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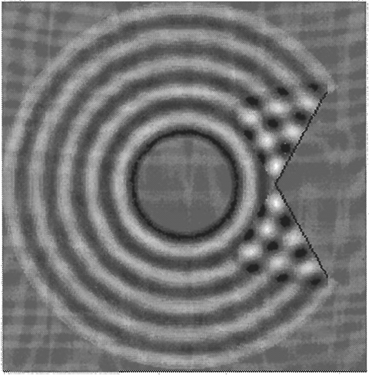

- Accelerometer Calibration
- Sound Card Data Acquisition
- Risk from Orchestral Music
- Ripple Tank
- Tonal Noise
- FASTS

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LOW-FREQUENCY ABSOLUTE CALIBRATION OF ACCELEROMETERS

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Abstract: At the National Measurement Laboratory, Australia, apparatus and techniques have been developed for calibrating vibration-measuring transducers in the low-frequency range, 2Hz - 250Hz. This paper describes the apparatus and the methods used to calibrate the built-in reference accelerometers absolutely in terms of the primary standards of length, time and voltage.

1. INTRODUCTION

Traceability, and estimation of uncertainty, are often of interest to engineers who measure low-frequency vibration, particularly if there is a possibility of legal challenge [1], in which case the component of uncertainty due to the calibration of the measuring transducers may need to be taken into account.

The National Measurement Laboratory (NML) maintains a horizontal air-bearing electrodynamic vibration exciter, which is big enough to accommodate most triaxial geophones and similar large transducers. Such transducers are routinely calibrated by comparison with the built-in low-frequency references, a set of servo accelerometers.

This paper is concerned with the apparatus, methods and techniques which are used at NML to calibrate the low-frequency reference accelerometers. To "calibrate" is defined as to determine the magnitude of the transfer function, generally referred to as the sensitivity of the accelerometer, in terms of the physical standards of length, time and voltage. In calculating the uncertainty of the sensitivity values, the methods used are taken from the ISO "Guide" [2].

2. STATIC CALIBRATION AT ZERO HERTZ

This method is a simple adaptation of the familiar "2g turnover" which is frequently used for field calibration of accelerometers which have a response down to zero hertz.

The accelerometer is first aligned with its sensitive axis vertical and the "positive" direction pointing up (Fig. 1). In the case of the NML reference accelerometers, this is achieved by standing on end the armature from the air-bearing shaker. The signed dc voltage output *V1* is then measured using a calibrated voltmeter.

Next, the vertical orientation is reversed, ie the accelerometer is turned over so that the "positive" direction is pointing down, and the signed dc output voltage *V2* is measured.

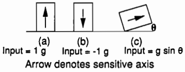

Figure 1. Static calibration of accelerometer using Earth's gravity field

The sensitivity S_0, in Volts per m s^{-2} , is then obtained as

$$S_0 = (V1 - V2) / (2 * g_l) \qquad (1)$$

where g_l = local value of the acceleration due to gravity, in m s^{-2} .

To convert this to Volts per g_n , S_0 is multiplied by g_n/g_l where g_n = ISO standard gravity, the value of which is defined to be 9.80665 m s^{-2}.

At the NML location of the calibration apparatus, the value of g_l is 9.79638 m s^{-2}, with an uncertainty of about 5 parts in 10^6. However, typically the true sensitive axis of an accelerometer may differ from the geometric axis by about 1.5 degrees, and the uncertainty in setting the geometric axis to vertical is about 1.5 degrees also, when the armature is simply stood on end on the bench. Hence for this calibration, the total uncertainty in the applied acceleration is approximately ±0.1% .

The inherent dc offset, V_0, in the accelerometer output is also obtainable from

$$V_0 = (V1 + V2) / 2 \qquad (2)$$

2.1 LINEARITY (i)

The static method gives an accurate value for the sensitivity at zero hertz, amplitude $1.0g_l$, but it is not reasonable to extrapolate to lower accelerations without knowledge of the linearity of the accelerometer. For an initial linearity check, the accelerometer was mounted on a precision rotary table

(Optical Measuring Tools Ltd), which was then rotated incrementally such that the sensitive axis was rotated in a vertical plane, and at each increment a reading was taken of the dc voltage output $V(\theta)$, where θ is the angle between the sensitive axis and horizontal. Linearity was then assessed from a plot of $V(\theta)$ versus $g_l \sin\theta$.

This method was found to be not entirely satisfactory. At very small angles, there is significant error due to finite transverse sensitivity of the transducers, and non-coincidence of the sensitive axis with the geometric axis. The two factors are not independent, but the nett error can be reduced by aligning the direction of minimum transverse sensitivity to lie in the plane of rotation (resulting in the smallest minimum output when rotated through "zero" angle), by which the effective transverse sensitivity was reduced by a factor of ten. At an angle of $\theta = 6$ degrees, corresponding to approximately $0.1g_l$, transverse sensitivity of 1% can produce an error of 9.5%, but the alignment strategy reduced this to a just acceptable 0.95%. The practical lower limit to this method is thus considered to be about $0.1g_l$ (1 m s^{-2}), corresponding to $\theta = 6$ degrees approximately.

3. ABSOLUTE CALIBRATION USING INTERFEROMETRY

In principle, the accelerometer is subjected to rectilinear simple harmonic motion (SHM) along the direction of its sensitive axis, and the displacement and frequency are measured, thereby defining the applied acceleration. The displacement measurement utilises the so-called "frequency ratio" method (FR) of counting optical interference fringes [3,4,5,6]. The voltage output is measured at the same time, hence the sensitivity is obtained.

3.1 THE APPARATUS

At NML, SHM is produced by an electrodynamic vibration generator ("shaker"), the drive coil of which is attached to an aluminium armature ("shaker table") which is constrained to horizontal rectilinear motion by air bearings (Fig. 2). The drive coil has no separate supports, and the only other constraints are four light rubber bands which centre the oscillation. Peak-to-peak displacements of 25mm are attainable, but displacement is restricted to about 10mm peak-to-peak for the lowest distortion .

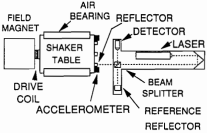

Figure 2. Air-bearing shaker and interferometer for low-frequency calibration.

Two servo accelerometers are permanently mounted in one end of the armature, and mounted adjacent to each of them is an optically flat mirror which serves as one of the reflectors in a simple Michelson interferometer. The entire shaker assembly, of mass approximately 100 kg, rests on a concrete and brick block approximately 2m long by 0.7m wide by 0.9m high, which in turn is cemented to the concrete ground floor of the NML building. There is a layer of about 3mm of bituminous felt between the shaker assembly and the concrete block.

Also resting on the top of the concrete block, at the opposite end to the shaker, is a steel cruciform structure which houses the rest of the Michelson interferometer: a beam splitting cube, a plane reference reflector, a 3mW HeNe laser, and a photodetector. The assembly can be moved laterally, to point at any of the plane reflectors on the shaker table. The light from the laser reaches the beam splitter after reflection by two mirrors, the purpose of which is to increase the distance between the laser source and the reflectors of the interferometer. Thus, by a deliberate tiny misalignment (approximately 2 mrad) of the interferometer, reflected light is prevented from re-entering the laser, and the resulting error in displacement measurement is insignificant.

In addition to the built-in accelerometers, there is provision for calibrating a small piezoelectric accelerometer, which can be attached directly to the back of one of the reflectors on the shaker table. This is routinely used to extend downwards the frequency range of absolute calibration of piezoelectric reference accelerometers.

The apparatus is used to calibrate the reference accelerometers over the frequency range 2Hz - 250Hz, with acceleration of up to 9.8 m s^{-2} available at frequencies not less than 10Hz. At 10Hz, the corresponding peak velocity is about 0.16m/s, equivalent to 500,000 fringes per second. This is easily handled by the photodetector, which is a PIN diode with a close-coupled wide-band amplifier giving an overall frequency range of 3 MHz.

3.2 ACCELERATION MEASUREMENT

The shaker is driven from a programmable oscillator via a power amplifier (Fig. 3), and the displacement, D, is measured by counting the passage of interference fringes past the detector during several complete cycles of excitation (see appendix A). The counter is "gated" with a signal from the shaker drive oscillator. The drive frequency f is measured with a second counter, the time base for which is derived from the NML Caesium Beam Frequency Reference. As the wavelength of the laser is known in terms of the legal standard of length, to an uncertainty of a few parts in 106 in the controlled NML environment, the applied acceleration ($= (2\pi f)^2 D$) can be known very precisely. Simultaneous measurement of the accelerometer output voltage completes the calibration.

In applying the FR method of displacement measurement, a correction is made for ambient displacement of the reference reflector. At the NML location this includes random noise with mean amplitude less than 0.5μm, plus components

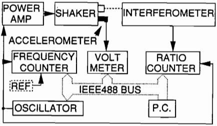

Figure 3. Block diagram of low-frequency accelerometer calibrator

at about 4.5Hz, 20Hz and 25Hz (attributed to structural resonances), with amplitudes which vary randomly between 0.5μm and 1μm. Denoting the mean ambient displacement by *Da*, measured by the FR method over an integral number of cycles of the drive frequency f with the drive coil disconnected, subsequent displacement measurements D_{meas} at frequency f are corrected as

$$D \text{ (corrected)} = \sqrt{(D_{meas}{}^2 - D_a{}^2)} \quad (3)$$

which is justifiable as D_{meas} and D_a are uncorrelated.

The ambient vibration is also of a suitable amplitude and velocity to provide "jitter" of the photoelectric signal at the turning points of the motion. By averaging counts made as the reference reflector is slowly moved, it is possible to extend the resolution below the expected ±1 fringe count (see appendix A, and Fig. 4). Hohmann & Martin [5] noted a tenfold improvement in resolution from moving the reference reflector with mean velocity much less than the velocity of the vibration being measured. In comparing the FR method with other methods at NML [7], it was found that, by moving the reference reflector, the displacement was measurable by the FR method with a resolution of 1 nm and an uncertainty of approximately ±2 nm. Von Martens [9] achieved even greater accuracy for SHM at frequencies > 500Hz.

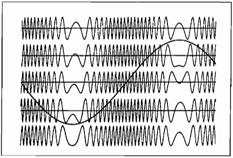

Figure 4. Successive observations of the photoelectric signal over one cycle of constant amplitude SHM, as the reference reflector is slowly moved.

3.3 LINEARITY (ii)

At 2Hz, 1 m s^{-2}, the displacement amplitude is 6.33257 mm, thus the peak-to-peak displacement corresponds to the passage of 20 014.46 interference fringes. Acceleration of 0.001 m s^{-2} at the same frequency corresponds to about 20 fringes peak-to-peak, which can be measured with an uncertainty of about ±2 nm, ie ± 0.03%. Thus linearity measurement can cover a 60 dB range at a single frequency. Similar measurements at 10 Hz, from 1 m s^{-2} to 10 m s^{-2}, effectively extend the linearity measurement to an 80 dB range.

3.4 VOLTAGE MEASUREMENTS

Several different instruments have been used for voltage measurement, and in each case the instrument calibration is traceable to the Josephson Volt Standard, via thermal transfer standards.

The first instrument used was a Fluke 931B True RMS Differential Voltmeter. This is a 5$^1/_2$ digit instrument which is calibrated "in house" by the electrical standards section of NML, over its full range of use. At frequencies not less than 30 Hz, the uncertainty in those calibrations is ±0.05%, increasing to ±0.3% at 2 Hz. The disadvantage in using this instrument is that each reading must be made manually, thus measurement is slow, tedious and cannot be easily automated.

A Hewlett-Packard hp3458A digital multimeter overcomes the above difficulties. This 8$^1/_2$ digit instrument measures by fast digital sampling and computation of true rms, with or without dc as required, and its response is flat within a few parts in 10^6 over the voltage and frequency range required. Uncertainty in its calibration is similarly small, of the order of ±30 parts in 10^6, and the instrument can be programmed and read via an IEEE488 general purpose interface bus (GPIB).

As the acoustics and vibration standards program has only one hp3458A, it has been decided to retain it as a reference voltmeter against which to check our other voltmeters. These include several hp34401A meters which are used at frequencies down to 20Hz, and an Analogic DP6100 analyser which is calibrated as a voltmeter for the frequency range 2Hz-500Hz. All of these have IEEE488 interfaces.

The hp34401A multimeter, on medium filter setting, can take 1 reading/sec with a claimed accuracy of ±0.3% for full scale at 20Hz, and about ±0.15% at higher frequencies. It was calibrated by comparison with the hp3458A, the uncertainty of this calibration was estimated as ±0.1% for full scale at 20Hz.

The DP6100 analyser is a computing instrument with a 16-bit 8MHz mainframe, a 14-bit A/D input which can sample at up to 100k samples/sec, and a built-in voltage reference. It can be programmed to compute true rms in the same way as the hp3458A, and when calibrated against the hp3458A the correction is less than 0.1% for the voltage range of interest. The additional uncertainty is about ±0.05%, with an extremely flat frequency response. To attain this performance, the program ensures that sampling is over an integral number of cycles.

The DP6100 can also compute Fast Fourier Transforms (FFTs), and has been used in this mode as a narrow-band voltmeter. After applying to the transformed data a correction for the so-called "picket fence effect" [7,8], it was found that these measurements could be made with an uncertainty of approximately ±0.1% .

4. CONCLUSIONS

At the National Measurement Laboratory, apparatus and techniques have been developed to calibrate reference accelerometers "absolutely" at frequencies down to 2Hz. By exercising great care in making measurements, correcting for errors, and by maintaining strict traceability to the primary standards of length, time and voltage, an uncertainty of approximately ±0.5% is achieved for these calibrations. The interferometric method is complemented by a static calibration using the local *g* field, which effectively extends the calibration down to zero hertz. When accelerometers and other transducers are calibrated by comparison with these references, the sensitivity value can have a least uncertainty, at the time of the calibration, of about ±0.6% in the 2Hz-20Hz frequency range, though this may be much greater for large transducers. Uncertainties quoted here are at the 95% level of confidence [2].

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APPENDIX A`

MEASURING VIBRATION DISPLACEMENT WITH AN INTERFEROMETER

Assume that the reference reflector and the reflector on the armature are initially stationary, and that the distance from the beam splitter to each of the reflectors is exactly the same, or differs by an exact number of half-wavelengths of the laser light. Light returning from the two reflectors is thus in-phase at the beam splitter, and there is constructive interference of the re-combined light emerging from the beam splitter. If the armature is now displaced by a distance of one quarter wavelength, light reflected from it travels an extra half-wavelength, and the resulting re-combined light exhibits destructive interference. A further quarter-wavelength displacement again produces constructive interference, and at the photodetector the re-combining light has now gone through one complete cycle of intensity variation. By converting such cyclic variations (or "interference fringes") of intensity to electric signals, the photodetector makes it possible to count them, and thereby measure the distance through which the armature has moved, in terms of the wavelength λ of the laser light. If the armature is subjected to rectilinear SHM with a displacement amplitude equal to one half-wavelength, then one "fringe" will be counted 4 times in each cycle of the SHM. Any given displacement amplitude *D* is thus measureable by counting the number of fringes per cycle of SHM, ie by measuring a mean frequency ratio *R*, thus

$$D = R\lambda / 8$$

This is essentially the principle of the "frequency ratio" method of measuring displacement interferometrically. If *R* is not an integer, then the extra fraction may or may not be counted, depending on the position of the fringe pattern with respect to the photodetector at the turning point of the SHM. Figure 4 shows successive observations of the fringe pattern, over one cycle of constant amplitude SHM, as the reference reflector is slowly moved. Averaging a large number of such observations gives the value of *R* complete with the fractional part.

APPENDIX B

ESTIMATION OF UNCERTAINTIES

Uncertainty values are calculated using the methodology in the ISO "Guide" [2]. The following describes how this is done for absolute calibrations of low-frequency reference accelerometers.

Type A Uncertainties

From n repeat measurements of the sensitivity of an accelerometer, the MEAN and STANDARD DEVIATION (S.D.) are calculated.

The S.D. gives an estimate of the uncertainty of individual measurements, but to estimate the TYPE A STANDARD UNCERTAINTY OF THE MEAN, (corresponding to the older concept of the Standard Error of the Mean, or S.E.M), S.D. is divided by $\sqrt{n}$.

Before factoring in type B uncertainties, the type A uncertainty is converted to per unit form, thus U_A (per unit) = S.D./($\sqrt{n}$ * MEAN)

Type B Uncertainties

These are all evaluated in per unit form:

Voltmeter resolution	U_1	(resolution/(√3 x reading))
Voltmeter calibration uncertainty	U_2	(0.001-0.003, see section 3.4)
Voltmeter sensitivity drift	U_3	(0.001)
Voltage uncertainty due to total noise & distortion (TND)	U_4	(after correction, 0.0002)
Frequency resolution	U_5	(resolution/(√3 x reading))
Frequency reference uncertainty	U_6	(1 x 10^{-6})
Uncertainty in displacement due to total noise and distortion(TND)	U_7	(after correction, 0.0002)
Transverse & rocking motion	U_8	(0.0005)
Temperature coeff(accelerometer)	U_9	(0.00018 for 1° shift)
HeNe Laser Wavelength	U_{10}	(2 x 10^{-6})
f ratio resolution(fringe counting)	U_{11}	(0.001/(√3 x ratio count))

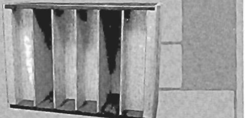
The above type B uncertainties are considered to be uncorrelated, and can be combined by Root Sum of Squares to obtain U_B (per unit).

