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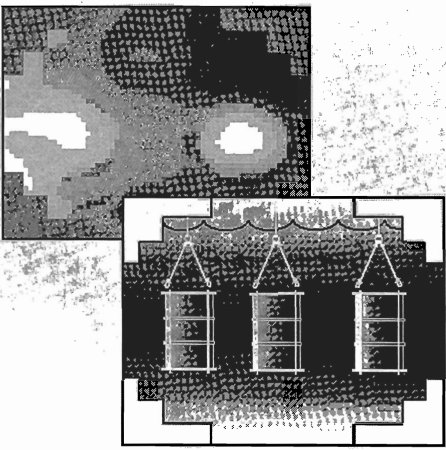

- Virtual sensors
- Noise barriers
- Acoustic daylight
- Underwater hearing

Australian Acoustical Society **Vol. 29 No. 2 August 2001**


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

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The Editor, Acoustics Australia
Acoustics & Vibration Unit
Australian Defence Force Academy
CANBERRA ACT 2600
Tel (02) 6268 8241
Fax (02) 6268 8276
email: acoust-aust@adfa.edu.au
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From the President

A sense of belonging.... Why are we members of the Australian Acoustical Society?

It is a question that has arisen at both divisional level and at council meetings over many years. For the acoustician in private practice and product manufacturer, is the predominant reason for membership simply to improve business opportunities, for the academic is it a matter of improved professional standing with the ensuing personal benefits, or is it balanced combination of these and other reasons?

The Society offers members these opportunities and much more. It provides a forum for debate on matters acoustical. It enables expression of opinion and submissions on international and community acoustic issues, it provides a pool of 'resource members' for standards committees to shape standards designed to meet the expectations and requirements of the community and educates and informs members through its publications, conferences and technical meetings.

The Australian Acoustical Society asks little of members, besides our annual subscription, and from some members receives much - particularly in time given to the Society in serving on divisional, conference and standards committees and publications to name a few. For many whose vocation is in this fascinating acoustics field there has been an innate gratitude which has led to the provision of their time in this way for which is Society is ever indebted. May more members feel so inclined in the future?

With this in mind, the Australian Acoustical Society has itself had the privilege to belong to the wider scientific community associated with such organisations as the Australian Academy of Science and the Federation of Australian Scientific and Technological Societies (FASTS). Council regularly however finds itself asking similar questions on membership - what benefit do we gain from being a member, is it worthwhile, is the organisation really interested in acoustics, should we withdraw our membership?... and so forth.

This has been an ongoing valid debate. In respect to the Society's involvement in FASTS there have been some interesting developments which I trust auger well for an increased involvement in the future. There is now an opportunity to highlight the field of acoustic endeavor in its variety of forms at a much higher and nationally accepted status.

Until recently the Australian Acoustical Society has been a member of FASTS under the umbrella 'Australian Institute of Physics' organisation which understandably has raised an acoustic eyebrow of our member architects, consultants, medical professionals and engineers. However with a restructuring within the FASTS organisation, the Society has been invited to join with two not dissimilar Societies to form a 'cluster' of three organisations involved in the physical sciences. In so doing, the Australian Acoustical Society will have the opportunity to appoint a FASTS Board Representative in consultation with the other two 'cluster' members.

Council will be meeting with FASTS at our November meeting to consider our future relationship. Whatever the outcome, the Councillors will hopefully come to a balanced decision, mindful of the duality of their role in expressing their respective divisional membership desires and looking at the bigger picture of the Society in its involvement on the national stage. Council would welcome any input from our membership in this regard.

Geoff Barnes

Australian Acoustical Society

NEW INTERNET ADDRESS

The AAS has now dispensed with that cumbersome long www address which has served well for many years now.

David Watkins, the AAS Secretary, deserves many thanks for establishing, updating and maintaining the page - no small task.

This responsibility is now to being taken over by Terry McMinn in WA.

The new streamlined domain name is

www.acoustics.asn.au

The 'asn' stands for association and will become a common part of the domain name for organisations and societies.

This page provides many details on the activities of the Society including contact details for office bearers, membership applications, conference information, contents of the journal Acoustics Australia, useful links and lots more. Check it out and pass any suggestions onto Terry McMinn.

VIRTUAL SENSORS IN ACTIVE NOISE CONTROL

This paper was awarded the
2000 PRESIDENT'S PRIZE.
This prize established in 1990 by the Australian Acoustical Society, is awarded to the best technical paper presented at the Australian Acoustical Society Conference by a member of the Society.

Colin D. Kestell, Colin H. Hansen and Ben S. Cazzolato
Department of Mechanical Engineering,
University of Adelaide SA 5005, Australia

ABSTRACT: Traditional active noise control systems achieve the greatest noise reduction at the locations of the error sensor(s). In many cases it is desirable to be able to achieve the maximum noise reduction remote from an error sensor. One way of doing this is to measure the transfer function between the desired location of maximum reduction and the error sensor and incorporate it in the control algorithm. The disadvantage of this method is that it is not robust to changes in the acoustic environment. Another method relies on using two or more microphones to estimate the sound level at a remote location using forward prediction. This method results in a lower performance but it can be adapted to changes in the acoustic environment as well as to changes in the location of the desired pressure minimum. This paper will report on a study that compares the relative merits of various forward prediction method in various situations. These commence with a free field environment (to introduce the concept) and then progress to a more practical application of an aircraft cabin. Single and multiple control sources will be considered as will sound pressure sensing and energy density sensing.

1. INTRODUCTION

Active noise control in modally dense and highly damped enclosures can result in small zones of attenuation that are centralised around the error sensors. In fact, an observer located close to a single acoustic pressure error sensor may not perceive any improvement in noise reduction as a result of active noise control, even though the error sensor may indicate that a significant reduction has been achieved. Consequently, research has recently been focused on finding alternative cost functions that results in a broader region of control that is sufficiently large to envelope the observer. Energy density is known to be more spatially uniform than squared acoustic pressure and can result in larger regions of attenuation when it is used as an active noise control cost function (Sommerfeldt and Parkins (1994)). However, for a multi-channel control system, the maximum attenuation in pressure is still likely to occur at the sensor location and the size of the zone of local control is inversely proportional to frequency (Cazzolato (1999)). The volume of the control region also tends to increase at the expense of reduced attenuation. An alternative to increasing the size of the control zone is to minimise the cost function at the observer rather than at the error sensor location by "virtual sensing", a concept first introduced by Garcia-Bonito *et al.* (1996). Their method was based on measuring the acoustic pressure transfer function between a permanently placed remote microphone and a microphone temporarily located at the observer location. With the temporary microphone subsequently removed, the signal from the permanent microphone was modified with the transfer function to create a *"virtual microphone"* at the observer location. However, any significant observer movement or environmental change within the vicinity of the sensors alter the transfer function and result in an error in the estimate of the acoustic pressure at the observer location. Kestell *et al.* (2000, 2001) introduced *"forward difference prediction virtual sensors"* which use multiple sensors to estimate a trend in the acoustic field and predict (via extrapolation) the cost function at the observer location. They have demonstrated various strategies of error sensing that not only shift the zone of attenuated noise towards an observer but combine the benefits of "virtual sensing" and energy density minimisation. This paper shows a summary of the theory, introduces the concept with an idealised free field example and shows how the virtual sensors perform in an aircraft cabin.

2. THEORY

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

1. Two microphone, first-order virtual micro-phone:

$$p_v \quad \frac{(p_2 \quad p_1)}{2h} x + p_2 \tag{1}$$

2. Three microphone, second-order virtual micro-phone:

$$p_x \quad \frac{x(x+h)}{2h^2} p + \frac{x(x+2h)}{h^2} p_2 + \frac{(x+2h)(x+h)}{2h^2} p_3 \tag{2}$$

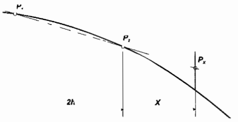
3. Two microphone, first-order virtual energy density sensor:

$$E_{D_x} \quad \frac{}{4\rho c^2} \left| \left(+ \frac{x}{2h} \right)^2 p_2^2 \quad \frac{x}{h} \left(1 + \frac{x}{2h} \right) p \; p_2 + \left(\frac{x}{2h} \right)^2 p_1^2 \quad \frac{1}{(2hk)^2} \left(p_2^2 \quad 2 p_1 p_2 + p_1^2 \right) \right| \tag{3}$$

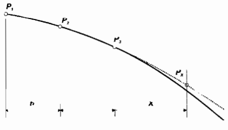
4. Three microphone second-order virtual energy density sensor:

$$E_{D_x} \quad \frac{}{4\rho c^2} \left[\left(\frac{x(x+h)}{} p_1 + \frac{x(x+2h)}{h^2} p_2 + \frac{(x+2h)(x+h)}{2h^2} p_3 \right)^2 \quad \frac{1}{k^2} \left(\frac{2x+h}{2h^2} p_1 \quad \frac{2x+2h}{h^2} p_2 + \frac{2x+3h}{2h^2} p_3 \right) \right. \tag{4}$$

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



(a) First-order



(b) Second order

Figure 1: Forward difference extrapolation

3. METHOD

The zone of local control around a "virtual energy density sensor" and a "virtual microphone" is compared with that achieved when using an actual energy density sensor and a single microphone. To introduce the concept, the analysis commences with a free field approximation in an anechoic chamber (figure 2) and then progresses to the more practical application of an aircraft cabin (figure 3).

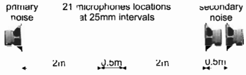


Figure 2: Schematic representation of the experimental configuration in an anechoic chamber.

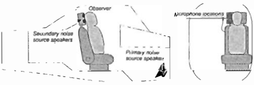
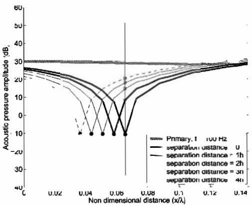
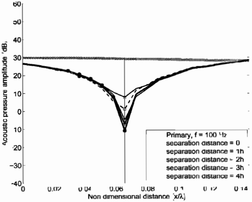


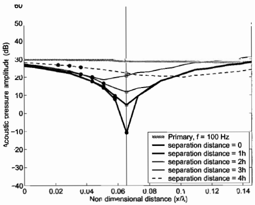
Figure 3: The speaker and microphone locations in the aircraft cabin.



(a) Control via one microphone



(b) A first-order virtual microphone



(c) A second-order virtual microphone

Figure 4: A 100 Hz primary sound source in an anechoic chamber controlled via one control source. The actual sensors are marked with a circle and the observer location by a vertical line.

In each example the primary noise was generated using a single acoustic source, the secondary (cancelling) noise was generated from either one or two control sources and the controlled sound field was analysed along a 0.5 m length at 25 mm increments. Minimising pressure at a single location only requires one control source, but Cazzolato (1999) showed that two control sources are required to effectively minimise energy density in one dimension. With two control sources, using a *first-order virtual energy density sensor* is identical to simply minimising energy density at the physical sensor location or acoustic pressure at two microphone locations (Kestell *et al.* (2000,2001)). This is because in a two sensor system the energy density estimate at the observer is a linear combination of the pressure and pressure gradient at the sensors. Therefore if these are zero at the sensors it follows that the estimated energy density will also be zero. Therefore, in the examples that follow, the use of a single control source is limited to observing the performance of a single microphone, a *first-order virtual microphone* and a *second-order virtual microphone*. Two control sources are used to observe energy density minimisation directly at the sensors and at the observer location with a *second-order virtual energy density sensor*.

Figure 5: Prediction errors in the absence of short wavelength spatial pressure variations.

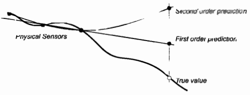
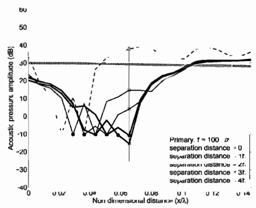


Figure 6: Prediction errors in the presence of short wavelength spatial pressure variations.

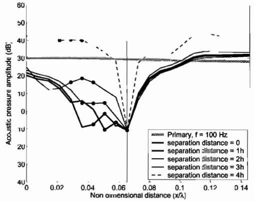
4. RESULTS

Control in an anechoic chamber

Figure 4 shows the results that are obtained when controlling a 100 Hz monotone in an anechoic chamber. The results in figure 4(a) show the level of control achieved when using a conventional pressure squared cost function, where the sensor is incre-mentally moved further from the observer location. The attenuation at the observer location is shown to reduces from 40 dB to 8 dB as the observer/sensor separation distance increases from *0h* to *4h* (100 mm). In figure 4(b) the control results for a *first-order virtual microphone* are shown. Since the algorithm adapts to an increasing separation distance, the attenuation only reduces to 22 dB when observer / sensor separation distance increases to 100 mm, demonstrating a practical advantage over the conventional remotely placed single microphone (figure 1). Figure 4(c) illustrates the performance of the theoretically more accurate *second-order virtual micro-phone* (refer to figure 1(b)), showing that its accuracy is adversely affected by small spatial pressure variations that are primarily due to reflections from the walls of the chamber (figures 5 and 6). In this example the *second-order virtual microphone* offers no practical advantage when compared to a single remotely placed microphone. Introducing a second control source allows the pressure to be independently controlled at two sensor locations and control of energy density either at the observer or the sensor location (Kestell *et al.* (2000,2001)). Energy density minimisation at the error sensor (or virtual first-order prediction at the observer location) is shown in figure 7(a).



(a) Energy density control (and first-order virtual energy density control)



(b) Second-order virtual energy density control

Figure 7: A 100 Hz primary sound source in an anechoic chamber controlled via two control sources. The sensors are marked with a circle and the observer location by a vertical line.

Because of the second control source, this cost function produces a broader region of control (when compared to that obtained using a single error micro-phone and a single control source) and hence maintains an attenuation envelope around the observer location, until the sensors are moved to a separation distance of 100 mm (4h). At this observer/sensor separation distance the prediction inaccuracies result in a gain of 8 dB at the observer location. In figure 7(b) the performance of the *second-order virtual energy density sensor* is shown. The second-order prediction of the energy density cost function at the observer location is more rugged in the presence of small spatial pressure variations and maintains the maximum attenuation at the observer location within a broad and practically sized zone of attenuation.

An aircraft cabin

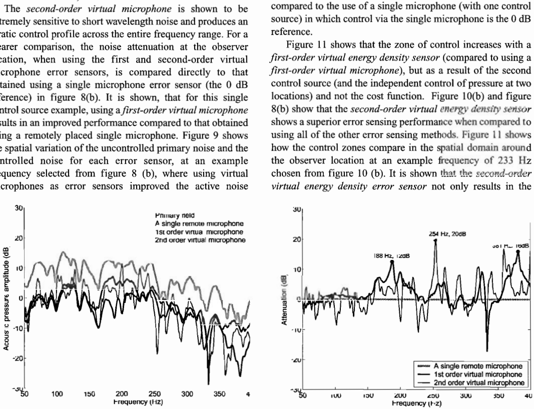
The results of actively controlling the primary noise between 50 Hz and 400 Hz with a single control source loudspeaker located in the head-rest of an aircraft cabin are shown in figure 8. Figure 8(a) shows how the uncontrolled noise levels at the observer location compare to the controlled noise levels using various error sensors, all located 100 mm from the observer.

