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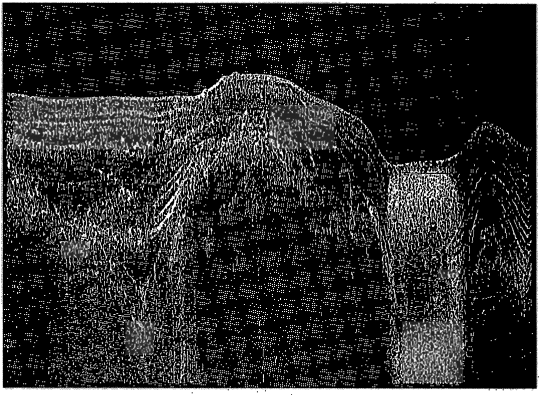

- Flute timbre
- Environmental noise
- Vocal tract resonances
- Monitoring a viaduct
- Underwater acoustic mapping

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Editorial

Over the 23 years of its lifespan, *Acoustics Australia* and it predecessor, the Bulletin of the Australian Acoustical Society, have served to keep the acoustics community in Australia aware of activities in acoustics around the country, as well as providing timely reviews of important areas of our subject. While we certainly look forward to continuing that role for our next quarter-century, we recognise that there are some areas in which new technology has particular advantages. It is therefore with some pride that we announce that *Acoustics Australia* has established a site on the World-Wide Web. Marion Burgess, of our Editorial Committee, and from the Acoustics and Vibration Unit at the Australian Defence Force Academy, has undertaken the task of setting up this information centre. The address is http://www.adfa.oz.au/~mxb

This Web site, the home page of which is entitled Acoustics in Australia, has several purposes, not all of which are yet established. Firstly it will provide information for contributors to *Acoustics Australia* about editorial policy, physical requirements for manuscripts and drawings, and other practical matters. It will similarly provide information about rates and other matters for advertisers and subscribers. But this is certainly not all. We aim to provide information about the Society itself, about conferences and short courses, and about graduate study in acoustics and vibration. The page will also provide links to material provided by acoustics consultants, universities, and government departments that maintain their own Web pages. The home page for Acoustics in Australia will similarly be cross-referenced in other information sources on the Web.

All of this takes time and effort, and we need your assistance. In our April issue, for example, we included a questionnaire about graduate work in acoustics in Australian universities. While we have certainly had some responses to this, I know that many of you have simply not got around to responding yet. Please do it soon, or your entry will be a blank! We plan to publish a summary of this material in *Acoustics Australia*, as well as making it available on the Web.

This venture is, I think, an example of the right sort of use for the internet. Those of us who use it regularly for e-mail and for computer file transfer give thanks continually for its existence, and it is clearly set to serve an important wider purpose in providing ready and world-wide access to information. The technology is there, although it still needs improving; the important thing is to ensure the quality of the information available. For this we will need the continuing help of the whole acoustics community.

There are some who see electronic communication as foreshadowing the demise of traditional printed books and journals. I now receive the Journal of the Acoustical Society of America on CD-ROM, with a consequent great saving of shelf space, but it is still simply an electronic version of the journal that I can easily convert to printed form. On the other hand it will surely not be long before telephone directories and similar printed data sets are obsolete, and no-one would contemplate printing them out. It would also be great to see daily newspapers, and similar ephemeral material, simply down-loaded onto portable electronic screens for reading and discard, with a resulting huge saving in trees. But for a conveniently accessible record of human thought that can be relied on to survive for a thousand years and still be readable, there is nothing yet devised that can match the printed book. I do not pretend that *Acoustics Australia* merits preservation on this time-scale, though I have recently found occasion to cite a paper that we published in 1976. Perhaps by the end of our next quarter century you will receive the journal in electronically coded form, but this will be a change in the medium rather than in its fundamental structure, and in this case surely the Medium is not the Message!

But enough pseudo-philosophy! I hope that the Australian acoustical community will find our new venture helpful, and that you will support it by keeping the message up to date.

Neville Fletcher

Timbre and Loudness of Flute Notes

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Abstract: Spectrum analysis of flute sounds published by Fletcher [*J. Acoust. Soc. Am.* 57, 233-237 (1975)] has been used to compute loudness level and tristimulus coordinates for three notes C_4, C_5, C_6 played both loud and soft by four players. The differing timbre values for the same note played by the four flutists and the differences between loud and soft notes are clearly revealed in tristimulus diagrams.

1. INTRODUCTION

As part of a study of the physical parameters involved in flute playing, Fletcher [1] presented tonal analyses of three notes played both loud and soft by four flutists. For the note C_4 the fundamental was found to be lower in level than either the second or third harmonics and remained at the same level for both loud and soft playing. For both C_5 and C_6 the fundamental was the dominant partial tone for both loud and soft playing but changed little in level. For all notes there was a marked reduction in the levels of the higher harmonics during softer playing. Both the loudness and timbre are dependent on the level of higher harmonics compared with the fundamental. In this paper the spectrum data has been reprocessed to quantify the changes in timbre and loudness that occur between loud and soft playing.

2. LOUDNESS

Fletcher's spectrum measurements have been grouped into 1/3 octave bands and the band levels converted into loudness values using standard ISO procedures [2]. Harmonics 1 to 6 fall in separate bands but it is necessary to combine spectrum levels for the higher harmonics since more than one harmonic falls within each band. Table 1 includes the mean loudness level in phons, the standard deviation and coefficient of variation (standard deviation divided by the mean) for each of the notes C_4, C_5, and C_6 played soft and loud by the four flutists.

3. TRISTIMULUS COORDINATES

Steady musical sounds are often analysed in terms of three main parameters: pitch, loudness and timbre. These parameters are not always independent. One method of presenting timbre information is to compute tristimulus values [3,4] which are independent of pitch and loudness. From 1/3 octave band loudness values, three normalised tristimulus coordinates may be computed:

$$x = N(5,n) \ / \ N$$
$$y = N(2,4) \ / \ N$$
$$z = N(1) \ / \ N$$

where $N(1)$ is the loudness of the fundamental, $N(2,4)$ is the loudness of partials 2-4, $N(5,n)$ is the loudness of partials 5-n, N is the total loudness, and $x + y + z = 1$. The loudness of each group is computed using Stevens Mark VII method [5].

Using the fundamental of the note as reference renders the analysis independent of pitch while the normalisation procedure renders the analysis independent of loudness. A further advantage of using normalised coordinates is that the data can be represented by a 2-dimensional diagram using a selected pair of coordinates. For flute notes, plotting x versus z is useful for showing the relative changes between the higher partials *(x)* and the fundamental *(z)*.

Figure 1 is a set of *x-z* tristimulus diagrams for the notes C_4, C_5, C_6 played both soft and loud by the four players A, B, C, D; solid squares represent loud notes, open circles soft notes. The points for C_6 all lie on the z-axis since $x = 0$ for all these points (there are no significant partial tones higher than the fourth).

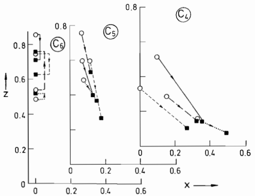

Figure 1. *x-z* tristimulus diagrams for flute notes C_4, C_5, C_6 played both soft (open cirles) and loud (solid squares) by players A, B, C, D. The lines point from soft notes to loud: solid lines player A, heavy dashed lines player B, dotted lines player C, light dashed lines player D. The points for C_6 all lie on the z-axis since $x = 0$ for these points. The mean distances (in tristimulus units) between soft and loud notes are: C_4 0.30, C_5 0.23, C_6 0.13.

Table 1. Mean values, standard deviation (SD) and coefficient of variation (% varn) for the loudness level and tristimulus values of notes C_4, C_5, C_6.

	Loudness Level (phons)	*x*	*y*	*z*
C_4 soft				
mean	29	0.142	0.536	0.322
SD	7	0.12	0.10	0.13
% varn	23	83	19	40
C_4 loud				
mean	45	0.356	0.525	0.119
SD	1.4	0.08	0.07	0.03
% varn	3	23	14	24
C_5 soft				
mean	39	0.082	0.310	0.609
SD	2.5	0.02	0.09	0.10
% varn	6	23	30	16
C_5 loud				
mean	48	0.144	0.467	0.390
SD	3	0.02	0.07	0.10
% varn	6	16	16	24
C_6 soft				
mean	37	0.000	0.346	0.654
SD	5	–	0.15	0.15
% varn	13	–	42	22
C_6 loud				
mean	50	0.000	0.347	0.653
SD	4	–	0.09	0.09
% varn	7	–	27	14

For notes C_4 and C_5 the lines joining soft to loud notes all slope downwards to the right indicating significant shifts away from a predominantly fundamental tone to a brighter tone containing more higher partials in accordance with Fletcher's observations.

Table 1 includes the mean value, standard deviation and coefficient of variation of *x, y, z* for each set of soft and loud notes. Note that the means of the data for both C_6 soft and loud notes overlap.

Fletcher also studied the effects produced by vibrato, an important contributing factor in assessing timbre. Vibrato can be studied by analysing segments of the steady tone [6] but such data is not included in this study.

4. CONCLUSION

From spectrum analysis of a set of musical notes and grouping of partial tones into 1/3 octave bands, measures may be derived which quantify the timbre of the notes. Computation of tristimulus coordinates and two-dimensional graphs using selected pairs of coordinates provide valuable tools for the understanding, design or teaching of a musical instrument.

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Progress in Underwater Acoustic Geo-mapping Technology*

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Abstract: The Shanghai Acoustics Laboratory of Academia Sinica has been involved in the development of underwater sound-sources and geo-acoustic processing techniques over the past 30 years. A range of underwater acoustic mapping systems (geo-sonar systems, and suspended-sediment monitoring systems) has been produced for applications in harbour construction, waterway dredging, seafloor engineering, marine resource exploitation and marine geological studies. The features and performances of these systems are described, and several new techniques employed in their implementation, pulse-compression with complementary coding signals and pattern recognition of acoustic profiling records, briefly introduced.

1. INTRODUCTION

Since 1964 the Shanghai Acoustics Laboratory of Academia Sinica (SAL) has been working on a series of projects to develop various underwater acoustic devices for different applications in harbour construction, waterway dredging, seafloor engineering, marine resource exploitation, and marine geological studies. Several kinds of geo-sonar systems suited to different environments (river, lake or sea), and acoustic suspended-sediment monitoring systems for sediment concentration profiling have been produced. To implement the acoustic geo-mapping technology, studies on the remote measurement of acoustic velocities of sea-bed layers have also been carried out [1,2], and a number of novel techniques developed, such as pulse-compression with complementary coding signals [3] and pattern recognition of acoustic profiling records [4].

2. DEVELOPMENT OF GEO-SONAR SYSTEMS

The geo-sonar system or acoustic sub-bottom profiling is a most effective device for exploring the upper sea-bed sediment layers. Consequently many kinds of geo-sonar systems have been produced and extensively used for marine geological surveys throughout the world. To meet the needs of many institutions in China involved in research and engineering projects, several types of geo-sonar systems with specified performances in resolution or penetration have been developed by SAL over the past years.

A. High-resolution geo-sonar systems

The key to developing a high-resolution geo-sonar system with good quality of sub-bottom profiling is to have a strong impulsive sound source with a suitable output signature (a peak followed by a very short ring) and directional pattern (very low sidelobes and back radiation). Acoustic arrays composed of 4 or 6 small size boomers (which are a kind of underwater impulsive sound-source driven by a strong electro-magnetic induction force) were developed and successfully applied in these high-resolution geo-sonar systems. By appropriately optimising the size of the radiating plate and the electrical parameters (inductivity and capacity) of the boomer, the frequency band of sound transmission could be varied in the range of 0.5–8 kHz, and a source level of 210 dB (re 1 μPa) achieved.

New techniques in geo-acoustic signal processing have also been developed and effectively used in these systems. These are: 1. multi-section time varying gain control for compensation of sound transmission losses caused by spherical spreading and absorption in sediments; 2. sea bottom tracking for hands off operation of the geo-sonar system; 3. time varying filtering for increasing the ratio of echo signal to background noise (S/N) and reducing multi-reflections between sea bottom and sea surface; 4. synthetic aperture processing (or signal stacking) for enhancing S/N and improving the resolution along the navigation line.

As a result of this improvement in performance of impulsive sound sources and signal processing techniques, three types of high-resolution geo-sonars (QPY–1, GPY and PGS) have been successively developed with specifications of layer resolution 0.1–0.3 m and soft-sediment penetration 50–100 m, and used in the water depths from several meters to 100 m. So far, over 8,000 km of marine geological surveys have been made by the GPY geo-sonar. A typical profiling record is shown in Fig. 1.

* *This paper was presented at the International Conference on Underwater Acoustics held at the UNSW, 5-7 December 1994.*

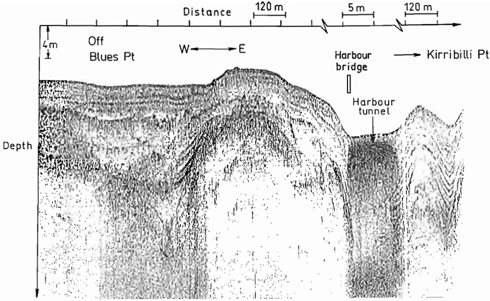

Figure 1. A profiling record using the GPY in Sydney Harbour, tracking from off Blues Point eastwards, and under the Harbour Bridge towards Kirribillii Point. Note change of distance scale as the boat as allowed to drift cross the tunnel.

B. Deep penetration geo-sonar system

For marine geological surveys in different areas of the West Pacific Ocean a large acoustic sub-bottom profiling system, the DDC1–1 geo-sonar has been developed [5]. This system comprises: 1. an electrical spark unit of 30 kJ; 2. an empennag-like underwater with an equally spaced coaxial construction between four pairs of positive (at the centre) and negative (at the edges) poles; 3. an echo-processing unit involving several of the above described signal processing techniques; 4. a 50 m long streamer with 20 hydrophones separated each by 2m; 5. a graphical recorder for real-time drawing of sediment profiles and a tape recorder for further data processing.

Developed with specifications of layer resolution 10–30 m and sediment penetration 1000 m, the system has provided valuable profiling records of hundreds of nautical miles of the continental shelf and slope areas in the East China Sea. A significant discovery was a sediment layer more than 500 m thick in the area of the Ryukyu Trench.

Figure 2 shows a reproduction of a seismic scan across the trench(the steep hard sides of the trench are evident as well as the softer sediments at the bottom of the trench. Some success has also been achieved in finding manganese nodules in water depths of 5400 m.

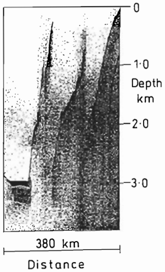

Figure 2. Seismic scan across the Ryukyu Trench using the DDCI–1. Note the two changes of zero in the recording.

3. SEDIMENT SUSPENSIONS IN WATER

The principle of acoustic back-scattering [6] has been utilised to measure concentrations of suspended sediments in the water column, and to monitor sediment dynamics in the benthic boundary layer. The equipment developed permits the continuous observation of real time concentration profiles of the suspended sediment without disturbing the environmental conditions around the observed site and is suitable for the observation of marine dynamic processes such as monitoring pollutants and zooplanktons in water, and for studies of sediment transport and deposition occurring in such areas as river mouths, waterways, bays and reservoirs.