If the type A uncertainty is "very large" by comparison with all type B uncertainties, then an expanded uncertainty, at 95% level of confidence, can be estimated by multiplying U_A by $t_{0.025}$ for (n-1) degrees of freedom, where t is from "Student's t" distribution, and corresponds to *k*, the "coverage factor" of the ISO Guide. For these purposes, "very large" means that no significant figures of the expanded uncertainty would be changed by the addition of type B uncertainties. In general, however, an expanded combined uncertainty, at 95% level of confidence, is obtained as

$$U_{exp} = k * \sqrt{(U_A^2 + U_B^2)}$$

where $k = 2.0$ if ν >30, otherwise $k = t_{0.025}$ for ν degrees of freedom, where ν is calculated from the Welch-Satterthwaite formula (appendix G of [2]).

Typically for a calibration at 5Hz, U_{exp} is about 0.005, ie ±0.5% uncertainty.



Noise and Vibration Data Acquisition using a 16 bit PC Sound Card

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ABSTRACT: Noise and vibration data acquisition cards for the Personal Computer have been available for about 10 years, commencing with 8 bit, then 12 bit and now 16 bit plug in cards. The data acquisition capabilities available range from two up to 64 or more channels, with sampling rate capabilities from a thousand samples per second to well over one million samples per second. The range of plug in cards available on the market is enormous. For a particular application, it is no easy task to determine the cheapest card available to meet the actual requirements. For data acquisition and analysis of rotating machinery noise and vibration, a frequency bandwidth of 10 to 20 kHz per channel is normally required. Unfortunately, the cost of special purpose 12 or 16 bit cards with this bandwidth tends to be at least two thousand dollars. This paper presents a detailed investigation, calibration and analysis of a mass market 16 bit sound card which is now available for under two hundred dollars and which has adequate performance for the analysis of rotating machinery noise and vibration. The data acquisition capabilities under the windows environment are discussed along with channel calibration, amplitude and phase response and the ease of transferring the data to post-processing environments such as MATLAB.

1. INTRODUCTION

The measurement and analysis of noise and vibration is recognised as being essential for routine condition monitoring for most types of rotating machinery. Special purpose data collectors tend to be used as the prime means of collecting, storing and analysing the routine vibration measurements in a large number of industries [1]. For more specialist data acquisition and machinery monitoring problems, tape measurements may be made prior to analysis with dynamic signal analysers or Personal Computer data acquisition systems may be used to capture and post-process the data [2]. An unfortunate aspect of the current generation of PC based data acquisition systems is the cost which starts at around two thousand dollars and extends up to five thousand dollars for typical 12 or 16 bit multi-channel cards. For university or research use, the cost for single or multiple cards can be prohibitive.

An alternate data acquisition capability is now available through the use of plug in sound cards [3]. The mass-market sound cards are typically used to produce high quality sound from the PC, and are used routinely for computer games, educational software and general multi-media applications. The major reason for the current interest in sound cards is the cost, with most two channel 16 bit cards selling for under two hundred dollars. In order to determine the suitability of the sound cards for general analogue data acquisition, a number of aspects of a Sound Blaster 16 Basic card were thoroughly investigated including the windows data acquisition capabilities, transfer of the WAV files into MATLAB, phase and amplitude response, input voltage ranges, calibration and the cross channel noise. This paper details the results of the investigation, provides a summary of the advantages and disadvantages of using sound cards for general data acquisition and describes a range of suitable applications for their use in Mechanical Engineering.

2. GENERAL DATA ACQUISITION CAPABILITY

The Sound Blaster 16 bit card provides two main options for general data acquisition using either the microphone or line inputs. The microphone input provides a single channel of data whereas the line input can be configured as either one or two (stereo) channels [4]. The Sound Blaster card comes complete with a range of DOS and Windows software products for controlling the channel gain, sampling rate and resolution for general data acquisition. The Windows software which was found to provide the easiest means of transfering the resulting WAV files into MATLAB was the Soundo'LE application. This could be run as an external executable application from within MATLAB using the *!c:\sb16\winappl\soundole.exe* command to execute the application.

The graphical user interface of the Soundo'LE application is shown in Figure 1 where the basic record, play back, pause, rewind and fast forward buttons are available. The recording option available under the options menu shown in Figure 2 allow the number of channels, sample rate and the resolution to be selected as required. The sample rate is per channel with simultaneous sampling on both channels. Figure 3 shows the menu to choose the actual data channel for recording purposes and the channel gain selection. The channel gain is independant of the channel selected which allows for the acquisition of the same data channel at different gains if required.

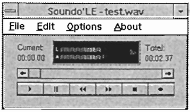

Figure 1. Sound Blaster 16, Soundo'LE Graphical user Interface.

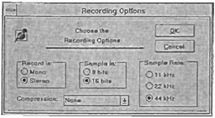

Figure 2. Control of the sample rate, resolution and number of channels.

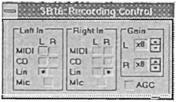

Figure 3. Channel and gain control interface.

Having specified the data acquisition requirements, clicking on the record button on the lower right portion of the menu shown in Figure 1 digitises the data and transfers it to the Windows environment using DMA. The data acquisition capabilities of the Sound Blaster card under Windows are impressive. At the maximum sample rate of 44.1 kHz per channel, for two channels and 16 bit resolution, the data is digitised and transferred continuously to the Windows environment at 176400 Bytes/sec until the acquisition is stopped or the hard disk is full. After acquisition, the data files are available to be saved as industry standard WAV files and are compatible with the Windows Media Player and Sound Recorder, allowing some basic editing to be done if required.

It is also possible to transfer the WAV files into MATLAB by writing a MATLAB M-file to read the WAV file once the format of the WAV file is known. Appendix A shows a typical M-file which can be used to read any version of the WAV files supported by the Sound Blaster series cards. The M-file first reads the file header to determine the format of the data, whether 8 or 16 bit acquisition was used, the number of channels and the sampling rate, etc. After the WAV file is read into MATLAB, the data can then be treated as any other MATLAB vector allowing very sophisticated signal processing techniques to be used to analyse the data [5].

3. INPUT VOLTAGE RANGE

The Sound Blaster 16 bit card has menu selectable independant gain control on the two channels. When the card is used to digitise analogue voltage waveforms through the line input, the maximum input voltage range for the various gains has to be determined as it is initially unknown and not specified in the technical documentation. In order to determine the input voltage range, harmonic distortion analysis was used to specify the maximum input voltage level as a function of gain. A Hewlett-Packard 35665A Dynamic Signal Analyser was used to provide a 1 kHz analogue sine waveform as input to the line-in on the Sound Card for various amplitudes and gains. With the input signal sampled at 44.1 kHz, power spectrum analysis was used to measure the amplitude ratio between the 1 kHz component and the next highest harmonic component in dB. Figure 4 shows the harmonic distortion results as a function of gain and the input voltage amplitude.

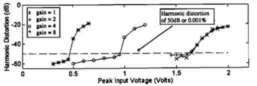

Figure 4. Harmonic distortion as a function of gain and input voltage.

With 0.001% harmonic distortion or 50dB being used as a basis for determining a maximum input voltage range, the voltage ranges can be read from Figure 1 as a function of gain. Table 1 provides a summary of the input voltage ranges corresponding to a harmonic distortion of 0.001%.

Gain	Input Voltage Range
1	± 1.65
2	± 1.6
4	± .95
8	± .47

Table 1. Input voltage ranges for harmonic distortion of 0.001% (50 dB) and 44.1 kHz sampling rate.

The input voltage range was not a linear function of gain. As shown in Table 1, the maximum input voltage range for a gain of 1 and 2 were very similar. The conversion of input voltage to quantum level at these gains did not cover the complete range of the A/D converter, (-32767 to + 32768 using 16 bit conversion) indicating that the conversion was less than 16 bit. This would have to be taken into account in determining the resolution and calibration of the card at these gains.

4. RESOLUTION

The resolution of the sound card was determined by grounding the input channel and digitising the resultant noise floor as a function of channel gain for both 8 and 16 bit conversion. The results are shown in Table 2 as standard deviation of the number of quantum levels in the noise floor.

Gain	8 bit conversion	16 bit conversion	Resolution Standard Deviation (mV)
1	0	2.2	0.27
2	0	3	0.18
4	0	5	0.145
8	0	9	0.13

Table 2. Typical noise level measured with grounded inputs and specified as standard deviation of the number of quantum levels.

With 8 bit conversion, the grounded input had a zero quantum level noise floor across all gains. With 16 bit conversion, the resolution became poorer as the gain was increased and had a typical maximum standard deviation of 9 quantum levels at a gain of 8. With a maximum input voltage range of 0.47 Volts, this corresponds to a standard deviation resolution of 0.13 mV as shown in Table 2. The resolutions obtained as a percentage of the input voltage range are also shown in Table 2. The resolution available with gains of 1 and 2 were found by taking into account the reduction in the number of quantum levels available for the input voltage ranges.

5. CALIBRATION

Knowing the input voltage range as a function of gain, a crude calibration from quantum level into voltage can be made. For a more accurate calibration, a statistical analysis of the input and digitised waveform was used. A 399.89mV peak sinusoidal waveform from the HP Analyser was captured at a sample rate of 32.768 kHz using the HP analyser and 20480 time points were transfered to MATLAB for analysis. The waveform was also digitised by the sound card and then transfered into MATLAB for analysis at the various gains. By computing the RMS of the two time signals, a calibration factor was then computed to convert the digitised sound card quantum level into Volts. Table 3 provides the resulting calibration values for the various gains and resolutions.

Gain	8 bit conversion	16 bit conversion
1	29.772×10^{-3}	11.663×10^{-5}
2	14.910×10^{-3}	5.814×10^{-5}
4	7.451×10^{-3}	2.913×10^{-5}
8	3.744×10^{-3}	1.464×10^{-5}

Table 3. Calibration factors as a function of gain and resolution.

The calibration factors will vary from card to card. The values shown above should be taken as indicative only.

6. DUAL CHANNEL FREQUENCY RESPONSE

The amplitude and phase response of the sound card was measured by using a random noise signal from the HP analyser. The signal was connected to both channels of the sound card and after digitising the signal and saving the data as a WAV file, the two channels of data were read into MATLAB and the amplitude and phase of the complex transfer function computed as a function of frequency. Using the 16 bit resolution and the 44.1 kHz sampling frequency, the amplitude and phase response of the sound card is shown in Figure 5. An external analogue anti-aliasing filter was used with a low pass cut-off frequency of 15 kHz, and so the results up to 15 kHz are shown.

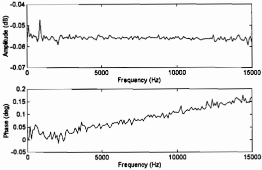

Figure 5. Amplitude and phase response across the two channels of the sound card.

The amplitude response between the two channels appears to be flat within 0.01 dB across the frequency range as shown except for the low frequency region. A closer inspection of the low frequency response of the sound card was undertaken to ascertain the low frequency behaviour. Table 4 shows the amplitude response of the card below 12 Hz. The amplitude response was found to be within 1 dB above 10 Hz which suggests AC coupling as would be expected for sound measurement.

Frequency (Hz)	Amplitude Response (dB)
1	-14
2	-8.3
4	-3.9
6	-2.2
8	-1.35
10	-0.9
12	-0.6

Table 4. Low frequency amplitude response of the sound card.

The phase response of the card shown in Figure 5 shows a linearly increasing phase within 0.2 degree up to 15 kHz which is representative of a small time delay between channels. At 15 kHz, the phase lead across the two channels was approximately 0.16 degrees which corresponds to a negligible time difference of 0.03 msec between channels. The time difference is most probably due to some small delay in triggering the A/D conversion on both channels. For the maximum sampling rate of 44.1 kHz, the data acquisition can be considered to be simultaneously sampled. Excluding the linearly increasing phase, the phase response is within 0.1 degree across the whole frequency range.

7. CROSS CHANNEL NOISE

The cross channel noise was investigated by digitising both channels at the maximum sampling rate using 16 bit resolution, with channel 1 having 0.4, 0.8, 1.4 and 1.4 peak Voltage sinewave inputs at the gains of 1, 2, 4 and 8 respectively for various frequencies while channel 2 was grounded. The resulting cross channel isolation from the input to the grounded channel is shown in Table 5 in dB. The worst case scenario occurs at the highest frequency with a gain of 8 where the inter-channel isolation is approximately 63 dB.

Frequency (kHz)	Gain of 1	Gain of 2	Gain of 4	Gain of 8
1	> 90	> 90	> 90	> 80
5	> 80	> 80	> 80	> 75
10	> 75	> 75	> 75	> 68
15	> 70	> 70	> 72	> 65
20	> 68	> 68	> 70	> 63

Table 5. Cross channel isolation as a function of frequency and gain (dB) sampled at 44.1 kHz.

8. DISCUSSION

From the investigation in using a PC sound card for data acquisition, a summary of the advantages and disadvantages which were found is shown in Table 6. The major advantage in using the sound card for data acquisition over the more expensive dedicated A/D plug in cards is the cost. For less than $200 the sound card provides 16 bit simultaneous 2 channel sampling capability under the MS-Windows environment, including DMA for continuous data capture. The software provided was very robust and did not crash even for long time capture records of tens of megabytes. The menu driven software was very easy to use and was seen as providing a usable and efficient data acquisition capability.

The inter-channel isolation of 63 dB at the maximum gain and frequency range is of concern and is probably the major deficiency of the card as compared with the more expensive dedicated plug in cards which can provide up to 90 dB of cross talk over the full frequency range [6]. The sound card had no DC A/D capability and the response dropped off below 10 Hz. For those applications which require a low frequency or DC measurement, then the sound card will not be suitable.

Advantages	Disadvantages
16 bit resolution	No calibration from bits to Engineering units
Adjustable gain, sampling rate and resolution	No anti-aliasing filtering
2 channel, simultaneous sampling	No DC capability
A/D capability under MS-Windows	Low level of technical information available
DMA for continuous data capture	Difficult to write MS-Windows A/D software
Easy to use MS-Windows software	63 dB cross channel isolation at 20 kHz
.wav files can be read using MATLAB	
Line and mic inputs	
Extremely cheap (< AUS$200)	
Readily available for educational and home use	
Available on desktop PC's, laptops and notebooks	

Table 6. Summary of the advantages and disadvantages of PC sound cards for vibration data acquisition.

A number of vibration and noise applications will be suitable areas for using the sound card such as sound intensity, gear vibration condition monitoring and general dual channel transfer function analysis. The sound card has been shown to provide high quality amplitude and phase response across a broad frequency range which is required for all of these signal analysis areas. Aside from the dual channel signal analysis areas, the card will also be useful as a general purpose single channel data acquisition system for those applications which require analogue signals with bandwidths below 20 kHz to be digitised. The card has the potential to be very useful in Mechanical Engineering undergraduate programs in laboratory situations as a general purpose data acquisition capability. This could include measurements such as pressure, strain, vibration, force, etc, for laboratories and final year projects where the expense of the normal data acquisition cards becomes prohibitive.

The sound cards present somewhat of a problem for the application specific data acquisition area where special purpose software is required to do acquisition and analysis all in one. While software libraries are available using 'C' and pascal for the sound cards, the task of writing the software under the windows environment is a difficult one which in the opinion of the author should be left to computer programmers. The ability to develop Matlab compatible 'C' data acquisition code under Windows would be very beneficial as a MATLAB graphical user interface could then be developed integrating the data acquisition and analysis.

9. CONCLUSION

The Sound Blaster 16 basic card has been shown to be a very capable general purpose 16 bit data acquisition card with 2 channels sampled simultaneous at a maximum rate of 44.1kHz. The inbuilt DMA provides a continuous sampling capability direct to the MS-Windows environment and will allow data to be collected until the hard disk becomes full. The easy to use menu driven software allows the selection of sample rate, resolution, number of channels and gain control. The WAV files can be read into MATLAB once the format of the WAV file is known and a sample version has been provided. The price of the 16 bit cards (< $200) means that they are readily available on the normal desktop computer at work, home, and for undergraduate student laboratory or project purposes. While the single channel amplitude and phase response of the card was not measured, the cross channel amplitude and phase response of the card contained less than 0.01 dB and 0.1 degree variation respectively across the bandwidth which was tested (<15 kHz).

The calibration of the sound card was relatively straight forward given a precision waveform generator. The calculated calibration factors then allow for the digitised waveform to be converted to Volts and then to engineering units once the sensitivity of the particular transducer is known.