The *second-order virtual microphone* is shown to be extremely sensitive to short wavelength noise and produces an erratic control profile across the entire frequency range. For a clearer comparison, the noise attenuation at the observer location, when using the first and second-order virtual microphone error sensors, is compared directly to that obtained using a single microphone error sensor (the 0 dB reference) in figure 8(b). It is shown, that for this single control source example, using a *first-order virtual microphone* results in an improved performance compared to that obtained using a remotely placed single microphone. Figure 9 shows the spatial variation of the uncontrolled primary noise and the controlled noise for each error sensor, at an example frequency selected from figure 8 (b), where using virtual microphones as error sensors improved the active noise control performance, compared to using a single microphone.

In the 254 Hz example it can be seen that when the error sensor is a single microphone, the high level of noise attenuation achieved at the sensor does not extend to encompass the observer 100 mm away with only 5 dB of attenuation achieved at the observer location. At the same observer location, the *second-order virtual microphone* results in 8 dB of attenuation and the *first-order virtual microphone* results in 20 dB.

Figure 10 illustrates the results of actively controlling the primary noise between 50 Hz and 400 Hz with two control sources located in the observer's head-rest. The spectra corresponding to the active noise control when using a single microphone, a *first-order virtual microphone* and a *second-order virtual microphone* are compared to the uncontrolled noise spectrum at the observer location, with sensors separated from the observer by 100 mm. Figure 10(a) shows that all of the control strategies considered here reduced the noise at the observer location across the entire frequency range of interest. In figure 10(b) the error sensing performance of both types of virtual energy density sensor are directly compared to the use of a single microphone (with one control source) in which control via the single microphone is the 0 dB reference.

Figure 11 shows that the zone of control increases with a *first-order virtual energy density sensor* (compared to using a *first-order virtual microphone*), but as a result of the second control source (and the independent control of pressure at two locations) and not the cost function. Figure 10(b) and figure 8(b) show that the *second-order virtual energy density sensor* shows a superior error sensing performance when compared to using all of the other error sensing methods. Figure 11 shows how the control zones compare in the spatial domain around the observer location at an example frequency of 233 Hz chosen from figure 10 (b). It is shown that the *second-order virtual energy density error sensor* not only results in the



(a) The uncontrolled and controlled spectra for various error sensing strategies

(b) The attenuation achieved with virtual microphones compared to a single microphone

Figure 8: ANC spectra at the observer location with one control source located in the observer's headrest. The sensors are located 4h (100mm) from the observer's ear.

highest noise attenuation at the observer location, but produces a broad zone (compared to a single microphone) of attenuated noise centered around the observer location.

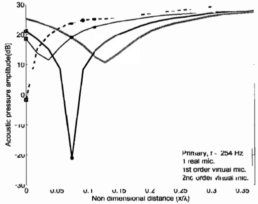


Figure 9: 254 Hz controlled using a single control source in the headrest. The sensors are marked with a circle and the observer location is at the far left hand side of each graph.

5. CONCLUSIONS

In the particular examples discussed in this paper, it has been demonstrated that the *first-order virtual microphone* (based on forward difference prediction) outperforms a conventional microphone (in terms of noise reduction at the observer location) for the same observer/sensor location separation distance. While the highest attenuation at the observer location should theoretically be achieved by using a *second-order virtual microphone*, the attenuation actually achieved was found to be very sensitive to short wavelength spatial pressure variations and seldom offered an advantage in practice to the use of a conventional microphone. It has also been shown that first-order prediction methods for energy density estimation at a remote location (the observer) offer no advantage to controlling energy density directly at the remote sensor. In terms of offering both a high level of attenuation and a broad control zone around the location of the observer, the *second-order virtual energy density sensor* produced the best results.

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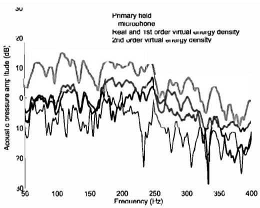
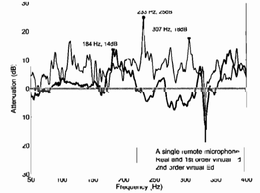


(a) The uncontrolled and controlled spectra for various error sensing strategies



b) The attenuation achieved with virtual microphones compared to a single microphone

Figure 10: ANC spectrums at the observer location with two control sources both located in the observer's headrest. The physical sensors are located 4h (100mm) from the observer's ear.

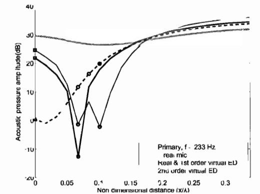


Figure 11: 233 Hz controlled using two control sources in the headrest. The sensors are marked with a circle and the observer location is at the far left hand side of each graph.

ACOUSTIC DAYLIGHT — USING AMBIENT NOISE TO SEE UNDERWATER

Mark L. Readhead
Maritime Operations Division, Defence Science and Technology Organisation

ABSTRACT: Detection of targets in the ocean using sound is traditionally achieved with either passive or active sonar. Acoustic daylight is a new technique being developed, which relies on the ambient noise in the ocean to provide the acoustic illumination necessary to detect a target. The presence of a target scatters some of the incident sound which can be collected by a suitable acoustic lens to produce an image of the target. An acoustic daylight imaging system developed at Scripps Institution of Oceanography is described, and images obtained of planar, cylindrical and spherical targets are presented. It was able to image all targets, with varying resolution and contrast between the target and background. In some cases it was able to distinguish between different target compositions through the reflected spectral content. A more sophisticated imaging system being developed by the DSTO will also be described.

1. INTRODUCTION

Traditionally the search for underwater targets by sound has been performed with passive or active sonar. In active techniques sound is projected into the water by the listening platform, and a target in the vicinity scatters some of this sound energy back towards the listener. Passive sonar relies upon the emission of sound by the target, which can be picked up by the listener.

Passive sonar is inherently a covert method. The listener does not emit any sound and so does not provide any acoustic signal by which the target can detect its presence. Since it relies upon sound being emitted by the target, it cannot be used for targets which are inherently silent. Active sonar by its nature flags the position of the searching platform to the target.

In both active and passive sonar the presence of background noise degrades the performance of the detection equipment and so lowers detection ranges.

2. ACOUSTIC DAYLIGHT

In optics there are three ways by which one commonly observes an object. In the first instance, it might emit light. This is how we see the stars. If it isn't a light emitter, but the observer is in dark surroundings, he can shine a torch and thereby see the target from the light it reflects. However, most commonly there is already sunlight present and objects are perceived when they scatter this light. The observer can distinguish between different objects because of the frequencies of light they scatter and/or the intensity of the light scattered by each. We call the first property colour and the second contrast.

In underwater acoustics, passive sonar is analogous to the first optical case. In this instance the object emits sound rather than light. Active sonar is like the second technique in which a torch is replaced by a sound projector. In the mid-1980's Buckingham suggested using the acoustic equivalent of scattered light in which ambient noise provides the source of ensonification. By analogy with optics the proposed method was called "acoustic daylight".

Ambient noise is generated in the ocean by several mechanisms, including distant shipping, breaking waves, and biological sources. In warm shallow waters around Australia's coastline, snapping shrimp are the dominant source, make a snapping sound extending from 500 Hz to more than 200 kHz.

3. FIRST EXPERIMENT

The first acoustic daylight experiment was conducted off Scripps Pier in southern California in 1991 (Berkhout, 1992; Buckingham et al., 1992). In this experiment the noise was produced by snapping shrimp under the pier pilings and from the surf. Targets consisting of 25 mm-thick sheets of 0.9×0.77 m plywood board faced with neoprene rubber were placed on poles 6.1 and 12.2 m from a hydrophone at the focus of a parabolic reflecting dish. As the targets were swivelled on their poles they appeared broadside or end-on to the acoustic lens. Depending on the orientation of the acoustic lens and the targets, the latter reflected the ambient noise or blocked it. It was also noted that the targets reflected some intensities more than others, providing evidence for acoustic colour.

The overall result of this first acoustic daylight experiment was to show that a target can alter the noise field, but being a parabolic reflector with a single hydrophone at its focus, it formed a single beam and so corresponded to just one pixel of an image. To build up an image a multi-beam acoustic lens is necessary. If the system was broadband, it would be able to make use of the acoustic colour characteristic.

4. ADONIS

The first operational acoustic daylight system was designed and built at Scripps Institution of Oceanography, in a research group including Mike Buckingham, Chad Epifanio and John Potter. The acoustic camera was called 'ADONIS', which stands for Acoustic Daylight Ocean Noise Imaging System. It was designed to collect broadband data between 8 and 80 kHz in ambient noise of 20-70 dB re 1 $\mu Pa^2/Hz$. Figure 1 shows its assembly; a detailed description appears in Readhead (1998).

It consisted of an approximately planar array at the focal plane of a 3 m reflecting dish. The dish was comprised of neoprene foam on a fibreglass base and provided

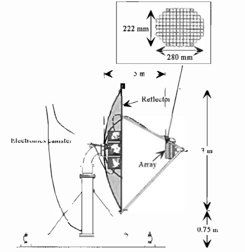


Figure 1. Side view of ADONIS. The array layout is shown in the inset.

approximately 18 dB gain. Beamwidths varied from 3.4° at the lowest frequencies, to 0.6° at the highest frequencies. The field of view was 10° in the horizontal and 8° in the vertical. The whole assembly could be rotated around a vertical mast, providing 360° coverage in the horizontal.

The array was made by EDO Corporation and consisted of 130 piezoelectric hydrophone elements arranged in an elliptical pattern as shown in the inset in Figure 1. Each element was 20 mm × 20 mm EC-76, a US Navy type-V lead zirconate titanate, with a sensitivity over most of its frequency range of -188.8 dB re 1 V/μPa.

Electronic gain of 100 dB was provided in multiple stages. Preamplifiers were incorporated into the array housing before transfer of the data to the underwater electronics canister. Here the signals were further amplified and pre-whitened. Rather than send the amplified sinusoidal data to the surface, 16 spectral estimates were sent instead. This cut down the data rate appreciably. Multiplexers were then used to serially transmit the data to an analogue to digital converter board in a computer on the surface where it was stored on hard disk. The computer also contained a digital signal processing board which processed the data for display on a video monitor. Moving images were displayed with an update rate of 25 Hz.

5. DEPLOYMENTS

ADONIS was deployed under a moored barge in 7 m of water in San Diego Bay in August 1994 and October-November 1995 as shown in Figure 2. Planar, cylindrical and spherical targets were imaged. The panels were fixed to a 3 m × 3 m frame and were mostly 1 m x 1 m sheets of 3.2 mm thick aluminium faced with 6.4 mm thick closed-cell neoprene foam, with the foam side facing the acoustic lens. The panels were also reversed and compared with 6.4 mm thick aluminium, 3.2 mm thick corrugated galvanised iron, and 6.4 and 12.7 mm thick plywood coated with a thin layer of resin or 5 mm of fibreglass.

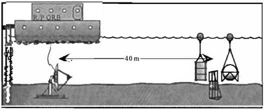


Figure 2. Deployment of ADONIS under R/P ORB.

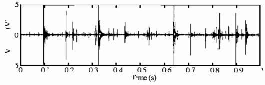


Figure 3. Time series of ambient noise collected by ITC6050C hydrophone.

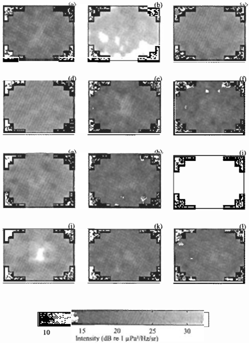


Figure 4. 12 sequential images of the suspended sphere at 75 kHz with boxcar averaging of 25 frames of logarithmic intensity data.

The cylindrical targets were 113 L polyethylene drums of 76 cm height, 50 cm diameter, and with a wall thickness of 5 mm. These drums were filled with wet sand, sea water or syntactic foam. They were deployed in the water column or dropped onto the sea floor. The spherical target was a hollow, air-filled titanium sphere of 70 cm diameter and a wall thickness of 15 mm. It was held in a metal cage in the water column and made negatively buoyant by the addition of lead weights.

Since San Diego Bay was shallow and calm, there were almost no breaking waves. The dominant sources of acoustic noise in the 8-80 kHz frequency range came from harbourside industrial activities, shipping traffic, sea mammals and snapping shrimp. The noise field was highly anisotropic, aiding in the illumination and detection process. It also had large temporal variations, as shown in Figure 3 by the 1 s time series of noise data collected by an ITC 6050C hydrophone. Figure 4 shows the effect of this non-stationarity in the noise field on 12 sequential images, representing 17 ms of data spread over 0.5 s, of the spherical target. Intensity variations of more than 20 dB are evident. By temporal averaging over 1 s and adjusting the colour axis for each image to account for the differing mean intensities, stable images were produced.

6. IMAGES

Figure 5 collects together a number of images formed during the deployments of ADONIS (Epifanio, 1997; Epifanio et al., 1999; Readhead, 1998). Most images consist of a boxcar average of a 10 s time series, corresponding to 250 frames. Often several frequencies have been averaged, and these are noted by specifying the range of frequencies. In most cases the resultant intensities are mapped into the jet colour map after bi-cubic spatial interpolation, in which the output pixel values are calculated from a weighted average of pixels in the nearest 4-by-4 neighbourhood.. This map grades from blue at low intensities to red at high intensities.

Bar target

Figure 5a shows the scene falling within the field of view of ADONIS, based on the known location, size and range of the target frame, and the field of view of ADONIS. The horizontal line in the background delineates the horizon, with the sea surface above and the sea bottom below. Three neoprene-coated aluminium panels form a bar on the target frame at a range of 38 m.

Figure 5b presents an image for the high frequencies of 57-75 kHz. The data corresponded in time to the use of an angle grinder for hull maintenance on a vessel moored along the pier. Acoustic noise was injected into the water for several seconds at a time, greatly increasing the ambient noise level, and raising the acoustic contrast from a more usual 3.5 dB to 9 dB at these higher frequencies.

Fenestrated cross

With the angle grinder still injecting noise into the water, the panels were rearranged to form a fenestrated cross (Figure 5c). Again all target panels are clearly defined and visible with an acoustic contrast of 9 dB for 57-75 kHz data (Figure 5d). Even the hole is visible in the image, with a contrast of 4 dB between it and the panels.

A different source of ensonification was provided by a boat passing behind the target. Figures 5e and 5f show two images formed from boxcar averaging 1 s (25 frames) of 57-

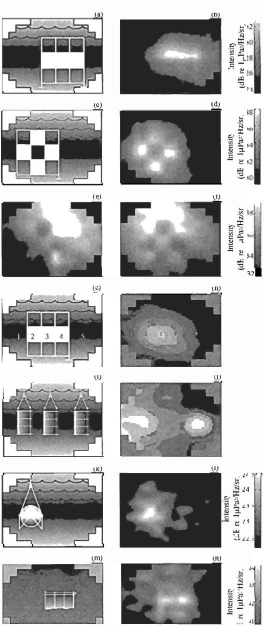


Figure 5. Sketch of field of view of ADONIS for a) bar target, c) fenestrated cross, g) multi-metal panels, i) suspended drums, k) suspended sphere and m) bottom drum. Acoustic daylight images for b) bar target, d) e) and f) fenestrated cross, h) multi-metal panels, j) suspended drums, l) suspended sphere and n) bottom drum.

75 kHz data. The two images are separated in time by 1.2 s. The boat is passing from right to left behind the cross, with Figure 5e showing the boat just to the right of the cross, and Figure 5f showing it almost directly behind the cross. The target panels block some of the boat noise, creating four holes in the noise field with an inverse contrast of more than 3 dB. Some of the boat noise passes through the hole in the cross. These images show that passing boats can be used as a source of opportunity to silhouette targets.

