, and I am aware that much of the course structure already exists.

If you have any interest providing assistance in teaching any aspects of acoustics (particularly industrial noise control) or have any other suggestions to make in relation to ongoing education for future acousticians or can suggest ways of promoting acoustics as a career, then please email me at president@acoustics.asn.au so I can collate the feedback.

As part of my original promise to provide amusing anecdotes, here's another example why we should always be ready for anything.

An engineer (with a reputation for not being the most careful with equipment) was conducting measurements on a wharf. With the Sound Level Meter and tripod out of the case, all it took was a slight gust of wind across the open lid to topple the case off a pile of timber into the harbour with only 1 bounce. Fortunately the case landed the right way up and was happily bobbing around a few metres below the wharf. The quick-thinking (sorry panicking) engineer soon spotted a boat hook, and leaning over the wharf could just stop the case from drifting away. He hoped to steer the case back to some steps nearby as someone else who had spotted the dilemma climbed down the steps. On reaching out that little bit further to steer the case towards the steps, his mobile phone fell out of his top pocket, but unbelievably landed in the case. Everything was rescued free of salt water. Please email me and tell me the moral of the story, although I wondered whether the engineer bought a lottery ticket on the way home.

Neil Gross

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From the Editors

You've entered a courtyard surrounded by public buildings, well protected from nearby roads. It's morning and the slanting sunlight filters through the spring leaves onto the stylish outdoor furniture, the well maintained garden and the high quality paving. You and your colleague have a few minutes before your meeting inside and you sit down to collect your thoughts and to drink the coffee that you bought on the way in. A magpie rehearses his coloratura song.

You can't help noticing that this time, the architects, landscape architects and gardeners have really done well and the pleasant surroundings lift your spirits noticeably. You wonder whether the employees and other visitors feel a similar lift as they pass through this space, or stop here to talk or to rest.

Just then you hear a screech and whirr as a compressor cuts in. It must be getting hot in one of the buildings and the air conditioning has started. And there is the compressor, unbaffled, near ground level on one side of the courtyard, radiating into a space largely bounded by brick walls and paving. You and your colleague have a few points to discuss before the meeting, but you go inside so that you can talk comfortably.

How could the designers have put so much care into the visual environment yet apparently no thought into the acoustic environment?

There are several probable answers. The sketch pads, the CAD programs, the fancy software that allowed the client to do a virtual tour through the then-nonexistent courtyard... none of these had sound (yet). And the air conditioner appeared just in a technical brief, possibly with an instruction to do it as cheaply as possible. Perhaps it was even an afterthought, if the designer did not calculate the various thermal effects. Finally, perhaps it didn't occur to anyone that a mistake like this could change the experience of an environment from positive to negative.

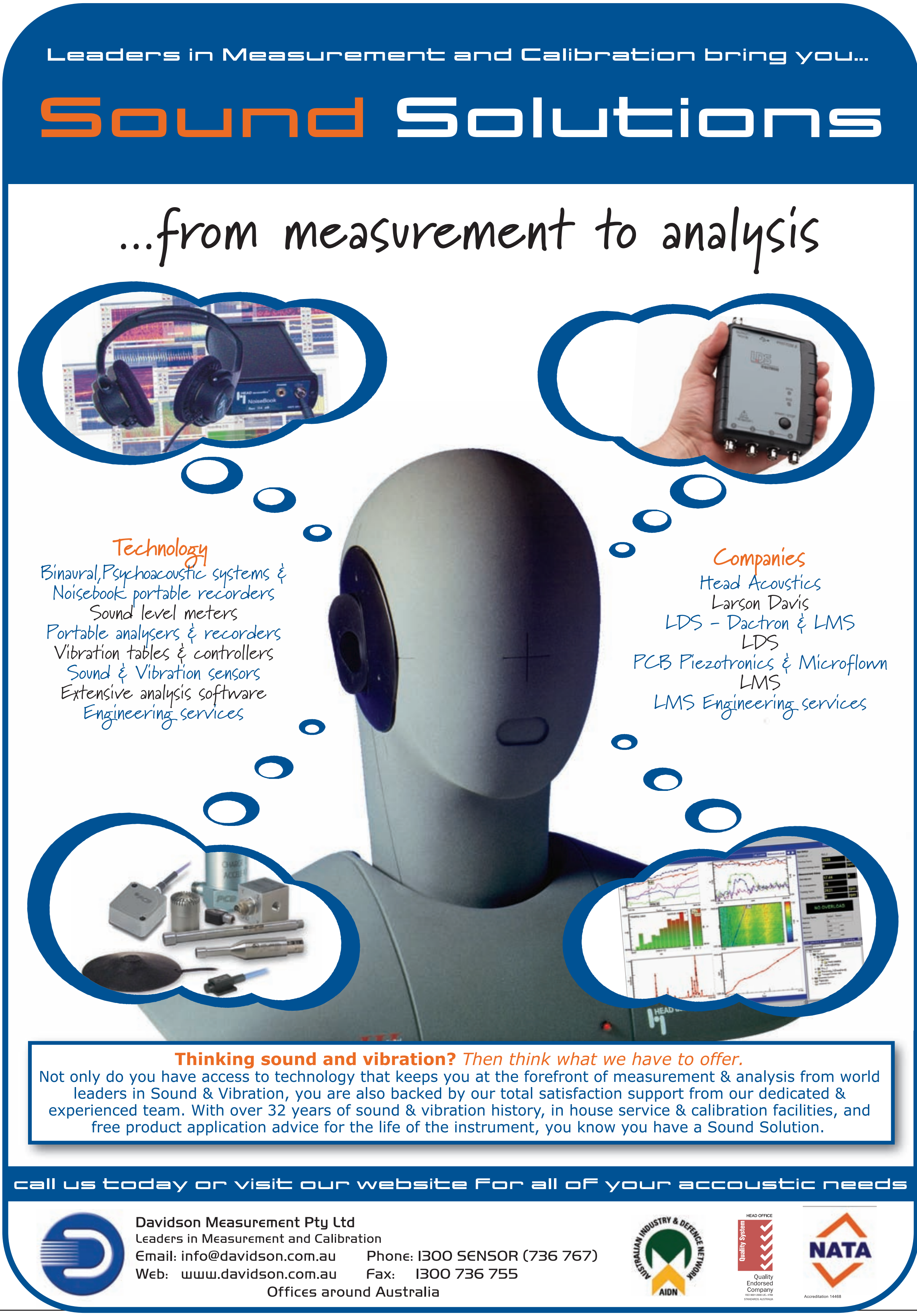
It can be done, of course. I once wrote a story[1] about the acoustic environment of Venice. In a city unblemished by cars, one would expect some care to be taken about the acoustic environment. It is.

Australia has legal constraints and guidelines, of course. Further, major projects have acoustical engineers. But it's not enough to create urban environments that are merely legal: we want their comfort and beauty to surpass the minimum standards imposed by law. And acoustics is important in the small as well as the large projects. Architects are interested in aesthetics of the eye. How can we get them equally interested in aesthetics of the ear? They already ask "what will it look like?". How to get them to ask "what will it sound like?"?

Here is a suggestion. The Society might produce a simple print and web document that would include a checklist of what an architect or planner should consider in a new indoor or outdoor environment and where to obtain professional advice. Then we might advertise its existence, aiming at architects and related professionals, urging them to ask "What will it sound like?"

Joe Wolfe

1. Wolfe, J. "Venice: an acoustical paradise", Sydney Morning Herald, June 16 (2001). http://www.phys.unsw.edu.au/~jw/Serenissima.html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ACOUSTIC SYSTEMS IN BIOLOGY: FROM INSECTS TO ELEPHANTS*

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ABSTRACT Nearly all animals use sound for communication, for seeking prey, and for avoiding predators. What physical principles govern their choice of frequency? What are their mechanisms of sound production and directional hearing? Why are cicadas so loud? How do birds produce those beautiful, or sometimes not-so-beautiful, sounds? Quantitative analysis of the acoustic mechanisms involved reveals (nearly) all: the action of the sensory hairs on caterpillars, the hollow bodies of cicadas that act as resonators, the horn-shaped burrows dug by crickets and their remarkably human-like auditory anatomy, the inflatable vocal sacs used by "pure tone" songbirds and by frogs, and the chaotic structure of the shrieks of sulphur-crested cockatoos. This lecture will explore all these matters and perhaps some more.

ANIMAL COMMUNICATION

Sound signals are important for nearly all animals. They listen passively for warning sounds signalling the approach of predators, they listen carefully for sounds given out by their own prey, and they use sound actively to communicate with other members of the same species. Some animals, such as bats and dolphins, also use active sonar methods to map their environment and seek out prey. While the variety of anatomical details and habitats can explain much of the variation between the sonic activities of different species, there are certain general principles that apply to all animals, while the ancestry of evolution gives clues for anatomical similarities between animals as diverse as crickets and humans. The present paper will deal exclusively with land-dwelling animals, leaving underwater communication to other speakers.

Since the number of books and papers published on biological aspects of animal behaviour is immense, I can perhaps be forgiven for concentrating on those to which I have contributed myself, which deal with physical and acoustic aspects of the subject. One of these (Fletcher 1985) gives a brief survey of the subject, while comprehensive treatments have been given in two others (Fletcher and Thwaites 1979a, Fletcher 1992). Of course I have benefited greatly from the research of others, particularly biologists, but I have left it to my biological colleagues to filter this work into my consciousness.

Let us look first at conspecific communication and see what general rules apply. It is not unreasonable to expect that there may be a large difference in behaviour between air-breathing animals such as elephants, humans and birds, and those animals such as insects that have to produce sound by mechanical vibration of some part of their anatomy, so we first examine these air-breathers.

Since one aim of conspecific communication is to maximise the distance over which the call can be heard, and since this depends on both the acoustic power that can be produced and the frequency of the call signal, we might expect a relation between the call frequency and the size of the animal. There is indeed such a relation and it is indicated by the summary in Fig. 1. To analyse the scaling rule that might be expected requires consideration of the sound-production mechanism, essentially air flow through a vibrating valve, sound radiation, propagation loss (which increases as the square of frequency), and auditory sensitivity. Putting these all together yields the rule that dominant frequency should be inversely proportional to the mass of the animal's body to the power 0.4 (Fletcher 2004). This is the line shown in the figure. Clearly there are some outliers in this general correlation, but the result is surprisingly consistent when the range of animal size and anatomy is considered. A similar scaling rule can be derived for the communication distance, which varies about as body mass to the power 0.6.

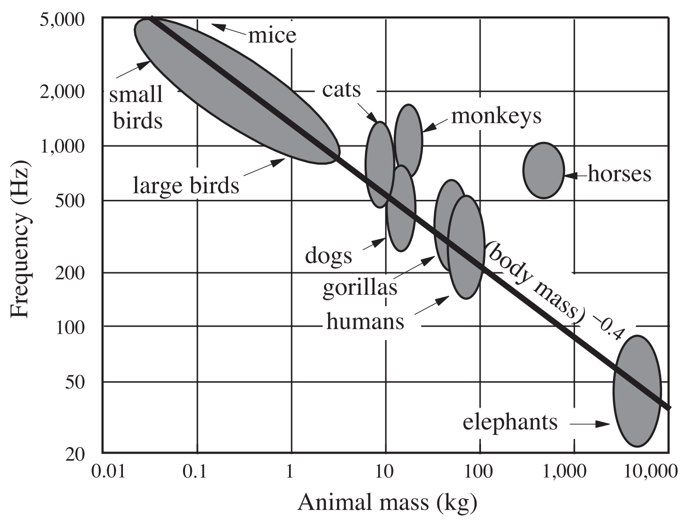


Figure 1. Distribution of dominant frequencies for a large range of air-breathing animals. The line is the calculated behaviour: frequency proportional to (1/body mass)$^{0.4}$. (Adapted from Fletcher 2004)

Insect song behaviour is, as might perhaps be expected, very much less consistent because the sound production mechanism varies widely between species, but it is clear that very small insects make sounds of very high frequency. We return to this later.

* Reprinted from the Proceedings of the Australian Acoustical Society Conference, 2005. Editor Terrance McMinn.

INFORMATION CONTENT

Information can be encoded in vocalisations in several ways, but the most important are the spectral structure and envelope, and the time variation of the signal. Insects generally have the simplest signals, which are essentially repeating pulses at a single frequency, the reason being that these are simply mating calls by the males of the species and need to convey nothing other than their existence and location. At the other end of the scale, humans use both time encoding (sentences, words, syllables) and frequency encoding (vowels, consonants) to construct a language with high information content. Birds are perhaps anomalous, since their songs are complex in both time and frequency but, because they are repetitive, the total information content is limited.

The case of elephants is particularly interesting, since the dominant frequency of about 30 Hz could be characterised as "infrasonic", and it propagates over long distances, particularly when there is a temperature inversion in the atmosphere. It turns out, however, that other elephants cannot recognise an individual until they are able to hear the information contained in frequency components above about 100 Hz.

VOCALISATION IN MAMMALS

All mammals have very similar vocalisation mechanisms, as shown in Fig. 2(a). Air is compressed in the lungs to a pressure that does not vary greatly across species or the size range, since muscle stress is about the same and both the thickness of containing muscles and the radius of the lung sac vary in the same way with animal size. The vocal organ contains a pressure-controlled flap valve, the oscillation frequency of which, and hence that of the air flow, is controlled by muscular tension. Above the valve is a vocal tract terminated by a flexible opened mouth, and it is the acoustic resonances of the contained air column that can be adjusted to create emphasised formants in the radiated sound. The frequency of the lowest formant band is typically several times that of the valve oscillation, and the formant frequencies can be adjusted over quite a large range by variation in mouth geometry.

While this vocalisation mechanism is very flexible, it is not very efficient, typically reaching a maximum of not much more than 1% at high sound levels. Typical maximum continuous sound output is of order 10 μW per kilogram of body mass. This amounts to about 10 mW (90 dB at 1 m) for a human and perhaps 1 W for an elephant. Birds and insects, as we shall see later, do much better.

Bats are particularly interesting animals acoustically because of their use of ultrasonic signals (around 60 to 80 kHz) for echo-location. Their vocal anatomy is similar to that of other animals except that their nasal tract often contains several cavities that appear to be matched so as to emphasise the preferred frequency. Bat calls usually consist of upward-sweeping syllables which are presumably reconstructed into sharp pulses by their auditory analysis system. This technique is reminiscent of the "chirping–dechirping" technique often used for radar signals and allows the emitted call to have high acoustic energy without requiring high peak power.

VOCALISATION IN BIRDS

The vocalisation mechanism in birds differs from that in mammals only in detail. The vocal valve, or syrinx, is duplicated in song birds and the two valves are at the upper ends of the bronchi, as shown in Fig. 2(b), rather than in the base of the trachea just above the junction of the bronchi as in mammals. Birds can thus divide the vocal effort between the two syringeal valves, using one for high and the other for low notes, or can even sing two notes at once. The valves themselves differ in structure from the larynx in mammals, and generally involve inflatable sacs that can be made to close off the airway and thus respond to pressure variations in an oscillatory manner.

The upper vocal tract is less flexible in birds than in mammals, since the beak is less adjustable than the lips and the tongue is generally narrow. Despite this, the song of birds such as ravens bears a close resemblance to human song, with adjustable formants at frequencies well above that of the fundamental (Fletcher 1988, 1992, Fletcher and Tarnopolsky 1999). This explains why parrots and cockatoos can imitate human speech, since they can reproduce the upper formants that encode the vowels, while the missing first formant below about 1 kHz simply makes the speech sound "artificial".

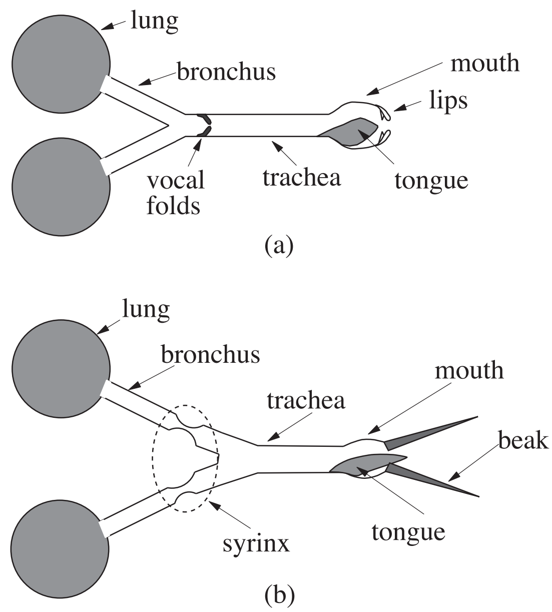


Figure 2. Anatomy of the vocal system of (a) a mammal and (b) a songbird.

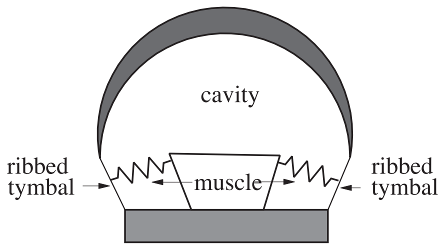
Some birds can tune their vocal systems to produce nearly pure-tone songs, particular examples being the Ring Dove, which employs an inflatable sac in the vocal tract, keeping its beak closed and relying upon direct sound radiation from the vibrating sac walls to produce its 'coo' sound (Fletcher et al. 2004). Analysis shows that the resonance frequency varies by only a small amount for a moderate change in the sac inflation, since the increased compliance of the enclosed air is largely balanced by the increase in wall area.

The Northern Cardinal produces a similar effect, but with a widely adjustable frequency range, by singing with its beak slightly open and relying upon a Helmholtz resonance in an adjustable vocal cavity to tune the formants. One of the most spectacular birdcalls is, however, that of the Australian sulphur-crested cockatoo, which produces an immensely loud shriek that can be shown by analysis to be actually a chaotic oscillation of its syringeal valve (Fletcher 2000).

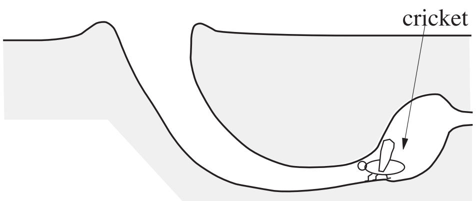
Although they are not closely related, animals such as frogs use a resonant vocalisation technique that is very similar to that employed by doves. It is easily seen that most frogs inflate a large thin-walled sac below their mouth when producing sound. The sac remains inflated during the call and the mouth is closed, so that sound radiation occurs through the agency of the vibrating sac walls and the resonance frequency is not very sensitive to sac inflation.

SOUND PRODUCTION BY INSECTS

When we turn to consider sound production by insects, the situation is very different, for they must rely upon resonant structures vibrating in the air. Indeed this method, but with surrounding water rather than air, is also used by crustaceans. Two significantly different methods are used, as we now discuss.



(a)



(b)

Figure 3. (a) Sound production system of a cicada.
(b) Geometry of the horn excavated in the ground by a cricket.

In the first, which is characteristic of cicadas, anatomy provides a large body cavity, in the walls of which are two rather stiff deformable ribbed plates (tympana) that can be made to vibrate by muscular action, as shown in Fig. 3(a). As the driving muscles contract, these plates deform progressively in as step-wise manner as each rib flips from one stable position to another, thus providing an acoustic displacement current with a frequency equal to the rate of individual rib collapse. Since there may be ten ribs, this mechanism multiplies the excitation frequency provided by muscle oscillation by a factor ten in this case. The body cavity volume has been tuned by evolution so that the resonance frequency of the two tympana, backed by the cavity, is equal to the rib collapse frequency, so that there is a large resonant amplification of the excitation. Because the two tympana move in phase, and their vibrations are closely coupled by the resonance, they act in combination as a monopole source and give highly efficient sound radiation (Fletcher and Hill 1978).

The radiated sound from a cicada thus consists of a string of consecutive identical "syllables", each one corresponding to a single buckling motion of the tymbals and containing within it a train of oscillations at the cavity resonance frequency. The information content can be varied by changing the number of syllables in a "word" or, more usually, by varying the syllable repetition rate.