The suspended sediment monitoring system is essentially a high-resolution geo-sonar system with an operating frequency above 200 kHz. Three parameters (observing time, water depth and intensity of back scattering) are required to be measured in real time for deriving the three dimensional concentration profiles of the suspended sediments. To suit different applications, two types of monitoring systems have been developed [7]—(the ASSM–1 for fixed site observations and the ASSM–2 for on-boat observations. Both systems comprise a signal transmitter, a back-scattered signal receiver and one or two underwater transducers all controlled by a computer.

Figure 3 shows some of the components of the ASSM–1 system mounted on a large four legged framework which is placed on the seafloor. These include two underwater transducers (at 0.5 and 1.5 MHz) for upwards and downwards observations, a pressure case enclosing electronics and 4 sensors for measurements of water temperature, water depth, current speed and orientation. A second system, the ASSM–2, is suspended into the water from the side of a boat during observation, and uses one underwater transducer (at 0.5 MHz) for downwards observations only.

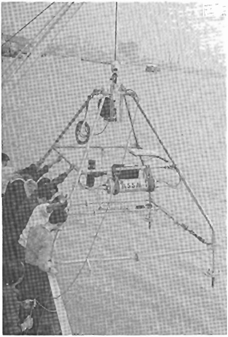

Figure 3. The ASSM–1 suspension monitoring system being deployed in the Yangtse River, China.

In both the ASSM 1 and 2 systems, transmission, reception and processing are controlled by computer. A three dimensional concentration profile of suspended sediment (depth vertically, time horizontally and the magnitude of concentration in different colours) can be directly viewed on a monitor in real time. Further data processing, such as compensation for sound transmission losses, in-situ calibration of scattering intensity to real concentration and averaging of the sampled data over different time-depth window sizes, permits three-dimensional concentration profiles to be printed out in a data table or as a set of graphs. (see Fig. 4).

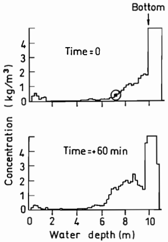

Figure 4. Typical records of suspended sediment concentration profiling by the ASSM–2 in the Yangtse River, China at two successive times. (Calibration point circled.)

The specifications of ASSM–1 and ASSM–2 are as follows:

1. maximum monitoring depth, 10 m
2. depth-resolution of concentration profile, 20 cm
3. time-resolution of concentration profile, 1 s
4. beam-width of observed region, 1.5°
5. measurement range of suspended-sediment concentration, 0.1–10 kg/m
6. statistical error of measurement (after in-situ calibration), 20%.

4. RECENT DEVELOPMENTS

A. Pulse-compression with complementary coded signals

Chirp sonar is a newly developed technology for acoustic profiling of the sea-bed [8]. The technique offers many advantageous features(smearing out of the sidelobes in the transmitted beam, a high signal to noise ratio in the recovered signal by cross correlating the recovered and transmitted signals to form a narrow compressed pulse. The pulse however may show significant sideband structure due to the correlation, and we have further developed the technique to reduce them(by the complementary coding of the signals [3]. (A pair of pulse sequences r1 are said to be complementary if the sum of their autocorrelations is null for delay times other than zero.) Thus two sets of coding signals of mixed polarities satisfying complementarity are transmitted alternatively. The return signals are autocorrelated and summed successively as they are received. Consequently only a single peak with no side bands is seen on the output signatures because of the definition of a complementary pair.

In practical applications problems arise if the travel times of echoes from a certain sediment layer are different due to up and down motion of the transmitting and receiving transducers. In the case where the movement is significant, the variations of intervals between every two adjacent units in the return signal may differ. As a result, successive correlations cannot be added exactly one to one in time (This is called the decomplement effect). Also the signatures of both correlations may themselves be distorted considerably due to wave induced modulation (called the decorrelation effect). Through computer simulations, it has been confirmed that the decomplement effect can be eliminated by a simple echo travel time compensation using a sea-bottom tracking technique, and that the decorrelation effect of wave modulation can be ignored in the cases where the wave-height h < 1.5 m and the wave-period T > 1 s (i.e. below sea-state 4)

B. Machine pattern recognition of acoustic profiling records

The characteristics of acoustic profiling records vary with different kinds of marine sediments and can be used to predict geological features. However this is often time consuming and expensive and much work is being done to develop automatic or machine based classification systems. In our "expert" system seven characteristic patterns exhibited by profiling records, each with three different states, have been defined on the basis of our previous experiences in the field and are shown in Table 1.

Ten different categories of marine sediment may be identified by different combinations of these characteristics as follows:

1. mud	A1,B1,C1,D1,E1,F1,G3
2. mud with silty sand	A1,B1,C1,D1,E1,F1,G1
3. mud and sandy clay	A1,B1,C1,D1,E1,F1,G2
4. mud and sand	A1,B1,C2,D2,E2,F1,G1
5. silty and fine sand	A2,B2,C1,D2,E3,F1,G1
6. gravel and coarse sand	A3,B3,C3,D3,E3,F1,G3
7. densified fine sand	A3,B2,C2,D2,E1,F1,G3
8. clay	A3,B2,C2,D2,E3,F2,G3
9. sandy clay	A3,B2,C2,D2,E3,F2,G1
10. rock	A3,B3,C2,D3,E3,F3,G3

The probability of every characteristic in determining the geological category of sediments has been calculated through an analysis of the statistics of extensive field measurements and records. Consequently, a computer-based pattern recognition system based on Zadeh's fuzzy set theory has been developed to produce a geological classification of each sediment layer shown on the acoustic profiling record.

An example is shown in Fig. 5, in which the left side is an acoustic profiling record obtained at Amon Port in China, and the right side is the corresponding geological profile after interpretation by this system. The figures in brackets are the probabilities corresponding to each prediction.

An alternative system called the dynamic reasoning system has also been developed using a principles similar to the computer based medical consultation (MYCIN) system [9]. Starting from an initial premise characteristic and following a "context-tree" with 18 reasoning rules, this system successively collects the next premise characteristic and makes the next reasoning step to a final conclusion. Its usefulness compares with that of the above "expert" system.

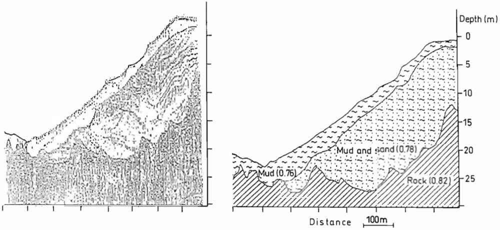

Figure 5. An example of geological interpretation by machine recognition. Left side: an acoustic profiling record at the Amon Port, China; right side: the geological profile derived after interpretation.

Table 1. Pattern characteristics of acoustic profiling records

Characteristic	Code	State		
		1	2	3
1. darkness between layers	A	light	medium	dark
2. variation of darkness between layers	B	none	slow	fast
3. size of scanning points	C	small	medium	large
4. smoothness of sub-bottom line	D	smooth	medium	rough
5. thickness of sub-bottom line	E	fine	medium	thick
6. undulation of sub-bottom line	F	small	medium	large
7. shape of lines between layers.	G	disjointed	jointed	no lines

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Real Time, Non-Invasive Measurements of Vocal Tract Resonances: Application to Speech Training

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Abstract: This study reports the determination in real time of the frequencies of the first two resonances of the human vocal tract from measurements of the acoustic impedance spectrum of the tract in parallel with the external field. The measurements were made using a broad band, frequency-independent acoustic current source, a microphone and a spectrum analyser which displays the acoustic impedance spectrum. The display provided real-time, visual feedback whereby subjects learned to imitate target vowel sounds without hearing them. Inexperienced subjects who used this feedback produced sounds that were approximately as well recognised as those produced by the same subjects imitating target vowel sounds after listening to them. The recognition rate improves with the subjects' experience in using the impedance feedback technique. This non-invasive technique could thus have possible applications in speech training and language teaching.

1. INTRODUCTION

Everyone who speaks has learned that different vowel sounds are produced by different shapes of mouth and tongue. Most adults who learn a foreign language know also that it is difficult to find the exact shape that will produce an authentic vowel sound from that language. This study reports the use of a technique[2] which measures two of the most important acoustic parameters of the vocal tract in real time. One possible application is in speech training and language teaching.

Phoneticians arrange vowels in a space whose two dimensions are the mouth opening (negative y axis) and the horizontal position of the tongue (x axis) [1]. Acousticians arrange vowel sounds in a two dimensional space whose dimensions are the frequencies of the first two formants [2]. With suitable choice of directions of axes, the relative positions of the vowels in these two representations are the same [3]. This similarity is usually explained thus: the formants in the sound are due to the first two resonances of the vocal tract, and the frequencies of these resonances are largely determined by mouth opening and tongue position [4]. The first two formants are traditionally called called F1 and F2. We shall call the first two resonances R1 and R2 in order to distinguish between formants (features of the sound) and resonances (features of the tract that produces it).

Direct measurement of the resonances of the vocal tract has both intrinsic and practical interest. The frequencies of resonance of the tract are functions only of properties of the tract (its geometry and the mechanical properties of the air it contains and its walls) and they can be measured and defined relatively precisely. The frequencies of formants in voiced speech are more difficult to measure precisely because the output sound depends on the waveform input at the glottis as well as on the transmission and radiation properties of the tract. Sundberg has measured the resonances by mechanical excitation at the throat and measurement of the radiated sound [5], and Badin and colleagues have used this technique to measure the transfer function [6,7].

The principal aim of this paper is to investigate whether real-time, non-invasive measurements of the first two resonances can be used to provide a visual feedback in speech training. Such feedback could be useful to those who have inadequate auditory feedback. One case is those with severe hearing impairment. Another is that of adults learning foreign languages: such students often find it difficult to distinguish between the the target sound (e.g. the sound of a vowel as produced by a native speaker) and their attempt to imitate that sound. This problem is attributed in part to categorisation: a listener who has learned to divide speech sounds into the finite categories of his/her own language has a tendency to divide sounds in a new language according to those same divisions [8].

Why is it necessary to measure R1 and R2 to provide visual feedback? If the object is to imitate a sound, why not just imitate the waveform? While it is true that the same waveform implies the same vowel, it is not true that two examples of the same vowel must have similar waveforms. This is especially the case if the sounds have different pitch. Figure 1 shows five oscillograms. Four are examples of the same vowel pronounced with different pitch and loudness (a,b,c,d). The fifth (e) is a different vowel. Of these five, the two which appear most similar in shape are (a) and (e). Further, it is not a simple task to distinguish vowels from inspection of the spectrum alone. The problem in this case is that the spectrum of a voiced vowel with fundamental frequency f_0 has frequency components f_0, $2f_0$, $3f_0$ etc. In

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[2] This technique is the subject of a patent application PCT/AU95/00729

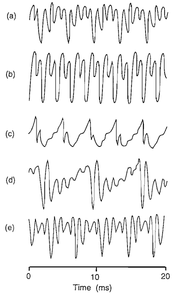

Figure 1. Oscillograms of five vowels with arbitrary amplitude. 1a, 1b and 1c were spoken by the first author (a soprano). 1a is that of the vowel /ɑ/ (as in "hard") at normal conversational pitch and volume. 1b is that of /ɑ/ at higher pitch and normal volume. 1c is that of /ɑ/ at normal pitch and lower volume. 1d is that of /ɑ/ spoken by the third author (a bass). 1e is that of the vowel /æ/ (as in "had") spoken by the first author at normal conversational pitch and volume.

the case where $f_0 << R1$ (a bass voice in its low register), the sampling of the spectral envelope is usually adequate to estimate R1 and R2 reliably. For high pitched voices, including those of children, f_0 is often of the same order as R1, or even higher, so the sampling of the spectral envelope is not adequate for the identification of R1, and sometimes even R2 cannot be estimated accurately[3].

This study reports the determination of the frequencies of the first two resonances of the human vocal tract from measurements of the acoustic impedance of human vocal tracts in parallel with the external field. The measurements were made from a position outside but near the lower lip, using a broad band acoustic current source, a microphone and a spectrum analyser which displayed the results in real time (< 100 ms). This display then provided visual feedback. The system was then used as a speech trainer, and its performance was compared with those of two other forms of feedback (Figure 2). In one series of trials, a photograph of the lower face of the speaker pronouncing the target vowel was showed to subjects who were then asked to imitate the mouth geometry of the speaker and to phonate (this protocol conveys the information about the vowel that is conveyed in speech reading, also called lip reading). In another series, the subjects heard a recording of the speaker pronouncing the target vowel and were asked to produce the same vowel. This protocol is a model of the feedback usually available to those learning to speak.

2. MATERIALS AND METHODS

2.1 Acoustic impedance

Acoustic impedances were measured using a technique described in detail previously [10,11]. Briefly: a computer produces a periodic waveform comprising the sum of many sine waves. This is output via a digital-analog converter to an amplifier and then to a loudspeaker. On one side of the speaker is a sealed enclosure; on the other is an impedance matching horn which connects it acoustically to an annular acoustic resistor. This resistor has an acoustic output impedance of 33 MRayl which is larger than the loads measured (typically 1 MRayl), so the source approximates an ideal current source. The sound source (the output of the acoustic resistor) is located next to a microphone in a measurement head. The microphone measures the acoustic pressure produced and its signal is input to a spectrum analyser. The digitised waveform output by the computer is calculated during a calibration procedure using a resistive load. The coefficients of the sine terms in the synthesized waveform are calculated so as to compensate for the frequency dependence of the amplifier, loudspeaker, impedance matching horn, output impedance and microphone, so the output acoustic current has the same amplitude for all frequency components. The pressure spectrum measured by the microphone is therefore proportional to the acoustic impedance at the measurement head.

A finite signal to noise ratio and a finite measurement time together impose a maximum information content in any measurement. A compromise must therefore be made for the acceptable values of frequency range, frequency resolution, amplitude resolution and measurement time. The signal to noise ratio in these experiments was limited by three constraints. First, the digital analog card used was only 12 bit. Second, the measurements were made in a room with a background noise of typically 45 - 55 dBA. Third, the external field is a low value acoustic impedance in parallel with the vocal tract. We decided not to improve these conditions for this study because a practical speech trainer ought be simple, non-invasive and able to work in a classroom environment.

[3] This raises the obvious objection that, since human ears and brains can usually identify vowels from the sound, even when spoken by high-pitched voices, it should be possible for a measurement system to do so as well. There are two obvious responses. First, human ears and brains do sometimes have problems in identifying vowels with a constant high pitch. Second, human brains have the added information of linguistic and syntactic context, and the relatively high redundancy of human speech [9]. A listener who is familiar with English will know which of the the syllables "hud" and "had" is intended by an English speaker because the first is not an English word. A listener will know which of "he heard me" and "he head me" is intended because the latter is not an English sentence.

The frequency range was chosen as 200 - 2500 Hz, with a resolution of 25 Hz. Thus the output current was a periodic waveform produced by summing 93 sine waves with frequencies 200, 225, 250... 2500 Hz. The microphone power spectrum was displayed using a Spectral Innovations MacDSP card in a Macintosh II computer implementing a Fourier transform with a sampling rate of 15.62 kHz and a Hamming window. The microphone and the output of the acoustic resistor were mounted 10 mm apart in a block of nylon used as a measurement head. This head was placed against the subject's lower lip for vocal tract measurements. For calibration, the measurement head was used to seal one end of a 35 m tube. During a measurement lasting less than 200 ms, the reflection does not return from the distant end of this tube, so it is effectively infinite and therefore a resistive load [13].

