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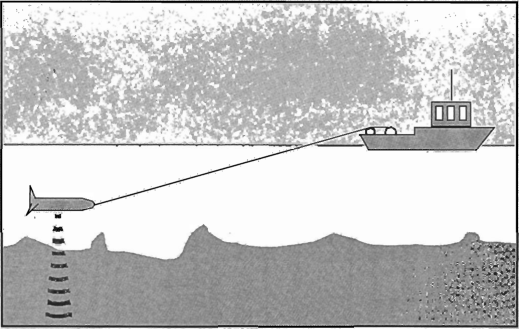

SPECIAL ISSUE: OCEAN ACOUSTICS

- *Scattering in the ocean*
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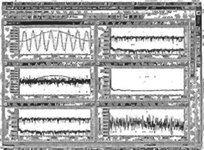

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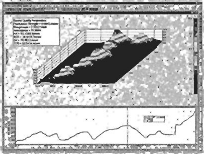

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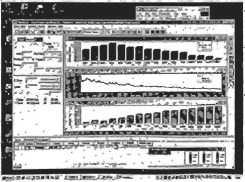

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From the President

What will be the situation of acoustics in Australia by 2020?

Simplistically, the members of our Society work in two broad areas. Many are in government funded institutions such as the National Measurement Laboratory, CSIRO, the EPA's as well as academia. However the majority are in private practice, consulting directly with the public and industry.

Senior acoustic consultants have a wealth of experience in solving the many common, and sometimes novel, noise problems that arise in the community. When new staff are hired, increasingly they have Degrees or Diplomas, but rarely are they in the specific area of acoustics. An engineering, science or architectural graduate may have had at most a few hours of training involving acoustics during their course and so they are ill prepared to rapidly become practicing acousticians. So in-house training usually occurs. The raw recruit learns acoustics from the master in the traditional way.

It is unfortunate that there is no full Degree involving acoustics in Australia and only a few courses that have even a modest component. As the years continue, the commitment to acoustics in education seems to be diminishing, rather than expanding, and this impacts not only on training but also the research and development which occurs in academia.

In the Government sector, acoustics is faring little better. Cut-backs have threatened the National Acoustics Laboratory, reduced the commitment of EPA's in the area of acoustics and, as CSIRO research scientist Dr. J. Davy comments in a recent submission about external earnings targets policy,

"CSIRO's acoustical expertise has been eroded to the point that it is almost unviable. Funding restrictions have meant that no succession planning has been possible in the building acoustics area."

If this trend continues, acoustic development could vanish from government installations within a few years, virtually leaving acoustics in the hands of the consultants. While I have no wish to denigrate their expertise and abilities, it would be a healthier situation for Australia if a balance remained between the private and the government sectors.

Charles Don

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SCATTERING IN THE OCEAN

L.J. Hamilton (editor), S. Anstee, P.B. Chapple, M.V. Hall and P.J. Mulhearn

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Defence Science & Technology Organisation (DSTO),
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ABSTRACT Acoustic scattering in the ocean can arise naturally from interactions of sound with suspended particles, volume inhomogeneities, bubbles, the moving random sea surface, the seabed, and organisms, either in resonant or nonresonant processes. Measurements of backscatter stimulated via these processes by active sonar associated with these phenomena generated by active sonar devices are becoming increasingly useful as remote sensing tools in highly diverse applications. These include assessments of fish stocks and fish migration, seabed and habitat characterization, inferences of turbidity, measurements of waves and currents, and detection of objects. Some of these applications are broadly described, together with the physical scattering mechanisms involved.

1. INTRODUCTION

Scattering processes in the from the ocean environment ocean causes reverberation, a major part of the unwanted background noise level that hinders military active operations of active sonars seeking to detect sound scattered by ships, submarines, and mines. Military sonar designs have previously sought to suppress environmental scattering to enhance their target-seeking ability. However, environmentally backscattered[1] sound Without backscattering in particular, which is that portion of the scattering that propagates directly back to the position of the transmitter, there would be no reverberation and sonar detection ranges would be vastly increased. So then, what good is marine acoustic scattering? Why should it be of interest? The answer is that from traditionally being a major handicap in marine sonic applications, backscatter now finds a surprisingly large number of applications in underwater acoustics. It is essentially used as a means of remote sensing, and as such can be used to quickly examine large oceanic volumes, or large areas of the air/sea or sea/bottom interfaces. Optical devices experience high attenuation, but direct sound transmission and acoustic backscatter can be used to probe oceanic processes over a very wide frequency range (Hz to MHz). Many interesting physical problems arise in marine acoustic scattering, since it involves interactions with physical, chemical, biological, geometrical, and geological properties of the environment. One of the more interesting applications can be found in sidescan sonars, which provide high resolutionhigh-resolution pictures of the seabed similar to video imagery. Other backscatter devices can infer concentrations of suspended solids at high levels where the usual optical measures are defeated.

Scattering is a function of frequency, being stronger for higher frequency components of a signal, and also of the size, compressibility, shape, and density of the scatterers, which can be discrete bodies (suspended particles), or roughness elements on a continuous surface. Scattering is a reradiation of incident acoustic energy. At low frequencies (wavelength λ much greater than the scatterer size) scattering is omnidirectional, while at high frequencies the scattering becomes directional (and the particle will cast a shadow).