Insects as a rule devote much more of their available muscular power to sound production than do mammals. Thus a continuously singing cicada weighing less than 1 g may produce as much as 1 mW of sound energy (80 dB at 1 m), which is comparable with that produced by a human opera singer weighing some 10^5 times as much!

The second class of insects we should consider consists of those such as crickets that produce sound by drawing a toothed file of some sort across a part of their anatomy, generally a wing or wing cover, thus causing it to vibrate. As the contact is lifted and released by each tooth of the file it generates a damped vibration at the resonance frequency of the wing panel, giving a series of these vibrations for each leg stroke. This is intrinsically a much less efficient sound production mechanism than that used by the cicada, since the vibrating source is a dipole, and generally serves for short-distance communication within a fairly large population.

To overcome this inherent dipole disadvantage, a few insects such as the cricket have developed the ingenious strategy of digging a horn-like burrow with a cavity at the buried end, arranging for this structure to be resonant at their song frequency, and positioning themselves at the junction between the horn throat and the cavity so that the dipolar flow created by their vibrating wing covers drives the whole oscillation effectively (Daws et al. 1996). This arrangement is shown in Fig. 3(b).

AUDITORY AND VIBRATION SENSORS

It is a notable feature of auditory systems that most of them rely upon sensory cells with thin hairs protruding from one end (Fletcher 1978). Deflection of the hairs by fluid displacement induced by the acoustic signal opens ion channels in the cells which, in turn, leads to an electrical signal in the attached nerve channel. In the case of some insects such as caterpillars, these sensory hairs are used directly to detect close-range signals from the beating wings of predatory wasps. In the case of aquatic creatures, the hairs may be loaded with small massive otoliths so that when the bulk of the body of the fish is displaced by an acoustic signal, the inertia of the otolith deflects the sensory hair. Some fish, however, have an air-filled "swim bladder" that has the same effect, though differing in phase by 180°.

In land-dwelling animals, including humans, these sensory hair cells have often been incorporated into assemblies with some sort of frequency dispersion mechanism, generally through waves propagating on a tapered membrane, in the organ known as the cochlea, as will be discussed later.

Sensing of vibration is also important for most animals – even humans can detect quite small vibrations through their fingertips and larger low-frequency vibrations through the legs. For some insects, however, the sensing of vibration is more important than the sensing of air-borne sound. Two obvious examples are the spider in its web, and the related water-skimmer that detects surface ripples generated by insect prey caught by surface tension. Some insects have specialised detectors just below their knee-joints (and therefore called "sub-genual organs") to detect these vibrations.

DIRECTIONAL HEARING IN INSECTS

It is usually important for an animal to be able to detect the direction from which an auditory signal arises, and for this reason nearly all animals have two symmetrically paired auditory organs. In the case of mammals, as for example humans, the two ears are very nearly separate from an acoustic point of view and comparison of the signals received by each is a task for the neural system. Each ear does, however, have a certain amount of directional sensitivity. In reptiles, birds, and insects there is actually a direct acoustic coupling between the two ears.

As with the sound production mechanism, the simplest auditory systems rely upon a diaphragm backed by a cavity and connected mechanically to some sort of neural transducer. Such a system can be tuned to produce a resonance, and thus maximum auditory sensitivity, at the conspecific call frequency of the animal concerned.

Two such tympana opening into the same volume are able to create a system with high directional sensitivity. This is despite the fact that the whole process relies upon the phase difference between the sound signals at the two ears, which is typically only about 30° (Fletcher 1992, chap 9). The auditory anatomy of a female cicada, shown in Fig. 4(a), thus looks like a smaller version of the male sound production system shown in Fig. 3(a), the males being the sound producers and the females the listeners. The auditory response of such a system for ipsilateral (I) and contralateral (C) sound incidence is shown in Fig. 4(b) for a particular set of parameter values. While there is no pronounced resonance for the ipsilateral ear, there is a marked decrease in response for the contralateral ear at the tuned frequency. The directional response at this frequency has a cardioid form with a directivity of more than 20 dB, as shown in Fig. 4(c).

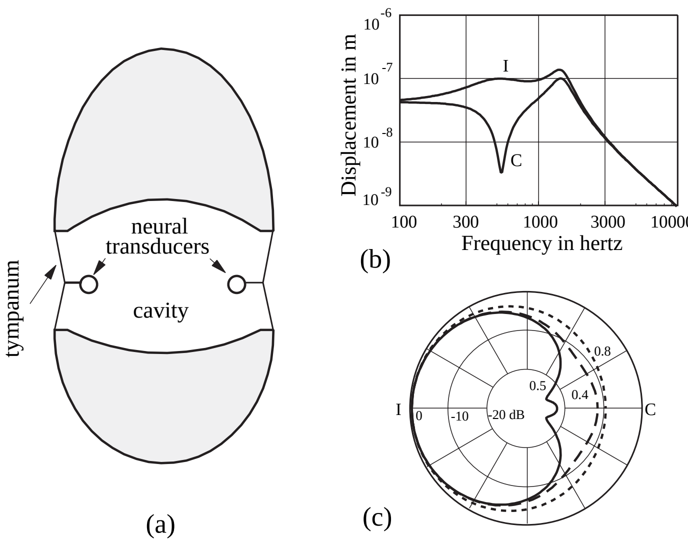


Figure 4. (a) Sketch of the auditory anatomy of a female cicada. (b) Calculated frequency response of the ipsilateral (I) and contralateral (C) ears for a particular set of parameter values. (c) Polar plot of the directional response for the two ears for several frequencies, shown as a parameter.

Some insects, however, have much more complex auditory systems. An example is the cricket, which has auditory tympana located one on each foreleg near the knee joint. Each tympanum is backed by a small cavity which is connected by a rather long flaring tube to an exit port (spiracle) on the thorax that serves to allow the ingress of air to maintain the life of the insect. The two tubes leading from tympana to spiracles are connected by a thin membrane or septum within the thorax, as shown in Fig. 5 (Fletcher and Thwaites 1979b, Fletcher 1992 chap. 11).

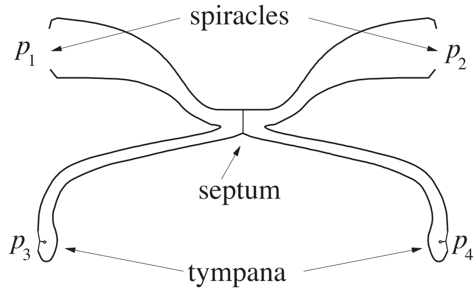


Figure 5. Schematic drawing of the anatomy of the cricket auditory system. The topology should be compared with that of the human auditory system

HEARING IN REPTILES AND BIRDS

The auditory sensitivity of birds is comparable with that of humans and generally extends over a similar frequency range, though biased towards higher frequencies as one would expect from the plot in Fig. 1. The same is true of small mammals such as mice.

Surprisingly, the auditory system of the frog (which eats cicadas if it can!) is very similar, with two simple ears opening into the mouth cavity. The presence of two small vents for the nostrils shifts the auditory sensitivity pattern somewhat away from the direct transverse direction. Since the mouth cavity is also employed to produce vocalisations, there must clearly be a mechanism for decoupling the neural transducers of the ears during song production.

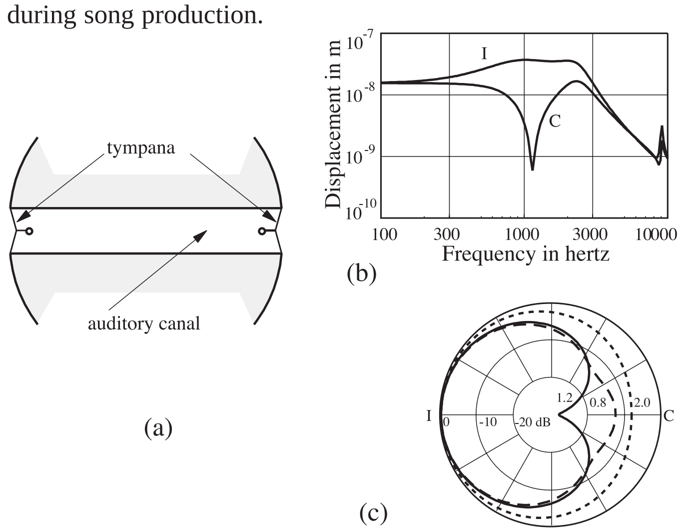


Figure 6. (a) Sketch of the geometry of the auditory system of a bird or lizard. The two tympana are connected by a simple tube. (b) Response of the ipsilateral (I) and contralateral (C) ears as a function of frequency for a particular set of parameter values. (c) Polar plot of directional response at various frequencies for this same set of parameter values.

Lizards and birds also possess auditory systems with acoustic coupling between the two ears. Instead of a simple cavity, however, they generally have a nearly straight canal to perform the connection, as shown in Fig. 6(a). With a typical canal length of say 20 mm, and appropriate values of the other parameters, such a system can give a cardioid response pattern for each ear with best separation at a frequency of around 1000 Hz, and a directionality of as much as 30 dB as shown in Fig. 6(b) and (c) (Fletcher 1992, chap. 11).

HEARING IN MAMMALS

Referring back to insect hearing, one of the interesting features of Fig. 5 is the topological similarity between this insect auditory system and that of mammals such as humans. To see this, compare the drawing with that of a human auditory system if we were to drag our ears, and the Eustachean tubes connecting them to the nasal passages, down to our elbows! Whatever the evolutionary significance of this observation, the two systems are acoustically very different, since the human Eustachean tubes are so narrow that very little acoustic energy can flow along them, while in the cricket system the acoustic connectivity contributes significantly to the overall behaviour.

The auditory systems of mammals generally possess an "outer ear" consisting of an obliquely truncated horn, the "pinna", leading to the tympanum through an auditory canal. Even a simple conical horn has directional properties, with the direction of maximum signal response corresponding to the symmetry axis. At very low frequencies the response is not notably directional, but becomes increasingly so at higher frequencies where the sound wavelength is comparable with the diameter of the open end of the horn.

Most pinnae, however, do not have this simple shape. The most obvious variation is that the horn is obliquely truncated so that the open end faces more nearly along the line of sight, and maximum sensitivity is achieved close to this direction (Fletcher and Thwaites 1988). Many animals, such as kangaroos but not humans, are able to rotate their pinnae to maximise high frequency sound and thus locate the direction of the source, even using just one ear. In humans the shape of the pinnae is rather convoluted and this leads to additional response peaks at particular transverse resonance frequencies that may assist in directional location.

Because of the much larger size of mammal heads in relation to the significant frequencies being detected, there are clear "shadowing" effects of the head, leading to reduction of the signal at the contralateral ear. This effect, together with pinna directionality and signal phase differences provides sufficient information for the mammal to detect the general direction of a sound signal. Timing differences are probably of equal importance if the signal has sharp amplitude variations, as with a sequence of clicks.

Since the encoding of information in the complex vocal signals used by mammals depends greatly upon variation in the frequencies of vocal formants, their hearing systems have evolved to be able to discriminate frequency variations to high precision. The major frequency-dispersive element is the basal membrane in the fluid-filled cochlea. Deflection of this membrane is achieved by injecting the signal to a membrane-covered port (the "oval window") situated on one side of the membrane and providing a pressure-relief port (the "round window") on the other side. The basilar membrane is tapered, as also are the fluid filled channels on each side of it, and this gradation tunes the local membrane resonance to progressively lower frequencies as distance from the oval window increases. The result is a wave that propagates with small amplitude through the high frequency resonances near the input, reaches a maximum displacement in the resonant section, and is then exponentially attenuated over the remainder of the membrane length. Hair cells situated along the membrane detect the local oscillations and thereby communicate a spectrally resolved signal to the auditory nerve.

This mechanism, proposed some fifty years ago by Georg von Békésy, explains the general behaviour of the ear but provides a frequency discrimination that is much less than is found in experiment. It is known, however, that in addition to the single row of "inner hair cells" that provide the signal to the auditory nerve, there are three parallel rows of outer hair cells, and it has been proposed that these constitute in some way a "second filter" to sharpen the tuning provided by the basilar membrane itself. One such mechanism, proposed by Bell and Fletcher (2004), involves generation of a particular form of transversely propagating waves on the membrane that are able to produce standing-wave resonances between the outer hair cell rows, with sharply tuned leakage propagation to the inner hair cells. Since the effective mass of the inner hair cells is much less than that of the basilar membrane and associated liquid, the quality factor Q-values of the two mechanisms are effectively multiplied together to produce the observed very sharp tuning.

CONCLUSION

This has been a short and selective treatment of a very wide subject that has interested researchers for more than a century. My purpose has been to show that, by applying the straightforward principles of acoustics to admittedly idealised versions of the sound production and hearing systems of a wide variety of animals it is possible to achieve a reasonably detailed understanding of at least those stages of the vocalisation and hearing systems that are closest to the environment. Of course this leaves a great deal to be dealt with in other ways: the electrophysiology of neural transduction, the encoding and decoding of information in the brain, and the active control of vocalisation and hearing systems through some of the muscles involved. These subjects all lie more clearly within the realms of biophysics and psychophysics and have attracted the attention of many researchers within those fields. I am sorry that I do not know enough of these achievements to be able to present an adequately clear and detailed summary, but must leave this to someone else.

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LEARNING ACOUSTICS THROUGH THE BOUNDARY ELEMENT METHOD: AN INEXPENSIVE GRAPHICAL INTERFACE AND ASSOCIATED TUTORIALS

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ABSTRACT The Boundary Element Method (BEM) is a powerful tool which has become an important and useful numerical technique applied to problems in acoustics. It is particularly useful for analysing sound radiation and acoustic scattering problems. Numerous commercial BEM codes with graphical user interfaces (GUIs) and mesh generators exist; however these are relatively expensive, which discourages their use by academic institutions and smaller companies. Helm3D is a three-dimensional BEM code available with purchase of a relatively inexpensive book, but the command file driven interface is difficult to learn and some mechanism to generate the mesh is required. In addition, there is a limited availability of suitable tutorial material, so the uptake of BEM throughout the acoustics community has so far been limited. In this paper, the development of both a mesh generator / GUI interface for the Helm3D code and an associated tutorial are described. The interface links the Helm3D code to a freely available numerical simulation pre/post processor. The tutorial demonstrates the capability of BEM in two application areas: interior acoustics and external acoustic radiation. It is envisaged that the availability of the interface and tutorial will accelerate the uptake of BEM by the wider acoustics community.

NOMENCLATURE

ρ	density
ω	angular frequency
a	source radius
c	speed of sound
$c(x)$	position dependent constant
$g(x_s\|x)$	free space Green's function
k	wavenumber
l	duct length
n	mode number
n_e	number of elements
n_n	number of nodes
p	pressure
r	radial distance
t	time
$v_n(x_s)$	normal surface velocity
x	position of the field point
x_{chief}	location of CHIEF point
x_s	position of the source
Z_s	specific acoustic impedance

INTRODUCTION

The acoustic Boundary Element Method (BEM) has been used to solve a wide range of practical problems in acoustics, such as the modelling of sound generated by loudspeakers (Pederson and Munch 2002, and Hodgson and Underwood 1997) or received by microphones (Juhl 1993), the sound power radiated by a particular structure such as an engine valve cover (Ciskowski and Brebbia 1991) or a fan (von Estorff 2000), and the sound scattered by hard structures (Morgans 2000).

Numerous commercial codes that implement acoustic BEM exist; however the licensing costs are prohibitively expensive for casual users, limiting the uptake of this technology by the wider acoustics community. There exist numerous non-commercial acoustic BEM codes, such as those associated with the book edited by Wu (2000). These source codes exist as pedagogical examples for teaching the basics of BEM at an advanced undergraduate or postgraduate level. They are written in Fortran 77 and are available the CD accompanying the book. They are fully featured and capable of solving practical problems (Morgans *et al*. 2004).

These non-commercial codes, whilst readily available with the purchase of the book, have not gained widespread use for a number of reasons: the interface is command file driven and requires access to some form of pre and postprocessor, and there is a limited availability of suitable tutorial material.

Thus there is a need for:

- an easy to use, freely available interface to an acoustic BEM code, and
- a well written, step by step tutorial on the use of BEM to solve simple relevant acoustic problems.

In this paper, brief outlines of direct BEM theory, the Helm3D BEM code and the GiD pre and postprocessor are presented. An outline of the Graphical User Interface (GUI), developed with GiD to solve direct BEM problems using the Helm3D code, is given. Finally, the tutorial material and how it will be used to teach the user fundamental acoustic and BEM concepts are described.

DIRECT BEM

The boundary element method is a general numerical method for solving the Helmholtz harmonic wave equation. The traditional (direct) approach to BEM is to numerically approximate the Kirchoff-Helmholtz (K-H) integral equation (Juhl 1993, Morgans ***et al.*** 2004, Koopmann and Fahnline 1997, and Pierce 1994):

$$c(x)p(x) = -\int_s i\rho\omega v_n(x_s)g(x_s\,|\,x) + p(x_s)\frac{\partial g(x_s\,|\,x)}{\partial n}\,ds \tag{1}$$

where $c(x)$ is a position dependent constant (unity outside the volume of interest, ½ on the surface of the volume and zero inside the volume), $p(x)$ is the complex pressure amplitude (with $e^{-i\omega t}$ time dependence) at location x, $i=\sqrt{-1}$, ρ is the fluid density, ω is the angular frequency, $v_n(x_s)$ is the normal surface velocity at location x_s and $g(x_s\,|\,x)$ is the free space Green's function relating locations x and x_s. The K-H equation can be derived from the Helmholtz equation using either physical arguments using monopoles and dipoles (Fahy 2001) or using vector calculus and Green's theorem (Koopmann and Fahnline 1997, and Fahy 2001). Equation (1) is the fundamental equation of direct BEM, and shows that the pressure at any point can be represented by the surface integral of a combination of monopoles (first term in the integral of Equation (1)) and dipoles (second term in the integral of Equation (1)) aligned with the surface normal. The monopole source strength is weighted by the product of density and surface acceleration and the dipole source strength is weighted by the surface pressure. Given a distribution of surface normal velocity (which is the boundary condition usually prescribed), once the surface pressure is found, the pressure field anywhere in the domain can be calculated.

Direct BEM can be used to solve the Helmholtz equation in either a bounded interior domain (interior problem) or an unbounded exterior domain (exterior problem). The surface pressure is found by discretising Equation (1) with n_n nodes and n_e elements similar to those used in FEA. If the field point is positioned at each surface node (or "collocated") then a series of n_n equations for the n_n surface pressures can be found for a given velocity distribution. The equations are generated by numerical integration over each element, and the integration technique used must be capable of dealing with the singularities found at the locations of the monopoles and dipoles. The equations can be formed into a matrix and inverted using standard linear algebra techniques. Once the matrix is inverted, and the surface pressures known, the field pressures can be calculated.

There are a number of disadvantages to the direct BEM approach. If the K-H integral equation is used to represent the sound field on the exterior of a finite volume, at the natural frequencies of the interior of the finite volume, the exterior problem breaks down and the matrix becomes ill-conditioned. This is well documented (Copley 1968) and many solutions have been attempted (Schenck 1968, and Burton and Miller 1971). The CHIEF method (Schenck 1968) is commonly used to overcome the interior natural frequency problem because of its simplicity. This technique solves an overdetermined system of equations formed by placing extra points (x_{chief}) inside the volume of interest. Provided the CHIEF points are not placed at a nodal line of the interior solution, this will improve the matrix condition number and allow the matrix to be solved using least-squares methods.

Another problem occurs when the two surfaces of interest are brought close together, resulting in "thin-shape breakdown" (Martinez 1991). This means that although some geometries are probably best represented with a thin surface, a direct BEM simulation may either be not possible, or the geometry must be enclosed in a larger volume.

Although the BEM is mathematically complex, once it has been implemented in a computer code the user is somewhat removed from this complexity. The BEM formulation can be verified by comparison with analytical solutions, ensuring that the equations are being solved correctly, and validated against experimental data, ensuring that the equations are correct. The user can then concentrate on generating the geometry and applying boundary conditions.