The input Voltage range which can be used on the line input can pose a problem as it is initially unknown. By using a harmonic distortion test, the input voltage range was determined as a function of gain and the maximum input range was determined to be ± 1.65 Volts with a harmonic distortion of 0.001% or 50dB. The card does not provide any anti-aliasing protection so a low pass analogue filter must be used with the appropriate setting to filter the input waveform prior to digitisation.

The sound cards are seen to provide a very inexpensive alternate data acquisition capability. Further investigation into various technical aspects not shown in this paper would seem to be warranted.

10. ACKNOWLEDGMENT

The time and effort given by Mr. Wang-Juin Yee in the initial investigation of the capabilities of the sound card is greatfully acknowledged. Thanks also goes to Dr R.M. Howard for the helpful technical discussions.

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Appendix A: MATLAB M-file for reading WAV files

```
function [chan1,chan2,dt,format]=lwave(wavefile)
% This function load any windows compatible
% .wav file
%
% the format of the file is returned in format
% the data is returned in chan1 and chan2
% the sample time period is returned in dt
%
% Modified from the MATLAB wavread.m file
% pop up window to select file
[filename,path] = uigetfile('*.wav');
if filename==0
    % cancel operation
else
    % rearrange path and filename of desired          % mat file
    wavefile = [path,filename];
    % load file into workspace
    eval('fid=fopen(wavefile,"rb");');
end
if fid == -1
    error('Can"t open .WAV file for input!');
end;
if fid ~= -1
    % read header
    header=fread(fid,4,'uchar');
    header=fread(fid,1,'ulong');
    header=fread(fid,4,'uchar');
    header=fread(fid,4,'uchar');
    header=fread(fid,1,'ulong');
    % read format from file header
    % PCM format
    format(1)=fread(fid,1,'ushort');
    % Number of channels
    format(2)=fread(fid,1,'ushort');
    % Sampling frequency
    fs=fread(fid,1,'ulong');
    % specify sampling rate
    dt = 1/fs;
    format(3)=fs;
    % average bytes per second
    format(4)=fread(fid,1,'ulong');
    % block alignment
    format(5)=fread(fid,1,'ushort');
    % bits per sample
    format(6)=fread(fid,1,'ushort');
    % read header
    header=fread(fid,4,'uchar');
    % Number of samples in file
    nsamples=fread(fid,1,'ulong');
    % read data in correct format
    if format(6)==8  % 8 bit data
       % read data in 8 bit format
       d=fread(fid,nsamples,'uchar');
    elseif format(6)==16 % 16 bit data
       % read data in 16 bit format
       d=fread(fid,nsamples,'short');
    end
    % reorder data if in two channel mode
    if format(2)==2
       chan1 = d(1:2:length(d));
       chan2 = d(2:2:length(d));
    elseif format(1)==1
       chan1 = d;
    end
    % close file
    fclose(fid);
end
```

Orchestral Music: An Assessment of Risk

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Abstract: Worldwide, a reasonable number of measurements have been made of the type of sound levels to which Orchestral Musicians are exposed. The conclusions are in conflict when compared in isolation because the previous studies have given little data as to true exposure levels over a longer period. The current study traces the sound exposure at various positions within a Classical Orchestra performing for Opera and Ballet in an orchestra pit. It determines Noise Exposure based on type and length of performance, rehearsal etc. on a daily basis for a full season of works. The results, when compared to industrial criteria for noise exposure, are relatively high as many musicians are often being exposed to levels over 90dB(A). The only person in the orchestra without risk is the conductor. The audience is also not at risk of NIHL.

1. INTRODUCTION

The establishment of the risk of Noise-Induced Permanent Threshold Shift (NIPTS) for orchestral musicians is more difficult than for process workers or other industrial exposures due to the large variation in sound levels and exposure times. This is caused by; the type of performance, the acoustic environment, the performance schedule and the rehearsal time. Also it has been commonly claimed that "music is harmonious and lacks the peaks of industrial noise and is therefore not as harmful".

There are two ways to assess the risk of NIPTS for musicians. The first is by evaluating the working environment of musicians. This is achieved by measuring and analysing the sound levels and then calculating the equivalent continuous sound exposure levels taking into account the musical instrument played by each musician and his position relative to other players during musical performances and rehearsals. The performance and rehearsal schedule also needs to be taken into account . The result obtained can then be compared to ISO 1999 Acoustics - Determination of occupational noise exposure and estimation of noise-induced hearing impairment.

The second method is by evaluating the hearing threshold levels (HTLs) obtained for each member of the orchestral group. A comparison to a non-exposed population can then be made. If the hearing levels for the musicians as a group are no worse than the general public, then the risk of NIPTS could be assumed to be small.

This paper presents the results of the first approach. It shows the results of measurement and determines exposure levels for a season of performance. As a result of the findings a follow-up audiometric study is being carried out. A further paper will be prepared after the conclusion of a four year audiometric study.

2. PREVIOUS STUDIES

Records of the measurement of sound levels produced by musical instruments and orchestras can be traced back to as early as 1931[1]. The whole spectrum peak power and the corresponding percentage of intervals as well as the frequency range containing the maximum peaks, their power and percentage of intervals, were measured and recorded for sixteen instruments ranging from drum to piano, and for 15, 18, 75-piece orchestras as well as a pipe organ. The highest sound levels obtained were from a 36 x 15" bass drum. The lowest levels obtained were from a violin played very softly. These levels were measured over short times at undefined positions and cannot be related to exposure. The sound pressure levels and exposures measured by other researchers are summarised in Table 1

TABLE 1.

Sound Source	S P L	Author
Piano	70 dB	Arnold
Symphony orchestra	70 - 95 dB	Lebo
Symphony orchestra	> 90 dB(A) for 3.51 of 14.4 hours recorded.	Westmore
Symphony orchestra	83 - 92 dB(A) $L_{Aeq,8h}$ = 76.5 - 85.2	Axelsson
Symphony orchestra	88.9 - 93.1 dB(A)	Jansson
Symphony orchestra	82.9 - 89.5 dB(A)	Woolford
Symphony orchestra	83.9 - 95.9 dB(A)	Woolford
Symphony orchestra	79 - 99 dB(A) $L_{Aeq,8h}$ =74.7 - 94.7	Royster

Arnold and Miskolczy-Fodor [2] measured the sound pressure levels (SPLs) of a concert grand piano. Placing the microphone at the level of a pianist, the SPLs obtained were

64 to 93 dB with the piano top raised and 59 to 86 dB with the top lid lowered. It was noted that maximum sound was achieved by repeatedly striking the keys with the sustain pedal depressed until the sound volume reached its maximum value. The authors concluded that the sound level produced by a piano during normal performance was about 70 dB.

Lebo and Oliphant [3] measured the SPLs of a symphony orchestra in an empty concert hall with the microphone positioned at the centre of the orchestra. The SPLs noted were usually below 70 dB and rarely achieved 95 dB, they were also fairly evenly distributed between 500 and 4,000 Hz.

In 1981, Westmore and Eversden [4] recorded the SPLs produced by a symphony orchestra for a total time of 14.40 hours. Their subsequent analysis found that sound levels exceeded 90 dB(A) for 3.51 hours and equalled or exceeded 110 dB(A) for only 0.02 hours. Peaks exceeding 120 dB(A), probably generated by the percussion section, were also measured occasionally.

Axelsson and Lindgren [5] measured sound levels during seven performances conducted in a concert hall and an orchestra pit by placing microphones on tripods near players. The L_{Aeq} obtained were 83 to 92 dB(A). The $L_{Aeq,8h}$ was estimated to be 68.5 to 86.4 dB. The data also revealed that the sound levels were slightly higher in the orchestra pit.

Jansson and Karlsson [6] obtained performance L_{Aeq} of 93.1 and 88.9 dB(A) at "exposed" and "normal" positions respectively with the microphones placed beside the musician at ear level during orchestral performances.

Woolford [7,8] measured SPLs with microphones mounted at head level. Eight microphone positions were used within the orchestra and included the conductor's podium. Measurements were taken of 66 to 85 musicians performing in a large studio for just over one hour. The L_{Aeq} recorded ranged from 82.9 dB(A) at the conductor's podium to 89.5 dB(A) at the point between the French horn and woodwind section as well as in front of the timpani. Seven locations showed maximum peak levels exceeding 115 dB with a maximum of more than 125 dB at a point located in front of the trumpet and bassoon and near the percussion section. The remaining position located between the double bass and cello recorded a sound level of 112 dB.

Woolford [7,8] took one hour samples of various orchestral musicians. Results were reported for:

An 18-piece brass choir performing in a recording studio with the measurements taken at the conductor's podium. The performance L_{Aeq} was 93.1 dB(A) with a maximum peak of 120 dB. At a corner of a large recording studio fenced with acoustic screens, the L_{Aeq} produced by 3 trombones, 3 trumpets, and 1 tuba, was 83.9 to 95.9 dB(A) with L_{peak} of 115 dB.

A 45-piece orchestra on a confined stage of 7.6 by 11.6 m and with the microphone placed in front of the brass and percussion instruments. The L_{Aeq} generated was 95.5 to 93.5 dB(A). The peak sound levels noted exceeded 125 dB. During a performance of the ballet Swan Lake in a theatre pit, the measured sound levels L_{Aeq} were:

95.9dB(A) with peak levels exceeding 125dB in front of the trombones for 1.27 hour;

93.9dB(A) and exceeding 125dB in front of percussion and tuba's for 0.6 hour;

94dB(A) and exceeding 125dB in front of drums and trombones for 0.52 hour;

93.4dB(A) and exceeding 119dB in front of French horns and piccolos for 1.17 hour; and

92.8dB(A) and in excess of 125dB in front of French horns and piccolos for 0.7 hour.

Measurement of SPLs were carried out during a performance in a hall of 11m *x* 20m *x* 4.3m high. All surfaces were hard and sound-reflecting except that one side was covered with a curtain to separate one quarter of the long side which was not in use. Woolford reported on four locations which gave L_{Aeq} 88 to 91.6 dB(A) and peak levels of 116 to 122dB over measuring times of 0.2 to 1.2 hour.

In a recent study, Royster, Royster and Killion [9] obtained 68 dosimetry samples from 23 violins and violas (group 1), 13 horns, trumpets and trombones (group 2), 17 clarinets, flutes, bassoon, and percussion (group 3), and the remaining 15 samples from bass, cello, harp and piano (group 4). Microphones were clipped onto the collars of the selected musicians on the side with higher noise exposure and the corresponding dosimeters were mounted around the musicians' waist or near the hip. The SPLs recorded are given in Table 2. The daily equivalent 8-hour exposures were calculated based on a 15-hour week.

TABLE 2. (Values in dB(A))

	L_{Aeq}	Peak	Max	$L_{Aeq,8h}$
Mean	89.8	124.9	106.4	85.5
S.D.	4.7	6.4	5	4.7
Median	90	124	106.8	85.7
Minimum	79	112	95.5	74.7
Maximum	99	143.5	115.5	94.7

The L_{Aeq} ranged from 79 to 99 dB(A) with a mean value of 89.8 dB(A). Groups 2 and 3 appeared in the upper portion of the overall range. The L_{Aeq} values for group 1 (violins and violas) were evenly distributed throughout the entire range, while group 4 (bass, cello, harp and piano) fell in the lower portion of the range. 82 % of the samples had a maximum peak level of 130 dB or below, and two samples (3 %) had peaks exceeding 140 dB throughout the period of measurement. 76 % of the samples had a maximum RMS equivalent sound level of 110 dB(A) or below. The highest measured peak was 115.5 dB. The mean $L_{Aeq,8h}$ was 85.5 dB(A).

This summary of the literature shows the variation in methodology and the lack of any determination of $L_{Aeq,8h}$ except for the day of measurement. The long term exposure has not been calculated for any orchestra. The SPLs reported ranged over 70-110dB(A). Prolonged exposure at these levels is capable of causing hearing damage.

ISO 1999:1990(E) requires that "daily noise exposure level shall be determined for a sufficient number of days for the individuals under consideration to allow the determination of the average exposure to noise for the years or decades under consideration with an overall uncertainty appropriate to the particular noise problem." It was therefore concluded that an estimation of risk for the Australian Opera and Ballet Orchestra could not be made based on the available literature. However the literature did indicate a significant number of high level measurements, from these it may be inferred that the probability of risk was significant.

The question of risk of NIHL however must be addressed by a combination of level and exposure. It is insufficient to extrapolate from a number of level measurements without taking into account the variation of exposure between performances. The only way to resolve this issue is to measure actual performance exposure and relate this to normal work practices and rosters. Therefore a long term measurement programme was undertaken.

3. MEASUREMENT OF SOUND PRESSURE LEVELS

A series of measurements of the Australian Opera and Ballet Orchestra were taken during performances and rehearsals throughout the 1992 winter opera season which extended from April 1 to October 31 1992. The recordings were limited to a representative sample of each performance. The L_{Aeq} of the performances of each opera were measured once. The L_{Aeq} of selected rehearsals of several events performed in the orchestra pit and at the Opera Centre were obtained and were used to estimate the L_{Aeq}'s of the rehearsals not recorded. The frequency spectrum was also recorded for later comparisons to industrial spectra. Measurements were taken at between 4 to 6 positions. The L_{Aeq} of a performance in the Concert Hall of the Sydney Opera House was also taken for comparison purposes.

Larson Davis 700 integrating sound level meters / dosimeters were used to measure the sound pressure levels. The computer capability of these instruments allowed a complete time history of sound levels during the measurement period to be recorded and statistically analysed.

The microphones were suspended from the ceiling in positions ranging from 100mm but always less than 1m from the musicians' ears in accordance with the Australian Standard 1269-1989 Acoustics - Hearing Conservation. The ceiling of the orchestra pit is low, varying from 1.8 to 2.3 metres. The relationships between microphone position and musician varied to a small degree from performance to performance depending on the number of musicians in the pit. The only unacceptable variation between performances occurred with the double bass in front of the trumpets. This microphone was therefore moved between positions 1 and 1a to retain proximity to the double bass. For calculation purposes the positions 1 and 1a were considered equal to the Double Bass exposure.

To establish the validity of fixed area sampling one microphone was fixed onto a musician's shoulder near the ear. The L_{Aeq} thus obtained was in agreement with that obtained with the fixed microphone used to monitor that position. It was concluded that the fixed microphones gave a valid reading of personal exposure due to the rest of the orchestra. Naturally for certain instruments such as the violin the exposure of the ear nearest the instrument may be higher. The figures used in this report are from microphones which were suspended from the ceiling or fitted to fixed positions during recording throughout the opera season.

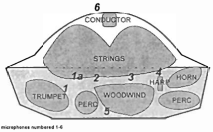

Figure 1. Typical layout of microphones during a performance.

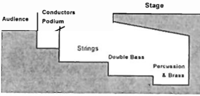

Figure 2. Cross section of orchestra pit.

Figure 1 and Figure. 2 show the plan and elevation views of the orchestra pit at the Australian Opera House Opera Hall together with approximate musician positions. Microphone positions are detailed in Table 3.

TABLE 3

Position number	Description of placement in the orchestra pit
1	Double bass in front of trumpets (full orchestra)
1a	Double bass in front of trumpets (reduced orchestra)
2	Double bass in front of percussion
3	Woodwind
4	Harp
5	Above contrabassoon, between percussion
6	Behind conductor

The L_{Aeq} was sampled on a regular basis by the dosimeters. These were then downloaded into a computer program and the sound exposure histories were plotted. One type of graphical output is shown in Fig 3 and this demonstrates the Equivalent Sound Level for each minute, $L_{Aeq,1m}$ and the maximum SPL (slow time weighting) achieved during that minute L_{Amax}.

The L_{Aeq},1m values were used to determine the exposure and the L_{Amax} values were compared to 115 dB(A), (the New South Wales maximum allowable industrial SPL).

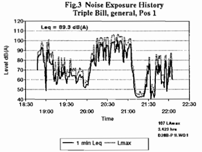

Figure 3. Example of plotted test results downloaded from dosimeters

Because of the extreme variability of performances it was necessary to sample operas over the entire operatic season to enable the determination of a realistic assessment of the overall level of risk. A graphical summary is shown in Figure 4. It demonstrates the relationship between the positions and the different types of performance. The documented levels are for the full performance including intervals and encores. The time of exposure varies with the length of the performance and is used in the next analysis. It can be seen that performances of the *Triple Bill* generate significantly higher outputs for the Bass in front of the Trumpets than say *Figaro*, *Alcina* and *L'Italian*. *Fiddler on the Roof* has a generally higher output for the rest of the orchestra, mainly due to the introduction of a modern drum kit. Analysis of all the dosimeter outputs showed no L_{max} in excess of 113 dB(A) slow, therefore no further analysis of maximum levels was carried out.

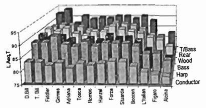

Figure 4. Comparison of noise exposure for complete performances of each Opera.

4. DETERMINATION OF EXPOSURE

After examining the data accumulated for the various Opera performances and rehearsals it was felt that to estimate the risk to musicians the simple taking of levels during an Opera was insufficient to establish long term exposure. It was also felt that, although many exposures were intense their duration may be short and their overall energy when averaged over the day may not be as critical as the spot measurements would indicate. It was therefore decided to calculate an $L_{Aeq,8h}$ for the musicians exposed.