Ocean water is turbid for light, but transparent for sound, because suspended particles are generally 1 to 10 microns in size, which makes them larger than optical wavelengths, but smaller than acoustical wavelengths (a 1-MHz sound wave has a wavelength of 1.5 mm). The optical cross section of a typical particle is similar to its geometrical cross-section, but its acoustic cross section is much smaller than its geometrical cross-section [6].

Optical devices experience high attenuation, but sound and acoustic backscatter can be used to probe oceanic processes over a very wide frequency range (Hz to MHz). Many interesting physical problems arise in marine acoustical scattering, involving as it does interactions with physical, chemical, biological, geometrical, and geological properties of the environment.

2. SCATTERING THEORY AND HIGH FREQUENCY SONARS (S. S. Anstee)

High-frequency sonars are the acoustic equivalent of vision systems, and work in much the same way. If something radiates sound, a sonar can use the phase and amplitude information in the radiated waves to estimate the location and nature of the source. However, most of the underwater environment does not spontaneously radiate sound, so manyost sonars rely on scattered sound, that is, sound bounced froming objects and interfacesfrom irregularities in the environment. Optical vision systems can often rely on intense external sources of radiation – the sun, room lighting and so on – to provide a radiation source. Natural sources of acoustic radiation are much weaker, although the technology for passive sonars relying on scattering of environmental noise, so called "acoustic daylight", is in development [26]. Most sonars relying on scattered sound are active, that is, they provide their own intense acoustic radiation source, most often adjacent to the receiver. The sound they emit is usually pulsed and coherent, more like a laser beam than a torch, with the energy centred on a relatively narrow band of frequencies[2].

When there is no change in sound speed, a sound wave propagates away from the source indefinitely, never returning.

---

[1] Backscattered sound is that part of the total scattered sound that goes back towards the source.

[2] Some active sonars are "broad-band", with bandwidths of one or more octaves. Such sonars emit pulses that can appear incoherent or "noisy", but knowledge of the exact waveform allows the sonar processor to select only echoes with exactly matching waveforms, thereby greatly increasing the signal to noise ratio.

However, when a travelling wave encounters an abrupt change or interface between two media with different physical properties, only part of the wave is transmitted across the interface, with the rest returning to the original medium. The phases and amplitudes of the transmitted and returned waves now contain additional information about the interface they encountered, encoded as phase and amplitude changes.

The field after the wave hits an interface can be expressed as

$$p(\mathbf{r},t) = p_{\mathrm{inc}}(\mathbf{r},t) + p_s(\mathbf{r},t) \tag{1}$$

the sum of the original, *incident* field and a new *scattered* field. Scattering is a reradiation of incident acoustic energy. *Reflection* is a special case of scattering where the scattered field retains most of the information in the incident field. If the interface is completely flat, the reflected field is (to within a scale factor) just the incident field that would have originated from a source placed at the reflected position of the true source. multiplied by a phase factor. *Scattering* is usually taken to mean the more general case where most of the original phase information is lost and the bulk of the information carried by the scattered field describes the interface it scattered from.

Scattering is a function of frequency, being stronger for higher frequency components of a signal, and also of the size, compressibility, shape, and density of the scatterer, which can be one or more discrete objects, or roughness elements on a continuous surface. At low frequencies (wavelength λ much greater than scatterer size, the Rayleigh criterion) scattering is omnidirectional, while at high frequencies the scattering becomes directional (and the object will cast a shadow). In general ocean water is turbid for light, but transparent for sound, even at several hundreds of kHz, because suspended particles (grains of clay) are typically 1 to 10 microns in size, which makes them larger than optical wavelengths, but smaller than acoustical wavelengths (a 1-MHz sound wave has a wavelength of 1.5 mm). The optical cross section of a typical particle (but not a bubble) is similar to its geometrical cross-section, but its acoustic cross section is much smaller than its geometrical cross-section [6]. Acoustic backscattering can therefore carry more energy over longer distances than optical wavelengths.

Discrete scatterers

The simplest scattering object is a sphere of gas immersed in a liquid, e.g., an air bubble in water. When a mono-frequency plane wave with frequency ω radians per second travelsing through the liquid and strikesing the sphere continues on, but the total field thereafter now includes a second, scattered field, p_s. For Rayleigh scattering the scattered pressure takes the form

$$p_s(r,t) \approx a_0 k^2 \frac{e^{i(kr-\omega t)}}{r} \tag{2}$$

Here, r is the radial distance; $k = 2\pi / \lambda$ is the wavenumber; and is a_0 complex constant. This is simply a travelling wave radiating outward from the scatterer, which functions like an elementary source. The wave contains no information about the source of the incident radiation, except for amplitude. A very small liquid or solid sphere also has this form of scattered pressure, but with an additional dipole term that preferentially forward- and back-scatters sound along the direction of propagation. An arbitrarily shaped small object also generates the same form of scattered field as a small sphere. Hence, when a sonar pings at water containing suspended sediments and plankton, each particle acts as a spherical scatterer and some of the energy is backscattered to the sonar as *volume reverberation*. Although the incoming sound is coherent, the particles are randomly distributed and the backscattered sound is an *incoherent* sum of waves with random phases and amplitudes.