HELM 3D

The direct BEM code used in this research is Helm 3D, a Fortran 77 implementation using linear triangular or quadrilateral elements. It is able to solve interior or exterior problems with a wide variety of applied boundary conditions. The code is available with the purchase of the accompanying book (Wu 2000). The code reads in the geometry, boundary conditions, field points and CHIEF points from a text based input file, forms the BEM matrix equations and solves the matrix for the boundary unknowns using least-squares routines. The sound pressure at user-specified points and the sound power and radiation efficiency for radiation problems are evaluated.

The code can currently only solve simple acoustic problems. There is currently no mechanism to solve a coupled vibroacoustics problem, where the acoustics can affect the vibration and vice versa.

GUI

GiD (http://gid.cimne.upc.es) is a general-purpose, fully featured finite element pre and post processor developed over a number of years by the International Centre for Numerical Methods in Engineering (CIMNE) in Barcelona, Spain. It has extensive geometry creation features as well as CAD import (IGES and others), supports the meshing of many different element types and the application of boundary conditions, and has a postprocessing capability for viewing results. Figure 1 shows a representative car interior meshed in GiD.

The academic version of this program is freely downloadable, the only restriction being limited to 700 3D elements. Fortunately for BEM, this is a reasonable size and many useful acoustic problems can be solved.

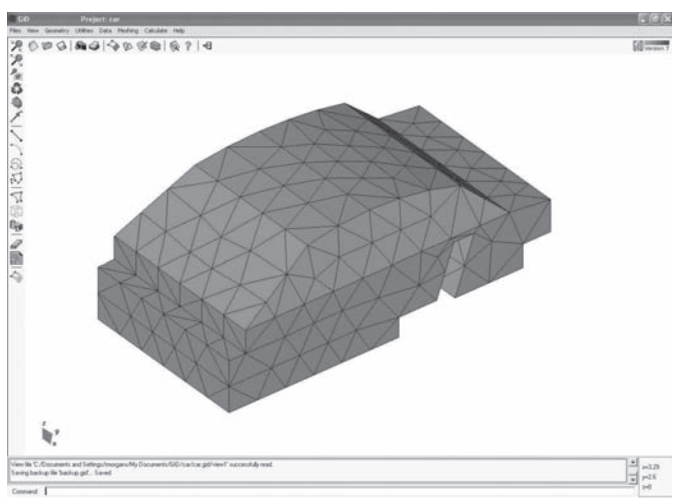

Figure 1. Car interior meshed using GiD.

GiD is designed to be easily customised and exchange data with a variety of numerical analysis codes. There are mechanisms available to apply custom boundary conditions, material properties and solution controls to the model. Most of these solvers, including Helm3d, require some form of text file as input. GiD completely wraps the creation of the text file, execution of the solver and interpretation of the post-processing data, making the operation transparent to the user.

The Helm3d GUI (graphical user interface) developed for this project is straightforward to install (installation instructions are included in the tutorial). Figure 2 shows the problem data dialogue box, which allows the user to specify most of the required inputs that control the simulation. These include the project title, the frequency range of interest, whether the problem is an internal or external problem, material properties such as density and speed of sound, the position of a field point (a “microphone” that can be placed anywhere in the domain), and the position of any required CHIEF point.

The boundary conditions that can be applied in Helm3d are a surface pressure (rarely used), a surface normal velocity or a surface normal impedance. These can be applied using the boundary conditions dialogue box, either to model surfaces, or directly to the surface mesh.

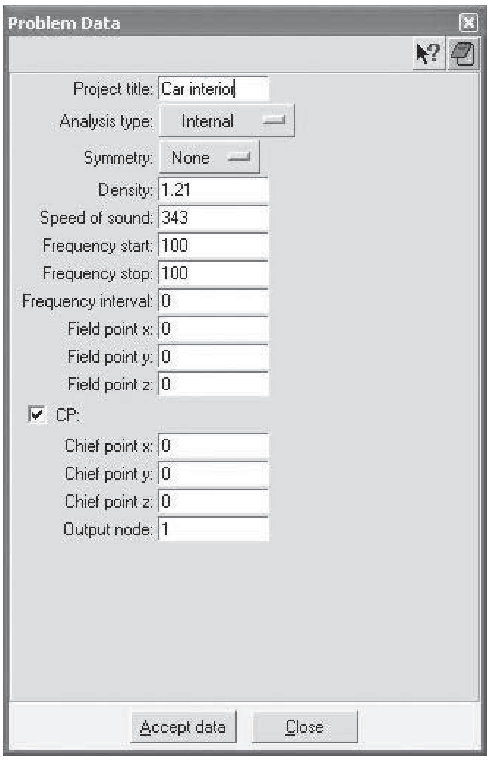

Figure 2. Problem data dialogue box.

An important requirement for a BEM code is control over surface normals. Each surface element has a positive “side”, and it is imperative that the side is facing outwards for internal problems (cavities) and inwards for external problems. GiD has a mechanism of visualisation of surface normals, and it is easy to modify normal directions until all surfaces are pointing in the required direction. Figure 3 shows the car surfaces with dark grey positive and light grey negative. For this simulation the 4 light grey surfaces must be flipped in order to solve the internal BEM problem.

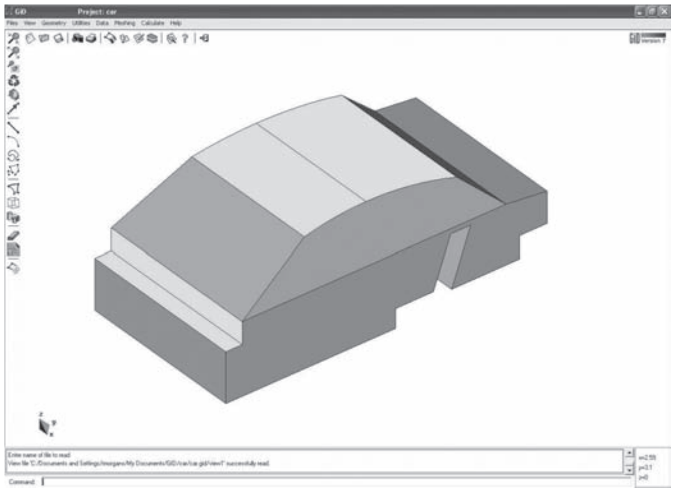

Figure 3. Surface normal visualisation.

The postprocessing capabilities of GiD are extensive, and the results of a Helm3d calculation can be read and displayed easily. Figure 4 shows an example of a plot of pressure magnitude at 100 Hz over the interior of the 3 m long, 1.2 m high and 1.8 m wide car. A velocity excitation represents sound transmission through the engine firewall.

The GUI interface to Helm3d developed for this project is somewhat rudimentary, although it is sufficient to learn the BEM and acoustics. Future developments of the GUI might allow: multiple CHIEF points; multiple field points or even a field mesh that allows visualisation of the sound field away from the surface; or the inclusion of acoustic scattering from within the GUI.

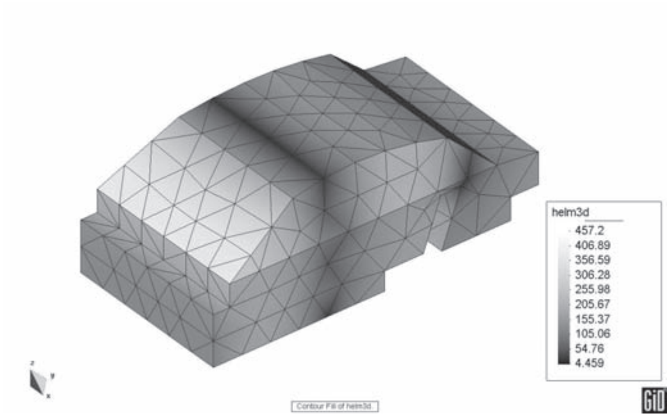

Figure 4. Pressure magnitude in a car interior (pressure in Pascals).

TUTORIALS

The tutorial guides the user through BEM modelling with eight problems, each introducing different aspects of:

- fundamental concepts in acoustics,
- BEM specific concepts, and
- using the GiD-Helm3d interface.

The tutorial material comprises step-by-step instructions which explain how to input each model, apply boundary

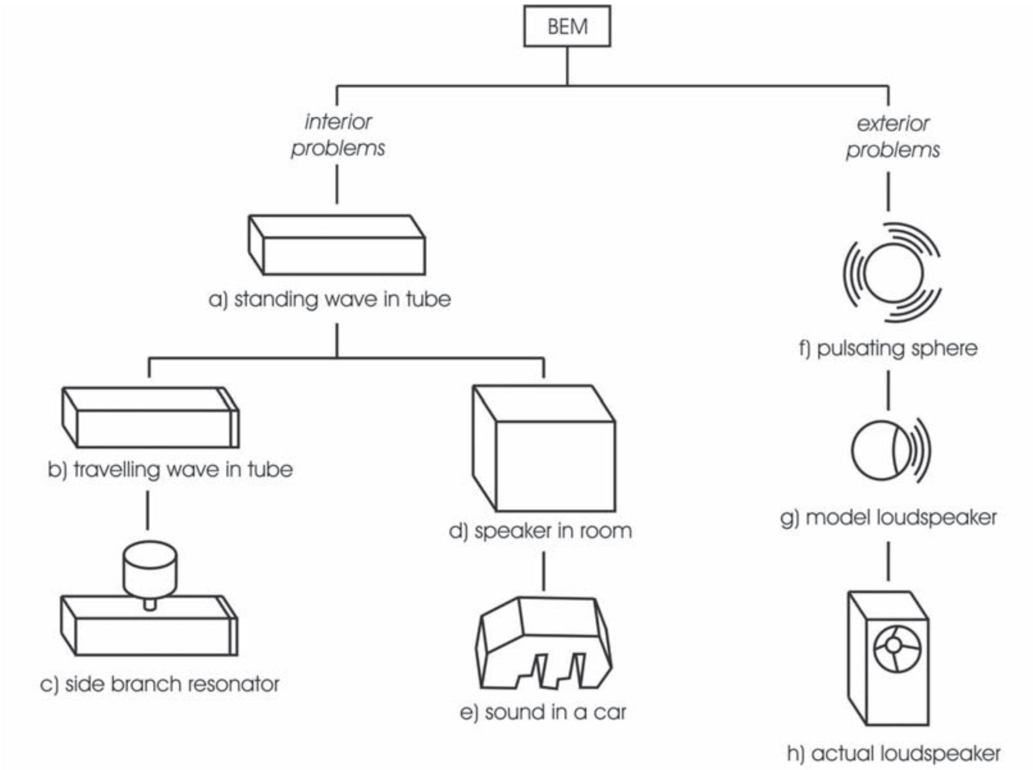

Figure 5. Breakdown of the tutorial problems.

conditions and postprocess the results. Comparisons with analytical solutions are given when possible.

By the end of the tutorial, the user should have had an introduction to these fundamental concepts in acoustics:

- one-dimensional standing waves,
- one-dimensional travelling waves,
- impedance (sound absorbing) boundary conditions,
- modes in a rectangular room,
- modes in more complex spaces,
- one-dimensional spherical waves,
- sound radiation from a sphere, and
- sound radiation from more complex shapes.

The user should understand these BEM specific concepts:

- advantages and disadvantages when compared to other techniques,
- interior versus exterior problems,
- element types,
- mesh size (6 elements per wavelength),
- non-uniqueness difficulty (CHIEF points),
- symmetry, and
- direction of normals.

The user should also have a working knowledge of these GiD-Helm3d interface concepts:

- inputting the geometry into GiD directly,
- importing CAD data into GiD for meshing,
- flipping surface normals,
- meshing the geometry,
- applying boundary conditions,
- solving the problem through the GiD interface to Helm3d, and
- post-processing results through GiD.

Figure 5 shows the breakdown of the tutorials. Two application areas are addressed: interior acoustics and external acoustic radiation. Simple problems with analytical solutions are introduced. The power of BEM is then demonstrated through application to more realistic problems.

INTERIOR PROBLEMS

A simple model of a 1D standing wave in a rigid walled duct (Figure 5.a) introduces the user to BEM through the very simple geometry of a long rectangle. Velocity boundary conditions, the required direction of normals and meshing are introduced. How the accuracy of results can be affected by mesh resolution is also demonstrated. Results obtained from the numerical model are then compared to the analytical solution. An example of sound with a wavelength identical to the duct length, resonating in a hard walled duct, is shown in Figure 6. A unit input velocity at the left end and zero velocity conditions elsewhere are assumed.

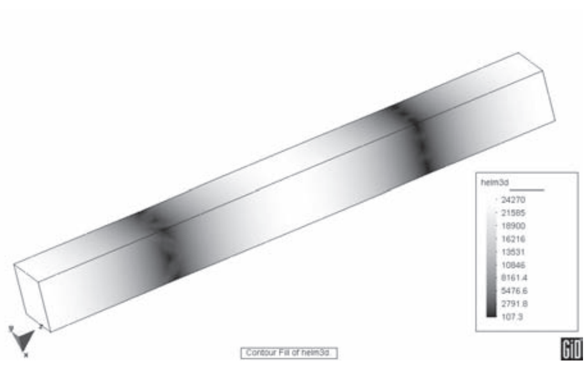

Figure 6. Standing wave in a duct at the second theoretical resonance frequency of the duct (pressure in Pascals).

The resonance frequencies of the system are simply the resonances of an open-closed duct and are given by:

$$f_n = \frac{nc}{2l} \tag{2}$$

where ν is the mode number, c is the speed of sound and l is the length of the duct.

The analytical specific acoustic impedance at the excitation location is:

$$Z_s = 0 - i\rho c \cot(kl) \tag{3}$$

where $i = \sqrt{-1}$, ρ is the density of the medium and k is the wavenumber. The theoretical specific acoustic impedance and the BEM specific acoustic impedance (the ratio between the acoustic pressure and particle velocity) at the point of excitation are compared in Figure 7 as a function of frequency. The BEM is shown to be in good agreement with the theoretically determined values.

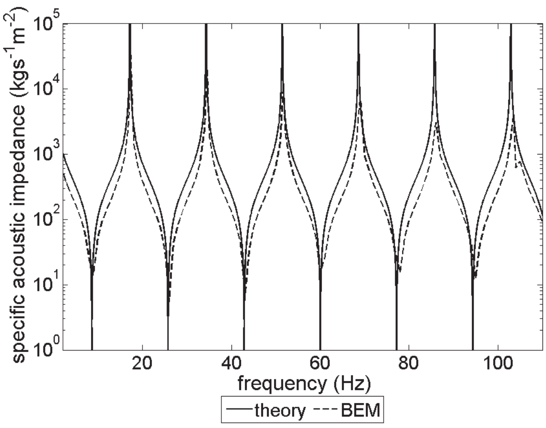

Figure 7. Harmonic response of an open-closed acoustic duct at the point of excitation.

The concept of impedance is introduced by the addition of absorption to the downstream end of the duct (Figures 5.b and 8), yielding a travelling plane wave, which is shown to have a very simple analytical solution.

The analytical pressure at any point in the duct is given by the equation:

$$p(x) = \rho c e^{-ikx} \tag{4}$$

where ξ is the distance from the point of excitation along the duct. As can be seen from Figure 9, the real and complex pressures of the travelling wave estimated using BEM agree well with the analytical solution.

Figure 8. Travelling wave in a duct (pressure in Pascals).

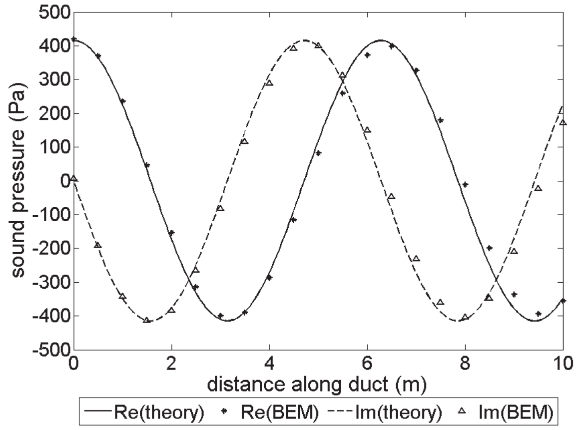

Figure 9. Sound pressure along the centre of one side of the duct.

A side branch resonator is then added (Figure 5.c), and the analysis frequency is swept through resonance. The results of the analysis are used to show how the resonator adds impedance in parallel with that of the pipe, resulting in a suppression of tones close to the resonance frequency. An example of a meshed boundary element model of a duct with a side branch Helmholtz resonator is shown in Figure 10.

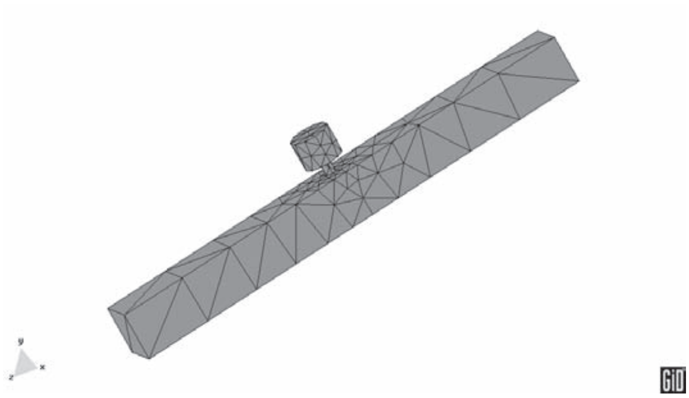

Figure 10. Mesh view of duct with side branch resonator.

A model of a speaker in the corner of a rigid walled room (Figure 5.d) introduces the user to the excitation of modes in a 3D environment. Rectangular rooms with three different axial dimensions are compared to those that have two or more identical dimensions. Various source shapes (of identical volume velocity) are also investigated, extending the user's understanding of room acoustics and BEM source modelling. An example of the excitation of room modes in two directions is shown in Figure 11. The room dimensions are 2.5 m × 5 m × 3 m. The source is a 0.04 m^2 sound source, located near the bottom left corner of the wall with the longest dimension, and operates at a frequency of 68.5 Hz, corresponding to a wavelength of 5 m.

The final internal problem, the sound pressure in the interior of a car (Figures 4 and 5.e), is an example of how BEM can be applied to a practical 3D problem. Figure 4 shows the response within the interior of the car. Rigid wall boundary conditions are assumed. In practice the flexibility of the enclosing structure would need to be accounted for; however,

Figure 11. Pressure on wall of room containing sound source near one corner.

coupled problems such as this would require BEM codes far more complicated than the Helm3D code.

EXTERIOR PROBLEMS

The first exterior problem presented is the classical fundamental radiation problem of a pulsating sphere (Figure 5.f). Key concepts covered are modelling symmetry and how this affects computational efficiency, appropriate direction of normals for an external problem and the use of CHIEF points in the interior to improve the condition number of the governing matrix. A meshed model of the half sphere (a symmetry boundary condition is used) is shown in Figure 12.

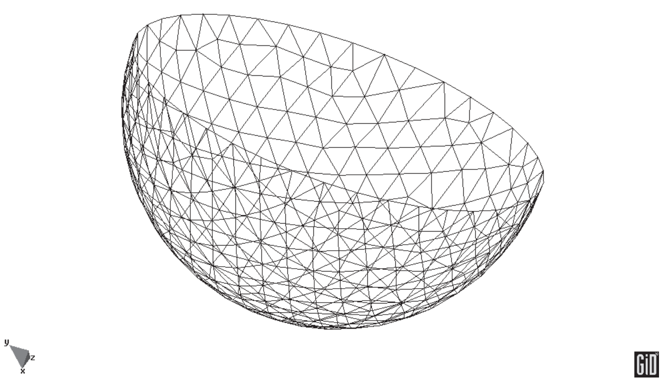

Figure 12. Mesh view of a pulsating sphere.