Because not every performance was measured, several assumptions had to be made regarding the validity of extrapolating a single performance measurement to all performances of the same programme. The assumptions used were:

1. The variation between levels for the same performance was not significant. Two measures of Peter Grimes gave the same result. The further extrapolation of this result is valid because the Conductor, Musical Director and the whole Opera Company strive to give a constant, historically accurate and polished performance.
2. Variations between rehearsal, stage orchestral, dress rehearsal, sitzprobe (rehearsal with orchestra and singers) etc would reflect the mood of play and the differing surroundings rather than the opera itself and therefore the variation between rehearsal in the studios and the performance at the Opera House would be the same for each performance.
3. Excessive noise outside the opera was not included. Only Australian Opera and Ballet Orchestra work was included.

The schedule was broken up on a day by day, performance by performance basis and the $L_{Aeq,8h}$ was calculated for each day.

The daily exposure was determined by combining the $L_{Aeq,T}$ from each performance, practice and sitzprobe in accordance with the rehearsal and performance schedule. Each performance was measured directly and estimates for each rehearsal, sitzprobe and audition were made by correlation with a full set of measured results for *Peter Grimes* in which performance, rehearsals, sitzprobe, stage orchestral, general rehearsal and auditions at the Opera Centre and the Opera House were monitored. By this computation it was possible to establish an estimate of exposure due to employment by the AOBO.

Fig. 5 shows the relationship between performance position, the performance schedule and the daily $L_{Aeq,8h}$. The shadings used show the level of hearing damage risk.

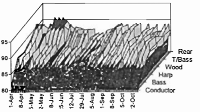

Figure 5. Representation of Noise exposure variation over the Opera Season.

Bottom Dark Grey: is an $L_{Aeq,8h}$ of less than 85dB(A). This is a low risk area. The only person with this low exposure is the conductor.

Middle Light Grey: is the area with $L_{Aeq,8h}$ between 85 and 90 dB(A). This is a level of significant risk. For continuous weekly exposure this level has been shown to cause hearing damage.

Top Dark Grey: level highlights an $L_{Aeq,8h}$ of greater than 90 dB(A) and will need to be avoided.

It can be seen that significant sections of the orchestra have a risk of hearing loss if this schedule is a true representation of normal exposure. The area of high exposure in May is due to two performances of the *Triple Bill* in the one day. This type of scheduling should be avoided. There are however some compensating factors which will reduce the apparent risk. These are:

- Not all members of the orchestra are present for the whole performance
- Not all members perform for each performance
- Each musician has a break of at least one opera in each season.

There are also factors contributing to risk which were not measured. These were:

- Extramural musical activities
- Practice at other venues
- Other noise exposures
- The close coupled output from the musicians own instrument.

The contribution of each of these factors could not be ascertained in this study.

5. CONCLUSIONS

This report has, by its long term nature, demonstrated some clear facts which were previously only conjecture. These are:

1. operagoers, ballet enthusiasts and the conductor are not put at risk of NIHL by these performances
2. the placement of the orchestra in the pit coupled with a tight performance schedule contributes to a significant risk of NIHL for the players.

Steps are currently being undertaken to modify the size and layout of the pit together with modifications to improve the acoustic coupling between the orchestra and the audience. In the meantime the orchestra are utilising hearing protection in the extreme portions of the loudest operas and ballets. Audiometric testing by air conduction and oto-acoustic emission has been started to establish whether the predictions, based on long term exposure, are valid for orchestral performers who typically have shorter exposure times and longer breaks.

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Simulation of a Ripple Tank

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Abstract: Visualisation of the reflection of waves off objects is useful in education, because we cannot see sound waves. Techniques for visualising sound fall into four groups: listening, mechanical analogues, measurement, and computer simulation. This paper describes efforts to develop the computer graphics equivalent of a ripple tank.

1. INTRODUCTION

The most common means of visualising sound propagation is a ripple tank, where an observer can watch the motion of waves in an artificial physical environment. The aim of our work is to produce the computer equivalent of a ripple tank by displaying the propagation of sound waves on a graphics display. While our motivation is to produce a visualisation system for research into ultrasonic sensing for mobile robots[1], such a system is very useful for teaching wave motion.

Educational software must run on a personal computer, placing considerable importance on the selection of algorithms. Also, educational software requires a good user interface to enable the student to interact with the system by changing parameters to see what happens.

The following models of wave propagation are examined: physical models, Transmission Line Matrix models and Lattice Gas models. Models for visualising wave propagation, the interference between multiple sources, reflection, and diffraction are discussed in Sections 3, 4 and 5.

2. VISUALISATION TECHNIQUES

Techniques for visualising sound fall into four groups: listening, mechanical analogues, measurement, and computer simulation.

2.1 Listening

People usually perceive sound through their ears. Humans have highly developed auditory perception for speech, music and other sounds. Wenzel et al. utilised this ability to develop an acoustic display for a virtual environment workstation[2]. This system generates localised acoustic cues in real time over headphones. Their aim is to make their virtual world sound real as well as look real.

2.2 Mechanical Analogues

Physics teachers use mechanical analogues to visualise sounds during laboratory classes. They demonstrate one dimensional wave propagation with springs and wave machines, and two dimensional wave motion with ripple tanks. Some ripple tanks have transparent bases to enable an image of the waves to be projected onto a screen using an overhead projector.

However, repeatable demonstrations are difficult to achieve due to the cumbersome nature of ripple tanks. For this reason, teachers refer their students to photographs of wave motion printed in most physics text books. A ripple tank can be used to visualise wave propagation, reflection, interference and diffraction.

2.3 Measurement

While a researcher can observe a ripple tank and record it photographically, accurate measurement of wave propagation is required in order to do calculations. All measurement techniques use microphones to measure the instantaneous sound pressure. These measurements can be recorded and displayed for visualisation purposes. To build up a picture of a sound field, a microphone is scanned or an array of microphones is used.

Prior to the availability of low cost computers, Winston Kock developed a method for recording an acoustic field on a photographic plate[3]. He attached a microphone to the end of a scanning device: a long rod oscillated by a motor to move the microphone in an arc transverse to the axis of the field to be measured. A second motor moved the scanning device linearly along the axis of the field to be measured. Fixed to the microphone was a lamp whose intensity was modulated by the measured sound field. A time lapse camera recorded the intensity of the lamp as it moved in the two dimensional scanning plane.

To show the intensity of the sound waves at points in the scanning plane, the measured and reference signals were summed to produce a standing wave pattern. With this apparatus he was able to photograph sound including diffraction at the edges of shadowing objects.

2.4 Simulation

The problem with measurement is that many points have to be measured in the acoustic field to gain an accurate representation of wave motion. This process takes a long time and requires expensive equipment. To gain an understanding of wave propagation and scattering, we are developing simulations.

To develop a useful simulation we have to choose a suitable model. This choice is constrained by the desired accuracy of the simulation, the required update rate of the graphical display and the method of presenting the information on the display. Complex models and complex rendering often result in simulations that are too slow for dynamic visualisation.

It is difficult to achieve dynamic displays on a personal computer with all but the simplest models. An example of a simple model used to produce a dynamic display for robotics research is the arc model[4]. In this technique, a sound chirp is modelled as an arc with arc angle equal to the beam angle of the transducer. This model has helped us to understand the problems that occur when using ultrasonic sensing to guide a mobile robot (Figure 1).

Sound waves can be modelled using geometric, physical and discrete models. Physical models, based on the wave equation, are the most accurate but take the longest to compute. Geometrical models, based on ray tracing, are useful for tracing the path of a wave envelope but give no detail of wave structure. In order to reduce the execution time of simulation, discrete models are solved with numeric techniques, with resultant loss of information. In the following sections, we examine the Transmission Line Matrix model (TLM)[5], the wave model, and the Lattice Gas model (LG)[6].

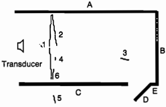

Figure 1. Simulator using arc model to show motion of chirp and reflection off specular surfaces. Reflection off 1. surface B, 2. surface A then B, then A, 3. surface D, then A, 4. corner between surface B and E, 5. surface B travels through opening between C and E, and 6. surface C during return of chirp.

3. DISCRETE MODEL - TLM

TLM modelling is a numerical method for solving scattering problems. This method produces a computer simulation of electric fields in both space and time. The two dimensional TLM model has a network analogue in the form of a mesh of orthogonal transmission lines (Figure 2). There is a direct equivalence between the voltages and currents on the lines in the mesh and the pressure and intensity of sound. With this mesh we can model two dimensional wave problems.

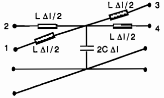

Figure 2. The building blocks of the two-dimensional TLM network. Equivalent lumped element model.

The model operates by propagating sine waves along the lines and, due to the simulated discontinuity at the nodes, results in transmitted and reflected waves being scattered back into the lines. These scattered waves then become incident on adjoining nodes at the next time instant (Figure 3).

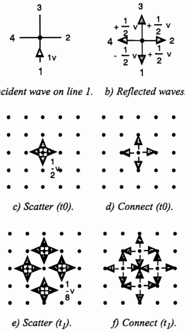

Figure 3. Transmission Line Matrix model.

The analogous relationships among the electrical and acoustic wave parameters are as follows:

Voltage V	Pressure P
Current i	Particle speed u
Inductance L	Density ρ
Capacitance C	Compressibility B
Impedance $\sqrt{\frac{L}{C}}$	Impedance $\sqrt{B\rho}$

Each iterative step includes two processes, scattering and connection (Figure 3, c..f). The scattering process is that waves scatter from a node after impulses incident on the node; the connection process is that waves propagate toward its neighbours after waves scatter from a node. The computation for the scattering process at each node, within each iteration, is the weighted sum of impulses incident on the node.

$$ {}_{k+1}V_n^r = \frac{1}{2}\left(\sum_{m=1}^{4} {}_kV_m^i\right) - {}_kV_n^i \text{ , (n = 1, 2, 3, 4)} \qquad (1) $$

where

${}_kV_n^i$ is the incident impulse at time step on k line n, and

the r superscript of ${}_kV_n^r$ denotes the scattering impulse.

The formulae for the connection process are:

$$
\begin{aligned}
{}_{k+1}V_1^i(z,x) &= {}_{k+1}V_3^r(z,x-1)\\
{}_{k+1}V_3^i(z,x) &= {}_{k+1}V_1^r(z,x+1)\\
{}_{k+1}V_2^i(z,x) &= {}_{k+1}V_4^r(z-1,x)\\
{}_{k+1}V_4^i(z,x) &= {}_{k+1}V_2^r(z+1,x)
\end{aligned} \quad (2)
$$

The mathematics of the TLM model is simple and hence rapid to compute. At each iteration step, values are calculated at nodes in the mesh. To render a continuous or a smooth image, we must have sufficient nodes per wavelength to enable accurate interpolation of the values between nodes. If we use linear interpolation, we can get the result quickly, but the image looks rough. If we use nonlinear interpolation, we get a better result at the cost of increased calculation time.

To smooth the image and to avoid the long time required for nonlinear interpolation, we use grey scale to render the sound pressure at all points in 2D space. A human's eyes are much more sensitive to the straightness of a line than variation in grey scale. The images in Figure 4 were calculated at time steps proportional to wave travel of one wavelength, with 20 nodes per wavelength. Then they were stored and displayed at the end of the simulation. Even with grey scale rendering, noise produced by this method can be seen in the images.

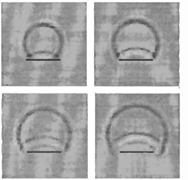

Figure 4. Play back of a time sequence of grey scale images of wave propagation and reflection off a flat surface calculated with the TLM model for one cycle.

4. CONTINUUM WAVE MODEL

To obtain a more accurate visualisation we can use continuous models based on the physical properties of sound waves. However, each property must be modelled separately and then combined to produce the final visualisation. Thus, we require models for propagation, interference, reflection, and diffraction. As the properties of sound waves are similar to the properties of light waves, models for light can be applied to acoustics after modification for medium properties and wave energy characteristics.

4.1 Propagation

Sound propagation is described by the wave equation:

$$\nabla^2 P = \frac{1}{c^2}\frac{\partial^2 P}{\partial t^2}, \quad (3)$$

where

P is the instantaneous pressure of the wave,

∇^2 is the Laplacian operator (the divergence of the gradient),

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2},$$

c is the propagation velocity of the wave, and

t is the time.

This expression applies to waves moving through non-dispersive mediums. The solution of the wave equation for a cylindrical source [8, p. 357] is:

$$P = A[J_0(kr) + iN_0(kr)]e^{-i\omega t} \quad (4)$$

$$\xrightarrow[r\to\infty]{} A\sqrt{\frac{2}{\pi kr}}\,e^{i(kr-\omega t)-i(\pi/4)} \quad (5)$$

$$\xrightarrow[r\to 0]{} i\frac{2A}{\pi}\ln(r)e^{-i\omega t} \quad (6)$$

where

A is constant,

ω is the angular frequency,

k is the wavenumber,

r is the distance from the source,

J_0 denotes the Bessel function of first kind of zero order, and

N_0 denotes the Bessel function of second kind of zero order.

To model wave propagation in two dimensions, as required to produce the graphical equivalent of a ripple tank, we use Equation (5) and place objects at several wavelengths from the source. Although not correct near the source it is a sufficiently good approximation to Equation (6) to produce an acceptable visualisation (Figure 5). Using Equation (5) results in faster calculation and in smooth rendering.

4.2 Interference

Another important area of ripple tank simulation is the interference of waves, as this allows us to study beam forming by arrays of sources. In a linear medium, one can apply the principle of superposition to obtain the resultant disturbance.

The superposition principle states that the actual displacement of any part of the disturbed medium equals the algebraic sum of the displacements caused by the individual waves.

Suppose we have waves P_1 and P_2 emitted from two sources, $P_1 = P(r_1,t)$ and $P_2 = P(r_2,t)$, where r_1 and r_2 are the distances of the wavefronts from the two sources at time t. The interference wave $P_{\text{int}f}$ is

$$P_{\text{int}f} = P_1 + P_2 \quad = P(r_1,t) + P(r_2,t) \tag{7}$$

Figure 5 shows the interference between waves from two point sources.

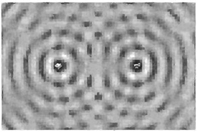

Figure 5. Wave interference from two point sources, calculated with the Equations (5) and (7).

4.3 Reflection

Waves are reflected when they reach a barrier. The law of reflection for specular surfaces states: the angle of reflection θ_r equals the angle of incidence θ_i.

To calculate the wavefront reflected off a barrier, we use the mirror equation[7] from optics which approximates the law of reflection when the incident waves strike the obstacle at points in the paraxial area. This approximation speeds up the calculation. The mirror equation describes the relationship between the wavefront curvature of incident waves and reflected waves. That is:

$$\frac{1}{s} + \frac{1}{s'} = \frac{2}{R} \tag{8}$$

where

s is the distance of the wave source from the obstacle,

s' is the distance of the focus point from the obstacle, and

R is the radius of the obstacle.

In the case of a concave barrier, the reflected rays near the axis pass through a focal point in front of the object (S' in Figure 6). In the case of a flat barrier, the reflected spherical waves appear to come from a point behind the barrier. This point, called the imaginary point, is the same distance from the flat reflector as the source S is.

Spherical waves reflected from a convex curved barrier appear to originate from a focal point behind the barrier but closer to the barrier than the source (S' in Figure 7).

Each geometric shape has to be modelled separately and the results combined using superposition (Figure 8).

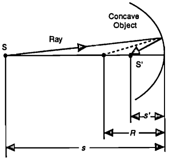

Figure 6. Graphical representation of mirror equation for a point source S and a concave object. S' is the focal point for the reflected paraxial rays.

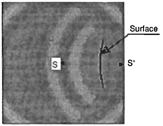

Figure 7. Spherical waves reflected from a convex surface appears to originate at the virtual source S'.

We use the mirror equation to simulate wave reflection off obstacles with simple shapes, - planes and arcs. For more complex curved shapes, we are experimenting with algorithms to calculate the amplitude of a reflected wave at a point in space from the curvature of the object.

4.4 Diffraction

When waves encounter an obstacle, they tend to bend around the obstacle. Diffraction is apparent by the waves in the shadow region and the interference between the diffracted waves and the incident and reflected waves near the edges of the object.

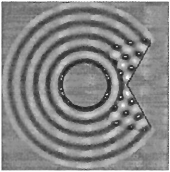

Figure 8. Reflection of spherical waves from a straight edge obstacle.