Larger objects and surfaces

Scattering by larger objects and surfaces is more complicated, with a combination of reflection and random scattering contributing to the total pressure field. The field scattered by an arbitrary closed surface can be entirely described by the pressures and pressure gradients at the surface. The surface can be considered as a collection of elemental sources and dipoles, each radiating in all directions. When the surface is perfectly flat, the individual contributions all add in phase (coherently), and the form of the scattered pressure is similar to the form of becomes the same as thethe incident pressure times a constant, but appearing to come from a different source – "specular" scattering.

Both the seabed and sea surface can be approximated as flat surfaces perturbed by roughness, and the scattered field can then be predicted. However, the resulting equation is generally difficult to solve.

If we assume that each surface element acts like an infinite plane and ignore any interactions between elements, then $p(\mathbf{r}')\approx (1+R)\mathrm{p}_{\mathrm{inc}}(\mathbf{r}')$ and, $\nabla' p(\mathbf{r}')=(1-R)\nabla' p_{\mathrm{inc}}(\mathbf{r}')$, where R is the plane-wave reflection coefficient the surface would have if it were uniform and flat. Then the solution for the scattered pressure equation collapses to a function of the incident pressure and is easy to evaluate. This is the *Kirchhoff* or *physical acoustics* approximation. Experimentally it is a good fit for backscatter when the sonar looks steeply down at the seabed or up at the sea surface, and for forward scatter, as long as the surface is not too rough. It is a poor approximation when the sound approaches the surface from a shallow angle, but in such cases, another approximation, the *small roughness* approximation, may be used. In this approximation, seabed roughness is treated as a vertical perturbation away from a flat surface and the surface pressure is perturbed by an amount $p_1(\mathbf{r}') \approx -h(\partial p_{\mathrm{inc}}/\partial z+\partial p_s^{(0)}/\partial z)$, where z is vertical direction, h the vertical roughness scale and the pressure field that would be scattered from a perfectly flat surface. It turns out that the first-order *coherent* field is zero – the roughness makes no difference to the energy reflected from the underlying flat surface, but the first order *diffuse* or *incoherent* field is non-zero. The diffuse field is sensitive to the proportion of points on the surface that happen to be correctly separated to scatter sound at the observing direction, as though the surface were a random ensemble of Bragg diffraction gratings. In between steep and shallow incident angles, it is possible to interpolate between the small roughness and Kirchhoff regimes, or use other, more general approximations. In situations of extreme roughness, all of these approximations break down and an empirical approach is taken.

3. ACOUSTICAL SEABED IMAGING
(P.B. Chapple)

Acoustic backscatter from the seabed can be used to image the seabed, enabling active sonar systems to provide valuable information about seabed properties. Acoustics is particularly important in this role, because ocean waters are usually too deep and turbid for optical imaging to be effective. Information obtainable includes bathymetry (depth), seabed hardness, clutter, slope and the presence of objects on the seafloor. At frequencies less than about 50 kHz, significant energy can penetrate the seabed, particularly for soft sediments, and some sub-bottom information can be obtained using suitably designed systems. At higher frequencies, there is very little seabed penetration, and information obtained from seabed backscatter essentially indicates the properties of the seabed surface. Using frequencies as high as 500 kHz, it is possible to image the seabed with 10 to 20 cm horizontal resolution, although range is often limited to about 100 m.

The most popular method of acoustically imaging the seabed is using sidescan sonar (Figure 1). Acoustic energy is emitted from either side of a moving vessel, or from a towfish pulled by the vessel, from horizontal linear arrays of transducers on the port and starboard sides which point slightly downwards. The beamwidth is narrow in the along-track direction, but broad in elevation or across-track direction, enabling a thin strip or narrow swathe to be ensonified perpendicular to the array with each sonar ping (Figure 1). Backscattered energy from the seabed is used to build an image of the seabed, strip by strip, as the vessel moves along. The timing of the return signal from each acoustic pulse is used for estimating the range of the patch of seabed contributing to the signal. A "waterfall" display of the seabed is formed as the vessel moves along (Figure 2(a)).

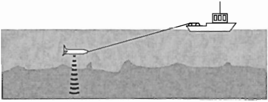

Figure 1: (a) Towed sidescan sonar.

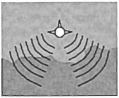

Figure 1: (b) End view of towfish

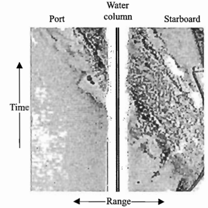

Figure 2: (a) Waterfall image, that scrolls downwards during data acquisition (from the Klein 5500 sidescan sonar). Smooth seabed on the lower left is disrupted by the rough surface of the Sydney Harbour tunnel.

Figure 2: (b) Mosaic image of the seabed of Sydney Cove, including Circular Quay wharves and the rough surface above the Harbour Tunnel.