2.2 Preliminary subject training

For most people, the relaxed position of the vocal tract at rest (i.e. when not phonating) has the velum (soft palate) lowered towards the dorsal aspect of the tongue. It was therefore necessary to show subjects how to hold the vocal tract in the phonating position while not phonating. Two different methods of feedback were used to teach this technique. Using a mirror, subjects found that they could see the palate in the relaxed position, and that when they phonated (saying "ah"), it lifted and they could see the backs of their throats. They were then asked to practise lifting the palate without phonating. The other method used the measurement of acoustic impedance: with the palate raised, two resonances were usually observed in the range of the impedance spectrum; with it lowered, only one resonance was observed. Most volunteers learned this skill in about 10 minutes, although some did not learn in 30 minutes and were not included in the study. More volunteers over the age of 25 (75%) than under this age (15%) were unable to learn this skill in 30 minutes.

2.3 "Target" vowel sounds and "target" impedance spectra

Two speakers (one male and one female) were chosen to produce vowel sounds and corresponding impedance spectra which were to be imitated by the test subjects. The male speaker was 22 years of age and had lived most of his life in the North of Sydney and has a mild Australian accent. The female speaker was 21 years of age and had lived the last 10 years in the North of Sydney. Her accent is predominantly Australian, but with a slight trace that suggests she is not a native English speaker. Both have university educations.

Nine vowels were chosen for this study: /ɛ/ as in "head"; /ɜ/ as in "heard"; /ɑ/ as in "hard"; /æ/ as in "had"; /ʌ/ as in "hut"; /ɒ/ as in "hot"; /ɔ/ as in "hoard"; /ʊ/ as in" hood"; /u/ as in "who'd". For each vowel, the speakers pronounced a sustained vowel which was digitised and recorded by a Macintosh computer. Immediately after they ceased phonating, an impedance spectrum was measured. This was repeated several times and the means and variances in the frequencies of the first two resonances were noted. The mean values were used as the target values, and the target sound was the vowel sound recorded immediately before the impedance spectrum whose resonances most closely approached the mean values. A photograph was taken of the lower half of the face of each speaker pronouncing each (sustained) target vowel.

2.4 Vowel imitation tests

Subjects were asked to imitate the nine target vowels using three different feedback methods.

i) **Photograph only.** This was designed to convey, under controlled conditions, the information that is available when speech reading ("lip reading"). During these tests, the subjects wore headphones playing white noise to mask other sounds and so to minimise the subjects' use of the sound of their own voice as a clue to modify the sound they were producing. The subjects were shown the photograph of the lower half of the speaker (of the same sex) pronouncing the target vowel. They were instructed to imitate the mouth position of the speaker and to phonate. This sound was recorded on a cassette recorder. An impedance spectrum was measured immediately following the phonation. This procedure was repeated three or four times for each vowel. (Figure 2a.)

ii) **Impedance spectrum plus photograph.** During these tests, the subjects wore headphones playing white noise to mask other sounds and so to minimise their use of the sound of their own voice as a clue to modify the sound they were producing (Figure 2b). The measurement head was placed at the subject's lower lip, and the impedance spectrum was continuously displayed on a monitor in the subject's view. The subjects were permitted to practise varying the frequencies of the two resonances in acoustic impedance, Z(f), and were told that opening the mouth raised R1 and that bringing the tongue forward raised R2. For each target vowel, a transparent sheet was placed over the monitor screen, positioned so that two vertical lines drawn on the transparency indicated the frequencies of the first two resonances of the target vowel, as articulated by the target speaker of the same sex. The photograph of the lower half of the speaker's face was also displayed. Subjects were instructed to use the photograph as a starting position, and then to move tongue and mouth such that the local maxima in Z(f) coincided with the target values. When the subject was satisfied that s/he could not easily improve the degree of match, s/he phonated and the sound was recorded on cassette tape. Z(f) was stored and the resonant frequencies noted. Each subject had three or four attempts at each vowel.

iii) **Auditory.** For these tests, the subject wore headphones through which were played the recordings of the target vowels pronounced by the speaker of the same sex as the subject (Figure 2c). The subject could listen to each vowel as many times as s/he liked, and could hear his/her own voice and thus adjust the sound to match that of the target. When s/he was satisfied with the match, the phonated sound was recorded and, immediately afterwards, an impedance spectrum was measured.

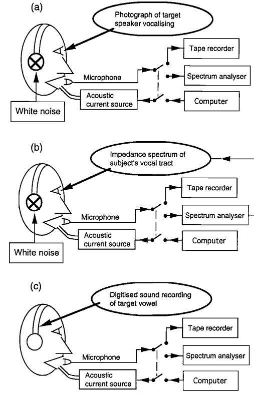

Figure 2. A schematic representation of the three different protocols used for the imitation of vowel sounds. In the first (2a) the subject sees only a photograph of the lower face of the target speaker. In the second (2b) s/he sees both the photograph and the impedance spectra of his/her own vocal tract, upon which is superimposed the frequencies of the resonances of the vocal tract of the speaker when producing the target sound. In the third (2c) the subject sees nothing, but hears a recording of the speaker pronouncing the target vowel.

2.5 Subjects

Nine subjects (six males and three females) each recorded at least once the complete nine vowel set using the three different feedback methods. 350 spectra and 470 vowel sounds were recorded. 5% of these were discarded because of either poor quality recording (extremes of sound level or wind noise), or the inability of the subject to maintain constant position with his/her tongue and lips.

Six speakers were born outside of Australia. Of these, four learnt a language other than English as their first language. This was not a deliberate attempt to include more variables, but rather the result of finding volunteers in a multi-cultural society. Two of the subjects did the complete set of imitations of all vowels twice. One of these subjects was a female, 13.5 years old, whose native language is Russian and who has lived in Sydney for 2.5 years and has an accent that is predominantly Australian, but with a trace indication that English is not her native language. The other was male, a native English speaker, had lived in Australia for 40 years and has a mild Australian accent. The data and recordings of these subjects were used for further analysis to investigate improvements in imitation between first and second trial.

2.6 Listening panel

The sounds recorded by the reference speakers, and the imitations made by the two subjects who completed the series twice (135 sounds in total) were transferred in random order onto a cassette tape. This tape was played independently to each member of a listening panel of six native English speakers (aged from 22 to 46 years). The listening panel were given a list of nine vowels described as the vowel sounds in the words "head", "heard", "hard", "had", "hut", "hot", "hoard", "hood" and "who'd". The sounds were each played four times, and the listeners could replay any sound if desired. They were asked to decide which of the nine listed vowels was most closely approached by the sound they had just heard. If undecided, they were instructed to leave that entry blank on the response form.

3. RESULTS AND DISCUSSION

Figure 3a shows the pressure spectrum recorded when the measurement head was connected to the "infinite" tube after calibration. The output signal of the digital-analogue converter has been adjusted to reduce the frequency dependence of the pressure spectrum to less than 0.1 dB r.m.s. into such a resistive load [10]. The acoustic current is therefore also independent of frequency. Further, because the output resistance of the source is high, this current is independent of external loads with low impedance. The measured pressure spectrum is therefore approximately proportional to the acoustic impedance of a load connected to the measurement head. The 25 Hz "ripple" in the nominally flat spectrum is due to the sampling frequency. This low resolution in frequency was a necessary compromise to allow measurements in the noisy, low-impedance laboratory field.

Figure 3b shows the measured pressure spectrum with the measurement head positioned next to the lower lip of a subject with his mouth closed. In a free field, the acoustic impedance Z(r) at a point r from an isotropic source is $\rho cjkr/(1 + jkr)$ where ρ is the density of the medium, c the speed of sound, k the wave number and $j = \sqrt{(-1)}$. The measurement head is much smaller than 1/k for the wavelengths considered here, so $r << 1/k$. For most of the frequencies used here, the dimensions of the subject's head are comparable with or larger than the wavelength, so his face acts as a baffle. Thus the sound is radiated into approximately 2π steradians, rather than 4π, which approximately doubles the impedance. For a small measurement head and an infinite baffle $Z(r) \approx 2\rho cjkr$. This condition is roughly approximated by the experimental arrangement, which explains the rise of about 3 dB/octave in the measured impedance spectrum.

Figure 3c shows the spectrum measured at the lower lip of the male target speaker with his tract prepared to pronounce /ɒ/ (as in "hot"). This is a measurement of the impedance of

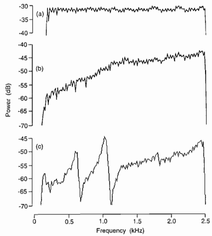

Figure 3. The measured pressure spectrum using the measurement head with three different loads. 3a shows the measured spectrum when the head is connected to an "infinite" tube for calibration. 3b shows the spectrum measured at the lower lip of a subject in the laboratory field, which his mouth closed. 3c shows the spectrum measured at the lower lip of the male target speaker with his vocal tract prepared to pronounce the vowel /ɒ / (as in "hot").

his vocal tract in parallel with that of the field of the laboratory. The latter is a low impedance shunt which dominates the measurement except at resonances of the vocal tract. Resonances are seen at 0.6 and 1.0 kHz. Note that the impedance rises and falls below and above the resonance frequency. The lab field impedance, including the baffle, is inductive. The impedance of the tract is capacitive below resonance and inductive above resonance, so the parallel impedance is respectively higher and lower than that of the lab field. There is some noise present at around 200-300 Hz. This noise was one of the reasons that led us to exclude the vowels /i/ and /I/ from this study. In Australian English, these vowels have R1 in the range 200-350 Hz. Further, the low and wide mouth opening associated with them means that relatively little acoustic energy from the measurement head enters the mouth. This low signal and the high noise in the relevant frequency range meant that we could not reliably determine R1 for these two vowels with the current version of the apparatus.

Figure 4 shows plots of the resonances (R1,R2), as determined from the impedance measurements, for the nine vowels studied for the female subjects only. The (R1,R2) of the target vowels are indicated by the heads of the arrows. Figure 5 shows the analogous data for male subjects only. Subjects attempted to imitate the vowels of the target speaker of the same sex. Flanagan [12] reports that the adult female vocal tract is on average 0.87 times the length of the male vocal tract, and this difference affects the range of formant frequencies. The values for (R1,R2) in Figure 5 are similar to, but not identical to, the mean values of (F1,F2) reported by Bernard [14] for 100 Australian speakers of English using a spectrograph. In all cases, the shaded ellipses represent the attempts by the subjects to imitate the target vowels. The centre of each ellipse is located at the mean values of R1 and R2 for the imitation of that vowel. The horizontal and vertical semi-axes of each ellipse are the standard deviations in the R1 and R2 of the imitations.

Figures 4a and 5a show the (R1,R2) of the imitations made by the subjects using only the photograph of the target speaker. As might be expected of a method that gives little information about the position of the tongue, the data are rather scattered. There is less scatter in R1, which is determined predominantly by mouth opening and less by tongue position, and more scatter in R2, which is determined largely by the front-back position of the tongue, a parameter which cannot easily be determined from the photograph. All of the subjects spoke English fluently, and all knew that they were imitating phonemes in Australian English. This

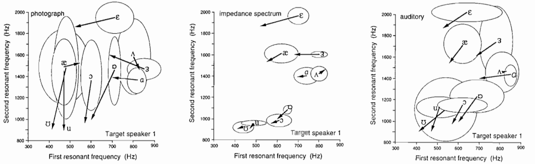

Figure 4. The vocal tract resonant frequencies (R1,R2) for the target vowels spoken by target speaker 1 (indicated by the heads of the arrows) and the mean values of (R1,R2) for the imitations (tails of the arrows) by the subjects using three different feedback protocols. Figure a shows photograph only, b shows photograph plus impedance spectrum, c shows auditory feedback. The horizontal semi-axis of each shaded ellipse is equal to the standard deviation of R1 in the imitations, and the vertical semi-axis is that in R2. Speaker 1 was female and the data are those of the female subjects imitating her target vowels.

/ɛ/ as in "head"; /ɜ/ - "heard"; /ɑ/ - "hard"; /æ/ - "had"; /ʌ/ - "hut"; /ɒ/ - "hot"; /ɔ/ - "hoard"; /ʊ/ - "hood"; /u/ - "who'd".

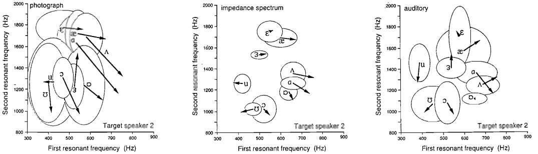

Figure 5. As for Figure 4, but for target speaker 2 (a male). The data are for the male subjects.
/ɛ/ as in "head"; /ɜ/ - "heard"; /ɑ/ - "hard"; /æ/ - "had"; /ʌ/ - "hut"; /ɒ/ - "hot"; /ɔ/ - "hoard"; /ʊ/ - "hood"; /u/ - "who'd".

information may have resulted in smaller scatter than would have been the case if the photographs were the only information. For instance, the vowel /ɛ/ has an unambiguous mouth shape in Australian English and the subjects may have known that only one tongue position is associated with that mouth shape.

Figures 4b and 5b show the (R1,R2) of the imitations made using the impedance spectrum together with the photograph of the target speaker. In this protocol, and in that using the photograph only, the subjects wore headphones emitting white noise which masked any noise they made themselves, and so they were unable to use their own voice as feedback. The scatter in both R1 and R2 is much less than in Figures 4a and 5a. In contrast with Figures 4a and 5a, the scatter in R2 was less than that in R1. Subjects commented that it was easier to match R2 than R1. This may be because R2 varies over a greater range, and is associated with a larger change in Z(f). Thus the variation in R2 was more noticeable in the spectrum and this may have encouraged the subjects to concentrate more on matching it than on matching R1. This feedback protocol shows the least scatter of the three used. Note however that the scatter is always rather greater than 25 Hz, the resolution of the impedance spectrum displayed. We suspect that this was due to the finite skill and patience of the subjects in matching the frequencies (discussed further below).

Figures 4c and 5c show the (R1,R2) of the imitations made using auditory imitation: the subjects listened to a recording of the speaker pronouncing the target vowel and then made as many attempts as they wished to produce the same sound. In this protocol there was no masking of the sound of the subject's own voice.

In order to summarise these data, we define a parameter to indicate the difference between the imitation and the target resonances. Displacement in the (R1,R2) plane is an obvious measure, but this gives extra weighting to the imitation of the second resonance because its range is larger than that of the first. For this reason, we weight the R1 and R2 components of the displacement with the reciprocals of the standard deviations σ_1 and σ_2 of R1 and R2 in all nine vowels used. The scaled displacement d in the (R1,R2) plane is therefore defined as:

$$d = \sqrt{\left(\frac{R1 - R1_t}{\sigma_1}\right)^2 + \left(\frac{R2 - R2_t}{\sigma_2}\right)^2} \qquad (1)$$

where the subscript t indicates the target value. Using this definition, a perfect match has d = 0, and a poor match may have d as high as 3. In the data of Peterson and Barney [2], the range of d for a typical vowel in the population studied is about 1, so a d of this order might be considered an acceptable match.

Table 1 shows the scaled displacement (d) for all vowels using all methods for both sexes. It is not surprising that imitation using the impedance spectrum gives the smallest displacements in the (R1,R2) plane: after all it is precisely the displacement of R1 and R2 that the subjects are seeking to minimise, and the scatter here is presumably just a measure of the limits of their skill and patience. It is perhaps more surprising that the scatter is so large for auditory imitation, given that all of the subjects have considerable experience in this feedback and were all presumably highly skilled at this when they learned to speak. This may, in part, be the result of the process of categorisation in the mature auditory system: an adult who has learned one language tends to divide the (R1,R2) plane into the vowels of that language, and fails to discriminate small differences. For example, one subject produced exactly the same (R1,R2) when imitating the target sounds /u / and /æ /. The /u/ was a good match, but the /æ / a poor one. This can be explained if he perceptually categorised the vowel as /u/ in both cases, and then produced his version of that vowel, rather than a good imitation of the target. (There are several other such examples in the data.) It is possible that much of the scatter is due to categorisation: once a subject categorises the vowel s/he hears, s/he then pronounces his/her usual version of it rather than a faithful imitation of the target vowel. Although several of the subjects in this study spoke two languages with reasonable fluency, none regarded themselves as particularly good at languages, and none had specialised voice training.