One way to model diffraction is to place secondary point sources at the edges causing diffraction. A simple source produces a wave front with equal intensity in all directions. As this is an inaccurate model of diffraction, we use the following equation to display the diffraction from a knife edge[9]:

$$P(r,\phi) = Ae^{-ikr\cos\phi}E[\sqrt{2kr}\cos\frac{1}{2}\phi] +$$
$$Ae^{ikr\cos(\phi+2\Psi)}E[\sqrt{2kr}\cos(\frac{3}{2}\pi - \Psi - \frac{1}{2}\phi)] \qquad (9)$$

where

- $P(r,\phi)$: wave pressure at a point (r,ϕ) relative to the edge (Figure 9),
- r : the distance from the knife edge to observation point,
- ϕ : the angle of the direction of incident waves to the direction of the observation point, (Figure 9),
- Ψ : the angle of the obstacle plane with the orthogonal direction of incident waves, and

$E(z)$ is defined as:

$$E(z) = \frac{1}{\sqrt{i\pi}}\int_{-\infty}^{z} e^{it^2}dt$$
$$= \begin{cases} 1 - \frac{1}{2}[1 - C(z^2) - S(z^2)] - \frac{1}{2}i[C(z^2) - S(z^2)] & z \geq 0 \\ \frac{1}{2}[1 - C(z^2) - S(z^2)] + \frac{1}{2}i[C(z^2) - S(z^2)] & z \leq 0 \end{cases} \qquad (10)$$

Fresnel integrals $C(z^2)$, $S(z^2)$ are defined as:

$$C(w) = \int_0^w cos(\frac{\pi u^2}{2})du$$

$$S(w) = \int_0^w sin(\frac{\pi u^2}{2})du$$

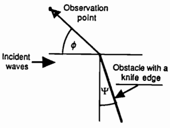

Figure 9. Parameters used in the model of diffraction (Equation 9).

Equation (9) is used to model the diffraction which occurs on both the transmitted waves and reflected waves as shown for diffraction from a knife edge in Figure 10. The diffraction of the transmitted waves can be seen in the region (B). The diffraction of the reflected waves is visible in the region (D).

5. LATTICE GAS MODEL

The complexity of continuous models results in long computation times. To reduce this time we use discrete techniques to solve the physical model. One approach is the LG model which is based on cellular automata theory. A cellular automata model is a grid of cells each with a finite number of states. At each time step a set of rules defines the evolution of these states. The rules for a cell involve a finite number of neighbouring cells and can be either deterministic or nondeterministic.

The LG model emerged as a means of modelling fluid dynamics by modelling the molecular dynamics of the fluid in order to calculate transport coefficients. The first application of this technique to sound waves was reported by Kadanoff and Swift[10], who used a continuous time model. Krutar et al.[6] were the first to apply a discrete time model to sound waves. The discreteness of the Lattice Gas approximation introduces some noise into the visualisation.

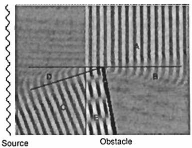

Figure 10. Wave reflection and diffraction, showing A the transmitted waves, B diffracted waves from a knife-edge, C reflected waves, D diffracted waves from reflected waves, E interference of incident waves with reflected waves.

5.1 Lattice Gas Calculation

The LG method models macroscopic wave motion by modelling microscopic particle motion. The cells in the lattice are connected in a square configuration[10] and, thus, each cell is connected to four others. The particles can be modelled as single particles, counts of particles or pressures[6]. These particles (or pressures) move along the links between cells. At each time step, the particles collide at the cells and then propagate out from the cells. Krutar developed a finite difference solution (Equation (11)) for the acoustic wave equation to calculate the derivative of pressure at a cell at each time step to generate a set of rules for the cellular automata.

$$dP(x,t+dt/2) = P(x,t+dt) - P(x,t)$$

$$ddP(x,t) = dP(x,t+dt/2) - dP(x,t-dt/2)$$

$$ddP(x,t) = \sum m_a P(x+dx_a,t) \qquad (11)$$

where

$P(x,t)$ is the pressure at time t and location x, equivalent to an integer number of particles,

dt is the time step,

the subscript a represents one of the five directions, N, S, E, W, and at the cell, and

m_a is weighted coefficient of the pressure P at the direction a.

The first two equations are discrete derivatives. The third equation is the finite difference equation used to represent the wave equation (Equation (3)). It calculates the double derivative of pressure as a weighted neighbourhood average of pressure. By changing the speed of sound at a cell we can simulate a different medium (Figure 11).

From Krutar's model, we derived the following equations to be applied at each cell at each time step,

$$P(x,y,t+1) = 2P(x,y,t) - P(x,y,t-1) + c_s^2(x,y)(P(x+1,y,t) + P(x-1,y,t) + P(x,y+1,t) + P(x,y-1,t) - 4P(x,y,t)) \quad (12)$$

where

$c_s(x,y)$ is the simulation speed (cells propagated / simulation step), and

$P(x,y,t)$ is the wave pressure at location (x,y) and time t.

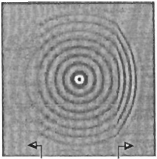

Figure 11. Wave propagation through different media. Left region : Speed = 2c. Middle region: Speed = c. Right region: Speed = 0.5c.

In a square grid the maximum speed of the simulated wave is 0.707 cells per time step[6]. Thus, the maximum speed of sound in any of the mediums, (there could be more than one medium), in the simulation is equivalent to this rate. In practice, the user wants to specify the frequency (f), spatial resolution (model scale) and the mediums used in the simulation. From this, the simulator calculates the simulation rate, based on the maximum speed of sound (C_{max}) in any of the mediums, where

simulate rate $R = \frac{C_{max} * S}{0.707}$ steps / second,

model scale $S = \frac{m * f}{C_{max}}$ cells / meter, and

m is the number of cells / wavelength.

Figure 12 shows that the LG model can simulate all wave phenomena: propagation, interference, reflection and diffraction. In this figure specular reflection is visualised by setting all cells on a straight line to have zero speed to represent an obstacle. As there are 20 cells per wavelength, diffusion may be modelled by modelling the texture of the surface.

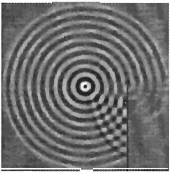

Figure 12. Wave propagation, reflection and diffraction visualised with the LG model.

6. VISUALISATION

Physical parameters of waves include: space, time, velocity, pressure, and intensity. In the figures in this paper space is represented by the 2D graphics screen, time by animation and wave pressure by grey scale or wire frame. Grey scale gives an image that looks like a photo of waves moving on a ripple tank.

Wave motion can be visualised with a variety of graphical representations. In Figure 13, wave generation by a point source is visualised with wire frame rendering.

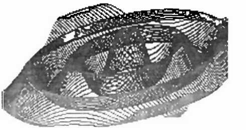

Figure 13. Wire frame rendering of a point source, modelled with the wave equation.

Most of the images in this paper are grey scale images at an instant in time, that is a snap shot. More information can be visualised by a time sequence of images to show the motion of waves (Figure 4). Animation is achieved by displaying the simulation results at the end of each time step. However, on a personal computer the update rate is very slow, so better animation is obtained by recording the images from each time step and replaying them.

7. CONCLUSION

A simulation of a ripple tank is a useful tool for teaching wave motion concepts. Further, it is useful in the study of sound propagation in natural systems, such as bat echolocation, and artificial systems, such as ultrasonic sensing for mobile robots. Visualisation helps us to understand a physical phenomenon that we cannot see. However, the results of visualisation are only as meaningful as the accuracy of the underlying models.

We have discussed the theoretical basis for wave simulation, and demonstrated current results. We have simulated sound with three models: two discrete and one continuous. The discrete models are simple to iterate and automatically show wave properties, such as propagation, reflection and diffraction. The TLM model is based on electrical field theory, and the LG model on acoustic theory.

Both models use a square grid and hence are suitable for real-time execution on a parallel computer. Also, they include all wave motion properties of interest in their equations. Due to the discretisation of space, the execution of the simulation is independent of the complexity of the environment. However, a number of problems arise as a result of the discretisation. First, special processing has to be done at the boundaries. Second, quantisation errors in the discrete calculations appear as small noise waves (Figure 4). Third, wire frame rendering shows this noise as a zigzag on all the lines. The result is rough looking images, unless nonlinear interpolation is used. These variations are not so visible if grey scale rendering is used.

The continuous model requires separate models for each wave motion property, which must be combined using superposition to produce the final result. Also, the complexity of the calculation increases rapidly with the number of obstacles in the environment. As pressure is calculated at every point in space without reference to neighbouring points, continuous models do not have the window edge problem.

When calculating the pressure at a point at an instant in time the calculation is fast. But a simulation using a wave model may only be fast enough to display a snapshot of the output at regular time intervals. As the output is based on a continuous model, it is suitable for both grey scale and wire frame rendering.

Finally, a very powerful computer is required for animation. For this reason, discrete models will be used in educational tools which must execute on personal computers. Researchers who are interested in the greater accuracy of continuous models will either require access to a powerful computer or be content with snapshots. With all models, it is difficult to achieve real-time animation, so the computer equivalent of a ripple tank will calculate and store the images and then play them back in real time.

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ACKNOWLEDGMENTS

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Note

Back on the F.A.S.T.S. Track

The Australian Acoustical Society is a member of the Federation of Australian Scientific and Technological Societies (FASTS) and represented within the Physical Sciences Board. FASTS is the science lobby group, and represents some 30,000 scientists through their membership of over 40 affiliated societies. The following item by **Ken Baldwin** and **Bob Crompton** has been extracted from a longer item prepared for the Australian and New Zealand Physicist (ANZP) and summarises the the revitalisation of FASTS. Dr Baldwin is a Fellow at the Research School of Physical Sciences and Engineering, ANU, and Vice-President of FASTS. Professor Crompton holds a Visiting Fellowship in the School, and is the AIP past-President and representative on the FASTS Board.

SYNOPSIS

The situation in 1993 could hardly have been worse:

- The Science Minister, Ross Free, was not talking to FASTS and had called for another body to supplant it.
- FASTS had no policies to put forward at the 1993 election which Paul Keating had won without once mentioning the word "science".
- The FASTS Executive Director, David Widdup, had found it increasingly difficult to interact with the government. A year later he left to pursue a new career, leaving FASTS with no permanent employees but with an opportunity for restructuring.
- The Institution of Engineers were publically (and perhaps justifiably) critical of FASTS' approach to lobbying.
- Organisations within FASTS such as the AIP, the Royal Australian Chemical Institute (RACI), the Australian Geosciences Council (AGC) and the Maths Sciences Council were giving notice of their intention to resign if FASTS did not lift its game.

Things were indeed grim. The organisation needed to change both internally and to become a pro-active rather than reactive body.

DIAGNOSIS

A number of changes to FASTS' operation were suggested in the May '93 article in the ANZP to place FASTS on a firmer footing:

1. Society Presidents should form the FASTS Board to place them directly in touch with their constituents.
2. FASTS should adopt a President-elect/President/past-President continuity.
3. Previous FASTS officers should form a FASTS Advisory Committee.
4. The Executive Director's position should be restructured for greater effectiveness and accountability.
5. FASTS should adopt an ongoing policy formulation process to reflect the opinions of its constituent societies.

Since that time FASTS has been conspicuously silent - a silence which reflected sustained internal re-examination and re-building rather than inaction. Although FASTS may have been unable (because of personnel shortages) to keep the channels of information flowing to its constituents, a lot of work was going on behind scenes.

METAMORPHOSIS

The result is that a new, mean and lean FASTS has emerged like a Phoenix from the ashes with the following milestones:

- November 1993: Prof. Graham Johnston, former President of the RACI, was appointed President, together with vice-Presidents Dr Gordon Burch (AGC) and Dr Ken Baldwin (then AIP representative on FASTS Board). These organisations represented some of the societies most critical of FASTS' operation. Prof. Bob Crompton, then AIP President, was elected to the FASTS Board.
- November 1993: A draft FASTS policy document was presented to the annual Council meeting
- June 1994: Resignation of the former Executive Director and advertisement of the vacant Executive Director's position which was restructured.
- June 1994: RACI rescinds their intention to withdraw from FASTS.
- November 1994: Election of a new FASTS executive, including treasurer Marion Burgess (from AAS), and Secretary, Dr Graham Heath (ANU, and RACI ACT President). The continuity of FASTS was assured with the appointment of a high profile new President-elect, Dr Joe Baker (OBE, MSc, PhD, FRACI, FTS) former Director of the Australian Institute of Marine Science and ACT Commissioner for the Environment.
- November 1994: Ratification of the redrafted FASTS Policy Document by the annual Council meeting of constituent societies.
- March, 1995: Appointment of Mr Toss Gascoigne, former CSIRO science communicator, as Executive Director.
- March, 1995: AIP rescinds their intention to withdraw.
- April, 1995: FASTS moves its premises to a centrally located office in Deakin, close to Parliament House, which offers better facilities for servicing members, and less all-round financial burden.

As can be seen, the changes have been major and substantive.

PROGNOSIS

The picture for the immediate future looks bright. FASTS has major programs which will enhance its effectiveness and cement its place in the science policy arena:

1. *The policy document was presented to Senator Peter Cook, Minister for Industry, Science and Technology, at Parliament House on June 8th.*

This event was well attended by the media, the Science and Technology community, and politicians of all major parties. The policy is an evolutionary document, which will be revised and used to respond to the Government's much vaunted Innovations Statement in September, and which will form the platform for FASTS' pre-election lobbying campaign in the following period. All member societies will be able to feed back their views on policy to the FASTS Board and to the annual Council meeting.

The S & T policy document sets down agreed statements for:

Educational Policy in Science and Maths Teaching
Industry and Commercial Research

Research in Government Institutions and National Facilities

University Research and Post-Graduate Research Training.

The emergence of this document, and its widespread commendation, marks a new stage in FASTS development. The current Board believes that it can influence Government most effectively if FASTS is pro-active in having its own well-developed policies that can be seen to have the wide endorsement of thousands of rank-and-file scientists and technologists.

2 *FASTS will increase its consultation and involvement with its constituent societies.*

In the period without an Executive Director, FASTS was unfortunately forced to neglect much of its internal communication while concentrating on restructuring. However, with the arrival of the new Executive Director, this situation will improve dramatically. Mr Gascoigne's prevous position was as Communications Manager with CSIRO's Centre for Environmental Mechanics. He is also a founding member and Secretary of the Australian Science Communicators (ASC) - a network of science journalists.

Toss has wide national experience in science policy articulation and presentation, and in training scientists in media skills. His role will be to liaise vigorously with member societies, to implement and represent policies defined by the Board, and to deal with the day-to-day business of the Federation, as directed by the Executive. His impact in reducing the office bearers' workloads and increasing their national effectiveness has been immediate.

The new FASTS office is now on email and hopes soon to have its policies and other information documents available on World Wide Web. The Executive Director has also resumed publication of the national FASTS Newsletter which aims to publicise both the ongoing policy initiatives and the science lobbying efforts of the new Board and Executive.

3 *FASTS will form a set of strategic alliances, with the aim to make its lobbying efforts more effective by approaching Government on a unified front.*

At the FASTS National Council in November 1994 a vigorous policy forum was held with senior panellists from the Australian Academy of Science, the Academy of Technical Sciences, ANZAAS, ASTEC, NTEU, ASTA (the Australian Science Teachers Association) and the ASC. As one consequence, the Executive Directors of eleven different science and technology organisations (the two Academies, the Institute of Engineers, RACI/AIP, the Deans of Science, ANZAAS and others) have agreed to meet on a quarterly basis, coordinated by Toss Gascoigne, to discuss joint action and mutual support. Further strategic alliances in the broader community are being planned.

Two years ago, a new organisational structure, documented policies endorsed by the elected Board, fresh appointments to senior positions, and prudent financial operation was sought. We believe that FASTS has delivered on these obligations, and has built a strong foundation for an active future in the science policy arena.

New Products...

ARO TECHNOLOGY

Acoustical Diffusers

Aro Technology has released a new range of number theoretical (Schroeder) acoustical diffusers. Schroeder diffusers are ideal for treatment of critical listening areas such as orchestra pits, theatres, studios, music education facilities, churches, etc. The new range offers high performance broadband operation in an economical, modular system which has a very distinctive and attractive appearance. The standard finish is African Ash which is stained and oiled to suit customer requirements.

Further details: Chris Morton, ARO Technology, PO Box 306, Prospect, SA 5082. Tel (08) 346 4199, Fax (08) 340 0069.

HEWLETT PACKARD

Data Recorder/Analyser

The HP E3211S Data Recorder/ Analyser system records, analyses and graphically displays noise and vibration test data. The new system is designed to replace analogue and digital tape recorders with a higher performance, multichannel system capable of continuously recording from 8 to 64 channels of data. Sampling rates from 65,536 samples/second/channel down to 1 sample/second/channel are provided, with a dynamic range of more than 80 dB. Data storage is provided by disk modules with either 2.1 or 4.2 GB of storage space, with DAT backup for archiving. Windows-based software for data analysis and graphic display is included.

Further details: HP Customer Information Centre, Tel 131347 ext 2902.

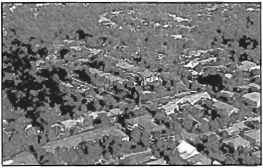
Note

Wind Generated Tonal Noise - A Practical Solution

R T Benbow
Principal Consultant,
Dick Benbow & Associates Pty Limited
Member firm Aust. Association of Acoustical Consultants

A consulting acoustical engineer is often called upon to solve unusual noise problems. Many of which are quite perplexing when first explained by the client and at times unbelievable. This article recounts my experience investigating and solving wind generated tonal noise from the television industry's transmission tower located at Chatswood in Sydney.