Multi-metal panels

To test the potential of acoustic daylight to discriminate between targets based on differences in both reflected intensities and frequencies, three metal targets were placed in the frame: 3.2 mm thick aluminium covered with 6.4 mm neoprene foam, with the metal side facing ADONIS, 6.4 mm thick aluminium, and 3.2 mm thick corrugated galvanised iron. Figure 5g shows the panels forming a bar in ADONIS' field of view, with the aluminium/neoprene panel labelled as 2, the thicker aluminium panel as 3, and the galvanised iron panel as 4.

In Figure 5h linear trapezoidal colour mapping has been employed in which red, green and blue correspond to low, medium and high frequencies, respectively. The aluminium/neoprene panel is seen with a reddish tint, indicating its propensity to reflect only lower frequencies well. The galvanised iron panel appears bluish, corresponding to its good reflectivity of only the higher frequencies. The thick aluminium panel reflects well at all frequencies and appears whitish. Note also that the luminosity of the three panels is well above the background.

Suspended drums

The panel targets presented a planar surface normal to the look direction of the acoustic lens. Cylindrical targets would only present a line normal to the look direction, and so would represent more of a challenge for imaging. Figure 5i shows the arrangement of the suspended drums as seen by the acoustic lens. The order of the drums from left to right was foam, water and sand-filled. Figure 5j shows the image with linear trapezoidal colour mapping depicting the different frequency components. The foam-filled drum reflected well at all frequencies as it had a much lower acoustic impedance than water. Thus it appears white. The sand-filled drum had a higher impedance than water, but allowed a greater penetration of low frequency sound as the sand was wet. Some of this energy could reflect off the rear wall of the drum back towards the acoustic lens. Absorption in the wet sand ruled out significant penetration to the rear wall and back by the high frequencies. As the sand-filled drum does not reflect high frequencies as well, it lacks a strong blue component and appears yellow. The water-filled drum has a slight blue tinge, indicating that it only reflects the higher frequencies to any significant degree. It was only weighed down by its 10 kg cage. When moving, the rusty metal parts of the drum cage and supporting shackle rubbed together, producing sound. This was most noticeable when large boat wakes passed over the targets. Hence the water-filled drum and shackle were probably not observed by scattered ambient noise, but by self-noise.

Suspended sphere

A sphere presented only a small patch normal to the look direction, and so was an even more difficult target to image. Figure 5k shows the field of view seen by ADONIS at the 20 range. The images formed from the upper three frequencies, 57-75 kHz are shown in Figure 5l. The acoustic contrast is more than 2 dB.

It is noticeable in Figure 5l that the equator and upper hemisphere of the sphere is visible, but that the lower hemisphere is not seen. The equator is illuminated by noise propagating in a horizontal direction from behind ADONIS, but the upper and lower hemispheres would not be visible by such noise, as it would be reflected up or down, away from ADONIS. The upper hemisphere may have instead been illuminated by noise scattering off the surface towards the sphere, and then back in the direction of ADONIS. There would be considerably less scattering of sound off the muddy bottom, and so the lower hemisphere would be much less illuminated. It is also notable that the image of the sphere is similar to the simulated image shown in Potter (1994).

Bottom drums

In all target deployments reported so far, the acoustic contrast has been between the noise scattered by the target and that scattered by or originating in the surrounding water. A more difficult test was to try and image the drums when on the sea floor. In this case the contrast would be between noise scattered by the drums and the mud.

ADONIS was tilted so as to point to the sea floor. Figure 5m shows the field of view of ADONIS with the foam-filled drum on the sea floor. The corresponding image is shown in Figure 5n for the upper frequencies (57-75 kHz). The drum is clearly visible, with an acoustic contrast of 4 dB. These values are comparable with or better than for the drum when in the water column, partly because there is less background noise around the drum. The possibility of the sea floor and drum forming a propitious corner reflector arrangement cannot be ruled out either.

Most of the images shown in Figure 5 were of stationary targets, for which 10 s boxcar averaging was used. For the moving vessel producing the silhouetting in Figure 5e and f, 1 s boxcar averaging was used. This averaging was also found to be suitable when imaging swimming divers, or when rotating ADONIS so that it panned past the stationary targets. An alternative averaging method which was also found to be suitable was exponential temporal averaging in which the most recent frames carried the most weight

7. BEYOND ADONIS

ADONIS' design bore some similarity to that of a modern conventional optical telescope. The reflector provided high gain, and by geometrically combining the incoming acoustic signals, data processing was simple. However, the apparatus suffered from several limitations common to geometrical systems. Because it used a spherical reflector it was afflicted with spherical and chromatic aberration. Like a telescope it had a restricted field of view, although at 10° it was fairly broad. The penalty for this broad field of view was low resolution. Since it was used in the near field, it could only resolve objects within its limited depth of field, rather like that of a camera. In addition to these geometrical limitations, the way in which the signal processing was implemented meant that most of the acoustic data was not used. This limited the testing of post-processing algorithms.

The next step is to build a phased array, which will remove some of the above problems. All the data can be used. and with dynamic focusing at different distances, the depth of field limitation is removed. Since summation of the signals reaching the various hydrophones is done mathematically to form the image, aberrations are not a problem. Increasing the resolution is obtained by sampling to higher frequencies or increasing the aperture of the array. To achieve a beamwidth of 1° requires a filled array of 10,000 elements, or a Mills Cross with 200 elements. The latter has large sidelobes in the orientation of the cross arms. A random sparse array of the same number of elements has the same total sidelobe energy, but it is more evenly spread in all directions (Steinberg, 1976). The computational load is high, since 64 Mbytes/s of data is acquired if 12-bit sampling is used for frequencies to 80 kHz. This can be compared to ADONIS' modest 3 kbytes/s.

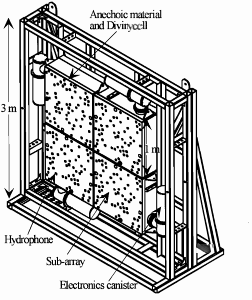


Figure 6. Design of DSTO's array.

8. DSTO'S ARRAY

The Defence Science and Technology Organisation (DSTO) is currently building a random sparse phased array of 2 m × 2 m aperture, which has 256 hydrophone elements. It is modular, comprising four identical sub-arrays, each 1 m × 1 m and with 64 elements. Figure 6 shows the design. The sub-arrays are held in a 3 m × 3 m galvanised iron frame, each being rotated by 90° with respect to each other to maintain the maximum randomness. The hydrophones are ITC 8257 units, which are sensitive between 10 and 150 kHz. They have preamplifiers of 60 dB fixed gain, leading to a sensitivity of -132 dB re 1 V/μPa over most of the frequency range. They are glued into stainless steel holders, which in turn are screwed into the face plate of a stainless steel box. To eliminate sound from penetrating from the rear of the array, the boxes are air-filled. Divinycell foam and an anechoic material reduce reflections of sound coming in from the front and reflecting from the box back towards the hydrophone elements. The hydrophone cables run through the box to an electronics canister.

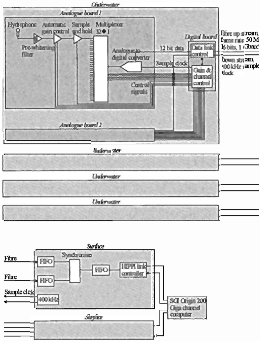


Figure 7. Block diagram of electronics for DSTO's array.

Figure 7 is a block diagram of the electronics processing. The signal from each hydrophone is amplified and pre-whitened. Based on experience with ADONIS where passing boats could swamp out the electronics, the next amplification stage incorporates automatic gain control. Each signal passes through a sample and hold stage and a group of 32 hydrophone signals are multiplexed before being 12-bit digitised at 400 kHz each. The digital stream from all 64 hydrophones is repackaged and sent to the surface via an optical fibre cable at a rate of 1 Gbaud. At the surface the data streams from two arrays pass through FIFOs, are synchronised, pass through another FIFO and are sent via a HIPPI link controller to an SGI Origin200 Gigachannel computer. Data from all four arrays is logged at a continuous rate of 154 Mbytes/s on a RAID array of 20 hard disks.

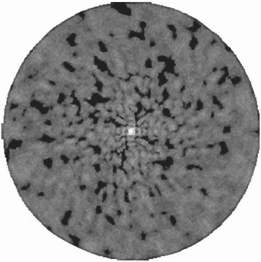


Figure 8. Point spread functions at 100-108 kHz.

Due to the very high data rate the data is post-processed. The first stage is beamforming. As the array is yet to be completed, in place of actual data the anticipated performance of the array is demonstrated by an example of a point spread function in Figure 8. This shows the image which would be formed at 100-108 kHz of a point target located at a range of 50 m, 0° longitude and 0° colatitude when ensonified by a point noise source, such as a snapping shrimp, located 40 m from the target at 0°. The beamwidth to the 3 dB points is 0.35°, and the highest sidelobes contained within ±10° are down by 15 dB. In reality the image would be degraded by other extraneous background noise. At 140 kHz the beamwidth has improved to 0.16°.

DSTO arrays will be deployed onto the floor of Sydney Harbour in the first instance, where depths are typically less than 20 m. The array has been designed to operate to water depths of 40 m, depths being constrained by the pressure on the oblong sub-array boxes. It is not intended that this array be hung from a vessel, but based on experience gained with this array a more mobile design will be built in the future. At water depths of less than 40 m around Australia's coastline the dominant source of ambient noise to 150 kHz is from snapping shrimp, although in Sydney Harbour additional contributions from industrial noise and boat traffic are expected.

9. CONCLUSIONS

Acoustic daylight potentially has a number of advantages over conventional active and passive sonar. Like a passive sonar, it can look for specific signals within one of its beams. It can also look for silent targets and does not have a degraded performance in regions of high ambient noise. In fact, since it uses the ambient noise, it should have an enhanced performance in such regions. Since it does not produce its own sound, it should have a lower power consumption than an active sonar, and so is suited to use on an underwater remotely operated vehicle. Its covert nature has important tactical advantages. Since it produces a pictorial image, with sufficient resolution it should be easier to interpret than current sonar system displays, which require trained operators. The introduction of false colour to the images should ease discrimination between different targets.

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AN APPROACH TO ESTIMATION OF UNDERWATER HEARING THRESHOLDS AND NOISE EXPOSURE LIMITS

Kazuoki Kuramoto, Kensei Oimatsu, Shin'ya Kuwahara
Maritime Safety Academy, 5-1 Wakaba, Kure, 737-8512 Japan

Shizuma Yamaguchi
Faculty of Engineering, Yamaguchi University, Tokiwadai, Ube, 755-8611 Japan

ABSTRACT: There are many difficulties to carry out hearing tests in water, for example, the necessity of preparing audiometric equipment for underwater measurement and diving equipment (SCUBA) for breathing of subjects, unavoidable background noise from surrounding and so on. As a result, there are very few studies on establishing the hearing thresholds and noise exposure limits in water even though they are fundamental and important characteristics of underwater hearing in man. One of the most efficient approaches to acquire these standard values is through transposition from air to water. We attempted to establish the relationship between the perceived loudness in water and in air by conducting hearing tests in a water tank. By applying this relationship to available data on hearing threshold and noise exposure limit in air, we have estimated the equivalent thresholds and exposure limits in water.

1. INTRODUCTION

Although both hearing thresholds and noise exposure limits in water are fundamental and important characteristics of hearing in man similar to the case in air, it seems that there is limited work done on acquiring these standard values. This is because of the difficulties to carry out hearing tests in water, for example, the necessity of preparing audiometric equipment for underwater measurement, diving equipment (SCUBA) for breathing of subjects and so on. Some investigators have examined the hearing thresholds in water [1-5] but there is a lot of scatter in their results. The main reason for the large scatter of existing experimental data may be attributed to the lack of appreciation of the significance of background noise and its masking effect on the threshold of hearing. Further, the influences of various factors have not been fully investigated, for example, differences in subjects, differences in experimental procedures, effects of water depth, influences of air trapped in the ear canal, effects of bubbles by breathing of divers and so on. So, the determination of underwater hearing thresholds need to be improved.

From the viewpoint of hearing protection for divers, it is necessary to determine the maximum sound pressure level that the divers can endure against noise exposure in water, that is, a damage-risk criterion for underwater noise exposure is required. Widely accepted damage-risk criterion for noise exposure in air already exists [6] but has not been found in water except for the recent work of Al-Masri et al [7,8]. In order to establish the criteria for noise exposure, it is necessary to carry out hearing tests of temporary threshold shift (TTS) [9-11]. In practice, however, many difficulties would be encountered in trying to realize the TTS measurements in water as mentioned above. One of the most efficient approaches to acquire these standard values is through transposition from air to water. Al-Masri and Martin estimated the value of underwater noise exposure limit from the value of hearing threshold in water by considering the "W-weighting scale" [7,8]. They assumed that the relationship between the 40-phon curve and the threshold curve is constant at each frequency both in air and in water. It is already mentioned that the threshold in water may be greatly influenced by the background noises or the experimental conditions. So, it is quite possible that underwater exposure limit will not be estimated accurately, if the exposure limit is derived from the hearing threshold as Al-Masri and Martin have done. Therefore, another approach for estimating the exposure limit in water becomes necessary.

The purpose of this study is to estimate the hearing thresholds and the noise exposure limits in water from the existing values in air using a different procedure from that of Al-Masri and Martin. We attempted to acquire the relationship between the perceived loudness in water and in air by conducting hearing tests in a water tank. Then, the hearing thresholds and the noise exposure limits in water are estimated respectively from the values in air by using this relationship.

2. HEARING TEST

In order to examine the relationship between the loudness in water and in air, two kinds of measurements for loudness levels were carried out by means of hearing tests in a water tank. One was to obtain, for a pure tone (175Hz, 1kHz, 5kHz), the sound pressure level in air that is perceived to be equal in loudness to a given sound pressure level in water. The other was to obtain the sound pressure level in air that is perceived to be equal in loudness as a constant sound pressure level of 142 dB (re 1μPa) in water for a range of frequencies. The water tank with dimensions 1m x 1m x 2m is shown in Figure 1. The spectrum level of the background noise in the water tank, determined by an FFT analyzer, is almost constant at 52 dB (re 1 $\mu Pa^2/Hz$) in the frequency range from 1 kHz to 5 kHz (Figure 5). We employed two male subjects with normal

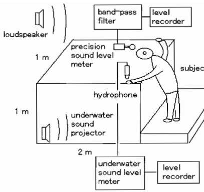

Figure 1 Experimental configuration of the water tank.

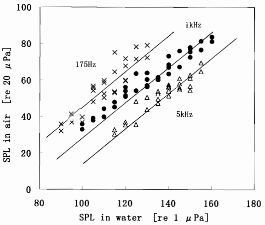

Figure 2 Equal-loudness relationship between SPL_A [dB re 20μPa] and SPL_W [dB re 1μPa] for a pure tone (X: 175Hz, ●: 1kHz △: 5kHz); Solid lines: equation(1).