Two of the subjects repeated the imitation trials. Table 2 shows their average d for the first and second session using each method of feedback. With the photograph only and with auditory feedback, there was no significant improvement

TABLE 1. Scaled displacement (d) for all imitations

Vowel	/ɛ/ "head"	/ɜ/ "heard"	/ɑ/ "hard"	/æ/ "had"	/ʌ/ "hut"	/ɒ/ "hot"	/ɔ/ "hoard"	/ʊ/ "hood"	/u/ "who'd"	Average: all vowels
(photograph,only)	1.24	1.53	1.91	1.72	1.51	0.92	1.40	1.51	1.59	1.48 ± 0.28
(impedance,feedback)	0.60	0.83	0.66	0.92	0.71	0.43	0.53	0.46	0.54	0.63 ± 0.17
(auditory,feedback)	1.30	1.17	1.23	1.42	0.92	0.75	0.98	1.09	1.07	1.10 ± 0.19

between the first and second attempts. With the impedance feedback, however, the improvement was significant at 95%. This could be because impedance provides the most novel feedback - we presume that all of the subjects had learned to speak using sounds and mouth shapes of speakers as targets. Despite this novelty, the goodness of the match in the second attempt suggests that this technique can be easily learned, which is an important feature for the use of the technique as a speech trainer.

TABLE 2. Scaled displacement (d) for first and second trials

	first session	second session
(photograph,only)	1.60 ± 0.90	1.36 ± 0.76
(impedance, feedback)	0.73 ± 0.39	0.47 ± 0.41
(auditory, feedback)	0.86 ± 0.50	1.03 ± 0.57

The data in Tables 1 and 2 suggest that the impedance feedback technique makes a very good speech trainer for vowels - perhaps even better in this respect than the traditional auditory feedback. It could be argued however that this comparison is unfair, in that the value d quantifies the very parameters that are minimised in the impedance feedback technique. What is important in vowel pronunciation is not the values of R1 and R2 *per se,* but rather how the vowel sound is interpreted by a listener. For this reason we conducted listening tests on the recordings of the phonations made by the subjects using the three techniques. Members of the listening panel listened to a cassette tape containing the target vowels and all of the imitations of them in randomised order. The panel members were given a list of the nine target vowels and were asked to note, for each sound they heard, which of the vowels it most resembled, or to leave the example blank if undecided. The raw data were then assembled in confusion matrices: tables with the target vowels in columns and the perceived vowels in rows[4]. The data were then summarised as a success rate (Table 3). The success rate for the target speakers is significantly different from all others at 95% confidence level, as is that from the photograph only. The success rates of the sounds produced using impedance feedback and auditory feedback are not significantly different.

TABLE 3. Identification from listening tests

Feedback protocol	(Percentage correctly, identified by listeners)
Photograph only	29 ± 6%
(Impedance spectrum)	39 ± 9%
Auditory feedback	40 ± 9%
Target speakers	61 ± 10%

A random choice with nine vowels would give a success rate of 11%. The imitations using a photograph only showed the lowest success rate: 29%. Most of the vowels were perceived as either /ɛ/ or /ɜ/ by the panel. This is difficult to explain, because /ɛ/ and /ɜ/ have similar R1 and differ in R2 in Australian English. They are however close to the middle of the (R1,R2) plane and are therefore "neutral" vowels. It is possible that the subjects, not having information about tongue position, automatically put it in a middle position vertically and longitudinally, leading to neutral vowels.

The vowels spoken by the target speakers gave the highest success rate: 61%. This seems surprisingly low at first, given that we are able to identify correctly a greater percentage of words. Part of the difference comes from the context. For example, in Australian English /ɑ/ and /ɒ/, pronounced in isolation, might be difficult to identify (see Figure 3 or [14]), but "hard" and "hod" are more readily distinguished if one knows that the sound is an English word. In the classic study by Peterson and Barney [2] on American vowels, listeners identified vowels with a success rate of 94% when they were presented in the context of syllables beginning with "h" and ending with "d". In this study, the vowels were presented without beginning and ending consonants, and this unfamiliar context may have deprived listeners of clues about the vowels that come from familiar transients. Vowel duration is also important [14]: /ɑ/ and /ʌ/ have very similar formant frequencies, but the words "heart" and "hut" are readily distinguished by vowel duration. The loss of information about vowel duration was probably important in this study, because all vowels were pronounced in sustained form. For instance, the listeners identified /ʌ/ less frequently than other vowels, presumably because they did not recognise it when presented as a sustained vowel.

Identification of the sounds produced by auditory imitation gave a success rate of 40%. This low value also seems surprising at first. In this case, all the problems mentioned in regard to the target vowels apply, and there is the further problem of categorisation. This protocol involves two perceptions of the vowel: once by the subject and once by the listening panel. At each stage the the opportunity for a categorisation error arises. This is supported by the observation that the success rate for auditory imitation is approximately the square of the success rate for the target vowels themselves.

Identification of the sounds produced using the impedance spectrum as feedback had a success rate of 39%. It is a little surprising that this novel and unfamiliar feedback technique

[4] The raw data for this study are presented by Dowd [15] in an undergraduate thesis. This thesis contains other data, such as measurements of an American speaker, measurements of the formants using other techniques and use of the impedance technique to measure the impedance of model systems for which the formants may be calculated analytically. Copies of this thesis can be supplied upon request.

was approximately as successful as auditory feedback. Further, those subjects who returned for a second session showed improvement both in the speed of production of a sound imitation and in the recognizibility of the sounds produced. From the first to second session the rate of recognition increased from 36 ± 10% (18) to 41 ± 9% (18) (significant at 90%). In contrast, the second session using the photograph only or auditory feedback showed no significant improvement in scaled displacement or recognition rate. These results are consistent with those of the scaled displacement.

4. CONCLUSIONS

Our non-invasive technique demonstrates the possibility of measuring the impedance spectrum of the vocal tract in parallel with the external field in real time. With the exception of /i/ and /I/, both of the first two resonant frequencies for vowels may be seen sufficiently clearly to allow the impedance spectrum to provide feedback in a speech trainer with minimal training of subjects. Inexperienced subjects who use this feedback to imitate target vowels produce sounds that are approximately as well recognised as those produced by the same subjects listening to and imitating vowel sounds. The recognition rate improves with the subjects' experience in using the impedance feedback technique.

ACKNOWLEDGEMENTS

We thank our volunteer subjects for their time and patience.

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Condition Monitoring of Bearings in a Viaduct

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ABSTRACT: The bearings used under the viaducts of the mass rapid transit system are of the sealed type. Though this type of bearings is useful in preventing the elastomer from exposure to ultraviolet light and the elements, it has the drawback of preventing the visual inspection of the physical condition of the elastomer. By measuring the end displacements of the viaduct, we could correlate the peak-to-peak displacements with the elasticity of the elastomer of the bearings used. Analysis shows that the ballast stiffness has very little influence over the end displacements, and the variations of the end displacements are more affected by the stiffnesses of the bearings than the variation in passenger load.

1. INTRODUCTION

Elevated viaduct for the rapid transit system in Singapore consitutes a significant portion of the whole system. The ends of the viaduct rest on columns via bearings as shown in Fig. 1. The bearings are introduced[1] to allow for the movements and rotations of the viaduct relative to the columns. Also shown in Fig. 1 are the general dimensions of a typical viaduct. The train runs on ballasted track. Fig. 2 shows a schematic view of the bearings used. The elastomer is totally sealed by metal rings. This type of bearing prevents the elastomer from exposure to ultraviolet light and the elements and thus prolongs the useful life of the bearing. However, it has the drawback of preventing visual inspection of the physical condition of the elastomer.

Though this type of bearing may have useful life from 50 to 80 years[1], it is essential that periodic inspection of the elastomer be carried out. Failure of the bearings may have undesirable structural consequences. As presently installed, physical inspection could only be carried out by jacking up the viaduct. This process could only be carried out when the system is not in operation, and therefore inspection work could only be carried out for a four hour period in the early hours. This is not only costly but also not practical. As precautionary measure, the bearings could be replaced before the end of the useful life; however, it is very costly. If the bearings could be replaced only when needed to, potential saving of a few million dollars per year could also be realised. As such there is a need for an alternative means to monitor the physical condition of the bearings.

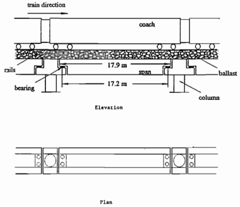

Figure 1. Elevated viaduct of rapid transit system.

2. VIBRATION MEASUREMENTS ON VIADUCT

Fig. 3 shows the configuration of the first three coaches of a 6-coach train. Each train rests on two bogies such as A1 and A2, B1 and B2, and so on. Each bogie carries two sets of wheels. As the train passes over a viaduct, the viaduct will be set into vibration. As such vibration measurements of the viaduct during a passage of the train could be used to monitor the condition of the bearings used on the viaduct; two parameters of the vibration, the acceleration and displacement signatures, were recorded and analysed during the passage of the train to determine whether the above parameters are suitable to condition monitor the physical condition of the bearings.

2.1 Acceleration Measurements

Accelerometers were placed on the underside of the ends of the viaduct at $x=0$ and $x=L_s$. $x=0$ is the end of the viaduct

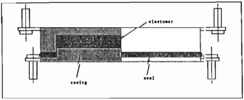

Figure 2. Schematic view of bearing.

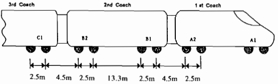

Figure 3. Configuration of the train.

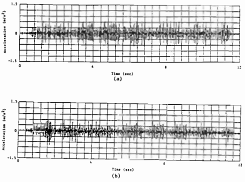

Figure 4. Acceleration signatures at (a) x=0, and (b)x=L_s.

where the train first enters the viaduct, while x=L_s is where the train leaves the viaduct. As the viaduct was quite near to a station, the speed of the train at the viaduct was about 58 km/h (15.9 m/s). At each bearing point, the train took about 9 sec to pass through. The acceleration signatures at x=0 and x=L_s were as shown in Fig. 4 .

The durations of the acceleration signatures were about 11 sec. This shows that the viaduct was set into vibration before the train has reached the viaduct and after it has left the viaduct. Furthermore, the time difference before significant acceleration signal was detected at x=L_s was about 0.4 sec later than at x=0. The time taken for the first set of wheels to travel the span of the viaduct was about 1.1 sec. This shows that before the first set of wheels was at a span, significant acceleration was experienced at x=L_s. It clearly indicates that the accelerations at the ends of the viaduct are much affected by movements of the neighbouring viaducts. From the above figures, we could estimate that the peak-to-peak acceleration during the passage of the train was about 30% higher than when the train was about to enter the viaduct and immediately after it had left the viaduct. There is no discernible pattern in the vibration signatures which could be useful in the interpretation of the acceleration signatures. As such the acceleration signatures may not be useful for condition monitoring of the bearings.

2.2 Displacement Measurements

Though the acceleration signatures could be twice integrated to obtain the displacements of the ends of the viaduct, the above procedure was not adopted. Preliminary work on the double integration of the acceleration signal produced unstable results as the dominant frequency of the dispalcement signature was around 1 Hz.

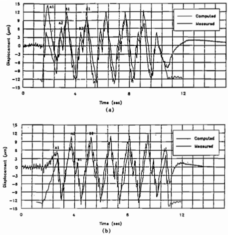

Figure 5. Displacement signatures at (a) x=0, and (b)x=L_s.

Direct measurements of the end movements relative to the columns were made with eddy probes. The eddy probes used were capable of measuring displacement from 0.25 mm to 2.3 mm, producing an output of 20 volts for the above range of displacement. With an initial gap setting of about 1 mm, the steady state outputs from the probes were about 10 volts. The end displacement amplitudes were of the order of 15 μm, giving rise to a variation of 0.12 volt signature superimposed onto the steady state value. As the variation of the displacement signatures was only about 1% of the output, it is desirable to improve on the reliability and accuracy of the output signals obtained.

The outputs from the eddy probes were passed through a high-pass filter with a cut-off frequency at 0.1 Hz. As the largest time interval of the wheels passing through a bearing point was about 1.1 sec, the filter should not have much effect on the output signals from the eddy probes. With the dc value filtered out, the accuracy and reliability of the outut signals from the eddy probes were tremendously improved.

The outputs from the eddy probes after filtering at x=0 and x=L_s were as shown in Fig. 5. Several observations could be made of the displacement signatures. The onset of the movements of the ends of the viaduct was distinct. The duration of the displacement signatures was about 9 sec, the time taken by the train to pass through each bearing location. This shows that the responses of the neighbouring viaducts have very little influence on the end movements of the viaduct under study. There were seven distinct groups, with groups A1, A2, B1, B2, C1, ... corresponding to bogies A1, A2, B1, B2, C1, ... as shown in Fig. 3. During the passage of the train on the viaduct, the peak displacement amplitude of the ends of the viaduct was about 13 μm, compared to less than 1μm when the train was not on the viaduct. The first displacement

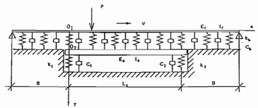

Figure 6. Model for the viaduct system.

peak at $x=L_s$ was about 1 sec later than at $x=0$. This corresponds to the travel time of the first set of wheels to transverse from $x=0$ to $x=L_s$. The displacement patterns showed that the end movements of the viaduct could be used as condition monitoring parameter for the physical condition of the bearings.

3. DYNAMIC RESPONSE OF THE VIADUCT

As shown in Fig.1, the train runs on ballasted track. The viaduct is supported at both ends by bearings mounted on the columns. The viaduct is modelled as shown in Fig. 6 to study its response during a train passage. The viaduct is divided into three sub-systems, namely: (a) the upper beam (the two continuous rails), (b) the elastic foundation (the ballast), and (c) the lower beam (which is the viaduct). The viaduct is supported by bearings which are being modelled by springs and dashpots.

The weight of the total coach (inclusive of the passengers) is assumed to be evenly distributed over the four sets of wheels. The forces acting on the rails are transversing the viaduct with velocity V.

A little digression is in order to complete the assumptions to be made in the above model. For an infinite beam supported on continuous elastic foundation as shown in Fig. 7, the deflection $Y(x)$ due to the point force P acting at $x=0$[2] is given by

$$Y(x) = \frac{P\gamma}{2k_b} e^{-\gamma x}(\cos\gamma x + \sin\gamma x) \qquad (1)$$

where k_b is the elastic constant of the foundation and γ is the characteristic of the system and is given by

$$\gamma^4 = \frac{k_b}{4E_r I_r} \qquad (2)$$

where $E_r I_r$ is the flexural rigidity of the beam. At $x = 7\pi/4\gamma$, the amplitude of deflection is only 0.4% of the amplitude at $x = 0$, and the total reaction force P' from the foundation between $x = -7\pi/4\gamma$ and $x = +7\pi/4\gamma$ is given by

$$P' = 2\int_0^{\frac{7\pi}{4\gamma}} k_b Y dx = 0.997P \qquad (3)$$

Hence for all practical purposes, the effect of the track and viaduct at distance B beyond the ends of the viaduct, where B is set equal to $7\pi/4\gamma$, on the dynamic response of the viaduct can be neglected.