The depth of a sloping seabed cannot be reliably estimated from sidescan sonar. A flat-bottom assumption is made in order to estimate the location of each part of the imaged seabed, which is calculated from a combination of range, estimated position of the towfish relative to the towing vessel and the differential GPS position acquired at the boat. Utilising this information, a mosaic image of the seabed can be formed (Figure 2(b)) from numerous boat tracks.

The texture of sidescan sonar images can be used to characterise the seabed, by segmentation into regions with different textural statistics, indicating the presence of mud or sand, scattered rock and other bottom types. Several difficulties arise in this approach: (i) The appearance of the seabed in a sidescan image depends on the distance from the nadir. There is generally poor horizontal resolution in the nadir region. (ii) The appearance of features such as sand waves depends strongly on the direction of ensonification. (iii) Seabed slope significantly affects the appearance of sidescan imagery, complicating attempts to determine seabed type.

Multibeam echosounder systems allow seabed imaging with bathymetric information. While the feature detection capabilities are not usually as good as for sidescan sonar, some modern systems such as the Reson 8125 have very high spatial resolution. Bathymetric relief images can be segmented to delineate different broad-scale texture regions, with the seabed characterisation independent of the direction of ensonification. Further seabed information can be obtained by measuring the backscatter magnitude as a function of the angle of incidence of the acoustic wave on the seabed.

4. SEABED PROPERTIES MODELLING AND INVERSION TECHNIQUES (P.J. Mulhearn)

The shapes and energies of echoes received by echosounders depend on bottom acoustic hardness and roughness. The first part of the echo shape is a peak dominantly from specular return, and the second part is a decaying tail principally from incoherent backscatter contributions. Rougher sediment surfaces provide more backscattered energy than smoother surfaces (which simply reflect the energy away from the direction of the transducer), so their echoes are expected to have lower peaks and longer tails than smoother surfaces of the same composition. Echo shape is also affected by sub-bottom volume reverberation including contributions from gas bubbles, and echosounder characteristics such as frequency, ping length, ping shape, and beam width.

A number of acoustic seabed classification systems are commercially available which can be used to estimate seabed properties from echo characteristics [14] using one of two empirical methods: (i) echo statistics are obtained at a number of sites with known seabed type, to calibrate the system. The whole area is then surveyed, and the seabed classified as belonging to one of these types; or (ii) an area is surveyed and the echoes are grouped by some statistical technique into a number of classes, which are subsequently ground-truthed. At times the first approach may reveal seabed types for which calibrations were not obtained, so that some post calibration is required.

The oldest commercial system is RoxAnn, which uses the first and second echoes from the seabed [4,16]. The first echo simply travels from the transducer to the seabed and back to the transducer. The second goes from the transducer to the seabed back to the sea surface (including part of the ship's hull), back to the seabed and finally back to the transducer. RoxAnn uses the energy in the tail of the first echo as a measure of sea floor roughness and the total energy in the second echo as a measure of sea floor "hardness". These two parameters are really indices of seabed acoustic backscatter and acoustic impedance, respectively.

The second most used commercial system is QTC-View, from Quester Tangent Corporation (QTC) [25,15]. QTC uses only the first echo, calculating 166 statistical parameters from it. Principal Component Analysis is used to derive three "Q-factors", which are linear combinations of the 166 parameters. These three Q-factors are the three major Principal Components specifying the shape of the waveforms. The system then clusters seabed types in either a supervised or unsupervised classification mode, much like methods (i) and (ii) above, respectively.

It is important to better understand what these empirical seabed classification systems are really measuring, and to determine how well they can be expected to work. To these ends existing models of seabed acoustic backscatter are being utilised to examine the characteristics of acoustic returns from the seabed at steep grazing angles (e.g. 65° to 90°) for frequencies between 10 and 100 kHz [22]. A widely used model is that of Jackson [2], in which seabed backscatter is modelled as the sum of both a surface and a volume term. The model provides backscatter as a function of grazing angle, but no information on backscatter versus time, so that it provides no information about the shape of a return pulse. Examination of the model indicates that for the above range of grazing angles, and all but the very roughest of surfaces, the Kirchhoff approximation provides a good model of the surface scattering contribution. It can also be concluded, for realistic ranges of input parameters, that the dominant factors influencing backscatter are: roughness size; the ratio of sediment to water acoustic impedance; and a volume backscattering parameter, σ_v, the dimensionless backscattering cross section per unit solid angle per unit area due to volume scattering below the sediment surface.

It should be possible, from real data of acoustic backscatter versus grazing angle, to estimate these three parameters, because of their different influences on the shape of the backscatter versus grazing angle curve. From these three parameters it would then be possible to infer sediment type. Curves for typical sediments are shown in Figure 3. However echosounders obtain backscatter versus time over a range of grazing angles, not backscatter versus grazing angle.

To examine the time evolution of the return pulse from a seabed surface a model, called BORIS-3D (Bottom Response from Inhomogeneities and Surface) was recently developed at NATO's SACLANT Undersea Research Centre in La Spezia, Italy [24,3]. This model uses the Kirchhoff approximation for the surface scattering and Small Perturbation theory for volume scattering. For a given transmitted impulse shape, surface and volume backscattered time-series are computed and summed. Figure 4 shows the geometry of the set-up. Surface and volume responses will generally overlap in time. Modelling of responses from various realistic sea floors is currently in progress.