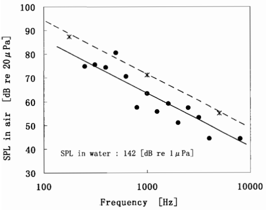

Figure 3 Equal-loudness relationship between SPL_A [dB re 20μPa] and a constant SPL_W of 142 [dB re 1μPa] for various frequencies *f*. Solid line: equation (2); * data from Figure 2.

hearing in air. The experimental procedure is as follows. Firstly, the subject submerged his head into water, making sure to remove air bubbles from the ear canals, and was exposed to a pure tone radiating from an underwater sound source in the water tank. Secondly, he raised his head above the water, clearing the air passage in the ear canals, and was exposed to the sound in air radiating from a loudspeaker. The sound pressure level in air was adjusted by the subject until the loudness in air was perceived to be equal to that heard in water. The above measurement was repeated five times per sound pressure level for various frequencies and the average value was used. All measurements were made for a pure tone and the sound pressure level and noise level were measured without using weighting filters. As the overall background noise in air around the water tank was about 50 dB (re 20μPa), we used a band-pass filter (RION SA-34) for measurements in air below 50 dB (re 20μPa). The sound pressure levels were obtained by reading the data sheet on level recorders (RION LR-4) calibrated, respectively, by an underwater sound level meter (OKI SW1020) for underwater and by a precision sound level meter (RION NA-20 at F-weighted characteristic) for air. The subject's head was suitably positioned in the water tank to minimise the influence of standing waves. Both the hydrophone in the water tank and the microphone in air were set up as close to the subject's ear as possible.

3. EXPERIMENTAL RESULTS

Results of the two kinds of measurements are indicated in Figures 2 and 3, respectively. From Figure 2, we can find a linear relationship between SPLA dB (re 20μPa) and SPLW dB (re 1μPa) as,

$$SPL_A = a\,SPL_W - C_1(f) \qquad (1)$$

where a is the slope and $C_1(f)$ is a value depending on the frequency. Here, for convenience, we use a=1 for all three frequencies (175Hz, 1kHz, 5kHz), and by fitting the data points with lines of best fit, C_1 has been determined to be 53.0 dB at 175 Hz, 70.8 dB at 1kHz and 85.9 dB at 5kHz.

From Figure 3, we can also find a linear relationship between SPL_A [dB re 20μPa] and the logarithm of frequency f under a constant SPL_W of 142 dB re 1 μPa as,

$$SPL_A = -24.6 \log(f/1000) + C_2 \qquad (2)$$

where C_2 is a value unrelated to the frequency but often varies with experimental conditions or subjects and has been determined to be 63.0 dB.

According to equations (1) and (2), a sound level of 142 dB re 1 μPa at 1 kHz in water corresponds to a sound level of 63-71 dB re 20 μPa in air. However, a sound level of 142 dB re 1 μPa in water has the same intensity as a sound level of 80 dB re 20 μPa in air. Therefore, it appears that a transmission loss of 9-17 dB has arisen from the internal ear and the exterior, probably because the coupling of the sound to the subject's head in air is different from that in water, resulting in different propagation paths through the head.

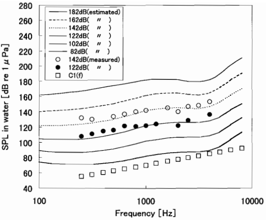

Figure 4 Comparisons of equal-loudness contours in water between experimental values [12,13] (○: 142dB and ●:122dB) and the estimations (six lines); □ : values $C_1(f)$ for each 1/3-octave centre frequency.

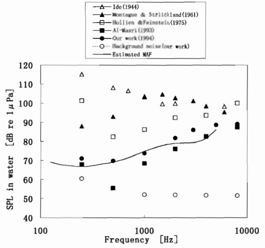

Figure 5 Comparison between underwater hearing thresholds measured in previous studies and estimations (solid line).

4. DISCUSSION

Practical expression between the loudness in water and in air

In order to estimate hearing thresholds and noise exposure limits in water from the values in air, we must derive a practical expression describing the relationship between the loudness in water and that in air. The expression can be derived from equations (1) and (2) as follows. Firstly, the sound pressure levels in air at three frequencies (175Hz, 1kHz, 5kHz) corresponding to the sound pressure level of 142 dB in water are obtained by means of equation (1). When these values (denoted by *) are plotted in Figure 3, we can fit a straight line to these data using equation (2). Thus, we can obtain the sound pressure level in air corresponding to the sound pressure level of 142 dB re 1 μPa in water for any frequency by using this line of best fit. By substituting these values for SPL_A in equation (1), where SPL_W is 142 dB re 1 μPa, we can determine each value of $C_1(f)$ in equation (1) for any frequency. The values of $C_1(f)$ obtained for each 1/3 octave band frequency are shown in Figure 4.

To verify the validity of this expression, we try to obtain the equal loudness contours in water from the values in air and compare them with the experimental results previously obtained in our study. The SPL_W is readily obtained from the practical expression by substituting the values of ISO R226-1961 [12] for SPL_A in $SPL_A = SPL_W - C_1(f)$. The contours thus obtained are described by six lines in Figure 4 together with our experimental values obtained by hearing tests in the pool [13,14]. The estimated results are in good agreement with the experimental values.

Estimate of underwater hearing thresholds

As mentioned before, the underwater hearing threshold has not been obtained accurately. Figure 5 shows the results of underwater hearing thresholds reported in the literature [1-8] and our previous work in the water tank [13,14]. It is found that there is a large scatter for the underwater hearing threshold value. In order to obtain the hearing threshold accurately, it is very important to consider the effect of background noise carefully. Our threshold values are more than 10 dB above the background noise. So, it is considered that our results could not have been affected by noise and are more reliable. It is advisable that tests of hearing threshold should be done in an anechoic chamber, which is difficult to realize in water. One alternative method is to estimate underwater hearing thresholds from values in air by using the practical expression obtained above. This method is simply based on the relationship between the perceived loudness in water and in air determined experimentally. By substituting the value of normal threshold of hearing in air [12] for SPL_A in $SPL_A = SPL_W - C_1(f)$, using the value of $C_1(f)$ at each frequency in Figure 4, the hearing thresholds in water can be readily obtained. The estimated threshold is described by the solid line in Figure 5. It is found that the estimated hearing thresholds in water show reasonable agreement with the ones obtained experimentally by us.

Estimate of noise exposure limits in water

Divers are sometimes directly exposed to vibrations and noises radiating from working equipment in water, e.g., water jet tools, rock drills, stud guns and so on. From the viewpoint of hearing protection for divers, it is necessary to determine the noise exposure limits in water. In air, damage-risk criteria for noise exposure has been recommended by the permission concentration committee of the Japanese Industry Sanitation Society in 1969 [6] and is widely adopted in our country for the purpose of hearing protection. On the other hand, a criterion for underwater noise exposure is difficult to find. Recently, Al-Masri and Martin estimated the value of underwater noise exposure limit from the value of hearing threshold in water by considering the "W-weighting scale"

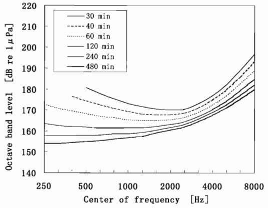

Figure 6 Estimated exposure limits for underwater noise.

[7,8]. But the value of hearing threshold is greatly influenced by the background noise or the experimental conditions. So, it is quite possible that the underwater exposure limit will not be estimated accurately. Therefore, the exposure limit in water must be verified from another viewpoint. In this study, we obtain the underwater noise exposure limits by transposition from air to water. By using the practical expression, $SPL_A = SPL_W - C_l(f)$ with the value of $C_l(f)$ in Figure 4, the noise exposure limit in water can be readily obtained from the values of exposure limit in air [6]. Figure 6 shows the estimated exposure limits for underwater noise. For example, the recommended maximum permissible noise exposure limit for an 8-hour day is 90 dB re 20μPa in air, whereas a maximum permissible octave band level for underwater noise exposure around 1 kHz for an 8-hour day is about 157 dB re 1μPa.

5. CONCLUSION

We examined carefully the relationship between loudness in water and in air by conducting hearing tests in a water tank and obtaining a practical expression describing the relationship of loudness between the two media. Then, the hearing thresholds and the noise exposure limits in water were estimated from the values in air by using this expression. It is very important to carry out the hearing tests in an anechoic chamber for thresholds and the measurement of temporary threshold shift (TTS) for exposure limits in water. However, there are many difficulties to realize this in practice. The present work provides additional data of underwater hearing threshold and exposure limit and develops the criteria for noise exposure. Our results may serve as a temporary standard for hearing threshold or as a guide to the evaluation of noise in water.

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RECENT DEVELOPMENTS IN THE DESIGN AND PERFORMANCE OF ROAD TRAFFIC NOISE BARRIERS

Stephen Samuels,
Director TEF Consulting and Visiting Research Fellow UNSW

Eric Ancich,
Roads and Traffic Authority of NSW

ABSTRACT: This paper deals with some recent developments in the design and performance of roadside barriers that are applied as a means of controlling road traffic noise. It is a review paper that is based on the outcomes of literature and information searches undertaken for and on behalf of the Roads and Traffic Authority of NSW. Some interesting, ongoing developments in the design and performance of traffic noise barriers have been identified. In particular, three types of innovative barrier designs were identified that appear to offer the potential for increased attenuation without the need for substantial increases in barrier height. Each of these developments is considered in some detail in the paper and recommendations are made for the possibility of pursuing them further.

1. INTRODUCTION

Roadside barriers represent an important means of controlling the noise generated by road traffic. As well documented in both Roads and Traffic Authority of NSW (RTA) (1991) and Road Directorate of Denmark (RDD 1991), there is a wide range of barrier types and designs available and in service at present in Australia and in many other developed nations. Currently, barriers used in urban/suburban areas are typically 2 to 3m in height and these can achieve attenuations up to around 10 dBA. However exceeding this and obtaining, say, 15 dBA is extremely difficult and, for practical purposes, generally not possible. To do so requires very tall barriers in the order of 8m. It is generally accepted that barrier attenuation increases with barrier height according to a deterministic function that is reasonably well understood. However, the cost of barriers increases dramatically with the attenuation provided and similarly with barrier height.

Advances in barrier design to improve attenuation performance have been slowly made in recent years. The present paper documents the outcomes of literature and information searches undertaken to determine current developments in the design and performance of traffic noise barriers. The work reported herein was conducted under contract to the Asset Performance Technology Branch of RTA.

2. EXISTING ROADSIDE BARRIER TECHNOLOGY

The application of roadside barriers for traffic noise control represents a well established technique that has found wide application within Australia and throughout the developed world (RTA 1991, RDD 1991). Based on the pioneering work of Maekawa (1968) and Kurze (1974), the technology revolves around some relatively simple algorithms that describe the combined effects of sound transmission loss through a barrier in conjunction with the diffraction of sound over (and in some cases around) the barrier. In terms of roadside barrier design, the most common application of this technology hitherto in Australia has been via the calculation procedure set out in UK DoT (1988). This well-known procedure puts barrier attenuation as a function of the path length difference between the diffracted wave path (over the barrier) and the direct wave path from source to receiver.

Some enhancements to this basic type of technology have been reported recently (Hansen and Burroughs 1998, Herman *et al* 1998, Clairbois *et al* 1998). A considerable Research and Development effort in the area of traffic noise propagation and the effects of barriers on this propagation was recently conducted in the USA. This work was performed within the overall program of developing the new US Department of Transportation, Federal Highway Administration (FHWA) Traffic Noise Model (TNM) (Menge *et al* 1998, Menge *et al* 1996).A significant limitation with all these developments is that applying their outcomes to achieve high levels of traffic noise attenuation generally involves the adoption of tall, imposing barriers. Typically such barriers are expensive (they are primarily governed structurally by wind load considerations), unsightly and difficult to construct and maintain. Overcoming these problems leads to the consideration of technological developments which now follow. Generally the concept behind this new technology is to achieve an increase in attenuation without an increase in barrier height.

3. CURRENT TECHNOLOGICAL DEVELOPMENTS

Barriers with Novel Shaped Cappings

Simple Shapes

Barriers of this type incorporate various capping arrangements which come in a range of design formats. Watts (1992) and Hothersall (1992) explained the features of such barriers and the attenuation performance they are purported to provide.

The original examples of these barriers had a uniform capping fitted such that the cross sectional shape of the barrier typically became like a T, as illustrated in Figure1. The increased attenuation produced by such a barrier is due to the increased effective height, again as shown in Figure1. Several variants of this design have appeared, common examples of which are the so-called multiple edged barriers sketched in Figure 2. Crombie *et al* (1988), Hajek and Blaney (1984), Hasebe (1988), Iida *et al* (1984) and Watts (1992) have all studied the performance of several of these barrier types and the concensus of all this work is that they can deliver small but useful increases in attenuation of around 2 to 3 dB, compared to conventional barriers.

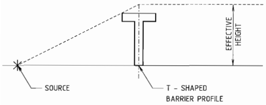

Figure 1. Effective height of a barrier. [Sketch based on Hothersall (1991) as reproduced in Watts (1992)]

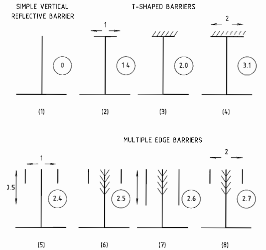

Figure 2. Various barrier capping arrangements. [Sketch based on Watts (1992)]

More Complex Shapes

Sophisticated and complex numerical modelling methods along with scale modelling techniques (Jean 1998, Hutchins *et al* 1984A and 1984B, Hothersall *et al* 1998) have evolved to facilitate the study of barriers with alternative shaped cappings. Some quite complex capping shapes have appeared recently (Fujiwara *et al* 1998, Shima *et al* 1996, Shima *et al* 1998), an example of which is shown in Figure 3. According to Amram and Masson (1992), these complex shapes are configured on the basis of their capability to create a destructive interference sound field around the top of the barrier, thereby producing increased attenuation. Amram and Masson (1992) suggested that attenuation increases in the order of 3 to 5 dB(A) are possible with such barriers. This finding has been confirmed in the results of Shima *et al* (1998), Watts *et al* (1994), Watts (1996) and Watts and Morgan (1996).

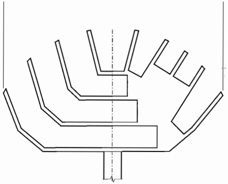

Figure 3. Cross-section of alternative capping arrangement. [Sketch based on Fujiwara *et al* (1998)]

Absorbing Edge Barriers

Absorbing edge barriers achieve a gain in attenuation by the attachment of a sound absorbing device on the top edge of the barrier. At its simplest this involves use of a barrier of curved cross sectional shape (Pierce *et al* 1986) and could typically take the form of an earth mound covered in soft vegetation. They indicated that, in theory, small increases in attenuation of the order of around 1 or 2 dB are possible with this technique.

More recently there has been some work reported on the use of absorptive cylinders to provide the absorbing edge (Fujiwara 1989, Yamamoto *et al* 1989 and Fujiwara and Furuta 1991). The type of barrier resulting from this concept is similar to that of Fig 3, with the device shown in Fig 3 replaced with an absorptive cylinder along the top of the barrier. The theoretical analysis of the behaviour of such a barrier is most complex and requires higher order numerical simulation techniques. It seems that the increases in attenuation attributed to barriers of this particular type arise from enhancing the capacity of the barrier to reduce the sound diffracted over the top of the barrier. Field tests reported by Fujiwara and Furuta (1991) suggested that the increased attenuation from such barriers is in the order of 2 to 3 dB(A). While these results are indeed encouraging, more work seems necessary to produce a satisfactory, serviceable engineering design for the absorptive cylinder units. Several types have been trialed experimentally and a design for a perforated metallic type has been suggested (Fujiwara and Furuta 1991). A more recent design involves a device with a cross sectional shape said to be like a mushroom (Yamamoto 1998). Again this device gave about 2 dB improvement in attenuation compared to a conventional barrier. Further work on barriers fitted with absorptive cylinders would appear to be warranted.