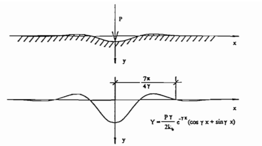

Figure 7. Point load on a beam resting on elastic foundation.

Each point force acting on the track is now given by

$$P(x,t) = P_o \delta(x - Vt) \qquad (4)$$

where

$$\delta = 1, \text{ for } x = Vt \text{ and } 0 \le x \le L_r$$
$$= 0, \text{ otherwise.}$$

L_r is taken to be $L_s + 2B$, where the constant B is defined above.

The mode summation method is used to obtain the deflection of the viaduct at $x = 0$ and $x = L_s$. For the upper beam, the origin of the coordinates is at O_1. As the upper beam is assumed to be simply supported at distances B from the ends of the viaduct, the mode shapes of the upper beam are assumed to be sinusoidal:

$$[\Phi_r] = \left[\sin\frac{\pi(x+B)}{L_r} \quad \sin\frac{2\pi(x+B)}{L_r} \ldots \sin\frac{n_r\pi(x+B)}{L_r}\right] \qquad (5)$$

For the lower beam, the origin of the coordinates is at O_2 The lower beam (the viaduct) has the following assumed mode shapes:

$$[\Phi_s] = \left[1 \; (\frac{L_s}{2} - x)\sin(\frac{\pi x}{L_s}) \;\; \sin(\frac{2\pi x}{L_s})\right] \qquad (6)$$

where rigid body translation and rotation are permitted. n_r and n_s are integers.

The modal matrix for the overall system can be expressed as:

$$[\Phi] = [\Phi_r \; \Phi_s] \qquad (7)$$

The Lagrange's equations can be obtained from

$$\frac{d}{dt}(\frac{\partial T}{\partial \dot{q}_i}) - \frac{\partial T}{\partial q_i} + \frac{\partial U}{\partial q_i} = Q_i \qquad (8)$$

where T is the total kinetic energy of the system, U is the total potential energy of the system, and Q_i is the generalized force which is given by the work done δW on the system:

$$\delta W = \sum_{i=1}^{n_r} Q_i \delta q_i = \sum_{i=1}^{n_r} P(x,t)\phi_i \delta q_i \qquad (9)$$

where the force $P(x,t)$ acts on the upper beam only. Substituting T, U, and Q_i into Eqn (8), we could obtain the following equations of motion:

$$[M]\{\ddot{q}\} + [C]\{\dot{q}\} + [K]\{q\} = \{Q\} \quad (10)$$

where [M], [C], and [K] are the mass, damping, and stiffness matrices, and {Q} are the generalized forces, and

$$\{ q \} = \{ q_r \, q_s \} \quad (11)$$

where q_r and q_s are the generalized coordinates of the upper and lower beams, respectively. Runge Kutta procedure is used to solve the above equations of motion. The deflection of the lower beam is now given by

$$Y_s(x,t) = [\Phi_s]\{q_s\} \quad (12)$$

4. VIADUCT PARAMETERS USED TO COMPUTE DYNAMIC RESPONSE OF VIADUCT

The following parameters shown in Table 1 are obtained from the constructional details of the viaduct monitored.

Table 1. Available parameters from constructional details.

L_s = 17.2 m	m_r = 121 kg/m (for 2 rails)
m_s = 9895 kg/m	E_r = 200 GPa
E_s = 25 GPa	I_r = 6.1 x 10^{-5} m^4
I_s = 0.529 m^4	m_b = 3850 kg/m

The other parameters required for the computation can be obtained from the characteristics of the train used, and these are:

Mass of empty coach = 14,000 kg.
Maximum number of passengers permitted per coach = 250.
Mass per passenger = 60 kg.
Assuming 50% passenger capacity, P_o = 52,729 N.
Velocity of train at viaduct = 15.9 m/s.

The stiffnesses of the bearings are estimated from the data supplied by the manufacturer and they are:

$$k_1 = k_2 = 8000 \text{ MN/m}.$$

The modulus of the ballast is assumed to be k_b = 900 MN/m²[3] with damping constant ς = 0.05.

The reason for the relatively low velocity is that this viaduct is about 150 m from a station, and that the train has not yet picked up speed then.

With the above parameters, the relative displacements of the ends of the viaduct were computed using Eq (12). The results were found to converge for $n_r = n_s = 5$. These are plotted in Fig 5 as well. Except for the segments of signals when the first set of wheels reached the viaduct and when the last set of wheels left the viaduct, the computed and measured signals are in excellent agreement. As mentioned earlier, in order to improve the accuracy and reliability of the displacement signatures recorded, the outputs from the eddy probes passed through high-pass filters with a cut-off at 0.1 Hz. With and without the train on the viaduct, the equilibrium positions of the viaduct varied, and this change in the equilibrium positions could not be measured with the system as set up. Disregarding the first and last segments of displacement signatures, the results showed that the peak-to-peak dispalcement could be used to condition monitor the physical condition of the bearings.

To examine how effective the end displacements could be used, we note that the following parameters affect the peak-to-peak displacements:

(a) ballast stiffness,
(b) total coach mass, and
(c) bearing stiffnesses.

Due to the regular maintenance of the track system by periodic tamping of the ballast, the modulus of the ballast is not expected to vary significantly. During the off-peak period, the passenger load is estimated to be within 30% to 70% of full capacity.

The next section will examine the sensitivity of the peak-to-peak displacements due to the variations of the above parameters.

5. INFLUENCE OF PARAMETERS ON DISPLACEMENTS

Ballast Stiffness

The nominal stiffness of the ballast used to compute the end displacements of the viaduct is k_b = 900 MN/m. As the ballast is tamped regularly to ensure that the system is running at optimal conditions, we would not expect the ballast stiffness to vary substantially from the nominal value.

Computer simulations have been carried out to determine the percentage changes of the peak-to-peak displacements at $x = 0$ and $x = L_s$ due to the variation of ballast stiffness. The peak-to-peak dispalcements were now represented by Y_1 and Y_2, respectively.

Fig. 8 shows the percentage changes in Y_1 and Y_2 for variation of ballast stiffness from 700 MN/m² to 1100 MN/m², corresponding to a decrease of 22.2% to an increase of 22.2% over the nominal value. However, the end displacements Y_1 and Y_2 show a variation of less than 1%. This implies that the ballst stiffness has very little influence over the end displacements. This means that condition monitoring by measuring the end diplacements need not necessary be carried out immediately after the tamping operation to ensure a consistent value for the ballast stiffness.

Total Coach Mass

From Eqns (9) and (10), the end displacements are proportional to the imposed load. Hence any change in the total coach mass will produce the corresponding changes in Y_1 and Y_2. As the empty coach mass (14,000 kg) is constant, the variation of the total coach mass is due to the variation in passenger load. Assuming a nominal load of 50% capacity, the total coach mass is 21,500 kg (assuming that each passsenger is of 60 kg). A 30% variation of passenger load (i.e. from 20% to 80% of full capacity), the variation of the total coach mass is ±11%. The corresponding changes in Y_1 and Y_2 are ±11% as shown in Fig. 9.

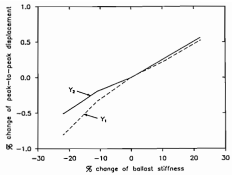

Figure 8. Variations of end displacements with ballast stiffness.

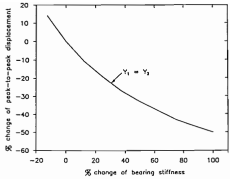

Figure 10. Variations of end displacements due to stiffness changes at both bearings.

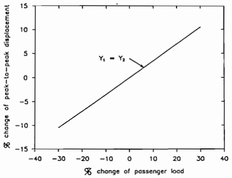

Figure 9. Variations of end displacements with passenger load.

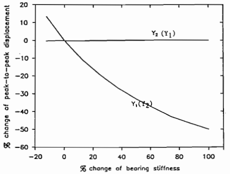

Figure 11. Variations of end displacements due to bearing stiffness change at (a) $x = 0$, and (b) $x = L_s$.

Bearing Stiffnesses - Both Bearings

As there are two sets of bearings for each viaduct, the bearing stiffness could change at either $x = 0$, or $x = L_s$, or at both ends. In this section, we will investigate the effect when bearings at both ends experience the same percentage change in stiffnesses. Fig. 10 shows the variations of Y_1 and Y_2 when the bearings stiffnesses vary from -20% to 100%, i.e., the stiffnesses decrease by 20% to an increase of 100%. For stiffnesses variation of only 12%, Y_1 and Y_2 vary by 11% which is of the same magnitude as 30% variation in passenger load.

When the elastomer ages and deteriorates, the stiffness is expected to increase by more than 50%. The corresponding changes in Y_1 and Y_2 reach 35%, far above that due to the change in passenger load. This shows that by monitoring the end displacements of the viaduct, we could correlate them with the elasticity of the bearings at both ends. When the bearing stiffnesses increase twofold, the end displacement amplitudes reduced to half their amplitudes, a very significant reduction.

Bearing Stiffness Change at $x = 0$ and at $x = L_s$

Assuming now that only the bearing at $x = 0$ has deteriorated, while that at $x = L_s$ is in good working condition. Fig. 11 shows the changes in Y_1 and Y_2. It can be clearly seen that the displacement at $x = L_s$ is not affected by the deterioration of the bearing at $x = 0$. However, Y_1 varies from +13% to -50% when the bearing stiffness at $x = 0$ varies by -14% to 100%. This clearly shows that the displacement at $x = 0$ is directly affected by the change in bearing stiffness at its support. The variation in Y_1 is about the same regardless of whether the bearing at $x = L_s$ has deteriorated or not. The same observation can be made if the bearing at $x = L_s$ has deteriorated instead of the bearing at $x = 0$. Now only Y_2 will experience a change whereas Y_1 remains the same. These variations are as shown in Fig. 11 (in brackets).

6. CONCLUSION

The above analysis shows that by monitoring the peak-to-peak displacements at both ends of the viaduct, we could correlate the results with the physical properties of the bearings at both ends. The variation of ballast stiffness has very little effect on the displacements.Variation in passengerload of up to 30% would cause at most a 11% change in the peak-to-peak displacements.

Variation of the bearing stiffness by 100% would decrease Y_1 and Y_2 by 50%, a value far above that due to the variation in passenger load. Furthermore, it can be observed that Y_1 would decrease due to an inscease in bearing stiffness at $x = 0$, regardless of whether the bearing at $x = L_s$ has deteriorated or not. Similar observation also applies to Y_2. Therefore the end displacements are affected directly by the stiffnesses of the bearings supporting the respective ends.

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Comments On Environmental Noise Assessment

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Abstract: The ambient background noise level at most locations varies throughout the day and from day to day. In addition, noise levels emanating from an operating plant are also likely to vary from hour to hour and day to day. A method of allowing for these variations in setting environmental noise criteria which are related to community response has been proposed with the purpose of opening discussion on this issue.

It is widely accepted that the annoyance due to an intrusive noise relates to the difference between the noise level and the background noise level determined in its absence. This principal is accepted in such Standards as Australian Standard 1055 - 1989 *Acoustics - Description and Measurement of Environmental Noise.*

In New South Wales, the Environment Protection Authority (EPA) recommends a noise criterion of background noise level plus 5 dBA for such intrusive noise. Where the intrusive noise varies in level, EPA recommends the use of the L_{A10} level and the background noise level is defined as the L_{A90} of the ambient.

1. NOISE LEVEL VARIATIONS

It is common to measure the L_{A10} and the L_{A90} levels over 15 minute periods and, consequently, these levels may vary throughout the day and from day to day. The L_{A90} (background) noise level is likely to vary as a result of variations in road traffic flow in the surrounding area, variations in weather conditions (particularly temperature gradients and wind) and variations in noise levels emanating from other industrial noise sources. The plant (intrusive) noise level may also vary due to variations in operation throughout the day and variations in weather conditions. The net result is that the $L_{A10,\ 15\ min}$ noise level from the plant will vary over a period of time and so will the ambient $L_{A90,\ 15\ min}$ level.

Figure 1 shows a typical $L_{A90,15\ min}$ trace and a possible $L_{A10,15\ min}$ trace of plant operation (only) during a one day period. These traces are also likely to be different on other days.

With variations in plant noise and background noise, the question arises as to how to interpret the variations and how to determine the noise criterion.

2. COMMUNITY RESPONSE TO NOISE

The answer to the question above lies in the response of residential communities to noise. However, we have limited knowledge of this response.

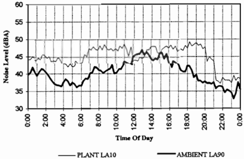

Figure 1. Possible relationship between plant alone and background noise.

Firstly, it appears important to divide the day into periods of different background noise level and periods of different operation. It is common for the day to be divided into three periods:

* Daytime 0700 - 1800 hours
* Evening 1800 - 2200 hours
* Night-time 2200 - 0700 hours

However, during each of these periods the background noise level can vary significantly on a relatively regular basis. For example, during the night time period (applicable for a 24 hour operation) the background noise level is likely to fall from 2200 hours to about 0100 hours and then remain constant to about 0500 hours. After this, the level is likely to increase. It therefore seems more appropriate to divide the day into shorter periods, the most important one for a 24 hour operation being 0100-0500 hours.

Each period must be treated separately in the assessment, although it is commonly found that one period is more critical than the others.

For each period, there is a natural tendency to want to average the background noise levels and also to average the plant noise levels. However, I do not feel that this approach relates well to likely community reaction to noise. A community is likely to be more aware of the periods of high noise level than the periods of average noise level and it is likely to react in response to the high levels, rather than the average. This may be demonstrated by considering noisy domestic parties, where neighbours often complain after only hours of noise, despite the fact that the party complained about may be the first one held in 12 months. Particularly at night-time, residents can be quite intolerant of short-term noise.

My personal experience in carrying out a social survey to determine community response to aircraft noise also supports this view. Around Sydney Airport, some communities were affected by overflights and the consequent noise on some days only, as opposed to all days. When asked in an in-depth interview what their overall response to the average noise was, residents within these communities had considerable difficulty in providing a single (presumably average) response. They preferred to indicate their response during those days with overflights, paying no regard to those days without.

From experience, I have developed the view that it is necessary for the intruding noise to comply with the criterion during the period in question for at least 90% of the time to avoid reaction from the community. From a different perspective, one can say that the intruding noise can exceed the criterion for up to 10% of the time without a community reaction. This seems to imply that residents tend to ignore, or at least tolerate, slightly higher noise levels for up to 10% of the time, especially when the noise levels during that percentage of time are not substantially over the criterion.

3. PRACTICALITIES OF ASSESSMENT

Assuming the plant whose noise level is being assessed is currently in operation, one could theoretically measure plant noise levels over an extended period of time (such as one year) and also measure the background noise levels over a similar period of time. This would allow determination of the percentage of time that the plant noise level exceeds the criterion (say background noise level plus 5 dBA during the critical period of the day).

Accordingly, the assessment of the impact of the plant noise would then be clear. However, such an approach is unlikely to be practicable because of the large cost involved and also because many assessments are carried out before the plant is in operation. Particularly in the case where the plant being assessed is not in operation, it is only possible to carry out an approximate noise assessment along the lines indicated above. Firstly, it is meaningful to attempt to establish if there is some relationship between the background noise level and the plant noise, that is, to establish if plant noise and background noise are partly in phase. Where the main source of background noise and the plant are located a considerable distance from the assessment location, then it is likely that the noise levels of both will increase during a temperature inversion and decrease during a temperature lapse. Equally, if the two noise sources are in the same direction from the assessment location, they are both likely to increase with a breeze towards the assessment location and decrease with a breeze away.