The analytical solution for the pressure produced by a pulsating sphere, which can be derived from the spherical wave equation, is:

$$p(r) = \left(\frac{a^2}{r}\right)\frac{i\rho\omega}{1+ika}e^{-ik(r-a)} \tag{5}$$

where a is the sphere radius, r is the radius at which the pressure is being calculated and ω is the angular frequency. The characteristic eigenfrequencies of the sphere, which are the eigenfrequencies of the interior Dirichlet problem, are given by the equation:

$$\sin ka = 0 \tag{6}$$

Figure 13 shows the variation in surface pressure ($r=a$) with frequency for the pulsating sphere for an analytical solution, and BEM calculations with no CHIEF point, a CHIEF point at the centre of the sphere and a CHIEF point at half the radius.

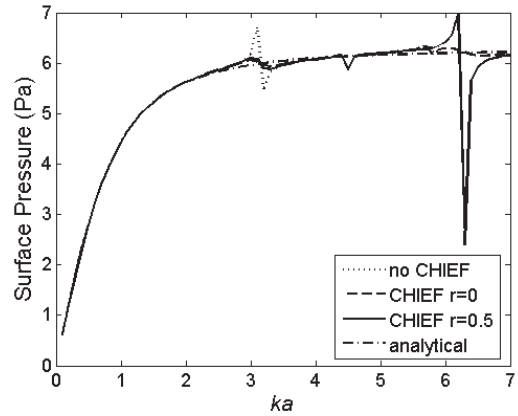

Figure 13. Surface pressure of a pulsating sphere

The BEM solution with no CHIEF point shows poor agreement with the analytical solution at $ka=\pi$ and $ka=2\pi$, where k is the wavenumber and a is the radius of the source. This is due to poor conditioning of the matrix. The placement of a CHIEF point at r/a = 0.5, where r is the radial location from the centre of the sphere, ameliorates the problem at $ka=\pi$; however, poor agreement at $ka=2\pi$ still occurs due to the CHIEF point being on the interior nodal surface corresponding to the characteristic eigenfrequency $ka=2\pi$, meaning that this resonance cannot be cancelled. Placing the CHIEF point at the sphere centre ensures that it does not lie on a nodal surface. The resulting solution is therefore in good agreement with the analytical solution. When using BEM to analyse more complex geometries, the user generally has no prior knowledge of the optimal CHIEF point location, and therefore multiple CHIEF points randomly distributed within the volume are used. The condition number of the matrix will also give an indication of whether there are any interior resonance problems.

A spherical volume with an external velocity over a proportion of its surface is presented as a simplified model of a loudspeaker in a rigid walled box (Figure 5.γ). Comparison of results at different frequencies is used to show that radiation is inefficient at low frequencies. The example shows how a BEM of a problem with simplified geometry can be used to model a more complex problem, producing results which exhibit a similar pattern of behaviour. Application of the external BEM to a more realistic situation is presented as the analysis of radiation from a speaker of more realistic geometry (Figure 5.h).

CONCLUSIONS

This paper describes: a freely available interface that has been developed between GiD and Helm3d; and tutorial material describing some fundamental acoustic problems and how they would be solved with BEM using the newly developed interface. It is hoped that the resulting practical and freely available introduction to BEM will be the basis for both student projects within universities around Australia, as well as for a series of lectures in acoustics courses at some universities. The proposed greater availability of the code and tutorial will accelerate the uptake of BEM by the wider acoustics community, including members of the acoustical society as well as practicing acoustic engineers.

For further information please visit

http://www.mecheng.adelaide.edu.au/anvc/helm3d.html

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ICA 2010

International Congress on Acoustics

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

The previous item in this series summarised the purpose and governance of the International Commission on Acoustics. This item aims to overview the major activity of the Commission, namely the International Conference on Acoustics held every three years. As the acronyms for the Commission and the Conference are the same, ie ICA, the congress is usually identified by the addition of the year and/or the location. Thus the next congress is referred to as ICA2007 or as in the web address www.ica2007madrid.org. This will be followed by ICA2010 in Sydney.

The Commission takes great care with the selection of the venue for the congress and the primary considerations include the proposed venue, dates, organising committee and their plans to work within the tight budget that the limit on registration fee requires. Lower priority is given to tourist features associated with the venue. The first Congress was held in 1953 in Delft, Netherlands. Following venues have been: 1956 Cambridge, USA; 1959 Stuttgart; 1962 Copenhagen; 1965 Liege; 1968 Tokyo; 1971 Budapest; 1974 London; 1977 Madrid; 1980 Sydney; 1983 Paris; 1986 Toronto; 1989 Belgrade; 1992 Beijing; 1995 Trondheim; 1998 Seattle; 2001 Rome and 2004 Kyoto.

We are all familiar with acoustics *conferences* such as those focusing on a specialist topic area, those drawing together workers from a range of areas with the link being a particular theme and those having a theme but not necessarily restricting papers to that theme. The annual conference of societies like the AAS and the NZAS as well as International conferences, like Internoise, are of this latter type.

There are many definitions for *congress* but in the scientific community it usually refers to a meeting organised by a representative body for a wide range of independent groups with some common link. Thus the primary difference between an acoustics *congress* and an acoustics *conference* is not the number of participants but the broadness of the spread of topics discussed at the congress. The International Congress on Acoustics is similar to a number of acoustics conferences being held simultaneously.

The International Commission provides the structure to ensure that the congress does cover all areas of acoustics; in particular it ensures that the technical advisory committee is truly representative. The congress welcomes participation from *any* topic area which has *any* involvement with acoustics. The congress organisation ensures that the program includes top quality invited plenary and distinguished speakers. So, in addition to participants learning the latest in their particular field, they can attend lectures in fields of acoustics that are on the periphery of their interest or even enjoy learning about topics or issues in acoustics they may not even known existed (unless they regularly read all the journals!).

Of course there are many parallel sessions over the five days of the congress but the structure aims to make it easy for the participants to participate in all the sessions of their interest. Each day there are plenary presentations, then distinguished presentations which may be in parallel sessions then multiple parallel sessions for the contributed papers. Therefore an ICA provides a wonderful education experience as well as the opportunity to meet with colleagues in your chosen area of acoustics.

Marion Burgess

To encourage participation in the ICA2007 in Madrid, the Australian Acoustical Society has introduced two travelling grants for AAS members, each worth $1,000. Information on the grants can be found on www.acoustics.asn.au or see p114.

VIRTUAL ACOUSTIC PROTOTYPES: LISTENING TO MACHINES THAT DON'T EXIST

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(This is an edited version of the keynote lecture at Acoustics 2005: Acoustics in a Changing Environment held at Busselton, Western Australia, in November 2005. A complete version is available in the conference proceedings).

A Virtual Acoustic Prototype (VAP) is a computer representation of a machine (e.g. a domestic appliance), such that it can be heard without it necessarily having to exist as a physical assembly. Whereas visualisation tools are well developed in the field of visual design, the analogous tools for auralisation, such as VAPs, are still in their infancy. Examples of VAPs for a refrigerator, a telecommunications cabinet and a washing machine are presented, through which it becomes clear that considerable sophistication is required to include all the various excitation and transmission mechanisms found in real machines. It is explained that VAPs cannot be purely 'virtual' and that some measured data will be needed for the foreseeable future, particularly to characterise active components. Some of the advantages of working with VAPs are outlined.

INTRODUCTION

One of the most difficult and interesting aspects of acoustics is that it spans two realms, the physical and the psychological. In acoustics, unlike most other technical disciplines, we deal with 'causes' that are physical, but 'effects' that occur literally between the ears of the listener, and are primarily psychological. Whereas the field variables in the physical domain are precisely measurable quantities, the 'field variables' describing human reaction are of a quite different nature. The feelings evoked by listening to a particular sound are not easily measurable or even repeatable. Furthermore, they are not necessarily related to the physical variables in a straightforward way. For example, most indicators for environmental noise now use the A weighted Leq, effectively quantifying the average energy of the sound after filtering by the ear. These work well where the character of the sound is fairly constant, as for example in the case of traffic noise. However, it is well known that the A weighted Leq is not a reliable method to compare sounds with a different character. For example, an impulsive sound could be judged as being louder than a steady sound even when it contains less acoustic energy. For these reasons, in the automotive sector, and increasingly in domestic products and the built environment, designers are coming to the conclusion that the only reliable way to judge the effect of a particular sound is to listen to it.

Let us look at this problem from the point of view of a designer of, say domestic or outdoor equipment. The designer wants the sound to evoke positive feelings in customers and other listeners. The design targets are therefore in the psychological domain (essentially they are 'feelings'), whereas the parameters under the control of the designer are physical quantities of quite a different nature (thickness of plates, type of material, etc). How then do we assess the effect of a design change (physical) on the target quantity (psychological)?

Architects and visual designers face a similar problem: the feelings evoked by a particular shape can best be judged by looking at the shape, and a wide range of visualisation tools has been developed. These range from hand sketches, drawings, physical scale models, computer models, prototypes, and, increasingly, virtual tools like virtual prototypes and virtual environments. These tools all aim to convey an accurate impression of the looks of the product to an appropriate level of accuracy and detail, depending on the stage to which the design has progressed. The level of detail needed in the visual representation may vary from a sketch taking under a minute, to a full 3D model taking weeks or months to assemble.

What tools of a similar nature are available for acoustic design? The answer at the current state of the art is very few. In concert hall design auralisation techniques have been available for some time whereby the reverberation in a computer-modelled hall can be added to music recorded under anechoic conditions. In the automotive sector, simulations of the sound and vibration of vehicles are nowadays produced prior to prototypes becoming available to give an impression of what the driving experience will be like. Looking at these two examples it is fairly clear that the level of technology required to achieve the acoustic equivalent of an architect's model is fairly sophisticated. This is surely a main reason why acoustic design tools are years behind those used for visual design.

It can be argued that, if acoustic design is to succeed in shaping sounds then designers need design tools, i.e. techniques to convey an accurate impression of the sound of a product whilst still on the drawing board. Furthermore, we can argue that an array of tools is needed to cater for different stages in the design process, ranging from simple methods to more 'high level' techniques. In this paper we will explore the use of 'virtual acoustic prototype' techniques mainly in the domestic and outdoor products sector. The examples of VAPs given were developed during the recent Nabucco project, funded by the EU.

For the purposes of this paper, a Virtual Acoustic Prototype (VAP) will be considered as a computer representation of a machine, e.g. a washing machine, fridge, lawnmower etc, such that its sound can be heard without it necessarily having to exist as a physical machine. Like a real machine, a VAP is constructed from 'components', although the VAP components do not necessarily correspond to the physical components of the real machine. Each constituent part of a VAP is a *representation* of some vibro-acoustic mechanism taking place within the machine. We will attempt to explain what this means, using the example of concert hall auralisation, which is more familiar than VAPs.

Substructuring into active and passive parts

Acoustic designers can listen to a concert hall while it is still on the drawing board. The main steps in this process are:

- A recording is made of a musician playing in an anechoic chamber,
- The impulse response function of the hall is measured, or calculated by numerical methods such as ray tracing,
- The anechoically recorded music and the impulse response function are combined in the computer by convolution and the result is auralised, for example by playing over headphones.

Thus, the original music and the reverberance etc. of the room are both heard on the auralisation. This approach is now fairly well known and increasingly used.

One of the features of this technique, which is relevant for VAPs, is that the data representing the source (the music) and the room are independent. Thus, source and response data can readily be interchanged so that, for example, musicians can be heard ‘playing’ in a hall they have never visited.

Constructing a VAP is similar in that the first step is to separate the sources from the remaining passive parts of the machine. The components in a VAP, as in the concert hall example, are therefore of two types: active and passive. Active components are associated with physical components that initially generate the excitation, e.g. fans, pumps, compressors, electric motors, etc. All remaining parts of the machine are categorized as passive and are collectively termed the ‘frame’. The frame does not generate excitation, but modifies that from the active components on its way to the position of the receiver (listener). The frame can be thought of as a filter, attenuating or amplifying certain frequencies by the action of resonances, diffraction, etc. Thus, like the concert hall, it plays an important role in what is heard by the listener, without generating any initial disturbance itself.

An important requirement for the VAP is that the data chosen to represent the source must be independent of the frame and *vice versa*. If this requirement is met, then each source can be combined with any frame and *vice versa*. In the concert hall analogy we saw that this allows musicians to ‘play’ in any hall, existing or not. In the case of the VAP, it allows a source, say a fan, to be installed virtually into any frame and the sound of the assembly to be heard.

A simple example

A fairly simple example of a VAP is the cabinet of a telecommunications base station, with two nominally identical fans mounted in its door as part of the thermal control system. This example is almost exactly analogous to the concert hall case: the fan (the source) corresponds to the musical instrument, and the ductwork and cavities to the hall; the only major difference was that the VAP calculations were carried out in the frequency domain. To model the base station, a fan was removed and mounted in an acoustically transparent box, using the methodology of ISO10302 (1996), so that the sound power could be measured in the absence of the frame. From the measured sound power, the ‘source strength’ was back-calculated. What is meant by source strength? In this case it was taken to be the net fluctuating force acting on the air by the impeller, which was assumed equivalent to the force exerted by a single dipole acting at the centre of the impeller along the axis of the fan. The frame was then represented by the transfer function from this excitation point to the external receiver position. This transfer function included the combined effects of cavity and duct resonances, transmission from the end of the duct etc. and was measured using a reciprocal technique [1,2].

The spectrum of sound pressure at the receiver location, calculated by combining the source strength and transfer function, is shown in Figure 1 and agrees well with the directly measured sound pressure spectrum. Furthermore, the auralised sound at this position was similar to the real sound (it will be described later how the auralisation was achieved from frequency domain data).

A more complicated example of a domestic fridge will be described later. First however, we will examine some of the practical limitations on VAPs.

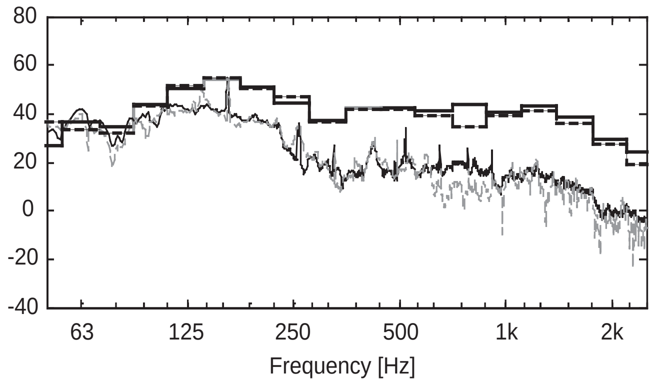

Figure 1: Sound pressure level measured on the real prototype cabinet (solid lines) compared with that predicted from the VAP (dotted lines). Narrow band in dBlin, third octave band values in dB(A). (after ref [1] 2003)

Practical limitations on VAPs

The ‘holy grail’ for designers is to carry out all their design in the virtual domain, ultimately working purely from electronic data and avoiding physical prototypes completely until the design is finalised. The advantages in terms of cost and time-to-market of this approach can be huge. However, it may have been noticed in the above example that the two sets of data, representing the active and passive components, were obtained by measurement. Clearly, this implies that the machine, or at least the parts of it, must already exist. What then are the advantages of the approach, and furthermore, how can we even claim that our model is a *virtual* prototype at all?

Before answering this question we must consider the realities of the situation: auralisation of machines ‘from scratch’, i.e. starting from drawing board data is a very ambitious aim, and is still many years off.

One reason is that auralisation places particularly high demands on the numerical prediction of sound transmission and radiation since neither finite element methods nor statistical energy analysis can generally cope with the entire audible frequency range. Hybrid methods [3] show some promise of overcoming this hurdle, but even so, many machines are likely to prove too complicated for some time. Take the example of a washing machine frame: to calculate the transfer function from inside to outside requires an acoustic model of the cavity, coupled to a structural model of the cabinet (with its own difficulties of modelling), coupled to another acoustic model of the external air. Hybrid methods could simplify this considerably, but for the foreseeable future it is unlikely that reliable numerical methods will be available to designers in medium technology industries like domestic and outdoor products. Despite the difficulties, it is even now possible to model some machine frames numerically (e.g. the base station cabinet discussed above).

The second reason that modelling from scratch is ambitious is that understanding of source mechanisms is not sufficiently advanced. It is beginning to become possible to predict the sound generated by some sound sources, for example fans, although this is likely to remain a highly specialised job for some time at least. However, other noise generation mechanisms, like stick-slip friction are still not sufficiently understood for reliable models to have been developed. Therefore, even when transfer functions can be modelled numerically, representations of the active components will almost invariably be based on measurement for some time to come.

Advantages of VAPs

What are advantages of a VAP if measurements are still needed? Not much if one only has a single component and a single frame: one might as well assemble them and listen to the real machine. However, once one starts to assemble a database of several active components and several frames, the possibilities start to become interesting. Take for example a washing machine. This is typical of many products where complete redesign from scratch is rarely needed. Rather, a new design is usually an evolutionary step from a similar existing design. Therefore, many of the components in the new design will already exist and their vibro-acoustic properties can be measured.

Consider the apparently simple choice of how to select the optimum washing machine motor from the many possibilities on the market to suit a particular frame? The potential advantages of a virtual approach in terms of cost and time are clear. It is less obvious that the virtual approach could actually be more reliable than real prototypes. This is because, to make a comparison, one needs to keep everything constant except the variable of interest, i.e. in this case one should change the motor and keep the frame constant. This is easier said than done: one cannot guarantee that the frame will be identical before and after disassembly. Indeed there is growing evidence that small structural changes can bring about significant differences in vibro-acoustic behaviour (see for example [4]). For example, a slight change in the angle of connected plates can alter sound radiation significantly [5]. On the other hand, using a virtual approach one can guarantee that the frame is *identical* by using the same transfer function data. Then one can listen to different motors in exactly the same frame. Naturally, the sound of the VAP cannot be a better likeness than the real thing in an absolute sense, but here we are interested in differences before and after modifications, i.e. *relative* effects, and here the VAP has some advantages over a conventional approach.

Perhaps the biggest advantage of the VAP approach is the insight that comes from breaking down the machine in a systematic way. For industrial participants in the Nabucco project this was considered the most useful aspect of the approach. The systematic approach can perhaps best be illustrated by an example, which is given in the next section.

AN EXAMPLE VAP: A DOMESTIC REFRIGERATOR

The previous example of the base station was a relatively simple one since only airborne excitation of the frame was involved. A refrigerator is considerably more complicated since the excitation from the compressor is a combination of airborne, fluid-borne and structure-borne vibration.

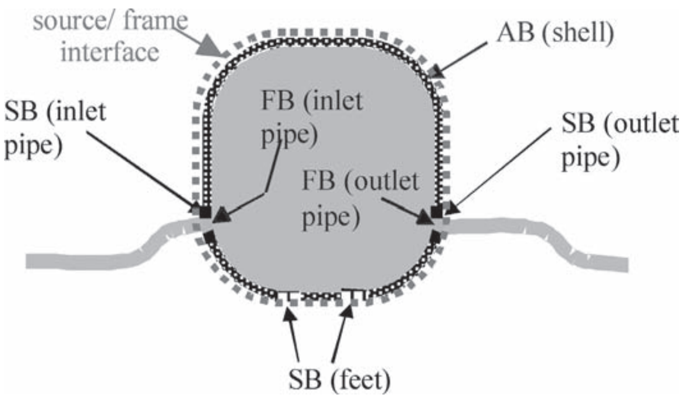

Figure 2: Source/ frame interface around the compressor showing structure-borne (SB), airbonre (AB) and fluid-borne (FB) excitation of the frame

General scheme for the refrigerator

These excitation types can be seen when we sub-structure the complete machine into source and frame. Where the source stops and the frame starts is sometimes arbitrary, for example the refrigerant pipes could be considered to be part of either. To define the substructures, a boundary is drawn around the source (Figure 2) so that all sound-generating mechanisms are inside and what is outside is purely passive. The excitation of the passive frame is then considered to be purely through excitation over the interface. Where the interface cuts through solid structures, the excitation is considered to be structure-borne (SB) in origin, where it intersects fluid in a pipe it is fluid-borne (FB), and where there is air on the frame side of the interface, it is considered airborne (AB).