The transmission tower is located adjacent to the Pacific Highway and from the top of the tower - approximately 240 very long metres above the ground - a magnificent view of Chatswood CBD and the whole of Sydney may be enjoyed - photograph 1 presents the view.



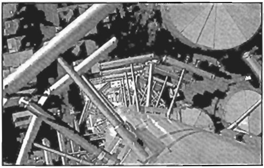
Photograph 1

A residential area is located to the west of the tower and approximately in the middle of photograph 2, the occupants of one residence began experiencing an unusual whooing noise during night time. A discussion with their neighbours failed to assist them in understanding where the source of this strange noise was located. It appeared that their home was being affected in isolation. Over a period of several months two other residents, one immediately north of the tower and another to the south east, registered complaints with the local council.

Photograph 2

How the transmission tower became the suspect source is not known but my client - one of the operators of the tower - requested that I speak to the affected residents. The residents to the west were being greatly affected by the tonal noise, their sleep patterns were significantly disturbed and the investigation concentrated on this residence. Acoustical instruments - a precision SLM and acoustic tape recorder were installed in the residence. The noise occurred during the early hours of the night and the residents were shown how to operate the instrument set.

Further enquiries were able to correlate the date of the first complaints with the installation of a set of new dipoles at the top section of the tower. A spare dipole was available and subsequently installed in a studio at the television centre. Wind speeds obtained from the Bureau of Meteorology for the times of the night recorded by the residents were adjusted for height above ground. A silenced fan and ducting were used to simulate the exact wind speeds and the whooing sound was suddenly audible in the studio. The dipole configuration is shown in photograph 3. Drain holes are provided in the ends of the dipole tubing.



Photograph 3

Now that the source has been located it should be a relatively easy task to design the solution!

Fortunately, there were very few options available. The common sense approach was to block the holes, however, this would cause unacceptable maintenance problems. The solution was designed using a very practical technique - masking tape was placed over the holes and a biro used to pierce the tape and gradually enlarge the diameter of the hole. A variety of equivalent wind speeds were generated until the best hole diameter could be found. Rubber grommets were designed and a rigger enjoyed swinging from a boswain chair inserting the grommets in all 36 dipoles. No more complaints were received from the residents. The project absorbed about 20 hours of consulting time.

One interesting aspect remains which has bedevilled me ever since in regard to the whooing sound. A third octave band analysis of the tape recordings showed the tone to be located in the 800 Hz band whereas the simulated tone was located in the 630 Hz band. I would enjoy receiving any technical explanations from the more analytically minded readers.

News...

Meeting on BCA

On 21 September 1994, a meeting was held at NAL Chatswood to discuss the suitability of the existing acoustical parts of the Building Code of Australia (BCA). A number of speakers presented their views and there was lively comment and questioning.

Athol Day said that the Association of Australian Acoustical Consultants was working with the Home Unit Owners Association in an attempt to improve some of the weaknesses in the BCA. The BCA requires that the floor and wall transmission loss generally should not be less than STC 45. However, between kitchens or bathrooms and bedrooms in adjacent apartment, the minimum requirement was STC 50 plus some form of impact noise control. Athol indicated that the AAAC considered these minimum performances too low.

Athol also addressed the control of plumbing noise in respect of which the BCA requires a construction with minimum between waste pipes serving one apartment and spaces within another apartment. The AAAC considered that structure-borne noise, including that from water flow in pipes, is the most common intrusion of plumbing noise within apartments. Cisterns refilling and cold water piping generated higher noise levels than waste pipes. BCA should therefore include a control over those forms of noise generation. Not all waste pipes generate the same noise level; relative levels for different types are approximately:

- cast iron 0 dB
- stainless steel +15 dB
- pipe with fibreglass and loaded vinyl wrapping -15 dB
- pipe within plasterboard bulkhead plus 100 mm airgap -15 dB

During toilet flushing and cistern filling, the noise level in the bathroom is commonly dominated by frequencies around 2,000 Hz, whilst the noise in the adjacent room (structure-borne) is commonly dominated around 500 Hz. The relative noise level generated can be roughly estimated by $L = 20 \log p + \text{const}$ where p = pressure. It is Athol's view that pipes containing a water pressure exceeding 300 kPa should not be embedded in or fixed rigidly to the building structure.

Peter Knowland then talked about suitable wall sound transmission loss. He indicated that the requirement for the wall and floor performance was dictated by the use of radios and sound systems. Classical music played at about 85 dBA has a frequency composition which requires the highest performance from the wall or floor around 250 Hz. Typically, a reduction of at least 55 dB is required at this frequency. For rock music, whilst the level of playing is also about 85 dBA, there is a higher component of low frequency sound requiring a greater reduction at 250 Hz. This results in the minimum performance of STC 45 not being good enough. Peter considered that the STC measure, despite its weaknesses, was a suitable measure for inclusion in the BCA and suggested a minimum of STC 55, but he also recommended no shortfall of the STC curve below about 500 Hz. Peter's view is that the performance required should be met in situ, as opposed to in a laboratory test.

In regard to floors, the control of impact noise is important and a carpet finish normally suffices. However, some people object to carpet because of personal allergies and others consider carpet unclean. A minimum impact noise rating is therefore required in the code. Peter favours the use of Impact Isolation Class (IIC) but further work is required to determine a suitable minimum performance. It is preferable that the impact rating apply to both floors and walls, particularly to allow for the fact that apartment layouts may change over time.

The third speaker was **Bob Fitzell** who talked about structure borne noise and external noise. It was his view that BCA addressed the easy acoustical issues and tended to avoid the harder problems which often require technical advice. In his view, the impact noise requirements in the BCA based on equivalent constructions were of little use. He also suggested the use of IIC and was of the view that an IIC value which was the same as the STC value resulted in a similar subjective effect. He therefore proposed a minimum IIC of 55.

Bob considered that external noise was a significant problem in many apartments and that there should be some control over its intrusion. He questioned if this should be covered by BCA or if it was the responsibility of Councils.

Graham Randall, of the Home Unit Owners Association, referred to the results of a survey of unit owners carried out in January 1989 and involving 8,000 families. The survey found that 40% of families considered that annoying noise was a frequent occurrence and 53% an occasional occurrence. It was his view that control of noise by law did not work and that noise control should be built in to apartment buildings. In this respect, BCA represented a part solution. He also referred to the fact that external noise intrusion into apartments was a problem that needed to be addressed and questioned the suitability of BCA for this.

The final speaker was **Mark Sydney** from Mirvac, a major home unit developer. He firstly indicated that his (Mirvac's) views did not necessarily represent the views of all developers. Mirvac's approach is to buy the land, have it rezoned where necessary and to develop the residential apartments. The design is commonly carried out in-house and acoustic advice is often sought externally. Construction is then carried out by Mirvac itself. In going through this process, Mirvac has to be aware that it is responsible to shareholders as well as to occupants of the apartments. The overriding factor is that Mirvac is a long term company and its long term success depends on the quality of the apartments constructed, including the acoustical characteristics. In New South Wales, there is a market resistance to plasterboard, brick being preferred, but this is not so in Queensland. The general view is that brick is good for acoustics, but quoting a figure like STC 53 is meaningless to most potential purchasers. During the construction stage, it is necessary to have builders who have experience in home unit building. All methods of acoustical detailing should be kept simple, particularly methods of fixing. In summary, he indicated that the desire to maintain a good long term reputation drives the acoustic standard to the which the Mirvac buildings are constructed. This incentive is more important than the requirements in BCA.

The meeting was then opened for discussion. Peter Knowland stated that it is possible to spend money on high cost walls without getting significant acoustical results. Andrew Zelnik, the Chairman of the meeting, advised that a number of professional panels were consulted to prepare BCA. The Home Unit Owners Association has also been involved for about 3 years. He questioned why AAS was not playing an advisory role in the review of BCA. Anita Lawrence expressed some concerns about Peter Knowland's view that the minimum STC performance apply to a field test. If the construction failed the test, it would be difficult to improve the acoustic performance in many cases and this would leave the building not complying. She suggested that there may be merit in producing a prototype for early testing. In reply, Peter Knowland stressed that the end result was the only important thing and that there may be some merit in considering prototype testing. Fergus Fricke told the meeting that he was aware of similar codes applying in other countries and that these may prove of assistance in the review.

Barry Murray

Active Noise Control

The NSW Division meeting on Active Noise Control, 26 April, was presented by **Assoc Prof Joseph Lai** of the Department of Aerospace and Mechanical Engineering at the Australian Defence Academy and Director of the Acoustics and Vibration Centre, University College, UNSW. Joseph spoke clearly and passionately on his subject providing a state of the art summary of the principles and current and potential applications of active noise control. Practical demonstrations of the principles of noise cancellation were also carried out and a set of active attenuating earmuffs was also passed around the audience.

Joseph indicated that active noise control based on the principle of destructive interference, can be used where passive control is considered impractical. Of the two active noise control techniques, feed forward is preferred over feedback which is potentially unstable. Active attenuation is generally most effective in the 20 Hz-400 Hz range with attenuations of up to 30 dB being possible. Some practical limitations include loudspeaker power, spacing between loudspeakers and noise source, signal phase, volume modes, working environment and cost. A few of the current applications either commercially available or under development relate to earmuffs and communications headsets, electrical transformers, wall sound transmission loss, air conditioning, motor vehicles and aircraft cabins. Reference was made to the EZANC (easy activated noise control) generalised electronic control system developed at the University of Adelaide under the direction of Dr Colin Hansen which is designed for mass production and application to consumer goods.

It would appear that at present much of the development work for active noise control systems is occurring in the US. The promise of cost effective, mass produced commercial applications is still likely to take a considerable number of years to be realised, hindered not only by technical challenges but also by patents and intellectual property law.

Joseph's talk was well received with many of the audience staying back to find out more about this relatively new area of acoustic research and development. It is interesting to note that some of the attendees came from the Institution of Engineers and the Audio Engineering Society.

Andrew Zelnik

Aircraft Noise

The NSW Division meeting on 31 May on the controversial topic of aircraft noise examined the ANEF system and was presented by **Rob Bullen** of ERM Mitchell McCotter and **Tony Williams** of Environmental Impact Reports. The ANEF (Aircraft Noise Exposure Forecast) System is based on the United States NEF system and was developed by Rob Bullen and Andy Hede in the early 1980's and is documented in their seminal NAL Report.

Rob indicated that the ANEF system was developed as a long term planning tool for siting and construction of developments potentially affected by aircraft movements. Rob's talk focussed on research findings from the NAL Study concerning community response to aircraft noise exposure. His principal points were that there appears to be little or no correlation between individual noise reaction (annoyance) and the level of noise exposure and that it is not possible to select an aircraft noise exposure level in terms of ANEF below which no one will be affected. The 20 ANEF was found to correlate with 10% of the exposed population considering themselves to be seriously affected and where aircraft noise would start to become the dominant source in the neighbourhood.

Rob also indicated at the ANEF system does not account for "short term" increases in noise exposure and consequent increases in the numbers and degree of annoyance experienced. "Short Term" appears to be defined by the period of resident turnover in a particular neighbourhood. He also indicated that in an existing situation residents tend to keep their reactions but newcomers to an affected area tend to adapt based on their foreknowledge of the noise environment.

A brief mention was made of other more physical factors such as disturbance to sleep and conversation, and health effects. Rob went on to indicate that some of the factors affecting ANEF are maximum flyover noise levels, average number of overflights, time of the day, and duration and spectrum of each noise source. He then examined the relationship between ANEF and maximum flyover levels (in dBA). For example: even 0 ANEF is equivalent to one flyover during daytime having a maximum level of 75 dBA. Reference was made to AS 2021 for the siting and construction of buildings affected by aircraft noise. It was noted that this standard does not address existing situations in which noise sensitive developments are exposed to more than 20 ANEF.

Tony Williams, has had extensive experience as an environmental consultant principally advising councils throughout Australia on aircraft matters and presently serves on the Sydney Airport Environment Subcommittee. His talk centred on deficiencies of the ANEF model which employs the Integrated Noise Model (INM) software package and on deficiencies of AS 2021. Frequent reference was made to the predicted ANEF contours for Sydney Airport with the Third Runway operating.

Tony indicated that ANEF model predictions have problems of both reliability and accuracy. In particular, some of the important factors influencing these problems in relation to Sydney Airport are the projection year (hence total numbers of movements) assumed, model version, aircraft types and models not yet in operation, omission of general aviation, noise database levels lower than those experienced in practice, insufficient modelling of topography, assumptions of single straight line approaches and take offs.

He questioned the applicability of maximum noise level limits for flyovers specified in AS2021 which appear to be for "intermittent" aircraft noise rather than the "continuous" noise experienced in some areas around Sydney Airport. Tony then discussed and compared four methods of determining flyover maximum dBA noise level for noise assessment and control purposes. These methods consist of using AS 2021, field noise measurement, INM generated Effective Perceived Noise (EPN) level minus 13, and modification of INM to provide dBA. It was highlighted that short-term field measurements are unlikely to give representative results because of uncertainty about variables such as aircraft type and engine loading, height and flight path.

Following the talks of both speakers, the majority of questions were from representatives of the No Aircraft Noise Party and other resident groups affected by aircraft noise around Sydney Airport, principally directed to Rob Bullen who came in for a fairly vigorous though controlled line of questioning at times. Later most of the audience then adjourned to a cafe, concluding yet another successful meeting.

Andrew Zelnik

La Trobe Boiler

The Victoria Division second Technical Meeting for 1995 was a site visit to the La Trobe University boiler installation and power generating station to learn about and inspect the associated noise control measures. Sixteen members attended. **Ivan Hipworth** (Asst Manager, Engineering, La Trobe University) introduced the two speakers, **Graeme Harding** (acoustical consultant) and **David Etherington** (Contract Manager, GEC Alsthom Aust Ltd) who described the boiler and generating plant before leading the inspection.

While the boiler installation provides heat in winter for the university buildings, and cooling in summer by absorption refrigeration, a co-generation set provides for the university electrical load and, through a waste heat recovery boiler, the thermal load as well. The centre of the electrical generating system is a 6.7 MW gas turbine driven alternator, which is the main unit requiring acoustic isolation. Noise levels in the gas turbine room were of the order of 115 dB(A), and hearing protection devices were provided to those on the inspection. The acoustic insulation, consisting of a combination of absorptive measures within the room, acoustic barrier materials for the partition walls and treatment of the ventilating ducts, provided attenuation of the order of 30 dB to reduce the noise levels to the criterion of 85 dB(A) maximum in areas where boiler attendants and others work.

The interesting meeting concluded with supper and general discussion.

Louis Fouvy

SA Meetings

On 14 March, about 30 members of the SA Division met at the IEAust hall to hear **Norm Mason**, president of Mason Industries, talk about the success of his company's passive vibration isolators in the California earthquakes.

On 11 April, a joint meeting with the Audio Engineering Society (SA Division) was held at the University of Adelaide's Department of Mechanical Engineering to hear **Dr Colin Hansen** talk about active noise control and demonstrate the Causal Systems EZ-ANC controller developed at the University. About 20 people attended.

At the invitation of the Audio Engineering Society, on 16 May about 20 AAS members visited the studios of SA-FM radio station to see the new Digital Commercial System which is an automated database for replaying commercials to air.

On 6 June, **Assoc Prof Joe Wolfe** from the Musical Acoustics Group of the University of New South Wales delivered a talk about Information in Music, at the University of Adelaide.

Carl Howard

ACT Meetings

As part of the third Australian Science Festival in Canberra in May, a series of talks were presented by DSTO scientists. One of these was by **Dr Doug Cato**, from the Maritime Operations Division of the Aeronautical and Maritime Research Laboratories. His talk was entitled "Whales, Shrimps and Sonar" and he discussed many interesting findings from his work on the sound from shrimps and whales. This sound can lead to noise problems for sonar and other underwater investigations. This talk was well attended and well received.

Aircraft Noise Assessment was the topic of a joint meeting between the ACT Group of the AAS and the Environment Panel of the Institution of Engineers on 13 June. **Mike Evenett**, from the CAA explained the noise certification procedures, the airport monitoring systems and the ANEF system. **Brian Beasley**, from Land Use Assessments in Dept Defence, explained the approach taken to noise assessment at military airfields and described how changes in military operations can affect the noise assessments.

On 20 July, a demonstration of Interactive Sound Information System (ISIS) for environmental noise management was presented by **David Dubbink**, from California, and **David Cohney** from Airplan in Victoria. This package was initially developed for aviation planning but can be used for other modes of transport and environmental noises. The capability to demonstrate the noise that is likely to be produced is of great benefit for planning and community consultatation.

Marion Burgess

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Claire Richardson has joined ERM Mitchell McCotter from ERM Oxford, England. Claire has experience in noise and air quality, and will be working in both those areas. Her addition to the company has brought the number of acoustics staff to 8.