Longitudinal Profiled Edge Barriers

Early Technology

Wirt (1979) originally suggested that improvements in barrier performance could be obtained by application of a longitudinal profile to the top edge of a barrier. The theory behind this suggestion also involves the creation of a destructive interference sound field. Wirt investigated this theory via laboratory based scale model tests on both flat topped and pointed sawtooth top profiles that were known as "Thnadners". In Figure 4 these two "Thnadner" shapes have been sketched. The results of Wirt's tests were that improvements in attenuation in the range 1.5 to 4.0 dBA were obtained with the profiled barriers.

Subsequently, similar laboratory model studies of "Thnadner" style barriers were undertaken independently by May and Osman (1980) and by Hutchins *et al* (1984). Both these studies contradicted the Wirt conclusions and indicated that the "Thnadner" barriers exhibited poorer performance than conventional barriers of the same height. The advanced theoretical analyses and laboratory studies of Maekawa and Osaki (1986) also supported this view. Technical debate about these differing conclusions focused on the nature of the scale modelling processes and, in particular, how ground absorption effects were included in the experiments. It has been suggested as a result of these debates that full scale field tests would be required to resolve the situation to an adequate degree of scientific rigour (Watts 1992). To date it would not appear that any such experimentation has been undertaken.

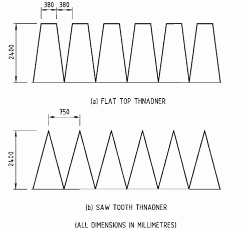

Figure 4. "Thnadner" designs. [Sketch based on Wirt (1979)]

Random Edge Barriers

More recently Ho *et al* (1995A), Ho *et al* (1995B), Ohm *et al* (1997), Ho *et al* (1997), Rosenberg and Busch-Vishiniac (1997) and Menounou *et al* (1998) have been investigating similar types of barriers where the profile applied to the top of the barrier is random in shape. The theoretical concept here involves the manner in which sound is diffracted over the top of a barrier. In the case of a straight topped barrier this particular theory assigns the noise source (that is the road traffic) as a straight line source comprising a long string of highly correlated point sources. Consequently the coherence of the sound diffracted over the barrier acts to set an upper limit on the attenuation performance of the straight edged barrier. To overcome this problem the theory suggests that the barrier be redesigned so as to interfere with the coherence of the diffracted sound, thereby increasing the attenuation performance of the barrier. One way of achieving this is to replace the straight edge top of the barrier with a random edge profile.

This theory has been embodied into a "Directive Line Source Model" (Menounou *et al* 1998) to predict the diffraction behaviour of sound over barriers with straight and random profiled edges. The model has been shown to perform well in extensive laboratory based evaluation trials (Menounou *et al* 1998, Rosenberg and Busch-Vishniac 1997). One particular finding of their work was that the performance of random profiled barriers increased as the profile became more pronounced or "jagged". An example of their random edge profiles is drawn in Figure 5, while some typical laboratory performance results appear in Figure 6. The profile demonstrates a reasonable degree of randomness as might be expected. However the experimental results showed two clear findings.

* The insertion loss (attenuation) produced by random edged barriers exceeded that of conventional barriers at the higher frequencies.
* However the insertion loss of random edged barriers was less than that of conventional barriers at the lower frequencies.

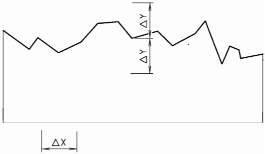

Figure 5. A random edge profile. [Sketch based on Ho *et al* (1997)]

It would appear that the transitional frequency that separated the above two ranges of performance was around 5000 to 7000 Hz and this seemed to vary with the distance of the receiver from the barrier. This is not a particularly good outcome as far as road traffic noise is concerned, as the majority of the acoustic energy generated by road traffic is in the range 50 to 5000 Hz (Samuels 1982). Ho *et al* (1997) indicated that they intended to work further on understanding and overcoming this problem. At the time of writing the present paper no further information on this work was available.

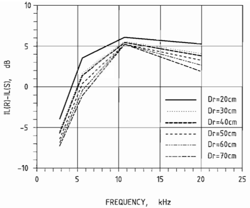

Figure 6. Performance of random edge barrier compared to a conventional barrier. [Sketch approximating that of Ho *et al* (1997)]

What may now be concluded is that the concept of random edged barriers is presently at an early stage of development. A theory has been developed and a laboratory based scientific investigation of this theory has shown some promising results. Further work is clearly required to understand and resolve the poor performance of such barriers over the frequency range in which road traffic noise sits. While such work might be partly laboratory based, serious consideration should be give to incorporating full scale field tests, in concert with similar recommendations made by Ho *et al* (1997).

Barriers Incorporating Active Control Techniques

Recently some attempts have been made to apply active noise control technology to the design and operation of traffic noise barriers. Again this has involved the fitment of devices to the top edge of a barrier. Examples of the analytical techniques associated with these types of barriers may be found in Fujiwara and Hothersall (1996), Guo and Pan (1997 and 1998), Ise *et al* (1991), Omoto and Fujiwara (1991 and 1993) and in Ise and Tachibana (1998). While the reported performance of barriers using active control varied a little, the overall results were consistently that such barriers provided increases in attenuation of around 5 to 10 dB compared to conventional barriers. Duhamel (1998) and Duhamel *et al* (1998), for example, demonstrated such performance potential via an outdoor experiment utilising stationary noise sources.

Ohnishi *et al* (1998) have been developing an active noise control device, known as an Acoustical Soft Edge (ASE), that is attached to the top edge of a barrier and incorporated into an active control system. A series of these devices is fitted to the barrier, where each device is controlled individually and may be tuned to specific frequency ranges. There are some limitations to the frequency range possible for a particular ASE device and these limitations are related to the physical size of the device. The devices investigated by Ohnishi *et al* (1998) operated from about 100 Hz to around 1000 Hz, which is particularly appropriate as far as traffic noise is concerned. They undertook a series of theoretical studies comparing the performance of ASE devices of various shapes against that of a conventional barrier. Overall they concluded that their active control devices improved barrier attenuation by 3 to 5 dB within the 100 to 1000 Hz frequency range and this must be regarded as a considerable achievement. As yet, however neither field nor laboratory trials have been conducted on these devices. So doing may well prove to be technically challenging indeed, given that traffic noise is essentially comprised of many time varying, moving, extended sources.

Consequently it may be concluded that the techniques of active noise control as applied to barriers appear promising but are presently at an early stage of development. It would seem that they may be applied in the frequency range within which traffic noise occurs. While considerable developments in the theory surrounding this technology have been made, these do not yet appear to have been explored further via empirical based investigations. Such investigations would appear to be warranted.

4 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

On the basis of what appears in the present paper, the following conclusions have been drawn.

1. Technological developments are being made in the design shape and configuration of road traffic noise barriers. These developments have resulted in three types of innovations.
   * Barriers with alternative shaped cappings
   * Longitudinal profiled edge barriers
   * Barriers incorporating active noise control techniques
2. Application of current barrier technology to achieve high levels of attenuation requires the adoption of tall and imposing barriers.
3. In regard to barriers with novel shaped cappings
   * Application of relatively simple shapes provides attenuation increases in the order of 2 to 3 dB compared to conventional barriers.
   * When more complex shapes are used the attenuation increases achieved are higher and range from 3 to 5 dB.
   * Absorbing edge barriers appear to have the potential to deliver attenuation increases of 2 to 3 dB.
4. In regard to profiled edge barriers
   * Early designs known as "Thnadners" have been shown to have inferior attenuation performance compared to conventional barriers.
   * Random edge barriers investigated via laboratory studies have demonstrated enhanced performance at higher frequencies but reduced performance at lower frequencies. The transitional frequency involved here is around 5000 to 7000 Hz which suggests that in their current format these particular type of barriers are not yet suited to traffic noise applications where the acoustic energy lies primarily in the 50 to 5000 Hz range.

5 In regard to barriers using active noise control

* Application of active noise control techniques to traffic noise barrier applications is at a very early stage of development
* These techniques have been demonstrated to have the theoretical potential to enhance barrier attenuation performance by possibly 5 to 10 dB. Confirming this potential empirically is likely to be technically difficult.
* The techniques can be applied within the 50 to 5000 Hz frequency range of road traffic noise.

Recommendations

What is contained in the body of the present paper along with the above conclusions leads to the following recommendations for further work in the field.

1. Pursuing the design and development of barriers with novel shaped cappings would seem to be worthwhile.
2. Random edge barriers clearly require a considerable research and development effort before they could be deemed suitable for traffic noise applications. Should such work proceed it is recommended that it should have particular emphasis on an empirical evaluation approach.
3. Barriers utilising active noise control technology also require a substantial technological program to achieve practical, engineered applications.

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Barriers with novel shaped cappings

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Future Meetings

ACOUSTICS 2001

This conference, organised by the Australian Acoustical Society (AAS), is being held from 21 to 23 November in Canberra, the seat of Federal Parliament. It is therefore appropriate to take noise and vibration policy as a theme for the conference. Recently there have been many changes and revisions of policies and this conference provides an opportunity for discussion of the various issues along with other aspects of acoustics.

The speaker at the opening will provide an overview of the noise and vibration policies and with comments on the way forward. For each of the sessions addressing various aspects of noise and vibration policy the session leader will be invited to summarise the current situation. Contributed papers related to the theme and to other topics on sound and vibration are invited. Each paper will be allocated 15-20 minutes. Papers related to the themes will be allocated in the sessions indicated in the preliminary program. Papers on other areas of acoustics will be in the parallel sessions.

All sessions, the technical exhibition and the social functions will all be held at RYDGES CANBERRA. All registrants are encouraged to stay in the conference hotel and a special room rate has been negotiated. This conference will combine contributed papers, technical presentations, awards and a range of social activities included in the delegate registration fee such as welcome buffet, breakfasts, tea breaks, lunch and conference dinner.

The speaker at the Conference Dinner will be Robyn Williams, who presents the Science Show which is one of the ABC's longest running and most popular programs. It can be assured that the dinner presentation by Robyn will be an interesting and stimulating view of acoustics related issues.

Further information: Acoustics 2001, Aust Defence Force Academy, Canberra, ACT 2600, tel:02 6268 8241 (0402 240009) , fax:02 6268 8276 m.burgess@adfa.edu.au and www.acoustics.asn.au

ACTIVE 2002

The 2002 International Symposium on Active Control of Sound and Vibration will be organised by the Institute of Sound and Vibration Research (ISVR), and held at Southampton University, United Kingdom, on 15-17 July 2002. The ACTIVE series of international symposia evolved from meetings on active control held at the Virginia Polytechnic Institute in the United States in 1991 and 1993, and an international symposium held in Tokyo, Japan in 1991. ACTIVE 95 was held in Newport Beach, California, ACTIVE 97 was held in Budapest and ACTIVE 99 was held in Fort Lauderdale. The format of the meeting will follow previous ACTIVE symposia with full-length papers being available to delegates at final registration.

For further information on ACTIVE 2002: Professor Stephen J. Elliott, ISVR, Southampton University, SO17 1BJ, United Kingdom, fax: +44 23 8059 3190, sje@isvr.soton.ac.uk, http://www.isvr.soton.ac.uk/Active2002

ISMA 2002

The 2002 Conference on Noise and Vibration in Engineering, ISMA 2002, will be held from 16 to 18 September. It is the 27th in a series of annual courses and biennial conferences on structural dynamics, modal analysis and noise and vibration engineering, organised by the Department of Mechanical Engineering of the Katholieke Universiteit Leuven.

The conference will provide a forum for engineers, researchers and other professionals active in the field of modelling, analysing, testing and improving the noise and vibration characteristics of mechanical systems and civil structures. The conference combines expertise in the noise and vibration fields by stressing common measurement, modelling, analysis and control technologies. The meeting will provide a further impetus to the cross fertilisation of ideas in both areas.

Further information from http://www.isma-isaac.be, fax: (+32) 16 32 29 87, lieve.notre@mech.kuleuven.ac.be

ICSV9

The Ninth International Congress on Sound and Vibration, sponsored by the National Aeronautic and Space Administration (NASA), the University of Central Florida, and the International Institute of Acoustics and Vibration (IIAV) will be held at the University of Central Florida in Orlando, Florida, USA, 7-12 July, 2002. IIAV is an international non-profit scientific society affiliated with the International Union of Theoretical and Applied Mechanics (IUTAM). The Ninth International Congress is part of a sequence of congresses held in the USA (1990 and 1992), Russia (1993 and 1996), Canada (1994), Australia (1997), Denmark (1999), Germany (2000), and Hong Kong (2001), each attended by several hundred participants.

Further information from http://www.iiav.org, fax 407-823-6334, icsv9@mail.ucf.edu

INTER-NOISE 02

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

The theme of INTER-NOISE 02 is Transportation Noise as it relates to automobiles, trucks, motorcycles, off-road vehicles, trains, subways, aircraft, helicopters, ships, and recreational vehicles. However, technical papers in all areas of noise control engineering are welcome, including: noise sources, airborne and structure-borne noise paths, noise and vibration control devices, active control techniques, modeling and simulation software, mid-frequency range analysis problems, measurements techniques and test facilities, characterization of materials, vehicle noise standards, building and community noise, legislation and regulations, effects of noise and urban planning policies, etc. A major technical exposition will be held at INTER-NOISE 02.

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

Further information: INTER-NOISE 2002 Congress Secretariat, Department of Mechanical Engineering, the Ohio State University, 206 West 18th Avenue, Columbus, OH 43210-1107, USA., peersen.1@osu.edu, http://www.internoise2002.org

WESPAC8 in Melbourne

"Acoustics on the move" is the theme of WESPAC8, an international conference being organised by the Victoria Division of the AAS. It will be held from 7 - 9 April, 2003 on behalf of the Western Pacific (Regional) Acoustics Commission. The conference venue will be the Carlton Crest Hotel, opposite Albert Park Lake and adjacent to a golf course and other sporting facilities. Melbourne city centre is 15 minutes away by tram. A range of accommodation is available at the hotel or nearby.

The Conference will cover a wide range of acoustics topics. For full details see http://www.wespac8.com. Included is a topic called "consultant acoustics" where, in a workshop environment, we aim to encourage consultants to exchange ideas on the practical application of acoustics in their profession. As many authors have requested that their papers be fully refereed, provision will be made for such papers to be submitted at an earlier date. These papers will be published in a separate part of the proceedings.

There will be a series of distinguished lectures as part of the technical sessions. It is anticipated that there will be an extensive trade display associated with the conference. The hotel has a spacious area overlooking the lake and adjacent to the session rooms, where the exhibition will be located, along with morning and afternoon refreshments. Again, the committee would be pleased to receive expressions of interest from organizations wishing to participate in the display or act as a sponsor.

One of the attractions of the conference will be a bush barbecue at "Emu Bottom", the oldest farm and homestead in Victoria. Delegates will mingle in an informal atmosphere while sampling Australian "tucker" and can try their hand at boomerang throwing and Two-Up. There will also be a conference banquet.

Further information:
http://www.wespac8.com

Meeting Reports

NSW DIVISION

On 1 March 2001 the NSW Division started the autumn season with a technical site visit at the Conservatorium of Music in the Royal Botanic Gardens in Sydney.