The scheme for the VAP is then as laid out in Figure 3. Although in the physical prototype there is only a single active component, in the VAP there are four sources, which must be treated separately.

Note that energy can be converted between different forms on its way to the receiver location. For example the FB excitation of the fluid in the pipe must be converted to pipe wall vibration and then into sound waves in the surrounding

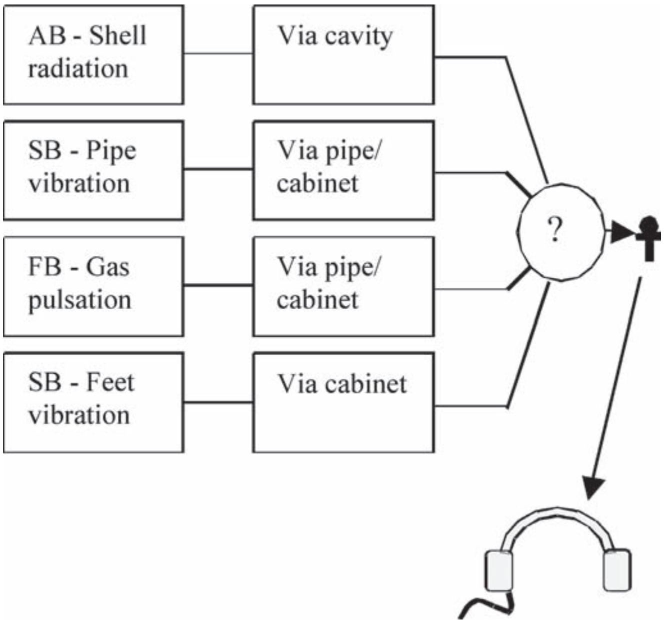

Figure 3: Vibro-acoustic scheme for refrigerator

air in order to be heard at the listener location. All these effects are grouped together as FB sound because this is the nature of the initial excitation. Similarly, SB sound starts as vibration, but must be radiated into the surrounding air to be heard. In the next subsections we will consider how each of the excitation types is dealt with in constructing the VAP.

Airborne sound

As described above, in order to construct the VAP we need to find a way to *represent* the excitation and transmission mechanisms. In this subsection, we consider how to find the data to fill the top line of boxes in Figure 3. For AB sound the real compressor shell is idealised as a vibrating and 'breathing sphere'. In other words, we represent the true shell by a combination of a monopole and three perpendicular dipoles. These motions can be extracted from the readings from six accelerometers positioned on the poles of the three principal axes. The strength of the monopole is given by the average in-phase outward acceleration:

$$Q_{\text{monopole}} = 4\pi r^2 (A_1+A_2+A_3+A_4+A_5+A_6)/\, 6j\omega \qquad (1)$$

where Q_{monopole} is the source strength of the monopole, A_1 etc, are the radial accelerations, r is the radius of the sphere and ω the radian frequency. The strength of the x direction dipole D_x is proportional to the rigid body acceleration in the x direction, i.e.

$$D_x \propto (A_1 - A_2) \qquad (2)$$

(similarly for y and z). We end up with four frequency spectra representing the strength of the monopole and the three dipoles.

Thus, the AB source strength is characterised without the need to perform any acoustic measurements. This indirect measurement has several advantages over a conventional sound power measurement, not least that the measurements are almost completely immune to background noise. The use of four equivalent elementary sources is also more accurate than using the compressor sound power, because the sound power is not an invariant quantity when there are reflecting surfaces and cavity modes in the near field of the source. For example, anti-symmetric modes couple well with a dipole with the same alignment, thereby amplifying its contribution, an effect that is not accounted for using a sound power approach.

Next we consider the transmission from the compressor shell to the external receiver location. This is represented by transfer functions, one for each of the four equivalent sources. The external sound pressure (due to AB excitation) is then given by:

$$p_{AB} = Q_{\text{monopole}} H_{\text{monopole}} + D_x H_x + D_y H_y + D_z H_z \qquad (3)$$

where H_{monopole} is the transfer function for the monopole and H_x etc. for the dipoles.

The transfer function H_{monopole} corresponds to breathing of the compressor shell. It quantifies the external sound pressure per unit volume velocity of the shell, (the volume of air displaced by the breathing per cycle, given in $m^3\, s^{-1}$). To measure this transfer function conventionally we would need to replace the compressor shell with an idealised sphere of the same size, pulsating with a known volume velocity, and to measure the sound pressure at the external receiver positions. However, it is difficult or impossible to perform tests in this way because of limited space within the cavity where the compressor is housed. There is also the difficulty of obtaining a suitable source. Instead, we make use of the principle of acoustic reciprocity [6], whereby the source and receiver positions are interchanged. Therefore, we place a monopole at the external receiver position and measure the average, in-phase sound pressure over the surface of the shell. This is done by placing microphones close to the surface, at the same positions as were previously used for the accelerometers.

The same microphone arrangement can be used to extract the x, y and z dipole transfer functions, but rather than the in-phase pressure we use the difference in pressure of the microphones on each axis in a similar way to equation (2).

Fluid-borne sound

The fridge was one of two products studied in the Nabucco project where fluid-borne noise needed to be taken into account. The other was a washing machine with a pump. For pumps, it is usual to characterise the source by a 'source strength' and a 'source impedance' as defined in ISO 10767 (1996). However, this same arrangement cannot be easily adapted to the fridge compressor. One of the reasons is that the refrigerant fluid undergoes changes from liquid to gas phases as it passes around the pipe circuit. Consequently its properties, wave speed in particular, at any point in the circuit are unknown. The measurement of source impedance is also problematic, even for specially equipped laboratories, and even more so for industries with limited time and resources.

Fortunately, a simplification was possible in that the suction pipe contribution was found to be negligible. The question of how to characterise the compressor as a source, independently, of the frame still needed careful consideration. Since the pipe is narrow compared with a wavelength, we can assume plane wave propagation only in the pipe. The pressure pulsations in the discharge pipe are then made up of the superposition of an outgoing and a reflected wave (the terms ‘pressure pulsation’ or ‘pressure ripple’ are usually used by refrigerant engineers where acousticians would use the term ‘sound pressure’).

The strength and phase of the reflected wave are determined by downstream discontinuities and are therefore affected by the frame. On the other hand, we can reasonably make the assumption that the outgoing wave is determined only by the source and is independent of the frame. The independence criterion needed for the VAP can then be met if we could find the amplitude of the outgoing wave.

The reflected wave cannot be physically removed. However, it is possible to remove it using appropriate signal processing techniques. It is well known that using two pressure transducers in a waveguide one can obtain the amplitudes of the outgoing and reflected waves, provided the wave speed is known (similar algorithms are used in two-microphone impedance tube measurements to obtain reflection coefficient). It turns out that if a third transducer is added then the wave speed (which remember is not known for the refrigerant fluid in this case) can also be deduced. Therefore, the measurement rig adopted consisted of three equally spaced pressure transducers in the discharge pipe. The source strength of the compressor was then characterised by the amplitude of the outgoing wave.

In order to measure the transfer function, the sound pressure due to FB excitation was measured directly. In order to do this it was necessary to eliminate the contributions of AB and SB sound. This was achieved by running the fridge from a compressor in an adjacent room (to eliminate AB contributions), connected via long pipes with flexible sections (to remove SB contributions). Note that it was also necessary to measure simultaneously the source strength. This is because the transfer function is defined as the output (external pressure) per unit input (FB source strength in this case), so the strength of excitation must be known. The source strength was measured using the three pressure transducers as described earlier.

Structure-borne sound

Having looked at AB and FB, the final contribution to consider was the effect of SB sound from the pipe and the feet. The source strength parameter for the pipe was defined as the sum of squared vibration amplitudes in three orthogonal directions. The feet were treated in a similar way.

These source strengths could be obtained by a transformation of the six velocity measurements used to characterise the AB sound source strength. Thus, no additional measurements were needed to obtain source strength data.

Transfer functions were measured using a forward technique in which a force was applied to the end of the pipes from a shaker through a force transducer. The resulting sound pressure was measured and then divided by the force input to obtain the sound pressure per unit force. The force was applied in several different directions and an average calculated.

It should be noted that the representation of the SB excitation and transmission mechanisms was significantly simpler than for some other cases because there was a large impedance mismatch between the pipe and the shell. It was then possible to assume that the vibration of the pipe was the same as that of the shell, i.e. that the compressor was a velocity source with respect to the pipe. In general however, it is necessary to include an impedance or mobility matching step to calculate the contact forces (see for example [7]).

What the customer hears: combining AB, SB and FB contributions

Having obtained source strength and transfer function data for AB, SB and FB excitation types, the sound pressure spectrum due to each could be calculated and summed together to predict the overall external sound at the receiver position according to the scheme of Figure 3. The sound pressure spectrum for each case is shown in Figure 4. (The SB contribution through the feet was relatively small, so only that through the pipe is shown).

In Figure 4, for each excitation type a harmonic series is evident, with strong peaks at multiples of the compressor speed. However, the spectrum shapes are significantly different. The AB component, which is dominant in terms of dB(A), contains a wide range of frequencies. The SB component is predominantly low frequency, consisting of a rapidly falling set of harmonics. The FB component contains strong peaks up to about 600 Hz, and the envelope of the peaks has a pronounced bell shape between the second and sixth harmonics. This shape would be caused by a resonance, probably somewhere in the pipe circuit, and is significant in terms of sound quality as will be discussed later.

Also shown in Figure 4 is the combined spectrum p_{total}, which was calculated assuming the AB, SB and FB sound pressure contributions (p_{AB}, etc.) to be incoherent, i.e.

$$|p_{total}|^2 = |p_{AB}|^2 + |p_{SB}|^2 + |p_{FB}|^2 \tag{4}$$

In theory, the separate AB, SB and FB contributions are coherent because they ultimately come from the same source, the compressor. However, in practice the transfer paths for each are rather different, and the relative phase with which they arrive at a receiver point will vary depending on the precise location. The precise spectrum shape will therefore vary with position. In practice, this effect can be heard by in a room with a fridge by moving the head around slightly: the sound can be heard to vary perceptibly from one position to another due to variations in phase. However, these differences are not significant in terms of sound quality, so the incoherent averaging represents the combined effect at an ‘average’ position and is reliable for auralisation as will be discussed later.

The breakdown given in Figure 4 allows the designer to perform a conventional rank ordering by comparing for example the dB(A) levels associated with each excitation type. The contributions in order of importance to the dB(A) level in this case were AB, FB, SB (pipe) and SB (feet). As all noise control engineers know, a rank ordering is the first essential step to designing effective noise control, so the ability to carry out rank ordering is an important function of a design tool.

As well as being used for rank ordering, the value of the above spectra can be extended considerably by auralising the results. The designer is then able to listen, not just to the combined effect as with the real prototype, but also to individual contributions, perhaps to identify the source of an unpleasant feature of the sound. The techniques to achieve the auralisation from frequency domain data are discussed in the next section.

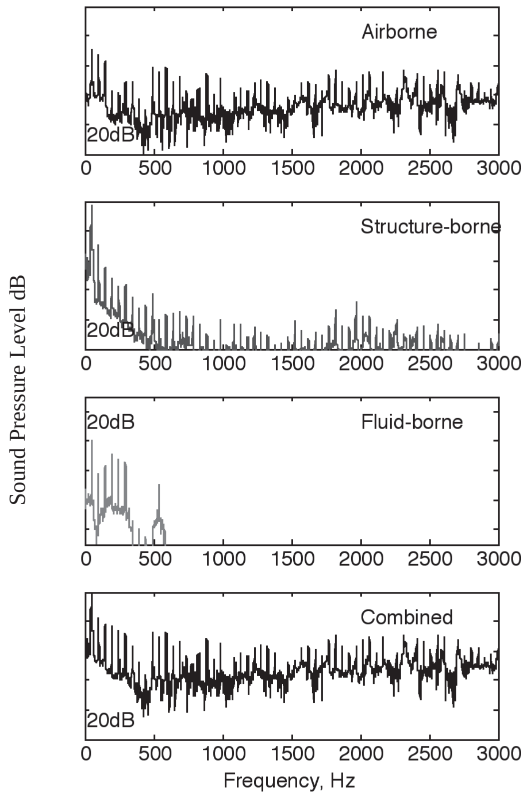

Figure 4: Contributions to the external sound pressure from AB, SB and FB excitation for the fridge.

AURALISATION: LISTENING TO THE VIRTUAL MACHINE

So far, all the calculations shown have been in the frequency domain, in the form of narrow band spectra. This is a different situation to that described in the concert hall analogy described in the introduction. For the hall, the calculations were done in the time domain, the time history of the source was convolved with the impulse response function of the hall to obtain the modified sound.

How then might we be able to perform the auralisation starting from frequency domain data? Naturally, any spectrum can be transformed to the time domain using Fourier analysis, but there are two problems that must first be overcome:

- the number of data points is sufficient only for a very short time sample
- phase data are missing.

Considering the phase issue first, we recall that sound pressure signals recorded in the real world are real functions. However, when transformed to the frequency domain, a complex Fourier spectrum results, i.e. the spectrum associated with a given time history has both magnitude and phase. If both magnitude and phase are known, then the time history can be reconstructed exactly by inverse Fourier transformation. However, the phase will be lost if any kind of averaging is carried out on the spectral data. In the example of the fridge discussed earlier, the most effective source strength for the SB component of excitation proved to be sum of the squares of the vibration levels in three orthogonal directions. During the summing operation, which effectively is a sum of the energy of the vibration in each direction, all phase information is lost. The resulting spectrum for SB sound therefore includes magnitude information only. In some cases it would be possible to retain phase data, for example the AB source parameters and transfer functions for the fridge could in theory all be measured as complex spectra. However, in practice, retaining the phase information creates measurement and data handling difficulties, particularly for medium technology industries that are the intended users of such techniques.

Therefore, we have to accept that we will not have explicit phase data for the auralisation. Fortunately, and somewhat surprisingly, it turns out that for steady state sounds this is not a major drawback. Such sounds can be auralised by assuming the phase spectrum to be random. The phase spectrum is therefore generated as a sequence of random numbers with magnitudes in the range 0 to 2π, (except for the zero frequency and maximum frequency values which are set to zero). The resulting phase spectrum is then added to the measured or calculated magnitude spectrum before inverse Fourier transformation and playback of the time history.

The question of the length of the time record obtained is now considered. Narrow band spectra do not usually contain more than 3200 frequency lines, and sometimes fewer. When transformed to the time domain the sampling rate is determined by the bandwidth of the spectrum. For example, for the fridge, the calculated spectrum extended to 6 kHz (only the lowest 3 kHz of which is shown in Figure). Because of aliasing, the sample rate must be at least twice the maximum frequency, i.e. at least 12 kHz. The 3200 samples will therefore produce less than a quarter of a second of audible sound, which is insufficient for auralisation. A short sample produced in this way could be lengthened by looping, but this usually creates an audible 'looping' artefact that gives a misleading impression of the sound.

The solution is to increase the number of data points without increasing the frequency range, which is done by interpolating the magnitude spectrum as will be illustrated in Figure 5.

A final problem to overcome is that the spectrum should be doublesided for inverse transformation, whereas so far we have only a singlesided spectrum. Therefore, one more step is required which is to add to the singlesided spectrum an alias spectrum, or a reflection of the spectrum with reversed phase.

A procedure for auralisation of steady state sounds is summarised in Figure 5.

Interpretation of auralised data

The results of auralisation on the fridge example from the previous section are quite revealing. The AB component sounds as one would expect a fridge compressor to sound. The SB component sounds like a 'low hum', although the higher

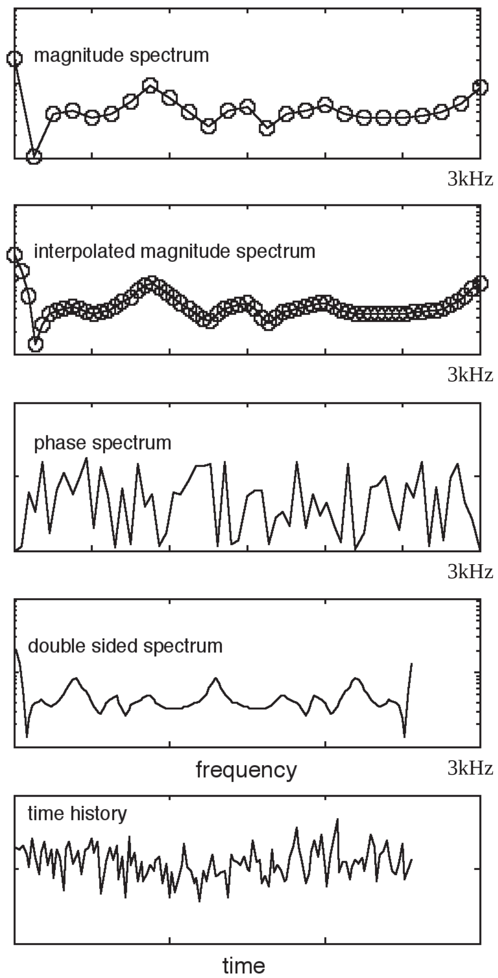

Figure 5: The sequence of operations for auralisation from a magnitude spectrum. The spectrum is interpolated, reflected, random phase is added and the complex spectrum is transformed to a time signal.

harmonics are also audible giving slight ‘rattle’ to the sound. The FB component gives a pronounced ‘boxy’ tone to the sound, which, on its own, sounds fairly unnatural. This feature is not particularly noticeable in the combined sound, being masked by the more dominant AB component. However, were the AB component to be reduced then the ‘boxiness’ would become audible. This scenario can be simulated fairly easily once the data are available by simply adjusting the levels before combining the different components. This tells the designer to be wary: a design modification that reduces the relative contribution of the AB component would make the ‘boxiness’ more pronounced, which may or may not be a desirable feature. It is even possible that a reduction in dB(A) could result in a sound that is subjectively louder.

Some applications of VAPs

It has already been mentioned that one of the main uses of VAPs is for comparison of different active components in the same frame. An example of comparing washing machine motors is given in Moorhouse and Pavic [6]. In this section some other types of comparison are considered.

Modifications to the frame

Another example from a washing machine involves modifying the frame by removing a small amount of the acoustically absorptive lining from inside of the cabinet. The conventional method to quantify the change would be to run the machine before and after modifications and to compare the measured sound power or pressure. However, even with a sophisticated motor control system it is impossible to guarantee identical operation of the motor for both tests. This introduces an uncertainty into the results such that differences of the order of 1-2dB could not be attributed with certainty to the frame modifications, but could equally be due variations in the motor. On the other hand, using the VAP approach the frame performance is quantified using transfer functions, which are measured using a controlled sound source, and the reproducibility is extremely good. Differences of up to 2 dB in the insertion loss of the washing machine cabinet were observed at some frequencies. Importantly, a check on the reproducibility of the results produced two curves that could not be distinguished, even on a narrow band plot. This means that the 2 dB differences can clearly be attributed to the frame modifications. The VAP techniques therefore prove to be rather a ‘sharp instrument’ capable of reliably measuring small differences in performance. As designs become more refined, differences of one or two dB are becoming more significant, so the capability of being able to measure small changes is becoming more and more important.

Listening to an installed motor under load

The second application also involves a washing machine, but in this case the objective was to auralise the sound of the motor inside the frame when operating under realistic loading conditions. This sound cannot be recorded directly using a physical prototype, because the load itself (the washing machine drum) generates noise, which would contaminate the recording. In keeping with the philosophy of VAPs, the data obtained for the motor should be independent of the frame and other sources (like the drum) such that the data are transferable. Therefore, the approach was taken of characterising the motor by measurements on a separate test rig. The source data obtained were then combined with measured transfer functions for the frame to predict the external sound. Both AB and SB sound from the motor were significant and had to be included in the VAP.