Andrew Zelnik has recently left acoustical consultants Wilkinson Murray, and intends to pursue a career outside acoustics, after 11 years in the acoustical consulting field. He will be maintaining links with the Acoustical Society in his capacity as Technical Meeting Convenor, Acoustics Australia Liaison Officer and Vice Chairman of the NSW Division.

Following Andrew's departure is the arrival of **Matthew Harrison** at Wilkinson Murray. Matthew was formerly with consulting firm Eden Dynamics.

Former directors **Graham Atkins** and **Steven Cooper** of Sydney firm James Madden Cooper Atkins have formed separate companies. Graham is director of Atkins Acoustics (tel 02 879 8544) and Steven is director of Steven Cooper Acoustics (tel 02 879 4111).

Kaz Nakayama, formerly of NSW EPA, has joined acoustical consulting firm Dick Benbow and Associates.

National engineering firm Bassett Consulting Engineers has appointed **Matthew Stead** as State Manager of its newly formed Melbourne division, Bassett Acoustics. The division will provide consulting and design services to commercial, government and educational clients, complementing the firm's mechanical and electrical engineering disciplines.

Kurt Jensen has joined Bruel and Kjaer Australia's Head Office in Sydney. He will be leading the Australian team on Condition Monitoring Systems.

Craig Porter has joined the Sydney office of the Acoustics Research Laboratories. He has recently completed his BSc(Electronics) and has experience as an Audio Engineer.

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Selby Scientific Move

Selby Scientific Limited has relocated its Head Office to 2 Clayton Road, Clayton, Vic 3168. The new building houses the National Distribution Centre, the National Customer Service Centre for the Scientific Instruments Division, Sales, Marketing, Technical Service, Finance, Administration and Export Services. The postal address remains unchanged as Selby Scientific Limited, Private Bag 24, Mulgrave North, Vic 3170.

ARL Office in WA

Acoustics Research Laboratories are opening a Perth Office which will offer the same sales and hire support as the Sydney office. **Bryan Vanderstelt**, an electronics engineer who has been with ARL since 1994 will be the manager of the office which will be located at 16 Kings Park Rd, West Perth 6005.

ARRB Name Change

The Australian Road Research Board Ltd (ARRB) has changed its name to ARRB Transport Research Ltd. The address is 500 Burwood Hy, Vermont Sth, Vic 3133, Tel (03) 9881 1555, Fax (03) 9887 8104.

New Members...

The following are new members of the Society, or members whose grading has changed.

Victoria
Member: Mr P McMullen

Western Australia
Subscriber: Mr P A Taylor

CONFERENCES

Annual AAS Conference

Planning is proceeding for the annual AAS Conference to be held 15 to 17 November at the Esplanade Hotel in Fremantle, WA. The technical program on the theme "Acoustics Applied" and the workshop on Otoacoustic Emission will be supplemented by a social program which will utilise the benefits of this location. Registration brochures for the Conference have been distributed - copies and further information can be obtained from Dr G Yates, Dept Physiology, Uni WA, Hackett Drive, Crawley, WA 6009. Tel (09) 380 3321, Fax (09) 380 1025, email gyates@uniwa.uwa.edu.au

Machine Condition Monitoring

The Centre for Machine Condition Monitoring at Monash University is organising its second forum on machine condition monitoring, Nov 8-10. The forum will include mini-courses, exhibition of test equipment and services, technical papers and application workshop sessions. All the relevant technologies will be covered including vibration, wear debris, non-destructive testing and performance analysis. For details contact the Centre for Machine Condition Monitoring, Tel (03) 905 5699, Fax (03) 905 5726.

Singapore

The Annual Meeting of the Society of Acoustics (Singapore) will be held on 10 and 11 January 1996 at Novotel Orchid, Singapore. The conference will cover a complete range of topics in acoustics, and contributed papers are welcome. The deadline for receipt of abstracts (two copies, not more than 200 words) is 30 September 1995. For details: Dr W S Gan, Acoustical Services Pty Ltd, 209-212 Innovation Centre, NTU, Nanyang Avenue, Singapore 2263, Republic of Singapore. Fax (+65)7913665. Tel (+65)7913242.

INTERNOISE 96

Internoise 96 will be the 25th anniversary congress of the International Institute of Noise Control Engineering. The congress will be held in Liverpool, UK, 30 July to 2 August 1996. The theme of the congress is Noise - the Next 25 Years: Scientists, Engineers and Legislators in Partnership. Every aspect of the legislative and technical assessment and control of noise lies within the purview of the conference. Call for Papers has been issued, with abstracts required by 1 December 1995. For details contact Institute of Acoustics, 5 Holywell Hill, St Albans, Herts, UK AL1 1 EU. Tel +44 1727 848195, Fax +44 1727 850553, email acoustics@clus1.ulcc.ac.uk.

CONFERENCE REPORTS

International Congress on Acoustics

The 15th in the series of triennial ICA meetings was held at the end of June in Trondheim, Norway. On this occasion the meeting ran from Monday to Friday, rather than including a weekend, and the organisers carefully scheduled the magnificent congress banquet (included in the conference fee) on the final evening, after the formal end of proceedings. This stratagem worked well and there was an excellent attendance during the customarily sparse final afternoon sessions (as well as at the banquet!). Sessions began at 8.15 each morning with the first of two invited plenary lectures to get people started, and this also seemed to work. Sunset was, of course, at about midnight and sunrise about 3 am, which probably helped.

The Congress was held in the buildings of the Technical University, a modest walk from the centre of town but far enough in the rather cold weather to discourage casual straying. There were more than 800 participants, and nearly the same number of papers presented, covering all the traditional fields of acoustics from speech and music to community noise and vibration control. These have been collected in four handsome volumes which were, unfortunately, too heavy for some of us to bring home — the organisers provided a rucksack as part of the registration kit to help with this problem on a local basis! There was also an equipment exhibition, but it was rather small.

It is not really possible to give a summary of the technical content of such a large meeting with its many parallel sessions. I can only say that the plenary lectures were excellent, and the specialist sessions had something new to offer everybody. For more information you should consult, or even buy, the proceedings.

The opening ceremony, held in the city's concert hall, was most impressive. The lights dimmed to near darkness and trumpet calls sounded from around the hall, to gradually coalesce into a most impressive brass jazz group on the stage. After the ceremony, all 800 participants were led by a high-school brass band in a traffic-stopping procession through the town to the University. Let's see what Seattle does to beat that at ICA-98!

As well as technical sessions, the conference featured lunch-time concerts every day, and a symphony concert at which Jurgen Meyer from PTB demonstrated some aspects of orchestral acoustics, such as the effect of different seating arrangements for the strings. The orchestra and soloist then gave an exciting account of the Grieg A Minor piano concerto. There was also a stormy boat ride to the island of Munkholm for dinner one night and, I am told, a hike in the woods, though the weather was not really right for this.

All in all, ICA-95 kept up the fine standard of this conference series. The next ICA will be held in Seattle in 1998, in conjunction with a meeting of the Acoustical Society of America. This will be conveniently accessible for Australians, and we may have even more representatives than the good-sized group who attended in Trondheim. I hope to see you there!

Neville Fletcher

International Symposium on Musical Acoustics

As has become traditional, a satellite meeting on musical acoustics was held in conjunction with the 1995 International Congress on Acoustics, this time in the little medieval town of Dourdan just south of Paris. Around 150 people attended and the 85 papers presented have been collected into a very nicely produced book of 614 pages. (Copies can probably be obtained from IRCAM in Paris.)

The papers covered the whole range of musical acoustics. Winds, strings and percussion instruments all received attention, and there were additional sessions on nonlinear acoustics and chaos, radiation, signal processing, physical modelling for computer synthesis, and human perception. Some of the papers were accompanied by demonstrations, such as the production of anomalous low-pitched tones on the violin and the controlled playing of sub-octaves on the bassoon, and for the whole duration of the meeting the hotel lobby was dominated by an immense computer-controlled Heath Robinson-ish instrument of pipes, bowed strings and drums that produced a great variety of fair-ground music during coffee breaks.

More formal musical fare was provided by a superb viola recital at the opening session, an excellent evening concert of saxophones and South American flutes, and an open-air carillon recital in the town square. A particular highlight was a specially arranged evening organ recital in Notre Dame de Paris after the tourists had all been turned out for the night.

In retrospect, many of the papers simply added detail to matters already published, but there was a good selection of new insights and previews of work that will not see publication for a year or more yet. The meeting was invaluable for the exchange of views and for catching-up with old friends, and I am sure the half-dozen Australians who attended found it very worthwhile.

Neville Fletcher

ACTIVE '95

ACTIVE '95, the 1995 International Symposium on active control of sound and vibration, organised by the Institute of Noise Control Engineering, was held in sunny California on July 6-8, 1995, immediately before Internoise '95. The conference venue was in the heart of Newport Beach, close to a myriad of excellent eating establishments, and boasted a bar on the top floor with a 360° view of the city and coastline. Many delegates took advantage of this facility to renew old acquaintances and discuss business; important aspects of any conference.

With five distinguished lectures and 121 contributed papers from 22 countries, the conference boasted a wide coverage of the field of active sound and vibration control and was attended by approximately 250 delegates. The attendance is a good indication of the high level of professional interest in this very specialised topic which is really a mix of acoustics and vibration, control theory, signal processing and electronics.

Distinguished lectures included a discussion of wave propagation in fluid filled pipes by Professor Fuller of Virginia Tech, USA, a discussion of reverberant sound field active control by Professor Tohyama, Kogakuin University, Japan, an excellent review of research on the active control of road noise inside automobiles by Professor Bernhard, Purdue University, USA, a discussion of the use of genetic algorithms for control source placement by Professor Hamada, Tokyo Denki University, Japan and a review of the application of active control to electroacoustics by Professor Kleiner, Chalmers University of Technology, Sweden.

There were entire sessions devoted to each of the following topics: active vibration isolation; structural vibration control; structural radiation control; control of sound in ducts; control of sound in enclosures; control of sound in vehicles; control of free field sound radiation; active control transducers; signal processing and algorithms; audio applications; non-traditional active control including system performance monitoring and diagnosis, smart structures and boundary layer control

The social program included a reception sponsored by Analog Devices on the first evening and a Beach Barbecue (including volley ball) on the second evening. These events were an important part of the conference as they contributed significantly to the interaction of the delegates.

Although there was no official trade exhibition, three companies took advantage of the opportunity to demonstrate their active control hardware to a captive audience. Causal Systems (based at Adelaide University, South Australia) had four of their low cost active control systems set up for delegates to fiddle with. Digisonix, USA, demonstrated their high cost active control system and Analog Devices, USA, showed their commitment to the development of special purpose signal processing and A/D converter micro-chips for active control.

The organising committee is to be congratulated for a well organised, enjoyable and interesting conference and I, for one, am looking forward to the next in the series to be held in 1997 with the venue yet to be decided upon.

Colin Hansen

InterNoise 95

InterNoise 95 was held 10 to 12 July at Newport Beach, California. The three distinguished lectures were: Applications of Noise Control in Japan by Masaru Koyasu; Applications of Active Control of Sound and Vibration by Jiri Tichy and Progress in Controlling Noise in the Workplace by Robert Bruce. There were 21 special sessions on specific topic areas. These sessions comprised both invited papers and contributed papers. There were over 300 papers in the 9 main topic areas: General, Emission Noise Sources; Physical Phenomena; Noise Control Elements; Vibration and Shock; Immission Environmental Noise; Immission Effects of Noise; Analysis and Requirements. As there were only 3 days for the conference there were many parallel sessions and the dilemma of "which paper to go to next" arose frequently. However the breaks in the program allowed for meeting with colleagues and friends.

There was an extensive technical exhibition where it was possible to see the latest instruments and products from around the world. The social program included two receptions at the venue. These informal gatherings allowed for further discussions with colleagues. The surrounding area, with seaside and vast shopping malls, was most interesting and provided a welcome break from the hectic technical program.

The Organising Committee were congratulated for the successful organisation of another InterNoise. The closing session incorporated an invitation for all to attend InterNoise 96 will be held in the UK - details in Diary of this issue.

Marion Burgess

STANDARDS REPORT

Standards Australia will soon be publishing the following standards:

AS/NZS 1591.1-1995: Instrumentation for Audiometry. Part 1: Reference Zero for the Calibration of Pure-Tone Bone Conduction Audiometers. (Adoption of ISO 389.3:1994)

AS/NZS 1591.4-1995: Instrumentation for Audiometry. Part 4: A Mechanical Coupler for Calibration of Bone Vibrators (Revision of AS 1591.4-1974). (Adoption of IEC 373:1990)

Hearing Aids in Radio Frequency Fields - Most of us have experienced the annoyance of trying to hear a radio or television program when an overlying buzz is interfering with the reception. It is not difficult to imagine how frustrating it would be to a person wearing a hearing aid when their electronic device acts in the same manner. The possibility of "buzzing" or interference occurring from extraneous radio frequency emissions has been recognised, and a new part of the existing standard for hearing aids is being published in an effort to minimise this annoying problem. Known as **AS 1088** Part 9: Immunity requirements and methods of measurement for hearing aids exposed to radio frequency fields in the frequency range 300 MHz to 3 GHz, the standard includes both the acoustic and electromagnetic methodology for verifying compliance with the classes of immunity.

ISO on Internet - ISO Online is a new electronic information service from the Int. Organisation for Standardisation (ISO), which is now available via World Wide Web (WWW). It provides the full catalogue of ISO Standards and drafts, classified and grouped, and locatable by keyword search or through their ISO reference number. Other available information includes committee details (including scope of activity of each technical committee) and memberships, meetings calendar, and general background on ISO. To gain access connect to the following Uniform Resource Locator (URL): http://www.iso.ch/. To get access to WWW servers over Internet, most people opt for one of the commercially-available softwares (browsers) such as Mosaic or Netscape.

ASTEC Update

The Australian Science and Technology Council (ASTEC) has been undertaking a study on "Matching Science and Technology to Future Needs". The response from the AAS was presented in the article by Charles Don in the last issue of the journal (vol 23, No1, p21-22). On the basis of the submissions from the various organisations around Australia, ASTEC has identified six key issues for Australia to 2010:

Need for innovation and entrepeneurship

Need for technologically literate society

Need to capture opportunities from globalisation

Need to sustain the natural environment

Need for continuous improvements in community well-being

Need for a forward looking science and technology system

Discussion papers, meetings and seminars are being held around the country to investigate each of these issues. In addition ASTEC is undertaking another study to "asses the adequacy of Australia's science base to contribute to the development of information and communications services and technologies"

Contact ASTEC (tel 06 271 5084, fax 06 271 5125) should you require further information or wish to be involved with consultations.

Books...

Environmental and Architectural Acoustics

Z Maekawa and P Lord

E & FN Spon, 1994, 377 pp, hard covers, ISBN 0 419 15980 0, Aust Distrbutor: DA Information Services, PO Box 163 Mitcham Vic 3132 Tel 03 9873 4411 Fax 03 9873 5679. Price A$ 179

The first sentence of the preface states that this book is "intended to present the practical technology needed to achieve a more acceptable acoustic environment for human life" Such a goal is very grand and while the book presents a great deal of information on various aspects of acoustics, it can hardly be expected to achieve this goal in a mere 377 pages. The book is based on Maekawa's lectures with additional information from research papers. The role of Lord has been to assist Maekawa to "present his work in a way which would be easily understood by the English reader".

The first two chapters deal with fundamentals of sound waves, hearing, measurement and rating. These are followed by chapters on room acoustics, sound absorption and sound insulation. The next chapter is on the isolation of structure borne sound and vibration. Noise and vibration control in the environment is covered in around 20 pages and the subsequent chapter on room acoustics is only slightly longer. The last formal chapter is on electro acoustic systems. Chapter 10 is entitled Addenda and has technical information such as procedure for calculation of loudness level in phon, sound diffration around a screen, along with general information such as an outline of the ear and the principles of statistical energy analysis. The data usually found in an architectural acoustics book, like sound absorption coefficients and sound transmission loss for a range of building materials, form the appendices. There is a list of over 50 research papers and then a Bibliography divided into 16 references for acoustic design and 43 for acoustic research.

Although the author considers the book provides a useful foundation for students of architecture and environmental engineering, I doubt that the book would be suitable as a text book for such courses in Australia. The mathematical approach throughout most of the book may prove too daunting for many. Also, some important aspects are dealt with very briefly or not at all. Such a topic is that of road traffic noise; certainly most important to both types students yet not listed in the index and only referrred to briefly in the chapter on the environment. Another example is that of the transmission loss for a wall comprising a number of elements. The mathematical relationship and an example are provided but the graphical method, normally included in such a section and which helps to reinforce the importance of the weakest link in a partition, is not included.

Certainly there is a wealth of information in this book and it would be a useful addition to a library and a reference collection.

Marion Burgess

Marion Burgess has been involved with teaching of undergraduate students for many years. In her current position at the Acoustics and Vibration Centre at the Australian Defence Force Academy she is involved with the organisation and presentation of short courses.

Disability, Ageing & Carers - Hearing Impairment, Australia 1993

Australian Bureau of Statistics

ABS, 1995, ABS Catalogue No. 4435.0, ISBN 0 642 20666 X. Distributor ABS, PO Box 10, Belconnen ACT 2616, Tel 008 020 608, Email: stat.info@abs. telememo.au Price $10.00.