Assistance in the assessment can therefore be gained from the measurement of wind speed and direction over a representative time period and from an estimate of the probability of temperature inversions.

If no wind or temperature gradient information is available, then I have established some basic rules of thumb which can assist in assessing the acceptability of a noise on the basis that the criteria can be exceeded for 10% of the time:

- Determine the *accumulated background noise level* in accordance with procedures developed by RTA Technology *(The Accumulation of Statistical Noise Levels*, Renzo Tonin, private communication) for the appropriate time period of the day. This level is basically the long term L_{A90} noise level, based on the relevant time periods and excluding extraneous measurement results. A preliminary analysis of some typical examples has indicated that the accumulated background noise level is approximately equal to the 75 percentile level of the L_{A90} (ie the $L_{A90,15min}$ level exceeded for 75% of the time) during the appropriate period.
- Estimate the probability of temperature inversions and breezes towards the assessment location during the assessment period.
- Estimate the probabilities of the noise producing operations at the plant and the overall noise emissions during each type of operation.
- Estimate the expected plant noise level (L_{A10} level for New South Wales) at the assessment location which is likely to be exceeded for say 40% of the time. This 40% figure is derived as follows. If the accumulated background noise level is used as the background level, then the level of a steady noise 5 dBA above this will just comply with the criterion for 75% of the time(ie the 75% of time when the background noise level is above the accumulated background noise level), but does not comply for 25% of the time. If we then assume that the plant noise level varies, we could make the 40 percentile level for the plant noise ($L_{A10,15min}$) equal to the assume background noise level + 5 dBA. The plant noise wound therefore be above this criterion for 40% of the time. Assuming a random relationship between background noise and plant noise, during the 25% of the time that the background noise level falls below the assumed level (accumulated background noise level), the plant noise would be above the criterion for 40% of the time. The plant noise is therefore likely to exceed the background noise level by an estimated 25% x 40% which is 10% of the time.
- Compare 40% level for the $L_{A10,15min}$ with the accumulated background noise level and check if the allowable difference between noise level and the background level is exceeded.

These rules of thumb are very approximate since the correct assessment would depend upon the profiles of background noise and plant only noise with time and also upon the degree of correlation between these two noises. They should also be applied carefully with due consideration of the particular circumstances; for example, it would be unreasonable to allow plant noise to exceed the criterion for the first year of a 10 year operation, even though this represents 10% of the total time.

4. CONCLUSION

The approach discussed above has been developed on the basis of experience over a period of time in an attempt to clarify the interpretation of the basic noise assessment procedures discussed in Standards and guidelines. However, it represents a first written attempt at such clarification with the objective of allowing debate on this issue. Comments and suggestions are welcome and can submitted to the editors of *Acoustics Australia.*

Publications by Australians

The following listing of publications by Australian authors is provided in order to encourage communications among those working in the various fields of acoustics.

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Books...

Computational Ocean Acoustics

Finn Jensen, William Kuperman, Michael Porter & Henrik Schmidt

AIP Press, 1994, 612 pp, hard covers, ISBN 1-56396-209-8, Distributor: American Institute of Physics, PO Box 20, Williton VT 05495 0020, USA Fax + 802 864 7626 Price US $85

Oceanography and Acoustics: Prediction and Propagation Models

Allan Robinson & Ding Lee (Editors)

AIP Press, 1994, 257 pp, hard covers, ISBN 1-56396-203-9, Distributor: as above. US $65

Given the impact of computers in virtually all disciplines of science, it is appropriate that a pair of books dealing with computational models for underwater acoustics should be published by AIP Press as the first two issues in its series on Modern Acoustics and Signal Processing. What is somewhat surprising is that two books which deal with such similar subject matter should be published by the same publisher, in the same year, each without acknowledgement of the other. It would seem that an opportunity to produce a complementary pair of authoritative books, employing consistent terminology and symbols, has been lost.

The first book, "Computational Ocean Acoustics" (COA), is jointly authored by four experts in the field. Their declared intention is ".. to present the state-of-the-art of numerical techniques as applied to solving the (acoustic) wave equation in heterogeneous fluid-solid media". This is achieved by way of the core chapters 3 - 7 which outline in detail the development of the five key numerical techniques, namely ray methods, wavenumber integration, normal modes, parabolic equations, and finite differences and finite elements. These chapters are presented at a level well placed between the style of junior university texts (such as Urick's) which give little detail of derivation, and the mathematically complex approach of Brekhovskikh & Lysanov's "Fundamentals of Ocean Acoustics" which can be very difficult to follow. Each chapter is sufficiently stand-alone that it could be referred to in isolation from the rest of the book. The first two chapters of the book present background knowledge essential for an introduction to underwater acoustic modelling, and the final three chapters deal with broadband modelling and the influence of ambient noise.

The second book, Oceanography and Acoustics: Prediction and Propagation Models (OAPPM), differs from the first in that it provides an overview of research progress in the coupling of ocean dynamical and acoustic propagation models. It is also different in that each of its 9 chapters is authored by different contributors (21 in all). This leads to a less well structured presentation, with occasional duplication of material and variation in notation.

Chapters 2 to 6 are concerned with the sensitivity of acoustic propagation to environmental factors; including "perceived" sensitivity which arises out of a poor choice of acoustic model. The second chapter commences with a useful list of underwater acoustic propagation models, together with a table of references and a brief guide as to the conditions for which they are most appropriate. Chapters 5 and 6 rely heavily on use of the Harvard Forecast System environmental model. Particular reference is made to the problem of converting the coarse sound speed and current fields generated by the large scale environmental models to a form suitable for input to the acoustic models. The last three chapters focus on the use of 3-D normal mode and ray technique solutions for range-dependent environments. It is interesting to learn that future passive line array systems may be able to determine the range and bearing of conspicuous noise sources (e.g. submarines, storms) while at the same time gleaning information about the ocean environment; a sort of passive ocean tomography. The idea is based on varying the likely source location and environmental field parameters until the simulated array signal matches that observed experimentally ("matched-field processing"). This topic is also met in the final chapters of COA (compare Figure 9.13 of COA with Figures 7.5 & 7.6 of OAPPM). There is further overlap between the two books with regard to the description of the various acoustic propagation models.

COA provides a name index(209 entries) and subject index (613 entries) together with numbered references at the conclusion of each chapter. AAPPM provides a central subject index (193 entries) and a central list of 266 alphabetically-ordered references. Both books include a set of colour prints of computer images which appear elsewhere in the text as black-and-white figures.

At the quoted prices, the books are best suited for the library shelves of institutions (our experience is that these prices inflate to the $170 mark when purchased locally). Although COA is strictly a review of work published in other references, its contents are sufficiently broad and thorough for it to fill a hole in the market. It would be a valuable reference for the underwater acoustician and could be used as an advanced text at honours and postgraduate level. OAPPM is directed specifically towards the acoustician or oceanographer interested in the coupling of ocean dynamic prediction models and ocean acoustic prediction models. It represents a good overview of research progress in that area, and provides the reader with a number of valuable references. However, if the reader is interested in either oceanography or acoustics alone, then this book is not recommended; there are many texts that address these individual subjects in a more complete and concise manner.

Craig Roy and Glen Stewart

Craig Roy is Officer-in Charge at the RAN Applied Meteorology and Oceanography Centre. He completed his MSc thesis on Underwater Acoustic Propagation Modelling: Theory, Operation & Comparison.

Glen Stewart is a senior lecturer in the School of Physics at the Australian Defence Force Academy and is responsible for courses in Marine Acoustics and Optics.

Sound Solutions, Techniques to Reduce Sound at Work

Health and Safety Executive

HSE Books, 1995, pp 80, Soft Cover ISBN 0 7176 0791 7 Australian Distributor: DA Information Services, PO Box 163, Mitcham Vic 3132. Tel 03 9873 4411 Fax 03 9873 5679. Price A$38.

The aim of this book is to show that noise problems can be solved in many ways. It is designed for the manager, engineer or safety representative and offers real examples of how noise reduction has been achieved. It is published by the Health and Safety Executive (HSE) in the UK which also produced the book "100 Practical Applications of Noise Reduction Methods" some years ago. This latest book represents a considerable improvement in presentation including many colour photographs.

First there is a checklist that the manager should work through to identify the problem and obtain guidance on the likely solution. Then follows a summary of the pitfalls that can arise with the various types of techniques. These are listed in point form and a very useful addition to such a publication.

The sixty examples cover a wide range of industries, noise problems and control methods. They are well indexed and there are summary tables which assist in finding similar noise problems and the possible solutions. The control methods range through damping, design, isolation, enclosure, silencer etc, with two on active noise control. For each problem the layout of the page is similar. First the problem is clearly explained, including difficulties with implementing control methods in the past. The solution is explained with sufficient technical details to enable it to be adapted to another application. A photograph and/or sketch shows the solution implemented in the industry. In most cases the costs, in UK Pounds is given. The final paragraph states the result in terms of the magnitude of the noise reduction achieved. In some cases the frequency data for the noise reduction is also provided.

The book is well presented with good overall graphic design. It certainly would help managers with noise problems to obtain some guidance on the type of solutions that may be available. It would also be of great assistance to those in education because of the good case studies that are documented. Consultants and engineers would find it a valuable addition to their bookshelves as it provides ideas, background information and could be used for examples in the discussions with clients.

Marion Burgess

Marion Burgess, at the Acoustics and Vibration Unit, Australian Defence Force Academy, is involved in education, research and consulting aimed at reducing noise exposure in industry.

The Music of the Spheres

Jamie James

Copernicus/Springer-Verlag, 1993, pp263, soft covers, ISBN 0-387-94474-5. Aust Distributor: DA Information Services, PO Box 163, Mitcham Vic 3132. Tel 03 9873 4411 Fax 03 9873 5679. Price $16.95

According to the biographical note in the book, the author is a New York music critic and contributor to several major newspapers and magazines, and he certainly writes fluently and entertainingly. I enjoyed this book and found its comments on the relations between "music theory" and arithmetic to be nicely put.

I must, however, express a disappointment at the outset. The sub-title of the book is "Music, Science and the Natural Order of the Universe" but the author reveals a very limited appreciation of the nature of science and of mathematics, and indeed takes a nineteenth-century "Arts Faculty" view of these subjects. Mathematics is regarded as arithmetic, or rather even as numerology, while science is said to have abandoned its search for ultimate answers in favour of a limited practical approach to phenomena. We find no reference to notions of symmetry or pattern (along the lines of either group theory or of Escher's drawings), no reference to the psychophysics of music perception (using that term in its proper scientific sense), no reference to modern views of the universe. A more accurate sub-title would have been "Pythagorean Philosophy and Music Theory".

Re-setting our expectations, therefore, what do we find? An excellent account of the Greek philosophical view that the order of the universe is governed by relations between integers, and that the pure music of the universe, musica mundana, was similarly numerical. The music made by actual instruments, musica instrumentalis, and that appreciated by human ears, musica humana, had a similar numerical basis but was of a less perfect order. The development of this theme in classical philosophy, in pre-modern science (Kepler's platonic-solids model of the universe, Newton's unpublished attempts to show that his physical laws derived directly from classical philosophical principles) is well discussed, and due credit is given to Galileo and to his father Vincenzo Galilei, about whom I, at least, had not heard before.

Bach gets only superficial mention, perhaps because of the author's concentration on numerology rather than the grander themes of mathematics, and we have a surprisingly large discussion of romantic music and opera, partly as a history of the break away from numerical tradition. The book then turns to the contemporary approach of Schoenberg and his followers, who re-enthroned numerology in music theory through their twelve-tone system and tone-rows. As with many modern musicians, the concern is not primarily with the sound of the music, but rather with its formal numerological structure.

I recommend this well written book to those whose interest is in classical philosophy, the early history of science, and the numerological basis of much music theory, though fortunately not of much actual music!

Neville Fletcher

The reviewer is a physicist and musician based at the Australian National University.

News...

ANNUAL CONFERENCE

The Annual Conference, for the Australian Acoustical Society, to be held 13-15 November in Brisbane at the Novotel Hotel is shaping up, with interest shown by a wide range of people. With the current review of noise regulations in most states of Australia, this years conference theme of **"Legislation and Innovation"** is timely. A two day workshop will be held in conjunction with the Conference with the theme of Noise Regulation Across Australia, and will be of interest to professionals working in acoustics who wish to gain insight into the status of noise regulation at present. For those presenting papers the deadlines for the paper for Proceedings is 1 September. All authors will be notified by 12 August and given requirements for manuscript preparation.

The **Excellence in Acoustics Award** will be presented this year at the Brisbane Conference, and we urge anyone who is interested to submit a project for consideration. Details form Les Huson on tel (07) 327 42744, fax 07 327 42844

With the beautiful weather in Brisbane, and it's close proximity to the Gold and Sunshine Coasts, a visit to the Annual Conference would offer a starting point for an enjoyable holiday. A registration brochure is inserted in this issue of the Journal; for additional copies please contact the Conference Secretariat: Jay Carter tel (07) 3806 7522 fax (07) 3806 7999

Piano Technology

The Victoria Division visited the Northern Melbourne College of TAFE, Preston, Melbourne to inspect the Department of Piano Technology on 6 March. This Department provides the only course in Australia for the accredited training of Piano Technicians. It began in 1983, with a student intake of four to six per year, and has since trained 63 students. Two courses, a one year Certificate, and a two year diploma course, are provided. **Mr Allan Moyes**, the Department co-ordinator, gave a technical overview of the courses available and led a tour of the Department's training facilities.

The students accepted for these courses are required to cope with both the musical and technical demands of this profession. They have to spend many hours in practical training in order to develop speed and accuracy in tuning pianos 200 or more strings. Because pianos are tuned to "tempered" rather than "just" intonation, in which all semitone intervals are meant to be equal (with a frequency ration of 21/12 = 1,05946), beats between harmonics occur when several notes are played simultaneously. Tuning is therefore the best compromise to minimize obviously audible beats. A further refinement of tempered tuning is the use of a "stretched" frequency tuning curve in which the higher notes are sharper, and the lower notes flatter than would be required by exact tempered tuning. While there are now numerous electronic tuning aids available, and these were demonstrated by Mr Moyes, he emphasized that the best results are still obtained through well-trained human hearing. A piano technician is required to be able to tune any note to within an accuracy of half a "cent", which corresponds to a frequency ration of 21/2400 = 1,000289. At the concert pitch A of 440 Hz, this half cent represents a frequency difference of about 1/8 Hz, or one beat per 8 seconds.

To obtain a Piano Technician's Certificate, students are required also to develop their skills in servicing and regulating a piano's hammer action, to achieve evenness of touch and tone. This is complex in that each one of a modern piano's 85 to 88 hammer mechanisms consists of over 100 individual mechanical components, with many possibilities of adjustment, including the shape and hardness of each felt hammer. Students of the two-year Diploma course are given a more extended training which includes full restoration of a piano, requiring, also, cabinet-making and metal-working skills. This Piano Technology Department possesses all the equipment necessary for training in piano tuning, servicing and restoration; and is also the birthplace of Wayne Stuart's fully Australian-built grand piano, featured in recent ABC radio and TV programs.