Initially a validation test was conducted on an unloaded motor. For the AB component, the motor was represented by an equivalent monopole whose volume velocity was back-calculated from the sound power of the motor running in free field conditions. The transfer functions were measured by a reciprocal measurement procedure, in which a calibrated monopole source was placed outside the frame and microphones were placed precisely inside at the position of the motor.

Handling the SB component was considerably more complicated. In the fridge example given above, it was found that the vibration of the compressor shell was not affected by the attached pipework. However, in this case no such simplifying assumption could be made since the motor velocity was significantly altered when attached to the frame. It was therefore necessary to include an additional step in the calculation to account for the 'mobility matching' between source and frame. This step is analogous to the impedance matching of imperfect voltage sources with a load impedance, but is considerably more involved because four feet were involved, each with vibration in three perpendicular axes. A description of the procedures adopted can be found elsewhere [1].

The SB source strength was initially taken as the free velocity (i.e. the velocity at the feet with the motor suspended on very soft springs). The SB transfer functions were measured using a reciprocal technique with accelerometers attached to the frame at the motor contact positions. The approach was validated for an unloaded motor by comparing measured and predicted sound pressure levels (validation for the loaded case is not possible because of noise generated by the load as described above). The agreement is good over most of the frequency range, the only significant discrepancies occurring at low frequencies due to errors in the prediction of the SB sound contribution. Such differences are common for this type of calculation and probably cannot be eliminated completely.

The next step was to obtain source data for the loaded motor. In order to achieve this, a special test rig was constructed in which the motor was attached to a rigid steel block. Lateral loading of the motor shaft was achieved by loading with a belt at the same tension as in the real machine. Torque loading was achieved with a non-contact eddy current brake, the discs of which could be moved further apart or closer together to decrease or increase the loading.

The AB source strength under load was obtained with a sound power measurement from which the volume velocity of the equivalent monopole source was calculated as before. For the SB source strength, free velocity could no longer be used because the feet were effectively blocked by the mounting block. Instead, the blocked force was used, i.e. the force exerted by the motor on the block. These forces were measured wth force transducers set into the mounting block at each foot.

Interestingly, the torque loading proved to make little difference either to the AB or the SB source strength. On the other hand, the lateral loading by the belt significantly increased the SB source strength. This could be due to the extra static load on bearings, and/ or distortion of the motor casing due to the lateral load.

Once the source strength data were obtained, the sound pressure level around the virtual washing machine, as well as its sound power, could be calculated in the VAP. The results are shown in Figure 6. The upper plot shows the sound power level over the 10 kHz range, and the lower plot gives the same data but with a zoom on the lower frequencies where the SB component is more significant. There are some differences in the spectrum, with some peaks changing in level. An interesting change is the frequency shift of the peak at around 650 Hz, which is thought to be due to modifications in stiffness of the motor casing due to distortion by the load.

The effect of the loading on the auralised sound was not strong; in fact the differences between the loaded and unloaded cases were hardly detectable by ear, particularly at high running speeds. Having carried out the exercise one would be fairly confident about using source data from an unloaded motor, which naturally simplifies things significantly. However, this result was a surprise; a much larger effect had been anticipated, and one would not have been so confident at the outset. It should be emphasised that a comparison of this sort could only be made using a VAP, or some similar virtual approach, because the sound of the installed motor running under load, but free from other sounds, cannot be realised physically.

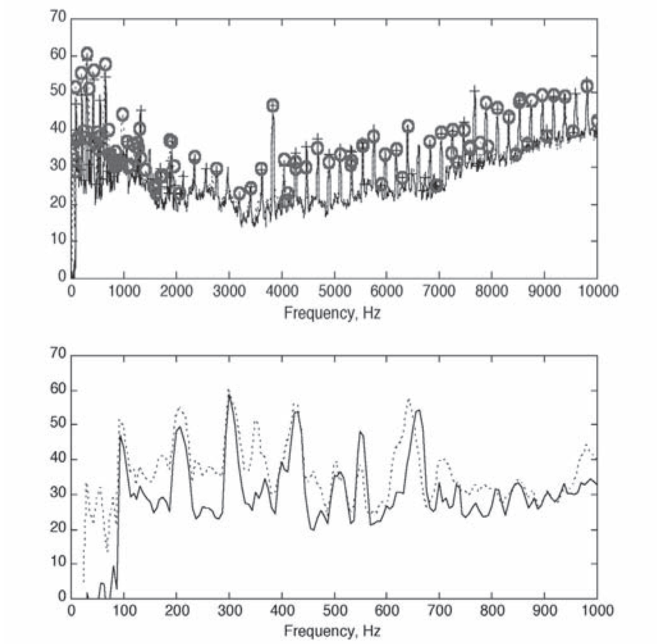

Figure 6**.** Comparison of (calculated) sound pressure level for the unloaded (solid lines) and loaded (dotted lines) motor installed in the washing machine frame described in [8]. Upper plot: 10 kHz range; lower plot: zoom on 1 kHz range. (after ref [9] 2005)

CONCLUDING REMARKS

The above examples illustrate that considerable sophistication is required to auralise the sound of even a fairly simple machine. It is also clear that, for the time being at least, a VAP cannot be purely 'virtual', but will necessarily include some measured data. However, the advantages of the virtual approach are many. Obvious advantages include reducing the cost and time associated with constructing physical prototypes. Less obvious advantages include the observation that the components of a VAP can be exactly reproduced so that more precise comparisons can be made of the effect of varying one element, such as a motor. The above example of the loaded motor also makes clear that some situations can be constructed in a VAP that cannot be realised physically.

There are two main advantages to the designer. Firstly, the process of constructing a VAP provides a systematic framework for understanding how and why the machine makes the sound that it does. Secondly, auralisation is a powerful tool for communicating ideas about acoustics. In the Nabucco project it became evident just how much difference it made to non-specialists like managers and accountants to be able to hear the sound of the machine as opposed to having it described to them. This observation makes clear that there is a strong potential to improve understanding of acoustics issues through auralisation techniques, but at the same time it also illustrates how big is the divide between specialists and non-specialists at current state of the art.

Acousticians in various sectors – buildings, automotive, transport, consultancy, etc. – are increasingly becoming aware of the potential for virtual techniques and auralisation in acoustics, and VAPs can be thought of as just one part of an increasingly wide movement. In the future we might see design drawings accompanied by sounds, and consultants reports routinely including computer auralisations.

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Acoustics Forum

Note: Contributions published in "Acoustics Forum" are aimed at promoting discussion. The views expressed are not necessarily those of the Editors of Acoustics Australia or the Australian Acoustical Society. Contributions are not formally peer-reviewed.

WHAT ARE WE DOING ABOUT EXHAUST NOISE?

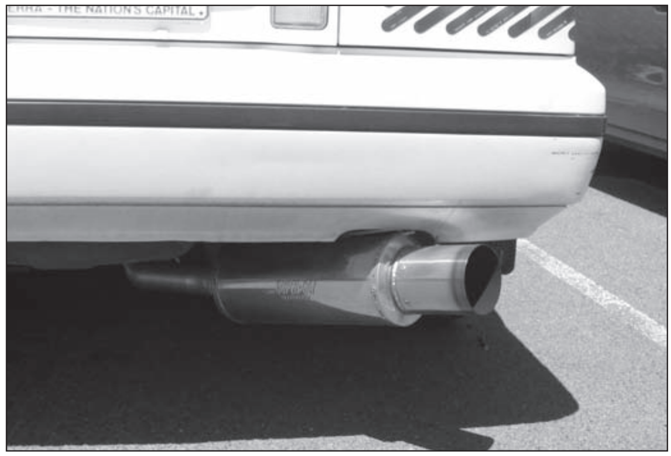
Neville Fletcher,

**Research School of Physical Sciences and Engineering,
Australian National University.**

One of the more intrusive noises heard in most cities is that produced by the exhausts of "hotted up" cars and motor cycles. Some of the worst examples are large motorcycles of the Harley Davidson type, small high-revving motorcycles, and cars that have been fitted with large-diameter modified exhaust systems. All of these can (and often do!) produce noise levels greatly in excess of those of buses or heavy trucks, and the bikes usually carry only one person. Is there something that the Society can and should do?

In the July/August 2005 issue of the NRMA magazine *The Open Road* their New Vehicle Evaluation Specialist, Tim Pomroy, is quoted as saying "The whole aim [of modified exhaust systems] is to reduce the restriction in the exhaust to maximise performance, but the reality is it doesn't deliver huge gains and it's more about noise than anything else. What's the use of having a V8 if it doesn't have the noise? It's partly an ego trip, partly personality and partly the show-off factor." The effect is then greatly magnified by the "hoon" habits of those driving these vehicles, who like to use maximum acceleration whenever possible and to produce maximum noise.

According to the article, the current statutory limit for exhaust noise is 90 dB(A), and this has not been reduced for many years. In addition, compulsory vehicle inspections have now largely been abandoned, so that non-complying vehicles are not identified except by their long-suffering neighbours.



Is it perhaps time for the Society to pressure government agencies to undertake more random roadside noise checks? The procedure for such checks is not complex, but is it currently adequate? The cost of sound level meters of adequate sensitivity and accuracy is almost trivial. Perhaps it is also time to tighten the noise emission standards by around 10 dB – surely acoustic muffler technology has progressed in the past twenty years! And while we are about it, let's do something about exhaust noise from lawnmowers – a mower rated "75 dB(A)" is still awfully loud!

Meeting Reports

Acoustics 2005

Acoustics 2005, the annual conference of the AAS, with the theme "Acoustics in a Changing Environment" was held at Abbey Beach Resort near Bussleton WA 9 to 11 November. On all fronts this conference was an outstanding success, with around 150 delegates. There was an impressive range of presentations including invited and keynote lectures and contributed papers. The program comprised up to four parallel sessions including special focused workshops. The lunches and tea breaks allowed time for the all important discussions with colleagues and viewing of the technical exhibition. The conference dinner, held at the conference venue, provided another social opportunity to be enjoyed by all. It was the time for the presentation of the inaugural award for outstanding contribution to acoustics to Neville Fletcher, the excellence in acoustics award for the Barn Owl, the best conference paper and the education grants. The talk by Mick the "Demotivational Speaker" put us all in the right frame of mind for the last day of the conference! Alec Duncan and his team are congratulated on organising such an outstanding conference and hopefully are taking a well earned rest after their sterling efforts. The proceedings of the conference are available on CD from www.acoustics.asn.au.

Workshop on Future of Acoustics

One of the plenary sessions of the 2005 Conference was a workshop on the Future of Acoustics in Australia. Marion Burgess convened this workshop and in her introductory comments focused on two main areas. One of these was the reduction in availability and resources for publicly funded acoustics facilities, an outcome of the government policies for rationalisation and commercialisation of such facilities. The second related to education in acoustics and the reduction rather than the expansion of education and training for those entering the profession. Then followed two short presentations: Warwick Williams, from the National Acoustics Laboratory, spoke on the requirements of government funded agencies and suggested that the Society should lobby for a source of research funding that was only available to those working in acoustics. Neil Gross followed on behalf of the consultants and highlighted the major difficulty in finding new staff with some experience in acoustics or finding appropriate education for those entering the profession.

A spirited discussion then followed. Much of this was aimed at increasing the profile of acoustics as a profession and at education. In regard to the former some points included:

- lack of perception of 'value added' by good acoustics design rather than just meeting regulations and hence the pressure for lower charge out rates as compared with other professionals;
- concerns about professional indemnity having an impact on innovative approaches that carried greater risks
- need for mandatory regulations for products
- importance of taking care when dealing with media to avoid misrepresentation
- need to raise an awareness of all aspects of acoustics in community
- acoustics fraternity is passionate about the various areas but the diversification dilutes this for the rest of the community.

In relation to education in acoustics the comments included:

- difficulty of attracting and keeping new staff, especially graduates
- importance of formal post graduate opportunities
- benefits of further education being available in distance learning format
- consideration of a diploma similar to that available in the UK
- encouragement an awareness of a career in acoustics at all levels of education.

The workshop was considered a great success in raising many issues. The concluding comments by the President, Neil Gross, were that, while there was much the AAS Council and Divisional committees could do, it was up to the whole of membership to take every opportunity to enhance the future of acoustics in Australia.

Marion Burgess

Vibration from Underground Railways

Dr Hugh Hunt from Cambridge University Engineering Department (UK) was the IEAust Eminent Speaker for 2005 and there were a number of joint AAS/IEAust meeting held around Australia. One of these was held in Sydney on 22 Aug and another in Melbourne on 26 Aug.

Dr Hunt starting with some practical demonstrations using; an empty lemonade plastic bottle; a coffee cup; a spoon and a schematic diagram of a mass-on-spring-and-damper vibratory system. These showed that noise and vibration problems, particularly those associated with underground railways, are more complex than a simply posed explanation might suggest. He followed with a discussion of some current means of controlling vibration from railways – such as vibration isolation at the track or elastomeric springs under buildings at the receiver. Dr Hunt described the various causes of roughness from railway systems such as trackbed roughness, bent rail, varying rail support stiffness, varying rail E.I, varying sleeper spacing, rail head surface irregularity, and wheel tread and other irregularities. In solving any such railway vibration and noise problem, it is necessary first to identify the dominant vibration and noise, and to understand that the vibration and acoustic noise have different frequency spectra.

Trains travelling in tunnels need the resilience of floating slab track. "Ballast mats" are useful. The Pandrol Vanguard rail clip provides a good resilient mounting in that it supports the rail web [rather than its base] by means of rubber blocks in horizontal compression and loaded vertically in shear. Hugh concluded by saying that: resilience under rails reduces roughness, in-track vibration control may show variations of up to 20 dB, greatest benefit (up to 20 dB) comes from trackbed effects, and least benefit occurs if roughness is on the rail.

Dr Hunt has much useful information including videos of many demonstrations on his site http://www2.eng.cam.ac.uk/~hemh/

From reports by Chris Schulten and Louis Fouvy

Embelton Tour

On September 27, a site visit to the Embelton factory and laboratory, 147 Bakers Rd, North Coburg was attended by about 25 members from the Victoria Division.

Brad Dunn of Embeltons, a company now 80 years old, began by describing its work, the chief activity being the manufacture of noise and vibration isolation devices such as elastomeric bearings, airbags, jacked-up concrete floors, impact mats (from recycled rubber tyres), loudspeaker suspensions, and noise and vibration isolation treatments in apartments. Other activities are pipe bending, metal fabrication (including with high temperature alloys), and timber flooring. The company now also has a 2-room reverberation chamber, with one room above the other and an opening between them for test samples, etc of Embelton's and others' products.

The ensuing factory tour showed pipe bending in the Metal Shop, the low-frequency shaker table (with variable frequency control), and a demonstration of the Tapping Machine in the upper reverberation room impacting several types of vibration isolating materials, while we observers listened in the lower chamber.

Following the tour, Michael Plumb of Embeltons described the work of designing the resilient supports for several large concrete floor projects (which included the use of finite element modelling), and the wall bracket for supporting a tapping machine, and of obtaining the test chamber reverberation times and the impact isolation material test results.

Louis Fouvy

Society News

AAS Council

During the year Ken Mikl had to step down due to health problems. Council passed a motion at its last meeting expressing appreciation for his leadership and work given to the Society over many years.

The Council of the Society met twice during the year. At the last meeting Neil Gross was appointed President and Terry McMinn Vice-President. Byron Martin, Terrance McMinn and David Watkins are continuing in the positions of Treasurer, Registrar and General Secretary. The other Councillors are Charles Don, Norm Broner, Ian Hillock, Colin Speakman, Peter Teague, Matthew Harrison and Alex Duncan.

Finances

The Council has no income of its own and relies on funding from the Divisions. This takes the form of a levy on membership subscriptions, conference registrations and the amount held in bank accounts of the Divisions. From this income Council pays the cost of running the Society website, subscriptions for organization such as I-INCE, ICA and FASTS, secretarial expenses, Education Grant, audit fees, meetings, etc. A copy of the Society Financial Report and Accounts can be viewed on the Society website.

This year Council has held the levies at the same level as last year. They are as follows:-

- A levy on membership subscriptions of 75%,
- A levy of 5% on Divisions cash assets held at the end of the financial year; and
- A levy on the annual conference of 15% of registration fees.

Membership

Membership of the Society has increased during the year but there are still many acousticians who do not belong to the Society. Members are asked to encourage their colleagues to join the Society. There has been a fall in the number of Sustaining members over the last few years.

Council has awarded the grade of Fellow to Dr Peter Swift with the following citation:

> *Dr Peter Swift has a distinguished record of practice as a Consulting Acoustical Engineer extending over nearly 30 years. The impressive list of projects with which he has had significant involvement in fields relating to architectural and building services, environmental noise, and defence and airport projects, involves numerous major projects, both in Australia and overseas. However, Peter is honored as much for his exemplary personal qualities in the promotion and practice of acoustics as his impressive technical contributions. His continuing passion for acoustics and his generous, open, genuine and professional manner have been appreciated by many current members of the society who have benefited substantially from Peter's experience and example. Dr Swift's elevation to the grade of Fellow of the society is richly deserved.*

Education Grant

The grant was initiated in 2002 to assist in the teaching and promotion of acoustics. The two winning entries were announced at the National Conference at Busselton. Dr Ralph James and Mr Shane Chambers were awarded $2,770.00 for a project titled: "Sonar Termination and its Role in Mass Cetacean Strandings". Mr David Luck, Mr Athol Day and Mr Stephen Gauld were awarded $2,500.00 for a project titled: "Duct Directivity Predictions at a Duct Termination"

The Education Grant will be continued next year and has been increased to $7000. It is open to anyone seeking funds to assist in the teaching and promotion of acoustics. The grant can be used for scholarships, funding for research projects, equipment for educational purposes and any other worthwhile use.

Award for Outstanding Contribution to Acoustics

The first award was presented to Dr Neville Fletcher during the 2005 conference at Busselton. It is an award made to a member of the Society to recognise an extensive contribution to the advancement of acoustics and significant service to the Society. The award consists of a plaque, the cost of travel and accommodation to a function of the Society where the award will be conferred and free life membership of the Society.

Conferences

There will be a combined New Zealand and Australian Acoustical Societies conference in November 2006 too be held at Christchurch, New Zealand.

The 14th International Congress on Sound and Vibration will be held in Cairns on 8-12 July 2007. It is proposed to hold a Society conference at Cairns in conjunction with ICSV14. The Society has provided seed funding to ICSV14 and has offered to assist the organizers of the congress.

Standards Australia

]is its involvement with the development and revision of standards. For a number of years the Society has been represented on Standard Australia acoustics committees. In addition, the Society is a member of the Council of Standards Australia. Most committee have not been active during the year. The table in the news section on Standards shows the Society's representatives and summarises the committees activities during the year:-

David Watkins

AAS Award for Neville Fletcher

The AAS award for an **Outstanding Contribution to Acoustics** is made to a member of the Society to recognise an extensive contribution to the advancement of acoustics and significant service to the Society. The inaugural award was presented to at the 2005 Conference in Busselton to Em Professor Neville Fletcher, MA PhD Harv, DSc Syd, FIP, FAIP, FAAS, FTSE, FAA, AM, with the citation:

> *Throughout his career Neville has made extensive contributions to the advancement of acoustics particularly in the areas of acoustics of musical instruments, biological acoustics and vibrations. He has achieved international recognition for his work and has published extensively. He has been a strong supporter of all the activities of the Australian Acoustical Society. In particular he has been the chief editor of the journal Acoustics Australia since 1993.*

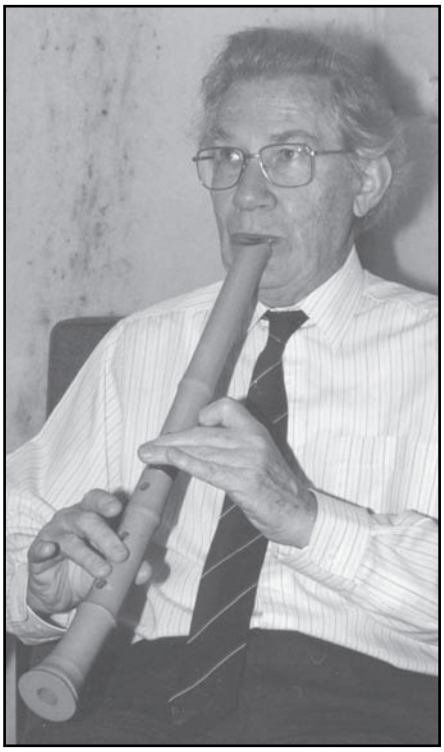
At the presentation during the conference dinner it was with great pleasure but also some trepidation that I accepted the challenge to attempt to encapsulate in just a few minutes the contribution that Neville Fletcher has made to acoustics and to the Society. The following is the essence of that presentation and more information on Neville's outstanding career can be found from wwwrsphysse.anu.edu.au/eme/profile.php/34

Neville had a distinguished academic career in semiconductor physics before he developed research interests in acoustics while at UNE from 1973. These interests continued in a spare-time mode when he rejoined CSIRO as an Institute Director in 1983, and became his main field of research since retirement from CSIRO in 1995. He is currently an Adjunct Professor both at ANU and at UNSW and involved with a diverse range of research projects.