The Survey of Disability, Ageing and Carers conducted in 1993 was designed to identify a range of disabilities and impairments which were likely to limit a person's ability to function in society. Any hearing loss was identified as such an impairment. This publication presents data on all persons with hearing impairment.

Statistics are presented on hearing impairment categorised into the following groups: age structure, living arrangements, country of birth, disability and disabling conditions, underlying cause, severity and area of handicap, communication, sign language, lip reading, aids, help needed, help received, employment, income and education. Within each group the data is presented in summary tables and graphs with explanatory text.

It is interesting to note that in 1993, 999,800 Australians (5.7% of the population) suffered from a hearing impairment. About 35,900 people had total hearing loss. Working conditions were given as the most common reasons for those reporting a hearing loss as their only disability. Disease, illness or a hereditary condition was identified as the second most common cause for those with hearing impairment only. Diseases most frequently reported were measles (4,500) and mumps (2,500). A smaller number reported rubella (1,800) as the underlying cause of their condition.

The data shows that the underlying cause of hearing loss varied greatly between males and females. Overall, work and working conditions was reported as the underlying cause of their hearing impairment by 157,800 (26.5%) males, but only 14,400 (3.8%) females. When hearing loss was the only disability this rose to 40% for males and only 4.5% for females.

The proportion of people with a hearing impairment using sign language was very small, totalling about 16,000. Sign language users were most likely to have had hearing impairment since birth or early childhood, probably had a total hearing loss and were more likely to be women. Hearing aids were used by 363,266 people, with other aids such as telephone attachments also used by some.

This booklet would be of interest to anyone wanting to obtain demographic data on hearing impairment within the Australian population.

David Eager

David Eager is a Lecturer in Manufacturing Engineering at University of Technology, Sydney. He is currently undertaking research on noise reduction in the sheet metal industry.

Principles of Vibration and Sound

Thomas D Rossing & Neville H Fletcher

Springer Verlag, 1995, 247 pp, soft covers, ISBN 0 387 94336 6, Aust Distrbutor: DA Information Services, PO Box 163 Mitcham Vic 3132 Tel 03 9873 4411 Fax 03 9873 5679. Price A$ 49

The text is a reprint of the first section of authors' longer book, The Physics of Musical Instruments, also published by Springer-Verlag in 1991. The book emphasises the mathematical basis of vibration and sound and is suitable for use in advanced undergraduate courses. A new chapter, Acoustic Systems, has been added as well as a set of problems for each chapter.

The book is noteworthy for the concise and elegant treatment of a wide range of topics including a number not usually found in an introductory text. The authors make frequent reference to relevant published investigations which prevents the book form becoming just another academic exercise. Part I is devoted to Vibrating Systems and Part II to Sound Waves.

Since the text was originally an introduction to a treatment of musical instruments, there are numerous comments throughout the book to musical applications of the mathematical models. Occasionally such a comment needs revision when reference is made to further treatment 'later', when 'later' means in the original book (for instance on p44 there is reference to a non-existent chapter 12: p45, 1st para-omit reference to 'later chapter': p134 last sentence; p186 1st sentence; p189,3rd para).

While on the subject of quibbles, on p146: The 'A' decibel scale is the inverse of the 40 phon contour, not the 0 contour; again on p146 2nd para - the phrase 'human bearing responds to acoustic pressure' is somewhat too general in view of the dependence of the sensation of loudness on energy rather than pressure and the complex relationships that exist between loudness, pitch and timbre. Also on p19. Fig 1.12(c) should read Fig 1.13(c): in Figs 1.13(b) and (c), B and G are not defined.

The first three chapters dealing with the fundamentals of vibration theory (free and forced vibrations, continuous systems in one and two dimensions) are clearly written with good illustrations and should prove to be useful introductory material. Two chapters on coupled and nonlinear systems complete a concise and lucid account of vibration theory. Included are sections not often encountered in such a book, for instance, rectangular wood plates, nonlinear vibrations in plates and shallow shells, vibrating string coupled to a soundboard, two strings coupled by a bridge.

Chapter 6 on Sound Waves in Air is a gentle introduction to the basic concepts regarding sound waves, reflection, transmission, absorption and normal modes in cavities. An expanded treatment of diffraction and scattering would have been welcome considering their importance in room acoustics and in relation to holography. If Sabine's equation is to be quoted, its limitations and some alternatives are probably worth including.

Chapters on Sound Radiation and Pipes and Horns are treated comprehensively and in a moderately advanced style. The necessary computational techniques are clearly described, there are suitable warnings of the complexities ahead when situation other than those contained within the particular mathematical model are encountered and direction signs are given for further treatment. At times in these and earlier chapters a little more discussion would be helpful when cases arise that deviate from the strict mathematical conditions.

The final chapter on Acoustic Systems is a useful introduction to the use of analogies for treating acoustical network problems. The book is rounded off with a bibliography and sets of problem for each chapter, (the figures have been omitted from problem 1.12). While answers have been provided for selected problems, some hints or outline solutions for the theoretical exercises would prove helpful for those who engage in self study. The book has been clearly set out and printed with an excellent array of diagrams which in most cases include fully descriptive captions. This text is a reliable and clearly accessible introductory account of fundamental problems and techniques and should prove to be valuable both to the instructor and to the student.

Howard Pollard

Howard Pollard was an Associate Professor in Physics at UNSW until his retirement and he has continued his invovement with part time lecturing. His research interests include many aspects of acoustics.

The Physics and Psychophysics of Music

Juan G. Roederer

Springer-Verlag, New York, 1995, 220 pp., softcover, ISBN 0-387-94366-8. Aust distributor: DA Books, DA Information Services, PO Box 163 Mitcham Vic 3132 Tel 03 9873 4411 Fax 03 9873 5679.Price A$40.75.

When Helmholtz wrote his classic "On the Sensations of Tone" in 1862, he laid the foundations for the whole subject of auditory perception, particularly in relation to the perception of musical sounds. Since then, however, most books on musical acoustics have concentrated on the physics of musical instruments

When the first edition of Roederer's book appeared in 1973, it represented a return to the Helmholtz tradition, though in a much more brief and modern form, with psychophysics — the quantitative study of perception — taking roughly equal place with a brief description of the acoustics of musical instruments. Now, with its third edition, it has direct competitors in Plomp's "Aspects of Tone Sensation" (1976) and Sundberg's "The Science of Musical Sounds" (1991), both of which are comparable in length and technical level. Everyone with a scientific interest in music should read at least one of these three books.

Rather more than half of Roederer's book is devoted to auditory physiology and psychophysics. The treatment, although brief, is comprehensive and up-to-date and has been extended in this edition to include subjects such as oto-acoustic emission (sounds emitted by the ears of most people). The discussion otherwise ranges from the neurophysiology of hearing, through pitch perception, to the specialisation of music listening in the right hemisphere of the brain and the effects of music on the emotions. The reference list is primarily in this area, with audition and psychophysics accounting for 120 of the 140 items. Of these, 45 are more recent than the second edition, and many are reviews, which are particularly useful for following up interesting topics.

The physics section is essentially unchanged from the earlier editions. There is a necessary introduction to the physics of sound, together with brief and rather dated accounts of musical instrument acoustics. Surprisingly, since Roederer is a physicist, there are a few minor lapses in these chapters, and the appendix on bowed strings is of very little use — the example string is bowed at its mid-point so that the characteristic bowed-string motion does not develop! The physics sections are, however, adequate to give background to the more important psychophysical part of the book.

We are told that the book arose from a course with the same title for non-physics students, but I suspect that it might tell an average Australian music student more than (s)he wants to know about the subject! While the book is a little densely written for casual reading, I would recommend it to anyone with a science orientation who wants to discover something about the psychophysics of hearing and its relevance to music. I certainly enjoyed re-reading it.

Neville Fletcher

Neville Fletcher is an adjunct Professor at the Australian National University. He has written extensively on musical acoustics.

Letters...

I write in response to the very thoughtful Editorial by Charles Don in Acoustics Australia, 23(1). Charles makes the observation that too much of the Council's time is devoted to the relatively mundane task of running the society and too little time on the broader, and many would say the more important, questions of the relevance of the society to its members and the future of acoustics at all levels within Australia. My humble opinion is that the main item is consideration of the role of the Australian Acoustical Society in the wider Australian Society; how we can increase our membership and relevance.

The mundane matters can generally be dealt with by the secretary and only bought to the council agenda when the matter is deemed contentious enough to merit Council's consideration.

Charles Don is to be congratulated for his editorial which makes the Council and all members consider their priorities. Meetings can all too easily become a habitual ritual driven by the previous minutes. All strength to him who questions what are the important priorities and why aren't we devoting our time to them?

Glen Harries, Vic

Information for Authors...

Acoustics Australia is the journal of the Australian Acoustical Society. It publishes general technical articles in all areas of acoustics of interest to members of the Society, together with relevant news and views. Review papers, covering particular fields of acoustics and addressed to a non-specialist acoustics readership, as well as papers of a "tutorial" nature dealing with important acoustical principles or techniques are most welcome. Acoustics Australia does not aim to be a primary scientific journal, and therefore does not normally publish primary research papers, with the exception of those that apply specifically to Australia.

Submission of an article carries the implication that it has not been published in the same form elsewhere, and is not currently under consideration by another publication. Upon acceptance, authors will be asked to transfer copyright to Acoustics Australia (to enable us to deal easily with requests for reprint permissions) but the author will retain rights to use the material freely.

Articles should generally not exceed five journal pages in length. This implies a maximum of about 5000 words, with each square single-column diagram being counted as 300 words, and pro-rata for diagrams of other shapes. Authors submitting longer articles may be asked to bear the extra publication costs involved. Shorter "Technical Notes", not exceeding one journal page in length, are also welcome. All articles will be submitted to independent review before being accepted for publication.

Three copies of text and diagrams, together with originals of all drawings, should be submitted to the Editor. The drawings must be of publication quality and lettering must be of such a size that it will be no less than 2mm high when the figure is reduced to single-column size (width 85 mm). The equivalent of either Times Roman or Helvetica type may be used in diagram lettering. The journal cannot undertake to re-draw unsatisfactory diagrams. Half-tone photographs of good quality may also be included.

All material for publication should be submitted to The Editor, Acoustics Australia, Acoustics and Vibration Centre, Australian Defence Force Academy, CANBERRA ACT 2600 email: m-burgess@adfa.oz.au.

Diary...

CONFERENCES and SEMINARS

* Indicates an Australian Activity

1995

September 3-7, BERLIN
1995 World Congress on Ultrasound
Details: J. Herbertz, WCU 95 Secretariat, Gerhard-Mercator-Universitat, 4708 Duisburg, Germany

September 19-22, BRISBANE
* Asian Pacific Conf on OH&S.
Education and Training.
Details: OH&S Conference, PO Box 515, Sunnybank, Qld 4109. Tel (076) 312 438, Fax (076) 345 4892

October 9-11, SYDNEY
* Airports 95. Airport Engineering: Innovation, Best Practice and the Environment.
Details: Convention Manager, Airports 95, AE Conventions Pty Ltd, PO Box E181, Queen Victoria Terrace, ACT 2600

October 20-22, VALDIVA
2nd Int Acoustics Meeting Chile
Details: INGEACUS'95, PO Box 567, Valdiva, Chile. Tel +56 63 217 368/221 338, Fax +56 63 213 986, email ingeacus@valdiva.uca.uach.cl

November 8-10, MELBOURNE
* $(CM)^2$ Forum 1995.
Machine Condition Monitoring
Details: Dept Mech Eng, Monash Uni, Clayton, Vic 3168. Tel (03) 905 5699, Fax (03) 905 5726

November 15-17, FREMANTLE
* AAS Annual Conference 1995
Acoustics Applied
Details: Dr G Yates, Dept Physiology, Uni WA, Hackett Drive, Crawley, WA 6009. Tel (09) 380 3321, Fax (09) 380 1025, email gyates@uniwa.uwa.edu.au

November 16-19, WINDERMERE
Reproduced Sound II
Details: Institute of Acoustics, Agriculture House, 5 Holywell Hill, St Albans, Herts AL1 1EU, UK. Tel +44 727 848195, Fax +44 727 850553
email Acoustics@clus1.vlcc.ac.uk

Nov 27-Dec 1, KUALALUMPUR
Asia-Pacific Vibration Conference
Details: Joseph Mathews, Dept Mech Eng, Monash Uni, Wellington Rd, Clayton, Vic 3168 Tel +61 3 905 3554, Fax +61 3 905 5726.
email: mathews@eng2.eng.monash.edu.au

November 27 - December 1, ST LOUIS
130th Meeting Acoustical Soc of America
Details: Acoustical Society of America, 500 Sunnyside Boulevard, Woodbury, NY 11797, USA

December 4-7, HONG KONG
SDVNC 95 Int Conf Structural Dynamics, Vibration, Noise and Control
Details: Prof De Mao Zhu, Nanjing Uni Aeronautics and Astronautics, Nanjing, Tiangsu 210016, China, Tel +86 25 449 2492, Fax +86 25 449 8069

1996

January 10-11, SINGAPORE
Annual Meeting, Soc of Acoustics (Singapore)
Details: Dr W S Gan, Acoustical Services Pty Ltd, 209-212 Innovation Centre, NTU, Nanyang Ave, Singapore 2263, Republic of Singapore. Fax +65 791 3665, Tel +65 791 3242

February 19-21, MELBOURNE
*Australasian Cong. on Applied Mechanics
Details: AE Conventions (ACAM 96), PO Box E181, Queen Victoria Terrace, ACT 2600. Tel (06) 270 6562, Fax (06) 273 2918

February 24-27, SYDNEY
* Occupational Injury Symposium
Details: Occupational Injury Secretariat, Professional Education Program, National Occ Health and Safety Commission, GPO Box 58, Sydney, NSW 2001. Tel (02) 565 9319, Fax (02) 565 9300

April 1-4, ANTWERP
Forum Acusticum 96
1st Conv. European Acoustics Assoc.
Details: Forum Acusticum, Technological Institute KVIV, Desguinlei 214, B-2018, Antwerpen, Belgium, Tel +32 3 216 0996, Fax +32 3 216 0689

April 26-28, MICHIGAN
Joint meeting of Catgut Acoustical Society and Michigan Violinmakers Assoc.
Details: Catgut Acoustical Soc. Inc., 112 Essex Ave, Montclair, New Jersey 07042, USA. Fax +1 201 744 9197

May 28-31, PISA
Noise and Planning '96
From technical to environmental standards
Details: Noise and Planning Conference Secretariat, Guido Lombardi, via Bragadino 2, 20144 Milano, Italy. Tel +39 2 48018833, Fax +39 2 48018839

June 24-28, HERAKLION, CRETE
European Conf on Underwater Acoustics
Details: Secretariat, 3rd European Conference on Underwater Acoustics, Foundation for Research and Technology - Hellas, Institute of Applied and Computational Mathematics, PO Box 1527, 711 10, Heraklion, Crete, Greece. Tel +30 81 210034, Fax +30 81 238868, email conference@iesl.forth.gr

June 24-28, ST PETERSBURG
4TH International Congress on Sound and Vibration
Details: M Crocker, Mech Eng Dept, 201 Ross Hall, Auburn Uni, Auburn, AL 36849-3501, USA. Tel 334 844 3310, Fax 334 844 3306. email mcrocker@eng.auburn.edu

July 30-August 2, LIVERPOOL
INTERNOISE 96
Noise - The Next 25 Years
Details: Institute of Acoustics, Agriculture House, 5 Holywell Hill, St Albans, Herts AL1 1EU, UK. Tel +44 727 848195, Fax +44 727 850553
email Acoustics@clus1.vlcc.ac.uk

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

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, USA. Tel +1 206 543 5539, Fax +1 206 543 2352

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COURSES

In accordance with the recognition of the importance of continuing education, details of courses held in Australia are included in this section at no charge. Additional details can be given in an advertisement at normal rates.

1995

November 7-10, CANBERRA
Basics of Noise and Vibration Control
Details: Acoustics & Vibration Centre, ADFA, Canberra, ACT 2600. Tel (06) 268 8241, Fax (06) 268 8276. email m-burgess@adfa.oz.au

November 15-16, CANBERRA
Basics of Underwater Acoustics

November 17, CANBERRA
Modern Sonar Systems
Details: Acoustics & Vibration Centre, ADFA, Canberra, ACT 2600. Tel (06) 268 8241, Fax (06) 268 8276. email m-burgess@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
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DIVISIONAL MATTERS

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

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Tel (02) 579 5566
Fax: (02) 580 9755

AAS - Queensland Division
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OMMANEY 4074
Sec: Mr B Thorne
Tel (07) 225 1772
Fax (07) 376 6236

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University of Adelaide
SOUTH AUSTRALIA 5005
Sec: Carl Howard
Tel (08) 303 3092
Fax (08) 303 4367
email: CQHOWARD@edison.aelmg.adelaide.edu.au

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Fax (03) 794 5188

AAS–W A Division
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