Noise Travels

A joint meeting with Association of Noise Control Engineers on April 24 took the form of a seminar on wheels. A total of 22 members travelled by bus to five locations for six sessions on aspects of noise control. At B&K's offices, Moonee Ponds, **Rob Smyths**, Senior Projects Officer with the Vic Health and Safety Organization, began with a brief history of the development of audiometric measurement, outlined the scope of the forthcoming Vic Health/Noise regulations (now to be focussed on the noise hazard), and made some comments on outcomes of the current 1992 regulations. At Melbourne International Airport, **Rick Gates**, Melbourne Manager Operations, FAC, described the various aircraft noise monitoring procedures, with an inspection of monitoring equipment. At Smorgon Steel, Laverton North, was demonstrated the on-going noise control program throughout the steel mill, in which various process supervisors' offices and control rooms have been fitted with suitable noise barriers. After lunch at Smorgons, the trip continued with a visit to, and inspection of the RMIT Acoustics Laboratory reverberation rooms, in which are measured the absorption coefficients or insertion loss of the many commercial products. At the Bionic Ear Institute, East Melbourne, **Dr Robert Cowan**, Melbourne University senior research fellow, introduced members to recent investigations into human hearing damage, and its remedial treatment. After a return to B&K, regional manager, **Mr Bill Simms** described and briefly demonstrated some of the latest available B&K sound level meters and analyzers. At the conclusion of the day **Geoff Barnes** and **Carol Harry** were duly thanked for organizing this interesting day of "Noise Travels". It is expected that similar future tours are to be arranged to continue this style of noise seminar.

Louis Fouvy

Guitar Family

On 23 April 1996 there was a joint meeting of the ACT Groups of AAS and Australian Institute of Physics on the Physics of the Guitar Family. The presenter was **Graham Caldersmith**, a well respected luthier based in the ACT. He discussed the history of the development of the guitar from the salon guitar to the modern day style where the goal of a very light faceplate has been achieved by the use of carbon fibres in the lattice stiffeners. The main modes of vibration and their radiation efficiency were explained and demonstrated with the aid of sawdust on the face plate. Graham then proceeded to explain the family of guitars that he has developed; a treble, baritone and bass to complement the standard guitar. The translation of the string frequencies and, most importantly the tonality, was not a simple exercise. The obvious solutions were not always successful and, while excellent instruments have been produced, there is always scope for further development. The music produced by a group using the family has been accepted internationally and one of their CDs provided background music prior to the commencement of the meeting.

Marion Burgess

AAAC

The mid year meeting of the AAAC was held at the Australian Defence Force Academy in Canberra on 14 June with representation from member firms in N.S.W., Victoria, Queensland and Western Australia. Prior to our meeting we were welcomed by **Assoc. Professor John Baird**, Head of School of Aerospace and Mechanical Engineering. **Dr Hugh Williamson**, Director of the Acoustics & Vibration Centre then gave an overview of acoustic activities at the Academy and highlighted the 3 main streams of research, education and consulting in acoustics and vibration. The group was then taken on an extensive tour of the facilities which included: anechoic chamber currently being used for an electric motor project, an "infinite" plate set up to study vibration propagation, impact noise control for an industrial application, friction saw noise reduction project, computer modelling using some extensive and sophisticated programmes, condition monitoring signal analysis, and human vibration data acquisition and processing.

The meeting continued through the afternoon covering topics of concern and interest to Consultants with, amongst many topics of technical and business relevance, specific coverage of certain of the Australian Standards pertinent to noise issues, the Building Code of Australia and aircraft noise.

Allan Herring

FASTS Update

The AAS is a member of the Physical Sciences Board of the Federation of Scientific and Technological Societies (FASTS).

A major activity has been the launch of the revised FASTS Policy Document on June 18 with formal presentation to Minister Peter McGauran. This document illustrates the essential steps to secure a strong scientific and technological platform from which to improve Australia's social, environmnental and economic position through the wise use of science and technology, in structured long-term planning. The policy is available both in hard copy, and on the FASTS' web page at: http://bimbo.pharmacol.su.oz.au/fasts/fastshome.html

The interests of the science and technology community need to be represented in a vigorous manner, which is a job for FASTS. The impact of Government cuts on science and technology are not fully known and there is a need to remind the new Government that pre-election promises should be taken seriously. The FASTS media conference at Parliament House in May, brought together science groups and the National Farmers Federation to ward off rumoured cuts to S&T funding. This sort "third-party endorsement" by the NFF of the value of S&T is particularly important in Budget discussions, and avoids the charge that science and technology are self-serving. The University sector also held a highly successful media event in Parliament House with FASTS playing a prominent role in putting the event together. The creation of an historic alliance of students, staff and administrators was announced, with all groups joining to protest threatened cuts to Universities.

FASTS has put several matters to Minister Peter McGauran, including a completely new approach to the funding of R&D by industry, and FASTS' views on how responsibilities between ASTEC (now ASETEC), PMSEC and the Chief Scientist should be divided, and the limited career path for younger and middle-ranking Australian scientists.

Any issues that could be taken up by FASTS should be forwarded to Marion Burgess, the AAS representative for FASTS, on tel 06 268 8241, fax 06 268 8276.

ASTEC Future Needs

The final report of the Australian Science, Technology and Engineering Council (ASTEC) foresight study: Matching Science and Technology to Future Needs: 2010, was launched at Parliament House in Canberra on 21 May 1996 by the **Hon Peter McGauran** MP, Federal Minister for Science and Technology. The report explores the uncertainties of the future. It does not attempt detailed prediction about events or developments in science, engineering and technology over the next 10-20 years. It takes the view that it is both possible and desirable to look ahead to how the future might unfold, and explore what the future outcomes and benefits of science might be.

In outlining the outcomes of the study at the launch, **Professor Ron Johnston**, Convenor of the study said: "Looking toward 2010, four forces are destined to shape our futures in many ways: global integration, applying information and communications technologies, environmental sustainability, and advances in biological technology.

The ASTEC report makes recommendations for the Commonwealth government to: develop a set of strategic principles, establish the broad parameters for a system of resource accounting, develop guidelines for ethical, environmental and equity issues, examine the scope and adequacy of sources of information on relevant science, engineering and technology, develop technological literacy, review of Australia's relative strengths and weaknesses in emerging 'hot spots' in research and technology, evaluate Australia's ability to provide relevant and timely scientific and technological information, and improve science and technology skills. *Further information: ASTEC, GPO Box 9839, Canberra, ACT 2600, tel (06) 276 1210 fax (06) 276 1374 email: astec@astec.gov.au*

Australia Prize

The Australia Prize was instituted in 1989 as an international award for outstanding achievement in science and technology promoting human welfare. The Prize consists of $300,000 and an inscribed medal. The field in which the award is to made in 1997 is Telecommunications. Telecommunications is generally used to describe both the services offered by the worldwide networks which provide voice telephony facilities, and the technology used to construct and support it. This includes - but is not limited to - transmission systems, switching systems, access techniques, network management software, fibre optics, broadband technology, wireless technology, satellite technology, microwave technology, cellular technology, frequency modulation, packet switching, and signal processing techniques. *Further information and nomination requirements from the Australian Prize Secretariat: GPO Box 9839, Canberra ACT 2601 tel 06 276 1246 fax 06 276 2002 email ausprize@dist.gov.au*

UNSW - France Link

Associate Professor Robert Randall, of UNSW's School of Mechanical and Manufacturing Engineering will be working with the Vibrations Group at CETIM (Centre Technique 'des Industries Mechaniques) University of Compiegne, France. This research will use vibration analysis to determine the condition of operating machines (thus avoiding the need for shut-down and dismantling). This development has been slower for reciprocating machine such as automotive and diesel engines. A collaborative research project has been initiated between the UNSW and researchers in France to combine their skills and experience in tackling diesel engine monitoring through vibration analysis.

STANDARDS

Australian Standards

AS2107 Design Sound Levels and Reverberation Times. This Standard is about to be revised and comments and recommendations are being sought from all interested.

Acoustics - Rail related noise intrusion - Building siting and construction. This is a possible standard which would provide guidance on the location and construction of new buildings and the acoustical adequacy of existing buildings in areas near rail lines. Proposed by the State Rail Authority of New South Wales.

Comments to Standards Australia, Grant Cooper (02) 746 4821.

AS 4269-1995 Complaints Handling. This defines a clear and comprehensive process which any business should follow to fairly and efficiently resolve customer complaints. By following the recommendations of this Standard, you have the opportunity to right a possible wrong, achieve "best practice", maximize customer goodwill and loyalty, and fulfil an essential element of ISO 9000 quality management. Using customer feedback can also point to any problems in your business.

A dissatisfied customer will, on average, tell nine other people exactly what they think of you.

American Standards

Instruments For The Measurement Of Sound Intensity. ANSI S1.9-1996 specifies the requirements for instruments to measure sound intensity employing the two-microphone technique and methods for performance verification to meet the requirements. It conforms as closely as possible to IEC 1043. The primary application of this standard is to instruments used for the determination of sound power of sources according to the requirements of ANSI S1.12-1992.

Measurement Of Sound Pressure Levels ANSI S1.13-1995 specifies requirements and describes procedures for the measurement of sound pressure levels in air at a single point in space. These apply primarily to measurements performed indoors but may be utilized in outdoor measurements under specified conditions.

Measurement Of Occupational Noise Exposure. ANSI S12.19-1996 presents methods that can be used to measure a person's noise exposure received in a work place. The methods have been developed to provide uniform procedures and repeatable results for the measurement of occupational noise exposure.

Determination Of Occupational Noise Exposure And Estimation Of Noise-Induced Hearing Impairment. ANSI S3.44-1996 is an adaptation of ISO 1999 but unlike the international standard, allows assessment of noise exposure using a time/intensity trading relation other than a 3-decibel increase per halving of exposure time.

Specification For Audiometers. ANSI S3.6-1996 covers those designed for use in determining the hearing threshold level of an individual in comparison with a chosen standard reference threshold level.

Specification Of Hearing Aid Characteristics. ANSI S3.22-1996 describes air-conduction hearing aid measurement methods that are particularly suitable for specification and tolerance purposes. Among the test methods described are output SPL with a 90 dB input SPL, full-on gain, frequency response, harmonic distortion, equivalent input noise, current drain, induction coil sensitivity and static and dynamics characteristics of AGC hearing aids.

Occupational Health and Safety Regulation

The Industry Commission Report into Occupational Health and Safety, 1995, turned the spotlight on an increasingly complex area of regulation in Australia. The Industry Commission Report provides an opportunity to reflect on what we are trying to achieve through OH&S regulation and how effectively the system is delivering results.

Changes have been introduced into State OH&S regulations, starting from the early 1980's aimed at turning around the culture in OH&S by making industry take more responsibility for managing workplace health and safety. These changes were based on the so-called 'Robens' legislation in the UK. What the Industry Commission found was that, to a large extent, this culture change generally has not taken place, particularly for small and medium enterprises (SMEs). The Report also expresses the view that despite ten years of regulatory reform, there is little to suggest that across-the-board gains are being made in reducing the tally of dead and injured at work.

Until this round of reforms was put into place, a fair level of uniformity was achieved between the nine OH&S jurisdictions by their commitment to the use of Australian Standards. In recent times they seem to be drifting further and further apart in terms of how they implement 'national' initiatives.

While the philosophical arguments for getting away from the old image of the DLI inspector coming around with his clipboard and tape measure are undeniable, now that he has gone, many in industry have found the replacement system all too hard and have simply left health and safety on the back burner. The frequently heard call from small business is for simple advice on what is safe and what is not. The Report found that, unfortunately, what they now have to deal with are a complex web of regulations and codes of practice that elaborate and re-interpret the legal requirements. Standards Australia has tried to fill gaps in the new system with Standards that give practical guidance, and have rewritten other Standards that continue to be used in regulations.

Extracted from The Australian Standard, April 1996.

Ultrasound Research

To promulgate the impact and importance of ultrasound in medical diagnosis and patient management by promoting education and establishing research opportunities in diagnostic ultrasound, the American Institute of Ultrasound in Medicine (AIUM) has developed an Education and Research Fund. The financial objective of the fund is to support important education and research projects while enabling an endowment fund to build concurrently. The fund will be financed through society reserves, the membership, corporations, and available outside grants.

Awards from the Education and Research Fund will initially support research in such areas as the development of Relevant standards, specifically directed toward one body region, with universally-applicable results for state-of-the-art equipment; the development of education standards necessary to perform ultrasound with competence and efficiency; the development of decision or cost effective analysis; the development of outcomes research, specifically designed to determine any procedural affects on patients; and the development of an AIUM Ultrasound Summit, scheduled to include representatives from all physician organizations interested in ultrasound, sonographer organizations, major ultrasound equipment organizations, and managed care organizations, to determine the direction of ultrasound in the next five years.

Futher Information: K.Wilson, AIUM, 14750 Sweitzer Lane, Suite 100, Laurel, Maryland 20702-5906.

ASHRAE Grant

VIPAC Engineers and Scientists Ltd has been awarded a significant second research grant by ASHRAE, the prestigious American Society of Heating, Refrigeration and Airconditioning Engineers. The objective and scope of this study is to conduct psychoacoustics testing of subjects exposed to various HVAC (heating, ventilation and cooling) noise spectra, with particular emphasis on rumble (and to a limited extent of roar), and to develop / extend / modify the Room Criteria rating and HVAC noise metrics as proposed in a similar earlier study. ASHRAE was concerned that very little work had directly addressed the question as to how people react to indoor noise in situations where the background sound is established by the noise level of operating HVAC systems. The project is being undertaken by a team led by **Dr. Norm Broner**, of VIPAC's Melbourne office.

NATA Data on Net

The National Association of Testing Authorities, Australia has established a Web site on the Internet to enable people seeking crucial data about quality certification, accreditation, testing, calibration and measurement services quick access to relevant information. The address is: http://www.aaa.com.au/nata

Singapore Conference

The Annual Meeting of the Society of Acoustic (Singapore) will be held 8-9 Jan, 1997 at Novotel Orchid, Singapore. Contributed papers are welcome in all areas of acoustics. The deadline for receipt of abstracts is Monday, 30 Sept 1996. *Information in diary.*

INTER-NOISE 97

This conference will be held in Budapest, Hungary on 25-27 August 1997 and the theme is "Help Quiet the World for a Higher Quality Life". Brochures will be distributed soon but for current information try the Internet page http://www.mmt.bme.hu/–khazy/active/inter-noise97.html also diary listing in this issue.

AES Convention

The 6th Australian Audio Engineering Society Convention will be held at the World Congress Centre in Melbourne, 10-12 September. **Ray Dolby**, founder and Chairman of Dolby Laboratories, Inc., will be special guest and keynote speaker. Dolby is a Fellow and past president of the Audio Engineering Society, and a recipient of its Silver and Gold Medal Awards. **Chris Steller** who has worked with synthesisizers and electronic music composition since 1978, will present midiworkshop, Life, The Studio and Midi. Chris is currently Product Support Co-ordinator for Music Products Division of Yamaha. *Further Details see Diary.*

Brainstorm

Brainstorm is an exciting nationwide competition, hosted by Sony Australia, seeking designs for the Home Entertainment System of the future. This is an exciting context, asking you to think 'outside the square' about the way you envisage tomorrow's TVs, VCRs, Hi-Fi, Telephones, Video Cameras, Portable Music Systems and Potable Disc and Cassette Players. Great prizes will be awarded to State and National winners in each of three categories: Junior (12 Years and under), Intermediate (13-18 Years), Tertiary (19-25 Years).

Further Information: Freecall 1800 803 470.

New Sustaining Member

Acu-Vib Electronics is welcomed as a sustaining Member for the Society. Acu-Vib Electronics is a one-stop facility for noise and vibration requirements. It sells, hires, trades in, buys, calibrates and repairs equipment. Further details from Jack Keilt, tel 018 470 179, tel/fax 02 819 6398.