Hard hats were the order of the day for the 45 members who eagerly gathered at the entrance of what first appeared to be a building site. A little way into the 'site' it was soon revealed that we were in a near to completion University of Music - the historic Sydney Conservatorium of Music. The initial introduction was given, on the bare concrete steps, by Barry Macgregor, architect of Daryl Jackson Robin Dyke. Barry discussed the design philosophy of the Sydney Conservatorium of Music and Conservatorium High School. He pointed out some of the difficulties of design, mainly the fact that the railway line runs within a few metres of where a recital hall is to be constructed. Ed McCue, the Acoustical Consultant from Kirkegaard & Associates in Colorado explained why an American acoustical consultant was in charge of the project when there are so many capable Australian acoustical consultants. The reason is that Ed has had many years specialising in the acoustical problems involved in the construction of Musical Universities, Colleges and places of learning. All was not lost, however, as Ed was ably assisted in the fine details by AAS mender Barry Murray and the crew at Wilkinson Murray Pty Ltd, just down the road apiece in Crows Nest.

Barry Murray gave the next part of the talk with a description of the vibration isolation and the huge, springs under recital halls & the pads under music workshop. Barry McGregor, lead a guided tour of the recital halls, percussion practice rooms and explained the logic of the building system with the aid of a scale model. The tour continued to the historic Verbrugghen Hall, which really did resemble a construction site. The tour finished in the High School lecture theatre intended for the further education of musically talented children.

The evening finished with a chance to socialise with old friends, to have a few beers and an excellent meal in a neighbouring Italian restaurant.

Ken Scannell

On Wednesday 4 April 2001, talks by John Mazlin of Camets Services and Michael Latimer of Acoustop were presented in the national headquarters of Soka Gakkai International of Australia. This is an international lay Buddhist organisation with 12 million members worldwide. The Buddhist centre, located in Olympic Park , was opened in February 1999 and contains an administration office, meeting rooms, publication area, boardroom and a 600-seat auditorium. The auditorium is further divisible into a 400-seat auditorium and two 100-seat auditoriums for use as a place of worship and as a general-purpose auditorium.

At an early stage in the project, Camets Services Pty Ltd were presented with the "classic" auditorium design. The architect had also included an oval-shaped central dome in the ceiling. Glazing was also extensively used in the rear and side wall of the auditorium. In the original design, the roof was to be a metal deck roof over a plasterboard ceiling. It was visually pleasing, but an acoustically challenging design.

The site presented outside noise environment difficulties. Although built in a generally quiet commercial area, the site backs onto Sydney Showground and each Easter, the site shares a boundary with the roar of sideshow alley. As well, the nearest permanent neighbours are commercial premises about 10 metres from the sidewall of the auditorium. The auditorium was designed to restrict the intrusion of outside noise, including rain noise, and to protect the nearby commercial premises from the internal noise emissions from the auditorium.

The major internal noise source is the congregation during prayer. Prayers can last from 20 to 60 minutes, consisting of up to 600 people reciting and chanting in unison. Typically within the seating area, the sound levels can range from 95 to 100 dB(A). This is a function of seating density and vocal power. To maintain rhythm, the leader's voice is amplified further, raising the internal sound levels to between 100dB(A) and 105dB(A). An Asian bell, a Quong, is also loudly rung to separate the sections of prayer and chanting.

The evening lecture was held in the auditorium with pre-meeting wine and snacks provided by Acoustop. During his talk, John Mazlin explained how the shape of the auditorium was modified to reduce the sound focussing of the original design. The curved front of auditorium was flattened and the height of the ceiling raised to achieve acceptable volume and sight lines. The front wall was upgraded to isolate the two plantrooms located behind the raised Altar platform at the front of the auditorium. The base of the Altar platform was also utilised to accommodate a large return air plenum. A large suspended oval was inserted into the central dome to deal with focussing effects and to provide additional sound absorption. The suspended oval and the supply air ring duct around the edge of the dome provide ideal mounting locations for the auditorium lighting, thus minimising ceiling penetrations.

The roof was constructed as the primary noise barrier using a combination of light metal decking over polyester batts and Acoustop loaded rubber dealt with the often tight curvatures of the structure and achieved a continuous unbroken noise barrier. This also addressed rain noise. The ceiling was constructed of plasterboard and Armstrong drop-in acoustic tiles. A combination of several ceiling treatments and slatted side wall absorbers resulted in a space with a room response suitable for prayer, music, singing, and conferences.

Brian Marston explained about the history and activities of the Soka Gakkai, and demonstrated several of the sounds normally heard in the auditorium such as the ringing of the ceremonial bell and a tape of the Buddhist chanting. Mr Michael Latimer, Technical Director of Acoustop spoke about the products available in the Acoustop range. Their foil faced heavy weight loaded rubber membrane material was an integral part of the roof/ceiling construction due its flexibility and ease of sealing.

The acoustics of the auditorium has been very favourably commented on by a number of prominent musicians, and it has become a sought after venue for performances and conferences.

Brian Marston

VICTORIA DIVISION

At the technical meeting on Apr 4, with 15 present, **Neil Huybregts** described the recent Draft Report prepared for Austroads on the *Proposed Guidelines for Undertaking Traffic Noise Prediction Model Validation Studies*. The purpose of this investigation for the association of Australian and New Zealand road transport and traffic authorities was to examine the several currently available traffic noise prediction models, and to determine their accuracy of prediction, in order

(1) to provide recommendations, on a technical basis, for a preferred traffic noise model for use in Australia and New Zealand,

(2) to develop a preferred methodology for validation studies of road traffic noise models, and

(3) to prepare guidelines for undertaking, reporting and assessing traffic noise validation studies.

In these traffic noise models, the independent variables comprised noise emission characteristics such as the traffic flow, a measure of the traffic speed, the proportions of cars and trucks in the flow, a measure of the degree of road surface roughness, and the road gradient, and propagation characteristics such as distance between centreline of trafficked lanes and observation point (each carriageway being treated separately to compensate for differential flows), and the presence of any shielding or ground effects. The dependent variable would be a composite noise index such as $L_{10(18h)}$, $L_{eq(24h)}$, $L_{eq(15h)}$, $L_{eq(9h)}$ or L_{dn}.

The process of validating any model would cover the accuracy of the calculation method through a comparison of its reliability and accuracy in use, validity of the calculations by comparing predicted and measured noise levels, and validation of the software through the use of standard test scenarios for which the "correct" outcome is known.

Important considerations in this process of validating calculation methods were the standard deviation for assessing numerical differences between predicted and measured noise levels, and the desirability of an ample number of individual site data sets. For the former, it was found as part of a related study that analyses of the noise level differences (= predicted - measured) by Analysis of Variance showed between-site differences to be significantly greater statistically than within-site differences. For the latter, the selection of an adequate number of sites was important, using a combination of random selection, stratification, and reasonable representation of different types of site.

During discussion several questions were raised, including the method of allowing for the effect of varying degrees of road surface roughness, whether or not a close succession of passing vehicles constituted a line noise source, and whether it was the *accuracy* or *precision* (or both) of predicted traffic noise levels that was being sought.

At the date of the meeting, the status of the report was a Draft for acoustical and other comment. [Papers on traffic noise prediction procedures to recent AAS Conferences were given by Huybregts and Samuels, and Fouvy (1999), and Batstone and Samuels (2000)].

The technical meeting held on May 8 at 6:30 pm, and in conjunction with the Association of Noise Control Engineering (ANCE), took the form of a site visit to Barrierboard P/L, Hallam (3803), manufacturers of composite plasterboard products, at which 12 were present. Charles Don welcomed those present and introduced **Neres Castelli** of Barrierboard, who then led a tour of inspection of the plasterboard factory, followed by a talk to further describe and demonstrate samples of composite plasterboards.

Barrierboard's composite 'Barriboard' of 32 mm thickness consists of two sheets of 16 and 10 mm thick plasterboard separated by a 6 mm thick layer of polyester/polyurethane foam glued together and also secured by polyurethane plugs at 30 cm centres. Composite board thicknesses of 29 mm are also available. 'Barriboard' is normally available in either 1200 x 2400 or 1200 x 2700 sheets.

In the manufacturing production line the 16 mm sheet is placed at the bottom, the 6 mm foam next, and the 10 mm sheet on top, with these bound together by both a water-based glue and the polyurethane plugs. For obtaining acoustically satisfactory joints between adjacent sheets the 16 and 10 mm boards are offset by an amount which can be varied from 0 to 25 mm, with a standard offset, initially, of 20 mm, but now (for easier compliance with fire rating regulations) of 10 mm.

Tests made at CSIRO or RMIT show that the composite 16 and 10 mm plasterboards with foam in between have an STC of the order of 58 dB, with the two boards without foam having an STC of the order of 55 dB. Surface density of the 16 mm board is 12.5 ± 0.1 kg/m². On-site tests at Barrierboard are made using a 2 x 2 x 2.5 m reverberant chamber test cell with 1.5 x 2 m aperture for test specimens, opening on to the large factory space. The cell chamber is equipped with a microphone and loudspeaker, while the outside microphone is placed at a set distance from the specimen. These non-standard plasterboard attenuation measurements are then correlated with the standard CSIRO or RMIT test results.

After the factory inspection, Neres Castelli gave a further description and demonstration of samples of 'Barriboard' in the conference room. The foam characteristics are between open and closed cell. Interior walls with 'Barriboard' on one side of the studs and 16 mm plasterboard on the other have a 90 minute fire rating; walls with 'Barriboard' on both sides have a 120 min rating. Volume density of the 32 mm board is around 10 kg/m³. For full acoustic sealing of walls of 'Barriboard', caulking is required at top and bottom. Tests to date on partition walls have been with both sides fixed to common studs; no tests have as yet been made with a staggered stud arrangement. Further details of these boards and tests were included in the brochure provided.

On the capital and installation costs of 'Barriboard' it was emphasized that, although its capital cost was higher than that of single layer plasterboards, with Barrierboard's policy of cartage and delivery, and of the ease of installation, the total cost of installing 'Barriboards' could be less than that of other boards. At the close, those present moved and carried a vote of thanks to Neres Castelli.

At a technical meeting held on May 30 at RMIT, attended by 21, and organized by ANCE to which AAS members were invited, **Ken Cook** described and explained the considerable changes brought about when the single number rating *'Sound Transmission Class'* (STC) became the *'Weighted Sound Reduction Index'* (R_w) when AS 1276-1979 was revised as AS/NZS 1276.1:1999/ISO 717-1:1996, *Rating of sound insulation in buildings and of building elements, Part 1: Airborne sound insulation*, a revision made because, inter alia, a partition's STC did not always appear to correspond well with the experienced sound insulation. "Single-number quantities...are intended for rating the airborne sound insulation and for simplifying the formulation of acoustical requirements in building codes".

In his exposition of the differences, Ken Cook began with the basic level differences (normally one-third-octave) used in calculating the Weighted and Weighted Apparent Sound Reduction Indexes, R_w and R'_w, and the Spectrum Adaptation Terms, C and Ctr (as now defined in AS 1276.1). These level differences are to be obtained according to the method of AS 1191 for laboratory determinations or AS 2253 for field measurements.

Individual one-third-octave band level differences (or octave as allowed for field measurements) are then converted to Sound Reduction Indexes (formerly Sound Transmission Loss), R (from lab measurements) or R′ (field measurements) for the revised frequency bands from 100 to 3150 Hz (now changed from the earlier range of 125 to 4000 Hz) or the extended range from 50 to 5000 Hz.

The single-number Weighted (or Weighted Apparent) Sound Reduction Index, R_w or R'_w as the value in dB of the reference curve at 500 Hz is calculated from the reference values for airborne sound in AS 1276.1, Table 3, or Figure 1 (one-third-octave values) or 2 (octave) according to the methods of this standard. In the revised AS 1276.1, the reference curve shifting procedure differs from that of AS 1276-1979. AS 1276.1 provides that the sum of the unfavourable deviations (or deficiencies) must not exceed 32.0 dB (in the 16 one-third-octave bands) or 10.0 dB (for the 5 octave bands), whereas AS 1276-1979 also provided that the maximum deficiency must not exceed 8 dB.

An important additional part of AS 1276.1 is the use of Spectrum Adaptation Terms which, as a value to be added to the single number rating (eg, R_w), enable account to be taken of the characteristics of particular sound spectra. AS 1276.1 provides the adaptation terms C and Ctr to allow for the effects of general noise (represented by A-weighted pink noise) and A-weighted urban traffic noise. These are calculated according to AS 1276.1, §4.5, and have been designed to improve the correlation between a partition's Rw rating and the noise attenuation experienced in practice.

Ken Cook concluded by advising that we should no longer rely solely on R_w or $D_{nT,w}$, but also calculate C and Ctr, especially as some partitions could have substantial negative values. This has serious implications should the National Building Code at some future date specify partition performance also in terms of C and Ctr.

Louis Fouvy

FASTS

Science Meets Parliament

Australia's peak body for science and technology has asked Federal Parliamentarians to identify the most important science-based issues. These issues were discussed at the annual "Science meets Parliament" Day, August 22, when scientists fly in to Canberra from all over Australia for individual meetings with Parliamentarians.

Ms Jan Thomas, Vice-President of the Federation of Australian Scientific and Technological Societies (FASTS), said the event is an important part of building a bridge between the science community and Parliamentarians. "Science is clearly going to be a definitive issue in the election later this year," she said. "This is a highly strategic time for 200 scientists and technologists to come to Canberra for personal meetings with federal Parliamentarians."

Knowledge Nation

Dr Ken Baldwin, of the Federation of Australian Scientific and Technological Societies (FASTS), said that "Knowledge Nation" is a welcome injection of ideas into a discussion vital to Australia. "The ALP has presented a plan of the scale that Australia needs," he said. "It's long-term, it's visionary, and it's full of good ideas. All sides of politics have clearly stated the importance of science and technology to Australia's future....We need a robust debate on where Australia is headed, so that we can set our own national directions."

Dr Baldwin said the science community believes investing national funds in science and education is the best investment Australia can make in terms of creating new jobs and new opportunities. But we need to carry the community with us. An investment of this size requires a national consensus that we need to change our course as a nation. He said that merely to catch up, the education and research sectors need an investment by the Commonwealth Government of $12 billion over the next five years. This has to be complemented by a further $6 billion from State Governments and the private sector. Additional funding of $18 billion over 5 years would enable Australia to restore its university sector to 1996 levels, and reach the OECD average investment in research and development.

More information on the activities of FASTS is available from www.FASTS.org . All members of the AAS are invited to provide comments on the value of the continued membership of FASTS and advise on any issues which may be appropriate for presentation to FASTS for action. Please send all comments to Marion Burgess, m.burgess@adfa.edu.au or Acoustics and Vibration Unit, ADFA, Canberra ACT 2600.

News

The Queensland Government Environment Protection Agency has recently released a Guideline on Noise Control Measures for using Scare Guns. Gas scare guns are a method of protecting crops from pests such as birds and flying foxes. Due to their simplicity, low maintenance and comparatively low cost, scare guns are the preferred method of crop protection by farmers. The scare gun emits a loud blast at predetermined intervals that act as a deterrent to pests. This blast from the scare gun can create an environmental noise nuisance.