5. VOLUME BACKSCATTER (M.V. Hall)

Volume backscattering from within the water column gives rise to reverberation at any frequency, but the results discussed here are confined to frequencies between 2 and 20 kHz (λ from 75 to 7.5 cm). At these frequencies the major scattering objects are fish swim bladders, which contain air. Many species of fish have a swim bladder, with general function to keep the fish neutrally buoyant. Large shallow water fish have muscles attached to their bladder, and use it as

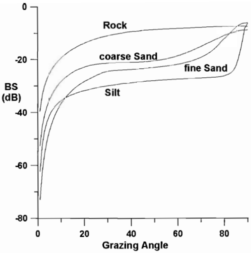

Figure 3. Modelled backscatter versus Grazing Angle Curves for different bottom types, using typical sediment parameters for each type. BS = Backscatter Strength.

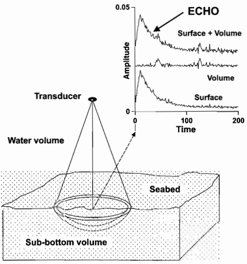

Figure 4. Construction of a simulated time series for reconstruction of bottom echoes. The echo starts on the first vertical contact of the ping with the seabed, and for subsequent sampling intervals is the sum of a surface contribution from annuli whose radii increase with time, coupled with volume contributions.

their vocal chord. Small deep-sea (mesopelagic) fish do not make sounds with it, but can pump dissolved air in, and back out, to maintain the bladder at a constant volume as they make diurnal depth migrations. Although only around 5% by volume of the fish body, the bladder dominates the scattering at all wavelengths greater than the fish dimensions because it contains air. In addition there is also a low resonance frequency, which is determined by the elasticity of the air and the mass of the surrounding tissue and seawater.

Simple bubble resonance theory

For a free spherical bubble of radius a in water of density ρ, the resonance frequency f_0 is given by [21]:

$$f_0 = \sqrt{}(3\, \gamma\, P_0/\rho)\ /2\, \pi\, a \qquad (4)$$

where γ is the ratio of specific heats, and P_0 is the local hydrostatic pressure: $P_0 = \rho\, g\, (z + 10)$, in which z is depth in metres. For a radius of 2 mm for example, the resonance frequency at the surface ($z = 0$) is 1.6 kHz ($\lambda = 94$ cm), whereas at a depth of 500 m it would be 12 kHz ($\lambda = 13$ cm). These wavelengths are much greater than the bubble size, so the scattering is omnidirectional. The resonance wavelength being orders of magnitude larger than the size of the object is an unusual phenomenon. For a conventional Helmholtz resonator such as the milk bottle, the elasticity and mass are both those of the internal fluid, and the resonance wavelength is comparable to its length. For a bubble however, the properties come from different media: the elasticity is that of the gas, while the mass is that of the water. For a bubble encased in solid tissue, the shear modulus also has an effect on the resonance frequency [1]. By modelling the bladder as a shell, the following approximate expression has been derived [11]:

$$f_0 = \sqrt{}\{3\, m\, \gamma\, P_0\, /[4\, \pi^2\, a^2\, \rho\, /\phi - 4(m-1)d]\} \qquad (5)$$

where m is the ratio of the external to internal volumes of the shell ($m \approx 2$), ϕ is the shape correction factor to allow for the bladder being non-spherical ($\phi \approx 1.1$), and d is the constant of proportionality in the relation between tissue shear modulus and frequency-squared ($d \approx 0.001$ kg/m).

Scattering cross-section

The scattering cross section (σ) of an object is 4π times its scattering or target strength, since σ gives the power scattered in all directions, while the scattering strength gives the power scattered per unit solid angle. At high frequencies ($\lambda < a$) the scattering cross section approximately equals the cross-sectional area of the object ($\sigma \approx \pi a^2$ for a sphere). At low frequencies the general behaviour is that $\sigma \propto f^4$ (Rayleigh scattering), and any resonance will appear as a perturbation. The scattering cross section at frequency f of an object resonant at frequency f_0 is given by [5]:

$$\sigma(f) = 4\, \pi\, a^2\, /[(f_0^{\,2}/f^{\,2} - 1)^2 + \delta^2] \qquad (6)$$

where δ is the acoustic damping term. An expression for δ for a free bubble was discussed by [8], and an adaptation to a swimbladder was given in [11]. In general its order of magnitude is 0.1.
At resonance the scattering cross section is

$$\sigma(f_0) = 4\, \pi\, a^2\, /\delta^2. \qquad (7)$$

As $f/f_0 \rightarrow 0$, $\sigma(f) \rightarrow 4\pi a^2 (f/f_0)^4$. Equation (7) is not valid for high frequencies, since its derivation assumes the pressure to be uniform over the surface of the bubble, which is equivalent to assuming $\lambda >> a$. As $f/f_0 \rightarrow \infty$, Eq. (6) yields $\sigma(f) \rightarrow 4\pi a^2$ for small δ, whereas the correct asymptote is πa^2.