His contribution to acoustics, and in particular to musical and biological acoustics, has been exceptional, and he is recognised as a world authority in these fields. Two of his books "Acoustics Systems in Biology" and "The Physics of Musical Instruments" are the authorative works in these fields and consulted by researchers and students alike. An indication of his ongoing amazing output is that in just the last five years he has published 4 books/chapters, 34 refereed papers and 7 refereed conference papers.

In recognition of Neville's outstanding academic career he was awarded a DSc from the University of Sydney in 1972 and the Silver Medal in Musical Acoustics from the Acoustical Society of America in 1998. He has also contributed to the profession by extensive participation in the activities of many relevant bodies including the Australian Academy of Science and has been elevated to the level of Fellow by most of these. He has been honoured nationally becoming a Member of the Order of Australia in 1990 and a receiving a Centenary Medal in 2001.

Scientific research is not the only interest for Neville. His family is important to him as are his recreational pursuits. Two of these are related to acoustics; playing the flute, bassoon and organ and keeping up with languages like Japanese.



Neville Fletcher demonstrates the Japanese shakuhachi

I have had the pleasure of knowing and working with Neville for almost 20 years, in particular from 1993 to 2004 as a member of his editorial team for Acoustics Australia. In all my dealings with Neville I have been most impressed by his ability to see through to the kernel of any problem, his wise advice coupled with his friendly, easy going manner, his generosity with his time and his willingness to undertake any task no matter how basic. Neville is truly a worthy recipient of this inaugural award of the Australian Acoustical Society Award for Outstanding Contribution to Acoustics.

Marion Burgess

Excellence in Acoustics Award 2006

This award aims at fostering and rewarding excellence in acoustics and entries are judged on demonstrated innovation from within any field of acoustics

The CSR AAS Excellence in Acoustics award for 2005 was awarded to SoundScience@WM Pty Limited for the "BarnOwl" Directional Noise Monitoring System.

Barn owls are famous for their ability to locate the direction of a sound. They can hunt in total darkness, using acoustic cues to find their prey. The 'BarnOwl' is a noise measurement system that goes some way toward emulating the barn owl's legendary performance. The monitoring system is based on the principle by which the direction of a sound source may be determined from the time delays between signals arriving at multiple microphones. These delays may in turn be found from the cross-correlation functions between signals from pairs of microphones. The detection system uses three microphones arranged in an equilateral triangle. Cross-correlation functions are formed between each of the three microphone pairs, and all local maxima in these functions are found. An algorithm then searches for sets of three maxima which could all represent a source in approximately the same direction, and at the same distance. The computed noise levels from all sources within a specified range of angles are accumulated, giving an estimate of the total L_{Aeq} noise level arriving at the monitor from that direction. More information on the Barn Owl can be found from www.wmpl.com.au

Ben Lawrence from SoundScience@WM demonstrating the Barn Owl for the award committee.

The 'Barn Owl' was considered a very worthy of the award for Excellence in Acoustics particularly as it is a unique system which was developed within Australia to meet a specific need and SoundScience@WM are continuing to improve the product.

There was no runner up award in 2005. Applications for the 2006 award are due by July 2006 and details available from www.acoustics.asn.au.

Education in Acoustics

At the Workshop on the Future for Acoustics at the 2005 Conference, the lack of suitable education opportunities was identified as a major concern for the profession (see report on this workshop elsewhere in this issue). This concern was further increased when it was found that the postgraduate programs for the Graduate Diploma and Master of Engineering Science in Noise and Vibration, offered by the School of Mechanical and Manufacturing Engineering at University of New South Wales, no longer existed. These programs were unique in Australia and all the individual courses were all available in distance learning mode, and many were also offered in direct mode at the Kensington campus. While some of the courses had good enrolments, the full programs had not met the number of students required by UNSW to keep them active programs. With the strong support of the AAS and the consultants, efforts are being made by staff at the Kensington and at the ADFA (Canberra) campus to try to review and to re-establish these programs.

In the meantime, those individual courses which attracted sufficient numbers of students continue to be offered. These courses can be taken individually as a non-degree program and if the student in the future wished to undertake the full Diploma or Masters program they would provide advance standing.

In 2006 the course **Fundamentals of Noise** will be offered both at the Kensington campus and in distant learning mode. The content of this course includes:

> *Development of the acoustic plane wave equation. Introduction of the concepts of acoustic impedance, characteristic impedance, acoustic energy density, acoustic intensity and acoustic power. Measurement of sound pressure. Decibel scales. Standing waves. The effect of noise on people. Wave propagation in porous media. Transmission phenomena including transmission of plane waves between different media, through walls and along pipes. The analysis of expansion chamber mufflers and pipe side-branches. Basic energy approach to room acoustics*.

Administrative information on this course is available from Sharon Turnbull, the External Studies Coordination (02) 9385 4085 or s.turnbull@unsw.edu.au. Technical or Academic advice can be obtained from Dr Nicole Kessissoglou on (02) 9385 4166 or n.kessissoglou@unsw.edu.au

FASTS

FASTS Structure

The AAS has been a long term member of the Federation of Australian Scientific and Technological Societies (FASTS) the peak lobby group for scientists and researchers in Australia. The membership structure has been based on clusters of member societies having somewhat allied interests each having a representative Board Member. FASTS business is conducted at Board meetings and the member societies only attend the Annual General Assembly and General Meeting (AGM) where they could participate in the discussion but had no voting power. On 21 November 2005 this all changed at the EGM, held prior to the 2005 AGM. Approval was granted for a more representative structure and importantly allowing all members voting rights on all motions at general meetings. There were other changes made to the constitution including creating two new positions on the Board for non-disciplinary based science and technology associations, abolishing the Past President position on the Executive and specifying that no person may serve in the one position for more than 4 years.

At the following AGM Tom Spurling took over as President from Snow Barlow whose 2 year term had come to an end. The summary of Barlow's final report from the Minutes of the AGM:

"Snow commented on how well placed FASTS was to continue in its role but still required a sharper edge, energy, commitment and passion from its members. It was a critical time to have an independent policy body taking important and responsible positions as an effective voice to Government for our constituency. Meeting the challenge of decreased funding in the last decade together with enormous GDP growth, made it more difficult to secure increased investment in science & technology and the future. Policy frameworks that can be forwarded for the 2007 Budget were therefore critical and the challenge ahead required traction to advance opportunities.

The recent structural changes in dismantling the Board of the ARC and changes to R & D, with implications for the quality and independence of research, must be dealt with. There is no strategic overview of science in Australia. The RQF is a major issue connected to strategic directions with potential for most attention to be focused at the basic level. The relationship between the RQF, ARC and NHMRC is yet to be defined and young scientists and non research-intensive universities may be excluded from grants. FASTS needs to voice their concerns to Government.

Snow explained the workings of PMSEIC and then the flow on from the RQF – Third Stream Funding. Preferably titled something other than 'third stream – possible 'triple helix funds' - FASTS has been approached by the Treasury to submit ideas on funding for commercialisation, interaction with the community and acceleration and encouragement of the flow of knowledge and innovation between universities, industry and the community."

FASTS Submission to Budget 2006/7

We will all watch to see if the government takes note of the points raised in the FASTS submission on the 2006/07 Budget. FASTS identified the "key challenges that must be addressed if Australia is to fully leverage its capabilities, including

- More sophisticated approaches to supporting the multiple pathways to adoption of knowledge including commercial use.
- Developing more effective modes of knowledge transfer between universities and industry and the community, including rapid migration of PhD graduates into industry;
- Developing the capacity for high level strategic analysis of the directions of Australian science;
- Forging stronger linkages between science, business and venture capital;
- Addressing science skills shortages in specific areas (eg statistics); and
- Strengthening the quality of science teaching.

FASTS urges the Government to take a long-term view and commit some of this surplus to investment in building Australia's productivity base through:

- Measures to increase the core rate of innovation in the Australian economy, including enhancing mobility between universities, public sector research agencies and companies;
- Addressing indexation deficiencies in university and R&D programs;
- Increased investment in research infrastructure;
- Additional funding to both bed in the Research Quality Framework, and to provide new money to ensure that the high ranking groups remain internationally competitive, and
- Providing additional funding to enable stronger partnerships in knowledge transfer (third stream funding)."

New Products

CSR Hebel SoundFloor™

CSR Hebel SoundFloor™ is an innovative Aerated Autoclaved Concrete (AAC) flooring panel which is laid over conventional bearer and joist framing to produce a premium quality flooring system with a ‘reinforced concrete’ feel. A recent price reduction makes CSR Hebel SoundFloor™ a serious contender for quality flooring in residential, commercial and industrial applications.

CSR Hebel SoundFloor™ is a unique product, as it alone combines the advantages of lightweight construction with a range of inherent advantages such as thermal efficiency, acoustic performance, environmentally friendly manufacturing, fire resistance, termite resistance and increased stability and stiffness. CSR Hebel SoundFloor™ is also extremely strong and provides excellent intruder resistance as each panel is reinforced with corrosion-protected steel mesh.

The unique cellular structure of CSR Hebel SoundFloor™ also directly assist in reducing noise entering from the surrounding environment and in controlling noise between rooms. CSR Hebel SoundFloor™ can be combined with all types of floor coverings and/or ceiling systems to produce acoustic systems for the most demanding specifications.

Information www.hebelaustralia.com.au

CSR Exterior Sound Control System

With homeowners in mind, CSR has developed Exterior SoundControl Systems which dramatically reduce noise inside the home, ensuring families enjoy peace and quiet at any time of the day or night. The CSR Exterior SoundControl Systems reduce the penetration of noise into homes by combining special acoustic building products in tailor made packages. The package includes: Gyprock Soundchek wall and ceilings; Bradford SoundScreen insulation and EnviroSeal roof sarking; Hebel powerpanel; Cemintel fibre cement sheeting; Monier and Wunderlich roof tiles; PGH bricks; Trend windows; Raven door seals; and Hume doors.

There are six SoundControl Systems available to suit every home for a range of exterior noise problems. By identifying the most relevant exterior noise threat near a home, and in turn the decibel level of the noise, the CSR team can advise which package is most suitable to achieve either a 35 or 40 dB outcome within the home.

For a comprehensive information kit: tel 1300 306 556, or www.gyprock.com.au, www.csr.com.au.

MSCADAMS LifeMOD

The LifeMOD Biomechanics Modeler is the most advanced and complete human modelling program available today. Explore the possibilities of creating true physics based biomechancis models for any living system. LifeMOD is a plug-in to the popular MSC.ADAMS software, providing a complete modelling environment to refine the task of creating passive, and forward dynamics biological models which interact with the environment, tools, equipment and each other. This technology empowers the investigator to understand the forces and the nature of the control strategies behind biological activities. The LifeMOD modelling environment is an accumulation of tools, databases and techniques developed over the past 20 years

Information from www.mscsoftware.com.au

Future Meetings

Acoustics 2006

First Australasian Acoustical Societies' Conference

The Australian and New Zealand Acoustical Societies have always encouraged participation at the conferences held by each organisation. The joint New Zealand and Australian Acoustical Society Conference further extends this collaboration. This will be held at the spectacular Clearwater Resort in Christchurch, New Zealand November 20-22, 2006. The resort has excellent facilities for the conference and also for relaxing in between sessions or before and after the conference.

The conference will take the usual format with plenary and invited papers, workshops, contributed papers, technical exhibition and social functions. While the theme is "Community response to noise", technical contributions are invited on all acoustical issues are invited, including: transportation noise, building acoustics codes and standards, underwater acoustics, automotive noise and vibration, psychoacoustics and physiological acoustics, room acoustics and sound systems. Abstracts are required by 31 March 2006.

Information from www.conference.co.nz/acoustics2006 or Conference Innovators Ltd, Tel: +64 3 379 0390, barry@conference.co.nz

ACTIVE 06

ACTIVE 06, The 2006 International Symposium on Active Control of Sound and Vibration, is being organised by the South Australian Division of the Australian Acoustical Society. The Symposium will be held on 18-20 September 2006 at the University of Adelaide, which is located in the centre of the city of Adelaide. The Symposium is a continuation of the series of biannually-organised meetings on Recent Advances in Active Control of Sound and Vibration which have been held for the past 15 years. The conference will be held in Adelaide, which is a delightful city with beaches, hills and vineyards nearby.

Michael Kidner and Carl Howard of the Active Noise and Vibration Control group at The University of Adelaide will be the general chairmen for the Symposium. Anthony Zander, also of The University of Adelaide will be the chair of the technical program. It is expected that approximately 100 technical papers will be presented covering all aspects of active control, including noise and vibration, enclosed sound fields, "smart" materials, and commercial applications.

Information from http://www.active2006.com

WESPAC IX 2006

The 9th Western Pacific Acoustics Conference will be held June 26-28, 2006 in Seoul, Korea, the Land of Morning Calm. The program will include papers on a wide range of acoustics topics along with a technical exhibition and a full social program. This conference is a wonderful opportunity to find out about the latest advances in all areas of acoustics as well as meeting with colleagues from our region of the globe. Those who attended the excellent Wespac conference in Melbourne will know the benefits that can be gained from attending Wespac conferences.

Wespac has a reputation for excellent invited speakers and the line up for 2006 includes Plenary speakers: Ronald A. Roy, *Better Life through Bubbles in Biomedical Ultrasound*, Sang-chul Lee, *IT as a New Social Infrastructure*, Hideki Kawahara, *A Precursor to Ecologically Relevant Speech Science* and keynote speakers: Xifen Gong, *Physical and Nonlinear Acoustics*, Jeff Simmen, *Underwater Acoustics*, Kirk Shung, *Biomedical Acoustics*, Victor Akulichev, *Underwater Acoustics*, Angelo Farina, *Architectural Acoustics*, Christopher Tam, *Aeroacoustics*, Jung-Kwon Ih, *Computational Acoustics*

Abstracts are due so now is the time to plan for your participation. The key subject areas include: product oriented topics, human related topics, speech: production, recognition, processing and communication, physics: fundamentals and applications, underwater acoustics, aeroacoustics, architectural acoustics, environmental acoustics and vibration, analysis: through software and hardware other hot topics in acoustics.

Information from http://www.wespac9.org

ICSV13

The13th International Congress on Sound and Vibration will be held July 2-6, 2006 at the Vienna University of Technology which is located in the centre of the city. Following the tradition of such conferences, ICSV13 will have a first rate scientific program. It is being held in the historic and beautiful city of Vienna so a good opportunity to explore this part of Europe. The date for submission of abstracts for this conference has been extended so check on the latest details from http://icsv13.tuwien.ac.at

There is a special request to the AAS from Dr Gan in Singapore, wsgan@acousticaltechnologies.com, for contributors to a session on nonlinear acoustics and vibration for this conference he is organising for this conference.

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

ISMA 2006

ISMA2006, Noise and Vibration Engineering Conference, is part of a sequence of annual courses and biennial international conferences on structural dynamics, modal analysis and noise and vibration engineering. The last was held in 2004 and attended by more than 450 people. The technical program included 2 keynote lectures, 3 tutorial lectures and about 300 technical papers.

ISMA2006 will be held in Leuven (Belgium) from 18 to 20 September 2006. The conference is organised by the division PMA of the KULeuven. Information on the conference topics, as well as on the procedure for submitting abstracts can be found on: http://www.isma-isaac.be/

Internoise 2006

Internoise 06 with the theme "Engineering a Quieter World" will be held at Sheraton Waikiki in Honolulu, Hawaii, USA 3–6 December, 2006. This conference will have all the features that one expects at an Internoise Conference as well as being in the relaxing environment of Honolulu. Information from www.internoise2006.org

This conference will be preceded by the 152nd Meeting (4th joint meeting of the Acoustical Society of America and the Acoustical Society of Japan), Honolulu, Hawaii, 28 November - 2 December 2006 http://asa.aip.org

New Members

Member

Masood Alikhail (Vic)
Robin Brown (Vic)
Carl Fokkema (NSW)
Wei Gao (NSW)
Najah Ishac (NSW)
Simon Moore (SA)
Stephen Pugh (Qld)
Helen Wu (NSW)

Graduate

Jonathan Cooper (SA)
Shaun Lay (Qld)
Malwinder Singh (NSW)
Renzo Arango (NSW)

Subscriber

Mark Scannell
Benjamin Wilson (Vic)

Standards Australia

ENews from Standards

News from Standards can now be read from www.enews.standards.org.au. This electronic newsletter provides access to the latest news from the organisation and lists of new, amended and draft Standards.

Management of Standards

During 2005 there has been considerable examination of the governance of Standards Australia. A comprehensive report into all aspects of the operation was commissioned. Consultation meetings were held around Australia with representatives from the various stakeholders to discuss the issues of concern and how these could be addressed. The AAS has representation on standards committees dealing with documents that clearly relate to acoustics. However one issue pertinent to AAS members is how best to have some effective participation in the committees that deal with the vast number of standards that have small, but important, acoustic sections. One example is the item below from Ian Hillock on the changes in the explosives standard in which, to our knowledge, no one from the AAS had any involvement. This is obviously a complex standard as the acoustic provisions are in the 10th Appendix but the change in method has significant impact on those doing assessments in that area. Another discovery by Marion Burgess was the inconsistency between the procedures for noise assessment in a marine related standard and those in the current occupational noise assessment standard. The AAS would like to keep track of these issues and can take the necessary actions to encourage Standards Australia to make the necessary changes. So please advise the General Secretary of any concerns you may have on these matters.

AS 2187.2 on Explosives

A substantially revised edition of AS 2187.2 "Explosives – Storage, transport and use" will be published early in 2006. In particular, there have been significant revisions to ground vibration and air blast criteria and associated assessment procedures. These are incorporated in a revised and expanded Appendix J "Ground Vibration and Airblast Overpressure".

For ground vibration, the Appendix now refers to the ANSI S3.18-1993 guidance for human comfort in buildings. The building damage ground vibration limits introduce frequency dependent vibration damage criteria, as per BS7385.2:1993 and USBM RI 8507. A modified and extended version of the existing frequency independent guidance (Table J1 of the current standard) is retained for those "explosives users who do not have the facilities to use frequency dependent assessment methods". The latter now incorporates the ANZEC recommendation that such limits not be exceeded for 95% of blasts.

The Appendix also includes significant revisions to blast monitoring instrumentation requirements and provides (for the first time) a standard equation for estimation of airblast overpressure levels.

Ian Hillock

AAS Representatives on Standards Committees

The AAS has nominated representatives on most committees whose primary duties relate to standards dealing with noise and vibration. If anyone has concerns about standards which are managed by these committees they can discuss these with the appropriate representative. Below is the listing of representatives and a summary of activities during 2005. Reports on the more active committees follow.