The guideline recommends keeping a distance of greater than 300m from any noise sensitive place; only operate during the period half an hour before sunrise and half an hour after sunset; no more than 70 blasts in any one day; interval between blasts must be at least 10 minutes; and neighbours to co-ordinate the timing of the blasts of their guns. For more information contact the Queensland Environment Protection Agency, http://www.env.qld.gov.au/environment

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WorkSafe WA has developed a new draft code to replace the present approved code - the National Code of Practice for Noise Management and Protection of Hearing at Work (1993). In November 2000 the National Code was revised to reflect recent changes to the National Standard for Occupational Noise (C-weighted peak and reference to AS/NZS 1269:1998). The WorkSafe Western Australian Commission has recommended these changes be incorporated into the WA Occupational Safety and Health Regulations. However, instead of adopting the new version of the National Code outright, the Commission considered a "user friendly" version aligned with the WA legislation to be more appropriate and to seek public comment on this approach. This draft code of practice is available from http://www.safetyline.wa.gov.au/pagebin/wswanews0050.htm, or tel 08 9327 8669.

Violin Octet Recordings Readers may be aware of the "New violin family" of 8 instruments, ranging in compass from an octave above a normal violin to a fifth below a normal double bass, developed by Carleen

Hutchins in the US. Two excellent recordings using these instruments have now been released by the Catgut Acoustical Society. The first, recorded by the St Petersburg Octet, uses the whole family in music by Vivaldi and others, while the second features concertos played on treble, soprano and mezzo violins by Grigori Seduckh. The normal price for these recordings is $29.95, but we are advised that a few copies are available for $17.50 including postage, from R.E. Henderson,19 Griffin Street, Hamilton 3300, phone (03) 5571 9720.

Plastyne Products has been sold back into full Australian ownership. So the range of noise insulation products which includes Wavebar, Soundune Quadzero is now 100% Australian made and owned. For more information call Mick Hunter, 0414 403265 or check on www plastyne.com.au

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Compumod has changed its name to MSC Software Australia in line with its liaison with the MSC Software Corporation. The company will continue to sell and support the range of CAE software. For more information tel 02 9260 2222 or check on www.mscsoftware.com.au

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Archives of Control Sciences (ACS) are calling for papers for a special issue on Active Noise Control. The guest editors will be M. Osman Tokhi and Jaroslaw Figwer. The goal of this special issue of ACS is to discuss the recent developments in this rapidly progressing research area, identify the most visible trends and study current and emerging applications. Further information available from www.ia.polsl.gliwice.pl/acs and manuscripts should be submitted by March 30, 2002 (publication is scheduled for July, 2002)

ASK Consulting Engineers Pty Ltd, is the new company name for Kamst & Simpson Pty Ltd. Gillian Adams has rejoined Mark Simpson and Frits Kamst as a joint Director of ASK. Gillian is currently Queensland Division Chairman and Federal Committee member for the AAS. She will be combining these commitments with her new efforts at ASK in developing the business. After 8 successful years ASK look forward to continuing our work in the interesting and challenging area of acoustics. Contact details: Tel 07 3831 7511 Fax 07 3831 7661 mail@askce.com

The **PULSE Solution Network** is a web-based community consisting of Brüel & Kjær, consultants, third party software developers and system integrators, who together provide PULSE™ solutions for applications not covered using standard PULSE software alone. With all the knowledge of its members gathered in one place, a few clicks of the mouse is all it takes for you to tap into standard solutions from Brüel & Kjær, a partner, or third party that fulfil your measurement requirements. Further information:
Bruel & Kjaer Austalia,
bk@spectris.com.au,
www.bksv.com.au

New Products

DAVIDSON Modally Tuned Impact Hammers

PCB's Series 291 modally tuned impact hammers have many benefits including elimination of hammer resonance from test results, reduction in double impacts, quick and convenient excitation of resonances etc. There are a variety of types to increase the frequency range and complete kits or individual units are available.

Further information from Davidson,
tel 03 9580 4366, fax 03 9580 6499,
www.davidson.com.au

VIPAC Environmental Noise Monitor

Vipac Engineers & Scientists have developed a portable, solar powered data logger for remote monitoring and accessing of environmental data. The unit contains a type 1 sound level meter, Larson Davis 870. An option for creating exceedence reports when the level rises above a user set threshold. The system then activates a MP3 recorder which assists with identification of the noise source. An internal cellular phone allows for remote access to listen to the sound in real time. Access to the data and control of the monitor is available via Vipac's website.

Further information and rental details,
contact Vipac on 1300 784722,
www.vipac.com.au

ARL NEC-Sanei Omniace II Data Acquisition Systems

Acoustic Research Laboratories Pty Ltd has released the Omniace II data acquisition systems from NEC-Sanei. There are three models in the range - the RA1100, the RA1200 and the RA1300 - each offering slightly different features to meet particular requirements. All models offer waveform monitoring and data acquisition and feature a 10.4 inch colour LCD display in a shockproof structure. The RA1300 features a built-in printer and a fast 100 mm/sec acquisition speed.

10 high resolution plug in amps provide up to 16 input channels. These are available to support voltage, vibration, revolution pulse, strain and temperature measurements. Long term data logging is possible with a sampling speed of 200μs. Data can be displayed on screen, stored to memory, printed or transmitted to a fax machine or via a modem to another computer. Similarly, a number of trigger options are available, including Input Signal, External Trigger and various Time Trigger modes. Optional features include FFT analysis and a number of interfaces (RS-232C, GP-IB and SCSI)

Rion Sound Level Meters.

Acoustic Research Laboratories are pleased to announce the arrival in Australia of a new family of sound level meters from Rion. All these new meters comply with the new IEC/CDV 61672-1 standard. The base model in the new family, the NL-20, is an easy to use meter which measures Lp, Leq, Lmax, Lmin and 5 values of Ln. This meter measures dB(A), dB(C) and flat, has 100 data sets storage capacity in manual mode and an AC/DC output. The NL-20 is a Type 2 meter under the new standard.

One step up in the new family is the NL-21 which is also a Type 2 meter. The basic features of the NL-20 are available in the NL-21 but, in addition, Lpeak, LCpeak, LAeq and LCeq can be measured. The NL-21 will measure a maximum peak sound pressure level of 141 dB and will measure impulse. The meter has substantial storage capacity consisting of 1 manual mode and 2 auto modes capable of storing over 600,000 data units and comes with a memory card slot to make the transfer of stored data to a computer very easy. This card slot can also be used to install a 1/1 and 1/3 octave band filter. Top of the range in the new family is the NL-31. This meter has all the features of the NL-21 but is a Type 1 meter under the new standard.

'Blue Box' Noise Controller

A continuing problem for pubs and clubs is to be able to restrict the level of noise from performing artists that encroaches into nearby dwellings. The 'Blue Box' Noise Controller is available to specifically overcome this potential area of conflict. It has been designed to limit the amount of noise escaping from entertainment areas to neighbouring residential areas. The 'Blue Box' is installed between the power point and the sound or stereo equipment and by setting the Monitor to a decibel noise threshold, you can ensure that any exposure to noise is kept within local regulations.

A series of warning lights on the LCD of the 'Blue Box' alerts you when the noise approaches the decibel threshold, when first it goes from green to orange. When the decibel level is exceeded, the lights change from orange to red and after 3 seconds, the current is cut off to the power point, removing power from the amplifiers. After 20 seconds, the 'Blue Box' automatically resets and restores the power.

Further information: Acoustic Research Laboratories on 02 9484 0800, your local branch of ARL or www.acousticresearch.com.au

CSR
Acoustic Ceilings Guide

CSR Gyprock is one of the leading distributors of acoustic ceiling products and systems including Ecophon, Celotex and Capaul Ceiling Panels. The Gyprock Ceiling Systems Guide has been developed to provide assistance in the selection and specification of acoustic ceilings.

For further information: CSR Design Link on 1800 621 117, ww.csr.com.au

BRÜEL & KJÆR
PULSE Version 6

Version 6.0 of PULSE, sound and vibration measurement platform takes advantage of developments in technology, and Brüel & Kjær's research and development, with Analysis Engine technology now offering even stronger measurement performance. PULSE front-ends are now more flexible: a new, modular front-end with up to 31 channels in 5 input modules and multiple front-ends of the same or different types.

The Acoustic Test Consultant is a new PULSE application that has been developed to simplify complex acoustic measurement tasks. It also handles automatic measurements with a robotic function. The existing Modal Test Consultant application has also received higher specifications and is even better able to handle structural dynamic measurements.

Uniting the different elements of PULSE and keeping your work running smoothly is a new version of WorkFlow Manager, which simplifies your test process from test cell to desktop.

Sound Level Meter, type 2239

The new Integrating Sound Level Meter Type 2239 is a rugged, easy-to-use workhorse, and conforms with IEC 60651 and IEC 60804 Type 1 as well as the new standard IEC 61672 Class 1. It allows for A- or C-weighted RMS and C-weighted Peak levels in parallel. Measurements can be manually controlled or you can pre-set the measurement time (from 10 seconds to 8 hours). Type 2239 can store up to 40 measurements, and if the time is pre-set, storage is automatic. In fact it's a one-button operation - just switch on and it measures, stops and stores automatically.

Operational Modal Analysis Type 7760

It's usually impossible to perform modal analysis on objects where traditional excitation cannot be used, such as on cars, aircraft, windmills, while they're in motion. Now, with Brüel & Kjær's Operational Modal Analysis Type 7760, developed in association with Structural Vibration Solutions, it's possible!

Operational Modal Analysis tests under real operating conditions and uses a new, unique technique which dramatically reduces the total test time. Structures can be tested in-situ, thus avoiding interference with, or interruption of, their normal function. Brüel & Kjær's Operational Modal Analysis is a highly effective stand-alone application, but it's also optimised for use with the PULSE real-time sound and vibration multi-analyzer platform, and with Modal Test Consultant Type 7753.

Acoustic Test Consultant

The Acoustic Test Consultant™ (ATC) is a PULSE™ application that has been developed to simplify geometry-driven, acoustic measurement tasks. With the production of reliable test data another primary objective, it also reduces test times and works with PULSE to support all aspects of the measurement process.

ATC works off a task bar setup to support workflow in a straightforward, logical fashion. The system comprises the basic ATC software and a separate robot option for automatic measurements. The robot option controls 2 to 8 motors allowing you to orientate a microphone-positioning system in up to five directions, thereby making it possible to measure all planar surfaces around an object.

Accelerometer 7593A

Model 7593A Variable Capacitance Accelerometer with its built-in signal conditioning is ideal for measuring shock, vibration and inertial motion in all fields of engineering. It has a full-scale range of ±2g with a frequency response from 0 to 50Hz. In addition, the 7593A provides superior performance in any commercial or industrial application with its ratiometric output signal of 1 volt per g at 5.0 volts DC excitation and low milli-g noise.

The fully calibrated accelerometer can be used for tilt applications and modal testing on large structures that vibrate at very low frequencies. Designed to withstand severe shock and vibration, the 7593A's thermoplastic case with mounting holes can withstand extreme environments, operating over a temperature range of -40°C to125°C (-40°F to 257°F) without the need for external compensation. Its high temperature performance and rugged construction make it ideal for use in automotive safety testing, vehicle barrier and sled testing, and vehicle dynamic testing of engines, exhaust systems, components and suspension systems.

Triaxial ISOTRON® Accelerometer

ENDEVCO's Model 35A is an extremely small, adhesive-mounted piezoelectric accelerometer with integral electronics designed specifically for measuring vibration in three orthogonal axes on very small objects. It is ideal for measuring vibration on scaled models, small electronic components, and other small structures that demand miniature, lightweight accelerometers. Model 35A weighs only 1.1 g (0.04 oz), minimising mass-loading effects. With a range of ± 1000g and a typical voltage output sensitivity of 5mV/g, Model 35A offers superior performance in any application. In addition, a temperature range of -55°C to 125°C (-67°F to 257°F) allows the accelerometer to perform in even the most extreme environments. Model 35A features a frequency response of 2Hz to 12kHz for precise measurement.

This accelerometer features ENDEVCO's PIEZITE® Type P-8 sensing element operating in a shear mode. The internal amplifiers of the accelerometer convert the high-impedance charge input into a low-impedance voltage output. The low-impedance output is then transmitted through the same wiring that supplies the required +3.5 to +4.5mA constant-current power. Model 35A is ground-isolated from the mounting surface of the unit by a hard-anodised surface. A tool is included for proper removal in the field.

4 Channel Microphone Power Supply

Type 2829 is a simple power supply which introduces negligible noise into the measurement system. It can power up to four microphones simultaneously. The correct functioning of the connected microphones and preamplifiers can be checked by the patented Charge Injection Calibration method. The test signal is applied to all the connected microphone and preamplifier combinations by means of the mini jack socket on the rear panel.

Applications include the production, testing and quality control of loudspeakers and telephones. The elegant design enables several 2829 units, if required, to be stacked on top of one another. Type 2829 can supply both 0V and 200V polarization voltage for the microphones.

New Conditioning Amplifier Range

Brüel & Kjær introduces the Type 2694 family of 16-channel DeltaTron conditioning amplifiers - general, signal-conditioning amplifiers for voltage and DeltaTron analogue input providing an analogue output. The amplifiers have been developed for multichannel applications, such as modal analysis, operational deflection shapes and microphone array measurements, where typically between 16 and 512 channels are employed.

Type 2694 amplifiers support DeltaTron, ISOTRON, ICP and IEPE transducers, such as accelerometers, microphone preamplifiers and tachometers, and are completely controlled by the provided Windows software, enabling the amplifier to be configured for specific measurement tasks. They also feature a multiplexing function that enables the number of transducer channels in the data acquisition unit to be increased 16-fold.

10-channel Signal Conditioner

ENDEVCO's new Model 2793M4 10-channel, ultra-low-noise signal conditioner is an economic power supply/buffer amplifier for high-gain, low-noise ISOTRON accelerometer and remote charge convertors. The ISOTRON signal conditioner surpasses the noise floor of existing instrumentation, furnishing a solution for a high-noise environment yet low vibration signal level. Tough ground loop/noise problems are eliminated. The wide frequency range is from 1Hz to 100kHz.

The unit provides switchable individual channel and chassis isolation for improved noise immunity. Channel-to-channel cross-talk is better than -80dB. Each channel provides a constant current excitation (4mA to 10mA) for the transducer or remote charge convertor.

Remote Charge Converters Enhanced with TEDS

Brüel & Kjær/ENDEVCO now offer a wide range of remote charge converters enhanced with TEDS (Transducer Electronic Data Sheet) designed for use with piezoelectric (PE) transducers. These devices transform a transducer's high-impedance charge output to a low-impedance voltage proportional to the transducer's charge. The products are small, rugged and lightweight. Operation is within a constant current range of 4 to 20mA. They are two-wire, single-ended devices with low inherent noise.

The products are: ENDEVCO's Model 2771B Remote Charge Converter with fixed gains of 0.1mV/pC, 1.0mV/pC or 10mV/pC, Brüel & Kjær's Charge to DeltaTron Converters Types 2647A and 2647B with fixed gains of 1.0mV/pC or 10mV/pC, Brüel & Kjær's Charge to DeltaTron Converter Type 2647 with dual switchable gain of 1.0mV/pC and 10mV/pC

Enhanced with TEDS means that the charge converters can be used with the newly developed Smart Sensor technology according to IEEE P 1451.4. The ability to store and recall TEDS data drastically reduces test setup time and allows cost savings through the use of existing PE transducer inventory in the Smart Sensor realm. The converter to be used depends on the application.