Bio-mass estimates

Volume backscattering has been used by several institutions world-wide to estimate biomass. In Australasia the most active have been the New Zealand Ministry of Agriculture & Fisheries [9,7], and the CSIRO Division of Marine Research [10,18]. These surveys used narrow-band ultrasonic projectors as the sound source, and made use of the beam pattern of the emitted signal. A study involving one of the authors [12] used small explosive charges as the sound source. These are omnidirectional but contain useful energy over frequencies up to 20 kHz. Midwater trawls were conducted concurrently with an 8-square-metre net. The fish caught were weighed and sorted into classes based on mass. For each class the swimbladder size was estimated and the corresponding resonance frequency, for the known trawl depth, was determined using Eq. (6). From the population density of each class, the reverberation in each third-octave band from 2.5 to 20 kHz was computed using Eq. (7), and the results were compared with the measured reverberation. There was generally good agreement at frequencies above 8 kHz. The main difference was that although the trawls did not catch any fish heavier than 3 g, the acoustic results indicated that many heavier fish were in fact present. This difference was attributed to the ability of these larger fish to escape capture.

Effect on sonar

It is important for active sonars to have a narrow beam pattern, for both localising a target, and also to reduce the level of reverberation. Because of the large volumes of water ensonified by a sonar beam at long ranges, volume reverberation is generally the environmental parameter that limits the performance of long range active sonar. By having a database or model of the dependence of backscattering on frequency, geographic location, time of day, and depth, a sonar operator can adjust the carrier frequency of a sonar to obtain the optimum performance for a given location and time of day.

6. TURBIDITY (L.J. Hamilton)

Measurements of suspended sediment concentration (SSC) profiles in aquatic environments are used for diverse purposes e.g. examination of turbidity or water clarity, pollution studies, underwater visibility, sediment transport rates, and knowledge of the dynamics affecting turbidity e.g. wave processes. It is possible to estimate SSC at high temporal (0.1–1 s) and spatial (1–10 cm) resolutions with Acoustic BackScatter (ABS) instruments, and to remotely and non-intrusively monitor and image suspension processes in real-time. ABS instruments infer SSC profiles by emitting bursts of MHz frequency pulses, and time gating the return. Narrow beamwidths are used e.g. 1.5°. Ranges of 10–20 m may be obtained at 0.5 MHz, and about 1 m for 3 MHz. After allowance for transmission losses, and by making some simple assumptions about suspended sediment properties, the backscatter can be directly related to SSC.

The backscatter processes may be described by single scattering theory [30]. Negligible grain shielding and negligible multiple scattering are assumed, with allowance for near and far-field transducer beam patterns, beam spreading, and absorption due to water and the suspended sediment itself. Absorption by suspended sediment is assumed to be proportional to SSC, a simple assumption yielding good results [30]. Attenuation constant for a particular sediment particle size may be calculated from formulae [27,28], and absorption due to water is calculated from temperature and salinity measurements. The backscattered pressure or voltage signals received by the transducer from scatterers in a particular range bin are treated as incoherent [29] (also see Section 2), allowing them to be squared and summed without phase considerations.

If backscatter were sensitive to particle volume, then for constant particle density, changes in size distribution during measurements would not affect inferences of SSC [20]. However, in the Rayleigh region the size, shape, and density of irregularly shaped particles chiefly determine the backscatter [28,27]. To overcome this it is commonly assumed particle size distribution and particle backscatter function at a site are invariant during measurements, and that only total concentration varies at any depth in the column, a necessary but weak link in the calibration [20]. To reduce variability in the Rayleigh distributed backscatter from a particular range bin, backscatter values are averages for pulse trains. With the stated assumptions, backscatter is linearly proportional only to concentration, and SSC can be obtained to within 20–30%.

Calibration is usually performed after laboratory determinations of SSC have been obtained from water samples, but useful field calibrations can be made in conjunction with optical devices [13]. In the latest developments in this field, multifrequency devices are used to infer both SSC and particle diameter [19,31], although inversions are subject to noise, and only short ranges of about 1 metre are obtained. ABS instruments provide a highly versatile means of routinely obtaining information on dynamic turbidity events and suspension profiles.

7. CONCLUSION

Acoustical backscattering is an extremely useful means of probing the oceanic environment which finds application over a wide range of technology and physical processes. In usefulness and scope it may be compared to satellite based remote sensing techniques, although having a more limited scale, with both technologies being able to probe large areas in short times in a repeatable fashion. Other applications of acoustic backscatter employing very different principles than those discussed here also exist e.g. use of Doppler shift from scatterers to infer current profiles; characterisation of vegetation by classifying the jagged pattern obtained when transiting the vegetation; and estimates of fish populations by echo counting. From being merely a hindrance to sonar applications, backscatter is now a fully realized tool for diverse oceanic investigations.