In relation to committees that did not meet, Peter Teague reports that EV-10 project on construction site noise is waiting for: greater representation from more relevant organisations and the release of the draft Construction Noise policy by the NSW EPA/ DEC, and that a revised draft is anticipated early 2006 from EV-16 on Wind Turbine Noise

ISO meetings With the increasing pressure to adopt ISO standards as Australian Standards it is important that Australia has participation in ISO. During 2005 Peter Teague attended ISO Plenary and Working Group meetings held in Canada. Some of the documents discussed during these meetings included; Definitions of basic quantities, Impulse Sound Propagation for Environmental Noise Assessment and most of the meeting was devoted to discussing two major scope changes for ISO 13474 standard. There was also discussion on the scope of a standard on shooting ranges. Peter comments that involvement in ISO working groups has provided an important link to the EV committees, Standards Australia and the acoustics community (AAS). I will be seeking input and feedback from others in Australia and looking to consider adoption of the working committee drafts in Australia.

	COMMITTEE	REP	COMMENTS
AV/1	Acoustics-Vibrations Terms, Units and Symbols	Mr J B Fowler Mr G E Harding	The committee has not met during the year.
AV/2	Acoustics - Instrumentation and Measurement Techniques	Mr P Alway Dr R. Tonin	Parts 1 & 2 of AS/IEC 61672 on Sound Level Meters has been adopted.
AV/3	Acoustics - Human Effects	Mr K Scannell Mr W L Huson	The committee met twice during the year and finalised the second edition of AS/NZS 1269.
AV3/3	Audiology	Tim Klar	The committee has not been active.
AV/4	Acoustics - Architectural	Mr N Gabriels Dr N Broner	The committee met once during the year and reviewed a number of standards.
EV/10, AV/5	Acoustics - Community Noise	Mr A R Brown Mr P Teague	Draft ISO 5130 was circulated for comment in February but otherwise the committee has not been active.
AV/7	Acoustics - Noise from Office and Household Equipment	Mrs V E Bray	The committee has not met during the year.
AV/9	Vibration and Shock Applications	Mr B Martin	The committee has not met during the year but some standards were reviewed.
EV/11, AV/11	Aircraft and Helicopter Noise	Dr R B Bullen Dr N Broner	The Committee has not met during the year.
EV/16	Acoustic Wind Turbine Noise	Dr P Teague Mr K Williams	The committee has not met during the year.

News

Singing Bridges Blog Award Jodi Rose beat 500 entries to win the SmartyBlog award – taking home a $10,000 cash prize for her “Singing Bridges Travel Diary” www.singingbridges.net. Jodie is a “sound artist” and travels the world recording the sounds of bridges. This blog is the travel diary that records the sounds of bridges from around the world. She started the blog in 2002 when she set out to record the vibrations of the cables of famous bridges around the world and plans to eventually link them together in a “bridge symphony”

For those who have not caught up with the term - blogging, or web logging, takes the form of an online diary or newsletter, spanning everything from pop culture to politics. It is estimated that here are more than 300,000 blogs in Australia, with a new blog created every second somewhere around the globe.

UK Science Week - Silent Aircraft The British Association for the Advancement of Science exists to create a positive social climate in which science, and the organisations dependent on it, advances with public consent and with the involvement and active support of non-scientists. One of its activities is the organisation of the BA Festival of Science Week which is one of the UK’s biggest science festivals. A feature of the 2005 Science week, held in Dublin, was the update on the Cambridge-MIT Institute’s ‘Silent’ Aircraft Initiative. This was launched in November 2003 with a bold aim: to discover ways to reduce aircraft noise dramatically, to the point where it would be virtually unnoticeable to people outside the airport perimeter.

Dr Tom Reynolds from Cambridge University’s Engineering Department gave the BA prestigious Isambard Kingdom Brunel Award Lecture at the BA Festival of Science in Dublin on “The future of civil aviation: the approach of the Silent Aircraft”. Dr Reynolds used practical demonstrations that are accessible to everyone to explore the proposed silent aircraft, the problems in trying to reduce noise and the benefits that this aircraft has over conventional aircraft. This lecture is available from http://www.cusp.org.uk/festival and information on the project from http://www.cambridge-mit.org/research/sai.

Academy of Science Scholarships - The Academy has an ongoing program to assist Australian scientists and researchers. Travelling fellowships allow for the exchange of scientific ideas, to increase public awareness of science and scientific issues and to carry out research; The Academy will also provide support for Research conferences that focus on relevant and rapidly developing fields of research. Information and the requirements for applications/expressions of intent are available at http://www.science.org.au/awards

ACEA Awards A record-breaking crowd of more than 370 industry professionals turned out to celebrate world class engineering solutions at the 20th annual Association of Consulting Engineers Australia (ACEA) Awards for Excellence in Brisbane. Two acoustic related project winners were GHD Noise Attenuation – 789C Truck Certificate, Specialist Services Audio Management Systems, (AMS) Project, Sinclair Knight Merz Silver, IT Projects.

EU Noise Summit and Awards EU policymakers and leading safety and health experts meet on 12 December 2005 in Bilbao, Spain, to discuss how to better protect European workers from noise and to award those organisations that have already managed to implement effective solutions. As many as 60 million workers in the EU are considered to be exposed to excessive noise during their working hours. The summit, jointly organised by the European Agency for Safety and Health at Work and the UK Presidency of the European Union, was the culmination of the 2005 ‘Stop that Noise!’ campaign. The European Good Practice Awards 2005 were given to the best practical solutions for the prevention of noise exposure. The winners include new low-noise concrete processing methods from Germany and France, a night club design project from Sweden, tools to protect farmers from Denmark, a Dutch example of how to calculate the most cost-effective noise solution and a training project from the UK aimed at orchestral musicians. For more information about noise at work, the summit and the Awards 2005 http://ew2005.osha.eu.int.

AUSTRALIAN ACOUSTICAL SOCIETY TRAVELLING GRANT 2006

The Australian Acoustical Society Travelling Grant has been established to encourage members of the Society to attend the International Congress on Acoustics in Madrid, August 2007. Two travelling grants will be awarded, each of $1,000. The grant is open to any member of the Society of Grade Fellow, Member, Graduate, Associate or Student.

What is required for entry?

The submission should not be greater than two A4 pages and should include:-

- A brief background of the applicant.
- An outline of how attendance at ICA 2007 will enhance their career and/or studies in acoustics.
- An outline of how their participation at the ICA will enhance the profile of Australian acoustics.
- Applicants proposing to present a paper at the congress should include an abstract.

The selection committee may seek additional information from the applicant as part of its selection process. Each applicant must provide a report (500 words) on return from ICA 2007 on the experience. These may be printed in Acoustics Australia.

Submission of entry.

Entires should be forwarded by 30 September 2006 in electronic form, to:-

GeneralSecretary@acoustics.asn.au

University of Sydney Acoustics Laboratory Fire

On the evening of Friday 21st October 2005, fire took hold of the anechoic room in the acoustics laboratory at the University of Sydney. Even though one would think that there is not much to burn in an anechoic room, the fire was sustained for some time, fanned by the air conditioning and a compressed air supply to the room. The cause of the fire remains unknown, but was probably due to an electrical fault in the lights. While the flames were mainly restricted to the anechoic room, hot smoke spilled into the rest of the laboratory, deforming plastics and leaving greasy corrosive soot throughout.

Nobody was injured by the fire, but a considerable amount of damage was caused. The aluminium body of a dodecahedral loudspeaker in the anechoic room melted completely. All of the loudspeakers and many microphones in the main part of the lab were damaged. Computers in contact with the smoke are written off. At least seven acoustic doors were damaged or destroyed. The lab will be unusable for quite some time.

The degree to which the event is insured for remains to be seen. Clearly the loss of access to the laboratory for at least one year is not insured for. The replacement of old equipment, which an assessor may deem to have fully depreciated, may pose some difficulties. Over 1000 items of equipment have been removed from the lab for assessment and cleaning. We have already found that obtaining a realistic assessment of reinstatement taking into account acoustic treatment and detailing requires great vigilance.

The lab has been built up over 35 years and has in the past has benefited from donations of equipment from the ABC, PWD, EPA and consultants to name a few. It has been a significant contributor to acoustical research in Australia especially in architectural and building acoustics but also in environmental acoustics and audio. Currently the lab has one full-time academic staff member, Densil Cabrera, one part-time staff member, Michael Bates, two technical officers, Ken Stewart and Matt Storey, several casual teaching staff (including John Bassett, Ken Stewart, Michael Fisher, Sam Ferguson and Chris Field) and eight honorary staff (Neville Thiele, John Goldberg, Joseph Nannariello, Andrew Madry, Nigel Helyer, Glenn Leembruggen, Jin Yong Jeon, and Fergus Fricke).

The laboratory has supported teaching of acoustics to architecture students, a popular graduate coursework program in audio and acoustics, and several research students working in areas such as optimised anechoic lining design, auditory room size perception, speech intelligibility, sound diffusion in auditoria, psychoacoustical modelling of operatic vocal sound, and sound absorber design for small rooms. It also has provided the base for our own research along with that of other honorary staff, as well as work linked to other faculties, other universities, industry and the community. It has had significant successes in collaborative research funding, sharing in $900k of grants in the past 5 years.

We hope to rebuild the lab better, and hopefully much better, but will need substantial support to do this. Please contact Fergus Fricke (ferg@arch.usyd.edu.au), Densil Cabrera (densil@usyd.edu.au, 02 9351 5267), or Ken Stewart (stewa_k@arch.usyd.edu.au, 02 9351 5116) if you or your organisation might be able to assist with the re-establishment of an improved laboratory.

Fergus Fricke, Densil Cabrera and Ken Stewart, Faculty of Architecture, University of Sydney

South Australia

Senior Adviser, Noise

REF NO: 8625/2005

ADELAIDE

PS03 - $64,060 - $67,989

Duties: The Senior Noise Adviser is accountable to the Manager, Air Quality and Noise Branch for developing, implementing and communicating noise policies and programs to government, councils and interested industry and community groups which ensures that appropriate, consistent and effective strategies are adopted and enforced. The incumbent represents the EPA as an expert in the environmental noise field on national and state committees and forums on noise pollution issues.

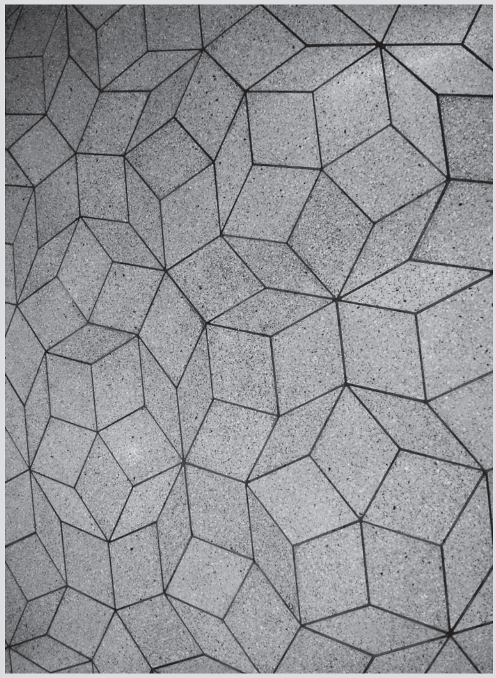
Essential Minimum Qualifications: A Bachelor of Engineering, Science or Applied Science Degree with eligibility for Membership to both the Institute of Engineers Australia and the Australian Acoustical Society.

Special Conditions: Please refer to the Job and Person Specification for special conditions Enquiries to: Jason Turner, EPA, telephone 08 8204 2046, email jason.turner@state.sa.gov.au

Applications to: Dannielle Davis, HR Client Service Officer, EPA, GPO Box 2607, Adelaide, 5001, telephone 08 8204 2089, email dannielle.davis@state.sa.gov.au

IMPORTANT: Your application will be assessed on the Job and Person Specification criteria. Please address this criteria in your application. Guidelines for applicants are available at www.epa.sa.gov.au/pdfs/application_guide.pdf . Job and Person Specifications are available from www.epa.sa.gov.au/vacancies.html or by contacting Sophie Giorgines, telephone (08) 8204 2063, email sophie.giorgines@state.sa.gov.au . Please reference 8625/2005 when applying. Please forward an original application plus four copies. If emailing your application, please be aware, for the application to be considered it must be received by 5.00pm on the closing date and hard copies need to be provided by 5.00pm on Monday the 13th February 2006. The EPA is an equal opportunities employer and safety is a core value.

Applications Close 10th February 2006



A funny tesselation happened on the way to the conference.

Acousticians are often interested by the presence or absence of periodicity. One of the editors made a slight detour to his way to the AAS2005 Conference at Busselton, in order to visit the new Molecular and Chemical Sciences building at the University of Western Australia.

The floor covering the atrium of this building is a delightful Penrose tiling (an aperiodic tiling made from only two simple shapes – see photo). There must be some way such an elegant structure might be useful in acoustics. Try the following web address for more details.

http://www.nature.com/nature/journal/v436/n7049/full/436332a.html

AUSTRALIAN ACOUSTICAL SOCIETY
CODE OF ETHICS

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

EXPLANATORY NOTES

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

Queensland Acoustics Awards Program

Although this article relates to the Queensland Division Acoustics Awards, there are similar awards in other Divisions. There is also the AAS Education Award administered by Federal Council and the CSR Bradford, Excellence in Acoustics Award. Readers of this article, with contacts at the various universities where acoustics is practised and taught, please spread the word about these awards and encourage the relevant people to persist in their endeavours and to promote the science and practice of Acoustics.

Division 1 – Schools Division is administered as part of the Queensland Science Contest (now in its 53rd year www.staq.qld.edu.au/science_contest) which is an annual competition open to students studying at primary and secondary schools in Queensland conducted by the Qld Science Teachers Association. AAS Queensland Division sponsors an "Acoustics" bursary and provides associated project judges for this annual contest. The bursary of $360 is awarded for "the best project in the field of acoustics (noise/sound/vibration); open to students in all Science Contest divisions.

The inaugural award of the schools division bursary was made in October 2001 to Naomi Jeram for a study entitled *"Comparison of Materials used for Violin D String Cores"*. The 2002 bursary prizes were awarded to Erik Merkley for *"Ultrasonics"*, to Kayla Begbie for *"The Phonograph"* and to Caitlyn Ward for *"Sound Waves and Hearing"*. The 2003 bursary prizes were awarded to Katelyn Ryan for *"Chimes"* and to Andrew Caitens for "*The Electronic Alert*". The Science Contest bursary was not awarded in 2004 and 2005 due to a lack of suitable entries.

Division 2 - Tertiary division is open to undergraduate and 1st year postgraduate students studying (full or part time) at a Queensland university in subjects of direct relevance to acoustics.

Category 1 bursary, now worth $1500, is "project based" and is intended to promote and support final year undergraduate and first year postgraduate projects in subjects of relevance to acoustics. "Subjects of relevance to acoustics" is interpreted broadly and is intended to encompass all areas of acoustic research and endeavour of interest to the Society generally. The winner(s) of this award makes a short presentation on the project results at project completion.

The inaugural award in 2002 was to Emma Carlisle of UQ for her project *The SCRAM Project - Small Chamber Reverberant Absorption Measurement*. Emma now works for Bassett Acoustics and presented a paper on her work at Acoustics 2004.

The 2003 bursary was shared between Thomas Teo for *Evaluation of Corrosion Film Strength Using Acoustic Emission* and Andrew Rohde for *Ultrasonic Tomography for Structural Health Monitoring – Intersections of Lamb Waves with Geometric Defects*. Andrew is continuing his work for a PhD at UQ.

The 2004 bursary was awarded jointly to Francis Tan, Owen Lim and Louis Wong of UQ, for their project *A Comprehensive Study of Acoustics Absorption Measurement Techniques* which involved comparative sound absorption measurements using the UQ Small Reverberation Chamber (SCRAM), impedance tubes and the large reverberation chamber at ACRAN. Louis Wong (now working for Hatch) presented the project results to a technical meeting held in the ACRAN test suite.

The 2005 bursary was awarded to Matthew Morrison (UQ/Rail CRC), for his project *Investigation into the Effect of Initial Conditions on Wear Type Rail Corrugation Model Predictions.* (Supervisor Dr Paul Meehan). Matthew also presented his project work at a technical meeting and recently graduated with 1st Class Honours.

Category 2 book prize of $150 is "course based" and is intended to promote and support undergraduate courses in acoustics. It is awarded only for work conducted in courses with a substantial physical acoustics component.

The Division 2 awards were initially made available to students studying at UQ, QUT and Griffith. Following the success of Acoustics 2004, the program was reviewed and awards extended to all universities in Queensland and the amounts increased.

Category 2 – Course work

The inaugural recipient of the Category 2 bursary (2005) was Scott Butterfield, for course work in *Mech 3250 Engineering Acoustics* at UQ. It should be noted that, Ron Rumble Pty Ltd has for many years also sponsored an award for *Mech 3250* (the award is administered through the University) and Scott Butterfield also received that prize.

From a report by Ian Hillock

Company Acquisition.

Heggies Australia has acquired the environmental/occupational health and safety and hazardous materials practice of New Environment Management and Technology Pty Ltd (North Ryde and Wollongong Offices) - as well as the respected practice of Eric Taylor Acoustics in Canberra. Branch Offices in Perth and Singapore will become operational in early 2006. These acquisitions add expertise in asbestos and hazardous materials management, occupational health and hygiene, confined space testing and land contamination to Heggies traditional consulting services in acoustics, noise, vibration and ambient air quality.

Noise-Con CD with much more.

The CD for the joint Noise Con 05/American Acoustical Society 150th meeting in October 2005 contains more than just the 198 papers of that meeting. It includes the papers from the 1998, 99, 00, 01, 03 and 04 Noise-Con conferences plus the 1998 and 02 Sound Quality Symposia. The CD can be ordered from the INCE/USA page at Atlas Books on ww.atlasbooks.com/marktplc/00726.htm

Diary

2006

03 - 04 April, Southampton
Futures in Acoustics.
http://www.ioa.org.uk

02 - 05 May, Dresden
Int Conf on Speech Prosody.
http://www.ias.et.tu-dresden.de/sp2006

05 - 07 May, Copenhagen
6th International Conference on Auditorium Acoustics.
http://www.ioa.org.uk/viewupcoming.asp

08 - 10 May, Cambridge, MA, USA.
12th AIAA/CEAS Aeroacoustics Conference.
Web: http://www.aiaa.org

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

16 - 19 May, Singapore.
Oceans'06 Asia Pacific IEEE Conference.
http://www.oceans06asiapacific.org

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

12 - 15 June, Carvoeira
8th European Conference on Underwater Acoustics.
http://www.ecua2006.org

13-15 June, Cavtat
7th WSEAS Intl Conf Acoustics & Music: Theory & Applications
http://www.worldses.org/conferences/2006/croatia/amta/index.html

19-23 June Anconia
Vibration Measurements by Laser Techniques
http://www.aivela.org

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

26 -29 June, St. Petersburg, Russia.
11th International Conference on Speech and Computer.
http://www.specom.nw.ru

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

7-10 July, Athens
2nd Int Con From Scientific Computing to Computational Engineering
http://ic-scce2006.upatras.gr/

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

18-20 September, Leuven
ISMA2006, Noise and Vibration Engineering Conf
http://www.isma-isaac.be

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

18 - 20 September, Bristol.
12th Int Conf on Low Frequency Noise & Vib and Control.
http://www.lowfrequency2006.org

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

27-29 September, Sydney
8th National Injury Prevention Conference
secretariat@aipn.com.au

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

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

3-6 December, Honolulu
Inter-Noise 2006
Engineering a Quieter World
www.internoise2006.org

3-8 December, Brisbane
AIP Conference
www.aipc2006.com

2007

16 - 20 May, Honolulu,
IEEE Int Conf on Acoustics, Speech & Signal Processing (IEEE ICASSP 2007)
http://www.icassp2007.org

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

26-29 August, Istanbul.
Inter-noise 2007.
http://www.internoise2007.org.tr
27-31 August, Antwerp
INTERSPEECH 2007.
conf@isca-speech.org

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

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

2008

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

2010

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

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

Acoustics Australia

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Vol 33 2005

PAPERS

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NATIONAL MATTERS

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

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Spectrum House
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ST IVES NSW 2075
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