Pressure Transducers

Piezoelectric Pressure Transducer Model 522M17/19 is designed for sensing dynamic pressure fluctuations up to 500psi, even in the presence of high static pressure and temperature. The transducer utilises ferro-piezoelectric ceramics in the charge mode. Rugged Inconel construction, a metal-sheathed integral cable, relatively small size, and the ability to operate continuously at 538°C make it ideal for R&D, engine test cell and field service testing of aircraft and industrial gas turbines, marine gas turbines and nuclear propulsion systems. Model 522M17/19 can operate intermittently at temperatures as high as 649°C and requires no external power.

Piezoresistive Pressure Transducer from ENDEVCO is ideal for OEM Pressure Measurements. This rugged, miniature, high-sensitivity Model 8515C is ideal for use in pressure-belt and flex-circuit applications on aerodynamic surfaces during flight tests, as well as on small-scale models in wind-tunnel tests. Other uses include OEM blast effect studies and helicopter- or turbine-blade surface pressure measurements. Available in 15 and 50 psia full-scale ranges, Model 8515C features full-scale output of 200mV with high overload capability, high frequency response, very low base strain sensitivity, and excellent temperature performance. Its small size means that the transducer can be adhesive-mounted on curved surfaces such as pressure belts and flex circuits with minimal effect on laminar air or hot gas flow.

SoundEar

SoundEar™ with its simple red, amber, green colour display can warn about uncomfortably high noise levels, teach people to keep noise levels low for the benefit of all and warn about harmful noise levels. If set to the warning level at, for example, 85 dB, the yellow ring lights up at 5 dB below the warning level, i.e., 80 dB. As soon as the noise reaches 85dB the red eardrum lights up together with the word "WARNING". Uses include hospitals, schools, kindergartens, workshops, factories and offices, etc. SoundEar and its designer Anders Heger have received the prestigious Danish Industrial Design Award.

SoundEar's response is based on an dB(A) and slow time response. This means that SoundEar does not respond much to short noises such as a chair moving or a handclap but it does respond to raised voices or sustained high levels from any source. The warning level can be set in the 40 to 105 dB range in 5 dB steps. The response is within ±1 dB of the set threshold.

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

FANTECH Interactive Product Suite

The selection of fans and silencers is made even easier with the release of version 3.0 of the Fantech Interactive Product Suite. This version includes an improved search facility, ability to copy fan and silencer schedules to the clipboard and a new Load and Save facility for acoustic analysis. Fantech's recently extended range of adjustable pitch axial impellers, ranging from 315 to 2000 mm, has also been added.

Further information from Fantech Pty Ltd, PO Box 346 Mulgrave Nth, Vic, 3179,
tel 03 9560 2599, fax 03 9561 4428, info@fantech.com.au

Acoustics Forum

Discerning readers will remember that, in the issue for December 2000, we announced the institution of a new section in this journal with the title "Acoustics Forum". The formal announcement was on page 127 or that issue, and it was also referred to in the Editorial. To refresh your memories, the formal announcement is repeated below. The purpose of this innovation was to provide a means whereby members of the Society could put forward new ideas, criticise accepted practices, and propose new solutions to old problems without going through the formality of preparing a full paper that would be subject to our normal refereeing process. The Editorial Committee was urged to take this action particularly by the New South Wales branch, some of whose members felt that the refereeing process, even though carried out by their peers (academics for academic papers, consultants for reports on work done, and so on), inhibited such an interchange.

We welcomed the suggestion and look forward to a flood of such short communications on matters of common interest. The Forum was considered an ideal medium for matters requiring more than a Letter to the Editor but either too confined or too controversial for a full paper. So far we have had no such submissions. Is everyone content with the situation as it is? The noise regulations? The equipment available from suppliers? The preparation in acoustics given to architects and engineers in our universities? Are the views put forward in our major papers completely convincing to all? Do you have a technical problem to which you have never been able to find a satisfactory solution?

Please let us hear from you soon!

The Editors

ACOUSTICS FORUM

Beginning in 2001, each issue of Acoustics Australia will include a new section with the title "Acoustics Forum". This is intended to provide an opportunity for members of the Society, or other readers of the journal, to raise matters for discussion, to describe recent achievements, or to seek advice on acoustics questions.

While there will be no formal refereeing process, the Editors reserve the right to rule on the acceptance of contributions for publication, and to make such editorial changes as are necessary.

The length limit for contributions is one journal page, though shorter contributions are also welcome. One page is equivalent to about 1000 words, with each normally sized illustration counting as 300 words. The contribution should be submitted either as an e-mail or on disk, with the text in plain-text format or as an attachment in Microsoft WORD. Illustrations may be submitted either as hard copy, or in electronic form as .EPS or .BMP files. For further information, consult the Acoustics Australia pages of the Society's web site www.users.bigpond.com /acoustics/journal While every effort will be made to ensure prompt publication, this cannot be guaranteed. The normal deadlines for receipt of contributions to this section of the journal will be 1 March for the April issue, 1 July for the August issue, and 1 November for the December issue.

Review of Books

My attention was drawn to books on acoustics by a leaflet that arrived today advertising the new three-volume *Encyclopedia of Vibration* published by Academic Press and available at a special price of US$799 (about A$1600) for a limited time. I have not seen a copy of this work, but it seems to be comprehensive and authoritative, with some 120 chapters by a wide range of international authors (including two from Australia) and a predominantly practical approach. The same publisher also has a single-volume *Dictionary of Acoustics* for US$64.

Looking at my bookshelves for comparable books, I see the four-volume *Encyclopedia of Acoustics* edited by Malcolm Crocker and published by John Wiley & Sons in 1997. Vibration occupies only 190 of the 2000 pages of this set, so the coverage is much broader, as indeed one would expect. There are in fact 166 chapters in this set by well known international authors, and I find it a valuable and easily readable reference work.

Where else would one look for enlightenment about the various branches of our subject? Well, I suppose it depends on your particular area of interest. Leaving aside my own special interest in musical acoustics, what books do I find most valuable for reference in the more basic areas of acoustics? Let me give a few instances.

Since I am theoretically inclined, I cannot do without the various volumes authored by Philip M. Morse of MIT. His classic small volume Vibration and Sound covers most of the basic theory that anyone would want to know but, if more detail is sought, then *Theoretical Acoustics* by Morse and Ingard will likely provide the answer. For the basic mathematics at an advanced level, one cannot do better than the two volume *Methods of Theoretical Physics* by Morse and Feshbach, another classic.

For a more practical approach to the subject at a more easily readable level, it is hard to go past *Fundamentals of Acoustics* by Kinsler and Frey (with other collaborators on more recent editions), though Leo Beranek's *Acoustics* is also a favourite and there are several more specialised books reprinted by the Acoustical Society of America. If the aim is a book for teaching, then one would also consider Tom Rossing's *The Science of Sound* and Daniel Raichel's *The Science and Applications of Acoustics,* reviewed recently in this journal, though again there are many competitive volumes.

The history of the subject also makes interesting and informative reading. The classic was Frederick Hunt's *Origins in Acoustics* published in 1978, and this has now been supplemented by Robert Beyer's *Sounds of our Times*, reviewed recently here. Both are published by the American Institute of Physics. Just as interesting are the many volumes of reprints of classic papers in acoustics, particularly those in the series *Benchmark Papers in Acoustics* published by Dowden, Hutchinson and Ross; the historical volume edited by Bruce Lindsay goes back to writings by Aristotle and Vitruvius, and other volumes in the series reprint key papers in particular branches of the subject ranging from noise control to the acoustics of violins. This latter subject is of particular concern in musical acoustics and the *Benchmark* volume in this series has been brought up to date by Carleen Hutchins and Virginia Benade in a two-volume set *Research Papers in Violin Acoustics* published recently by the Acoustical Society of America.

Looking at my shelves, I see a large collection in my particular area of interest of musical acoustics. There are many titles that I would like to write about, but I am sure that others would feel just the same about their own interests. We can only be grateful for the wealth of fascinating literature that is available to us and to our students in this, our chosen field.

Neville Fletcher

Letters

More on Errors in Noise Modelling

I have received some comments on experiences with errors in noise modelling in reply to my letter in the last issue of the journal. I am still interested in obtaining more information on this topic including personal experiences and any references to publications. I would be grateful for your comments.

Namiko.Ranasinghe@environ.wa.gov.au
Phone: (08) 9222 7141 or (08) 9389 9334

Scientific Editors Needed

I run a business that edits scientific papers for non-native speakers of English and I am searching for Australian scientific editors who are interested in freelance work. In general, the freelancers we use have a PhD in the field of the paper they are editing. We look forward to hearing from you if you are interested in working for us.

Scott Butler,
Editor in Chief,
English Manager Science Editing
editor@sciencemanager.com
http://www.sciencemanager.com

New Members

New South Wales

Member: John Bassett, Peter Eisehuth, Andrew Wearne,

Graduate Densil Cabrera

Associate Stephen Childs

Queensland

Member: David Mee

Graduate Matthew Terlich

South Australia

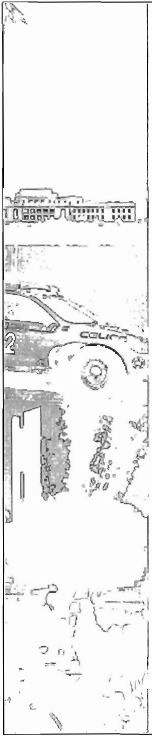
Member: Amanda Robinson

Victoria

Member: Paul Tierney

West Australia

Member: Michael Cake, Terry George



ACOUSTICS 2001

Noise and Vibration Policy – The Way Forward?

Australian Acoustical Society Annual Conference
21 to 23 November 2001 CANBERRA, ACT

The annual conference, organised by the Australian Acoustical Society (AAS), is being held in Canberra, the seat of Federal Parliament. It is therefore appropriate to take noise and vibration policy as a theme for the conference. This conference will combine contributed papers, technical presentations, awards and a range of social activities included in the delegate registration fee such as welcome buffet, conference dinner and farewell lunch.

CONFERENCE SESSIONS

A key representative from Government has been invited as the Opening Speaker at the conference welcome buffet on Wednesday evening. The sessions will be held on Thursday from 0800 to 1800 followed by the Dinner and on Friday from 0800 to 1400.

The conference will include **special sessions** on aspects of noise and vibration policy and the session leader has invited presentations on relevant areas:

Occupational noise	Environmental noise	Noise in buildings
Transportation noise	Vibration control	Airport/Aircraft noise

Contributed Papers related to the theme and to other topics on sound and vibration are invited. Peer review is available for all papers.

Technical Exhibition will be open from breakfast each day for the duration of the Conference for manufacturers and suppliers to show their latest products.. Those interested in exhibiting should contact conference organisers for details.

Technical Tours Wed afternoon: a 'behind the scenes' tour at Screen Sound Australia, the National Screen and Sound Archive, focussing on the techniques used for audio preservation. Friday afternoon: a special tour of Parliament House focussing on the diverse acoustic requirements.

Social Activities throughout the conference will all be held at Rydges. The welcome buffet, conference dinner and farewell lunch as well as breakfast, lunch and tea breaks each day are included in the registration fee. They will give plenty of opportunities for the delegates to discuss issues that have been raised in the sessions as well as to renew friendships and establish contacts for the future.

The after dinner speaker will be **Robyn Williams** from the ABC Science Show. If it can be assured this will be an interesting and stimulating view of acoustics related issues.

Standard Registration $450. Discounts: Early registration $50, Student registration $100, AAS Member $50. These rates include the proceedings, welcome buffet, conference dinner and farewell lunch plus breakfast, lunch and tea breaks.

Accompanying Members program includes the welcome buffet, conference dinner and farewell lunch. The extended breakfast on Thursday will allow for planning of the afternoon tour. **Accompanying member registration $150**

Critical Dates Paper Submission:		**Critical Dates Registration:**	
Abstract	extended to mid Aug	Early	by 21 August 2001
Paper	21 September 2001	Standard	by 21 October 2001

INFORMATION and REGISTRATION DETAILS
Acoustics and Vibration Unit, ADFA, CANBERRA 2600
Tel:02 6268 8241 Mob: 0402 240009 Fax:02 6268 8276
m.burgess@adfa.edu.au www.acoustics.asn.au

Diary...

2001

September 2-7, ROME
17th ICA
http://www.ica2001.it/ or A. Alippi, 17th ICA Secretariat, Dipartimento di Energetica, Universitá di Roma "La Sapienza", Via A. Scarpa 14, 00161 Roma, Italy, Fax: +39 6 4424 0183,

September 10-14 , PERUGIA
ISMA 2001 , CIARM & Catgut Acoust Soc
http://www.cini.ve.cnr.it/ISMA2001, Musical Acoustics Laboratory, Fondazione Scuola di San Giorgio - CNR, Isola di San Giorgio Maggiore, I-30124, Venezia,Italy, Fax: +39 041 5208135, isma2001@cini.ve.cnr.it

September 10-19, BRUSSELS
Responsive systems for active vibration control
ASI-NATO@ulb.ac.be, http://www.ulb.ac.be/scmero,

September 26-30, SKIATHOS
Acoustics and music: theory and applications
http://www.worldses.org/wses/conferences/skiathos/amta/

October 7 - 10, ATLANTA
2001 IEEE Int Ultrasonics Symp joint plus World Cong on Ultrasonics.
http://www.ieee-uffc.org/2001, fax: +1 217 244 0105

***October 9, SYDNEY**
Acoustics Workshop
National Voice Centre, University of Sydney, NSW 2006 tel 02 9351 5352, fax 02 9351 535, voice@cchs.usyd.edu.au

October 29 - 31, MAINE
NOISE CON 2001
http://users.aol.com/noiseconf/nc01.html, fax: +1 845 463 0201, hq@ince.org

October 24-27, MAINE
7th International Workshop on Railway Noise
http://www.7iwrn.com/

*** November 21-23, CANBERRA**
Acoustics 2001 AAS Annual Conference
http://www.users.bigpond.com/Acoustics, Acoustics 2001, Aust Defence Force Academy, Canberra, ACT 2600, avunit@adfa.edu.au

December 3-7, Ft LAUDERDALE
142nd Meeting of the Acoustical Society of America.
http://asa.aip.org, fax: +1 516 576 2377

2002

3-7 June, PITTSBURGH,
143rd Meeting of the Acoustical Society of America.
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4-6 June, ST. PETERSBURG,
6th Int Symp on Transport Noise & Vibration.
http://webcenter.ru/~eeaa/tn/eng/tn2002,
fax: +7 812 127 9323

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

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

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

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

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

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

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

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

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

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

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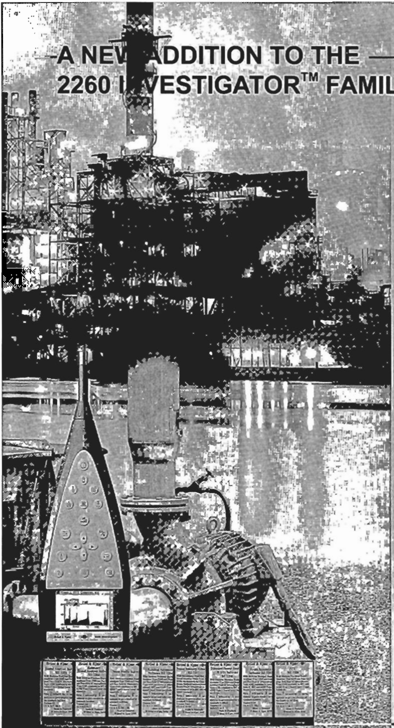

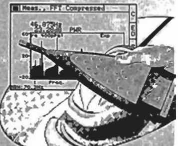

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