Excellence In Acoustics Awards 1996

Entries are welcome from members and non-members for work completed in Australia in the period between 1 July 1994 and 30 June 1996.

The awards will be presented at the 1996 Australian Acoustical Society Conference in Brisbane.

For information pack with entry conditions:

Les Huson

Tel: (07) 327 42744
Fax: (07) 327 42844

New Products...

SoundPLAN

SoundPLAN is an integrated PC-based suite of programs utilising acoustic ray tracing methods for analysing noise and air pollution from road, rail and aircraft, indoor factory and industrial noise, plus wall design and air pollution dispersion calculations. The three dimensional computer displays and animated colour graphics are ideal for project, community and court room presentations. The original SoundPLAN proved to be a very versatile product and now Version 4.0 has been released with additional features for industry noise, wall design and graphics.

Further information: VIPAC Engineers and Scientists Ltd, 275 Normanby Rd, Port Melbourne 3207. Tel 03 9647 9700 Fax 03 9646 4370

LARSEN DAVIS

Sound Level Meters

The **System 814** represents the first of a new family of Type 1 Precision Digital Integrating Sound Level Meters from Larsen Davis and offers two options of integrated, autoscanned filters, the 1/1 Octave (9 filters) and the 1/1 and 1/3 Octave (25 filters), both within the range 31.5Hz - 8kHz. This hand-held, totally digital, lightweight instrument offers both an extensive statistical analysis and logging capability in real time. The new generation instrument, together with the Models 712, 720, 820 and 870 B, feature Windows - based software for setup, control and high speed data download and reporting. Also available as optional is an Advanced Windows-based software package which provides remote operation via modem, secured modem access, data archiving / research capabilities and post-measurement analysis features, together with advanced sorting and graphics / report generation tools.

The **Model DSP80** Integrating Digital Sound Level Meter offers a compact, Type 1 meter featuring digital signal processing technology at an economical price. With a single measurement range of 40-140dBA and A,B and C frequency weighting, the DSP 80 feature Fast and Slow RMS detectors, plus C-weighted Peak and Leq. It also comes in three versions, the Model DSP 81, the basic model to which digital octave filters (31.5Hz - 8kHz) have been added, Model DSP 82, with an impulse detector and the DSP 83, to which Digital Octave Filters (31.5Hz - 8KHz) have been added.

Further information: VIPAC Engineers and Scientists Ltd, 275 Normanby Rd, Port Melbourne 3207. Tel 03 9647 9700 Fax 03 9646 4370

ONO SOKKI

Sound Level Meter

The LA-5120, LA-5110 and LA-2110 are compact, lightweight digital integrating sound level meters featuring 100 dB of linearity range. A variety of internal options is available, particularly real-time 1/1 octave analysis. In addition to this option, scanning-type 1/1-octave and 1/3-octave filters are available. Any combination of these three options can be installed in these sound level meters. Three different memory function can be utilised for data storage, and a printer (RQ-110, sold separately) can be connected for creating printouts.

Signal Analyser

The CF-5200 FFT Analyser Series heralds the arrival of a high performance, user-friendly signal analyser for the engineer demanding high computational power. The CF-5200's two measurement channels are completely separated electronically, guaranteeing high precision measurements. Ono Sokki has incorporated into the 'Quick Expert' easy operation system which is activated by the press of a key categorised by measurement type. All parameters are set out on the screen with detailed instruction for the selected function. Extra amplifiers or signal conditioners are no longer required as direct sensor inputs are installed. The DC power input permits the CF-5200 Series to be used in outdoor and remote locations.

Further information: VIPAC Engineers and Scientists Ltd, 275 Normanby Rd, Port Melbourne 3207. Tel03 9647 9700 Fax 03 9646 4370

DYNAMIC INSTRUMENTS

Transducers Test Set

The Transducer Test Set (TTS) is a portable, completely self-contained, vibration transducer tester. Used in the field or lab, the TTS tests and verifies the performance of most vibration transducers, including accelerometers, velocity pickups, and displacement probes. It is also used to test and troubleshoot machinery vibration monitoring/alarm systems, including cabling and associated system instrumentation. The TTS not only vibrates the transducer under test, but also measures, calculates, and stores in memory the transducer sensitivity. A built-in printer permanently records test results.

Further information: Int. Scientific Instruments Co. 40 Chonley St., Prahran, VIC 3181,Tel 03 9539 3660 Fax 03 9529 7524

VIBRANT TECHNOLOGY

MEscope

The Mechanical Engineering Oscilloscope (ME'scope) is a family of post-test analysis tools that make it easy to observe, analyze, and document the dynamics behaviour of machines and mechanical structures. ME'scope uses experimentally derived time or frequency domain data, acquired during the operation of a machine, or excitation of a structure. All popular time and frequency domain measurement types imported. The ME'scope sweeps through a set of time histories and animates a 3D model of the test structure, allowing observation of its response. The ME'scope has a built-in Fast Fourier Transform (FFT) so that signals can be analyzed in the time or frequency domain. It also has windowing functions so that selected ranges of data can be analyzed, and unwanted portions removed. ME'scope V3.5 has many new features.

Further information: Int. Scientific Instruments Co. 40 Chonley St., Prahran, VIC 3181,Tel 03 9539 3660 Fax 03 9529 7524

BRUEL & KJAER

Pulse Analyser

Bruel & Kjaer has just released PULSE, a new generation, PC-based FFT Multi-analyzer System.

PULSE combines the latest Bruel & Kjaer technology with new, state-of-the-art PC-based software packages, controlled by LabShop Tools. The system is a highly modular, multi-channel front-end with a range of high quality conditioning modules for use with both acoustic and vibration transducers.

Leading edge DSP technology is employed within the PC, optimising its flexibility. The ability to perform multi-analysis dramatically reduces test time. This is achieved by using several different analyzers, or variants of the same analyzer, in parallel. The system is controlled from software which runs on a PC under Windows NT™ or Windows® 95, providing a well-known, easy-to-use, graphical user interface.

PULSE provides today's busy professional fast, comprehensive results and automatic reporting facilities.

For your free PULSE CD and booklet, contact Bruel & Kjaer on: 1 800 802 852.

Diary...

CONFERENCES and SEMINARS

* Indicates an Australian Activity

1996

September 2-6, CHRISTCHURCH
ROADS 96 - Joint Aust/NZ Conference
Details: ARRB Transport Research, 500 Burwood Hwy., Vermont Sth, Vic 3133.
Tel +61 3 9881 1555, Fax +61 3 9887 8104

September 9-12: OXFORD, UK
Vibrations in Rotating Machinery
Contact: 1 MECH E, 1 Birdcage Walk, London SW1H 9JJ, UK Tel: +44 171 973 1249
Fax: +44 171 222 9881.

September 10-12: MELBOURNE
6th Aust Audio Eng Soc Convention
Details: AES Convention, C/- ICMS, 84 Queensbridge St, Southbank, Victoria 3006
Tel 03 9687 0244 Fax 03 9682 0288, aes96@icms.com.au

September 18-20, LEUVEN
Noise & Vibration Engineering Conference
Details: L Notre, K.U. Leuven-PMA, Celestijnenlaan 300B, 3001 Heverlee, Belgium.
Fax +32 16 32 29 87,
email lieve.notre@mech.kuleuven.ac.be

September 23-25, ST PETERSBURG
FASE Symposium: Transport Noise
Details: FASE Secretary, K.U. Leuven-ATF, Celestijnenlaan 200D, 3001 Leuven, Belgium.
Fax: +32 16 3279 84,
email jan.thoen@fys.kuleuven.ac.be

September 25-27, JAPAN
Autumn Meeting Acoust Soc Japan.
Details: Acoustical Society of Japan, Ikeda Building, 2-7-7 Yoyogi, Shibuta-du, Todyo, 151 Japan. Fax +81 3 3379 1456

September 29-October 2, BELLEVUE
NOISE-CON 96
Visions for the Next 25 Years
Details: NOISE-CON96 Conference Secretariat, Engineering Professional Programs, 3201 Fremont Avenue N., Seattle, WA 98103.
Tel +1 206 543 5539, Fax +1 206 543 2352

October 3-6, PHILADELPHIA
4th Conf. Spoken Language Process
Details: ICSLP96, Sci & Eng Labs, AI du Pont Institute, PO Box 269, Wilmington, DE 19899 USA, Fax +1 302 651 6895,
email ICSLP96@asel.udel.edu

October 7-11, CALGARY
Acoustics Week in Canada 1996, 'Environment, Society and Industry'
Details: Dan Meier, 640, Fifth Avenue S.W. Calgary AB T2P 3G4 Fax 403 297 3520, meierd@mail.eub.gov.ab.ca

October 24-27, WINDERMERE
Reproduced Sound 12.
Details:Institute of Acoustics, Agriculture House, 5 Holywell Hill St Albans, Herts AL1 1EU, UK.
Fax +44 1727 850 533; acoustics@clus1.ulcc.ac.uk

November 3-6, SAN ANTONIO
1996 IEEE Intl Ultrasonics Symposium
Details: J S Schoenwald, Rockwell International Science Center, Mail Code A9, 1049 Camono dos Rios, Thousand Oaks, CA 91358, USA.
Fax +1 805 373 4810

November 13-15, BRISBANE
*1996 AAS Conference
Making Ends Meet. Innovat. & Legislation
Details: Ross Palmer, Tel 07 3806 7522,
Fax 07 3806 7999

December 2-6, HONOLULU
3rd Joint Meeting of the Acoustical Society of Japan and the Acoust Society of America
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797, USA.
Fax +1 516 576 2377, email elaine@aip.org

1997

January 8-9, SINGAPORE
Soc of Acous (Signapore) Annual Meeting.
Details: Dr W. Gan, Acoustical Services Pte Ltd, Innovation Centre 209-212, NTU, Nanyang Avenue, Singapore 2263. Tel +65 791 3242 Fax +65 791 3665, chenzhen@pacific.net.sg

March 24-28, HAVANA
2nd Ultrasonics Symposium
Details: Carmen Alvarez, Calle 15 No. 551 e/C y D. C.P. 10400, Diudad de La Habana, Cuba. Fax +53 733 3373, cimaf@redacc.cu

April 13-16, BOSTON
23rd Int Symp on Acoustical Imaging
Details: S. Lees, Bioengineering Dept., Forthys dental Center, 140 Fenway, Boston, MA, USA.
Fax +1 617 262 4021, slees@forthys.org

April 21-24, MUNICH
International Conference Acoustic, Speech & Signal Processing
Details: H. Fastl, Technical University Munich, 80290 Munchen, Germany. Fax: + 49 892 105 8535, fas@mmk.e-technik.tu.muenchen.de

May 12-16, GDANSK
13TH FASE Symp on Hydroacoustics
Details: Inst Exp Physics, Ul. Wita Stwosza 80-952 Gdansk, Poland.
Fax +48 58 413175, fizes@halina.univ.gda.pl

June 24-27, PRAGUE
1st Europ Conf on Signal Analysis & Prediction.
Details: ESCAP SEcretariat, Institute of Chemical Technology, Technicka 5 166 28 Praha 6, Szech Republic, escap@vscht.cz

August 19-22, EDINBURGH
Int. Symp. on Musical Acoustics.
Details: Dept. Physics and Astronomy, University of Edinburgh, James Clerk Maxwell Building, Mayfield Rd, Edinburgh EH9 3JZ. Scotland. Fax +44 131 650 5902, isma.97@ed.ac.uk,

August 21-23, BUDAPEST
Int. Sym on Active Control
Details: ACTIVE Secretariat, OPAKFI, Fo u. 68, 1027 Budapest, Hungary. Fax +36 1 202 0452

August 25-27, BUDAPEST
Internoise 97
Details: OPAKFI, H-1027, Budapest FO U68 Hungary, Tel/Fax: +36 1202 0452

September 1-4, JAPAN
IMAC-XV 'Bridge Over Virtual & Real Design'
Details: IMAC-XV, Dept. of Precision Mechanics, Chuo University, 1-13-27 Kasuga, Bunkyo-ku, Tokyo, 112 Japan. Fax 81 3 3817 1820
jmac@okubo.mech.chuo-u.ac.jp, www page.

September 10-12 , NEW ZEALAND
Biennial Conference - NZ Acoustical Society
Details: NZ Acoustical Society, PO Box 1181, Auckland, NZ Fax +64 9 623 3248

December 1-5, SAN DIEGO
Meeting of the ASA
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797 USA.Fax +1 516 576 2377, asa@aip.org

December 15-18, ADELAIDE
* 5th Int Conf on Noise & Vibration
Details: Dept Mech Eng, Uni Adelaide, SA 5005, Aust. Tel +61 8 303 5698, Fax +61 8 303 4367, CHANSEN@watt.mecheng.adelaide.edu.au

1998

May 12-15, SEATTLE
IEEE Conf. on Acoust, Speed & Signal Processing
Details: L. Atlas, Dept. EE (FT 10), University of Washington, Seattle, WA, USA. Fax +1 206 543 3842, atlas@ee.washington.edu

June 20-27, SEATTLE
International Congress on Acoustics & ASA
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797 USA. Fax +1 516 576 2377, asa@aip.org

October 12-16, AMERICA
Meeting of ASA
Details: ASA, 500 Sunnyside Blvd., Woodbury, NY 11797 USA.Fax +1 516 576 2377, asa@aip.org

November 16-20, CHRISTCHURCH
INTER-NOISE 98
Details: NZAS. P.O. Box 1181, Auckland, NZ, Fax +64 9 309 3540

November 23-27, SYDNEY
* ICBEN 98, Biological Effects of Noise
Details: N. Carter, NAL, 126 Greville St, Chatswood 2067 Australia Fax +61 2 411 8273

Courses...

Signal Processing - various courses Sept, Oct, Nov & Dec
Details: Cooperative Centre for Sensor Signal and Information Processing (CSSIP), SPRI Building, Technology Park Adelaide, SA 5095 Tel: 08 302 3928 Fax: 08 302 3124 mayre@postoffice.cssip.edu.au

4 Dec - Vibration and Shock for Test & Evaluation
Details: Acoustics and Vibration Unit, Aust Defence Force Academy, Canberra ACT 2600, Tel 06 269 9241, Fax 06 268 8276, avunit@adfa.oz.au

AUSTRALIAN ACOUSTICAL SOCIETY ENQUIRIES

NATIONAL MATTERS

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

General Secretary
AAS– Professional Centre of Australia
Private Bag 1, Darlinghurst 2010
Tel/Fax (03) 9887 9400
email: watkinsd@melbpc.org.au

SOCIETY SUBSCRIPTION RATES

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

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Private Bag 1,
DARLINGHURST 2010
Sec: Mr D Eager
Tel (02) 9330 2687
Fax (02) 9330 2665
email D.Eager@uts.edu.au

AAS - Queensland Division
PO Box 150,
OMMANEY 4074
Sec: Mr B Thorne
Tel (07) 3225 1772
Fax (07) 3376 6236

AAS - SA Division
C/–Department of Mech Eng
University of Adelaide
SOUTH AUSTRALIA 5005
Sec: Carl Howard
Tel (08) 303 3092
Fax (08) 303 4367
email: cqhoward@mecheng.adelaide.edu.au

AAS - Victoria Division
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MELBOURNE 3000
Sec: Mr A Rogers
Tel (03) 9905 3610
Fax (03) 9905 3637

AAS–W A Division
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WEST PERTH 6872
Sec: Mr T McMinn
Tel (09) 351 7175
Fax (09) 351 2711
mcminn@puffin.curtin.ed.au

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Acoustics & Vibration Centre
ADFA
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