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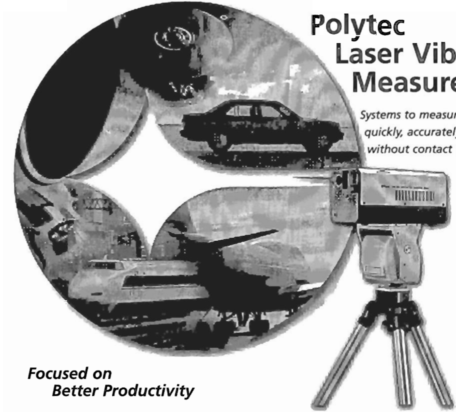

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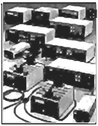

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AUSTRALIAN RESEARCH IN AMBIENT SEA NOISE

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ABSTRACT: Ambient noise in the ocean results from the contributions of many different sources and varies over a wide range of levels, more than 20 dB variation being common. It causes a wide variation in sonar performance and prediction methods are required for the effective design, acquisition and operation of sonars. Ambient noise in Australian waters is substantially different to that in the waters around North America and Europe where most earlier measurements of noise were made. Consequently, ambient noise prediction methods developed in the northern hemisphere are of limited use in Australian waters and there has been a continuing, though low level, research effort to categorise ambient noise in this part of the world. This paper reviews recent research on ambient noise in Australian waters in the context of earlier work. The main components of ambient noise are the noise of breaking waves at the sea surface and the noise of the marine animals. Distant shipping traffic and rain on the sea surface are also significant. Lower levels of traffic noise in this part of the world have revealed aspects of natural noise not examined elsewhere. The extraordinary range and variety of marine animal sounds are of particular interest both in the impact on sonar and the significance in animal behaviour.

1. INTRODUCTION

Ambient sea noise is the acoustic background noise in the ocean from all sources. It is of interest in its own right in terms of what we can learn about ocean processes and communication and behaviour of marine animals. It is also a major limitation on sonar performance since signals must be detected against this ambient noise. We and the marine animals use sound extensively in the ocean because under most conditions, it is the most effective means of transmitting information over any distance through water. Shallow, clear waters, such as those of the Great Barrier Reef are exceptions where light and vision play a major role. Even so, sound is used extensively by animals in such environments. Under most conditions, electromagnetic radiation is so limited by absorption of energy in water that it is effective only over very short ranges. Sound, on the other hand, loses very little energy in water by absorption, at least in the audio frequency range, and travels to great distances, some sources being detectable across the full width of an ocean basin. This very low absorption contrasts with the conditions in air where the high absorption rate causes sound to be generally a local phenomenon, most sources being effective over distances of metres to tens of metres. Sound travels two orders of magnitude farther in water than in air for the same amount of absorption attenuation.

While the transparency of the ocean to sound allows transmission over large distances, it also means that sources at large distances (up to tens and sometimes hundreds of kilometres) contribute to the ambient noise, leading to high and very variable ambient noise levels. It is common for ambient background noise, excluding contributions from close sources, to vary over a range of about 20 dB as a result of varying weather conditions, distant shipping densities or biological behaviour or habitat, and this variation may be temporal, seasonal or geographical. The full range of variation of ambient noise, however is more than 30 dB, and ambient noise levels over the frequency band 50 Hz to 10 kHz are typically in the range 90-120 dB re 1 mPa. This variation applies to the background noise and does not include the much wider variation caused by close sources such as a passing ship. A change of 20 dB in noise level will change the propagation loss that can be tolerated at the threshold of detection of a sonar by an amount that typically corresponds to a factor of 10 in range (though is quite variable). Ambient noise is the main component of background noise in passive sonars, dominating in most but the quietest conditions, so is critical to its performance. Ambient noise is less of a limitation on active sonar, since it is reverberation limited for shorter range targets, though there have been examples where active sonar performance was so degraded by ambient noise that it was barely effective. These comments apply whether the sonar is man made or the acoustic function of an animal.

Because of the major effect on sonar performance, it is routine for sonar operators to make ambient noise predictions to estimate the detection ranges they can expect to achieve for the prevailing conditions. The wide variations in noise and thus sonar performance can be exploited tactically in naval operations, and computer based prediction systems are now used for this purpose. Most sonars are designed for waters around north America and Europe where ambient noise is significantly different to that of the warmer waters around Australia. Some sonars have needed significant modification to perform effectively in Australian waters.

The early research into ambient noise was concentrated around North America and Europe. Ambient noise is substantially different in the Australian region because of environmental differences so there has been a continuing research program aimed at understanding and predicting the noise for Australian conditions. Some aspects of ambient noise would be expected to be common to all environments, an example being the noise of breaking waves, so our research has also contributed to universal knowledge of ambient noise and has been able to build on results from other parts of the world. Nevertheless, even after 60 years of research world wide, there remains a lot that is not understood about ambient noise.

While it is generally recognised that ambient noise is a limitation on sonar performance, there are conceptual difficulties in dealing with this problem. The first is the failure to understand that the noise varies over such a wide range that a few spot measurements at a location are almost useless in typifying the ambient noise at that location. The other is that the noise has only a weak dependence on position: it varies far more with time. The noise depends on the weather as it influences sea conditions and on the behaviour, distribution and migrations of marine animals. The dependence on position and time is so complex that there is little point in trying "map" ambient noise from routine data collection over the waters of interest, even if we had the enormous resources required. Consequently, our approach has been to understand the phenomena, the physical processes that generate the noise and the behaviour of the biological sources. Noise prediction depends on distilling the resulting knowledge to relatively simple relationships between the components of noise and readily available variables. For example, noise from breaking waves can be predicted from wind speed, and consequently changes in noise can be forecast from weather forecasts. Biological noise can be predicted from known behaviour, migration and habitats of marine mammals, once their acoustic behaviours are known.

Early Work

The first significant study of ambient noise was conducted during the second world war in response to degradation of sonar performance caused by unidentified noise. It was not known at the time whether this was jamming by the enemy or natural noise. The study showed that in fact it was the natural ambient noise (the sounds of shrimps) and the resulting publications (Knudsen, Alford and Emling, 1944, 1948) provided a remarkably comprehensive summary of the major components of ambient noise. The noise prediction curves — the "Knudsen curves" — are still sometimes quoted today. They identified the main components of noise in shallow water as (a) water motion near the sea surface (breaking waves), (b) marine life and (c) ships. Noise from breaking waves was related to sea state. Noise from marine life included choruses such as the wide spread noise of snapping shrimps that abound in shallow water.

Wenz (1962) refined the interpretation of the ambient noise, based on a large series of measurements. He presented "traffic noise" spectra which he defined as the background noise from many ships, none of which was detectable as such. This resulted from contributions from a large number of ships over distances of hundreds of kilometres and provided a general low frequency background, with a spectral slope of -3 to -6 dB per octave, falling below other components above 100-200 Hz. Traffic noise around Australia varies widely, generally in accordance with the shipping densities and propagation conditions (Cato, 1978). Wenz also presented revised sea surface noise spectra as "wind dependent noise," having a broad peak at around 500 Hz and differing significantly from the Knudsen curves below this frequency. Relating breaking wave noise to wind speed rather than wave height may be counter intuitive, but further studies (e.g. Perrone, 1969) supported this. The noise correlates much better with wind speed than with any measure of wave height. It is the action of wind that causes sea surface waves, but it takes many hours for a sea to develop fully, and the wave height at any time depends on the wind speed, on the wind duration and on the fetch. If the wind drops, it may take hours for the waves to diminish but the breaking of waves and the noise generated drops concurrently with the wind.

2. NOISE GENERATED BY SEA SURFACE MOTION

Any motion of a fluid interface that is a discontinuity in density or sound speed generates sound, and the source strength depends on the difference in the product of density and sound speed squared (i.e. difference in the inverse of compressibility) either side of the interface (Cato, 1991a). There are a number of such interfaces in the vicinity of the sea surface with large differences in density and sound speed, so each are potentially significant sources of sound. A simple example is the oscillation of an air bubble in water, which has been extensively studied in classical acoustics (Minnaert, 1933).

Noise of Breaking Waves — Wind-Dependent Noise

Although this was recognised as a major component of noise in the earliest studies, it was not until the late 1980s that the source mechanism was determined. Laboratory experiments by Banner and Cato (1988) using a simple breaking wave showed that the noise resulted from the oscillation of bubbles immediately on formation by air entrainment as the wave broke. Further experiments built on this work (Medwin and Beaky, 1989; Pumphrey and Ffowcs Williams, 1990) providing further evidence of the source characteristics. Observations of individual breaking waves at sea were consistent with these results, though the individual bubble contribution could not be detected (Updegraff and Anderson, 1991).

Air is entrained in the breaking wave and is compressed by the weight of the overlying water to pressures greater than the surrounding water pressure. The excess pressure causes the air to expand to form a bubble, and as it expands the momentum carries it on beyond the size at which the internal pressure matches the water pressure, resulting in lightly damped oscillation. Since the bubble oscillates volumetrically it is a monopole source, and few natural sources of sound are so efficient. The proximity to the sea surface, however, changes the radiation pattern to effectively that of a dipole, since reflection from the surface provides almost perfect reflection with a phase reversal, i.e. an out of phase surface image. This results in breaking wave noise radiating preferentially downward, as Ferguson and Wyllie (1987) have shown experimentally.

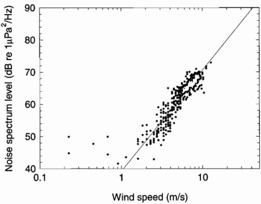

Figure 1. Noise from breaking waves at the sea surface as function of wind speed (spectrum level averaged over the 1/3 octave band centred at 1 kHz). Measurements were made at a fixed position in Spencer Gulf where there is little contribution from other sources. There are more than 500 data points.

An example of the dependence of noise on wind speed in Spencer Gulf, South Australia, is shown in Fig. 1 (Cato et al. 1995). Such a good correlation (coefficient 0.93) is, however, an unusual result. Spencer Gulf is an unusually quiet site, with little noise from other sources, so that wind dependent noise is evident for wind speeds as low as 2 m/s. In the open ocean, other sources of noise such as traffic noise dominate at low wind speeds and the contamination of these sources results in a poorer correlation of noise with wind speed and a regression line with a lower slope than in Fig. 1, since other sources of noise contribute at the lower wind speeds in a way that is not possible to remove. The slope of the regression line in Fig. 1 gives noise intensity as proportional to the cube of the wind speed consistent with the dependence of wave breaking on wind speed.

Typical spectra of this component of wind dependent noise were given by Wenz (1962), and similar spectra have been measured in many subsequent studies. It shows a broad peak at about 500 Hz and is usually dominant from about 100 Hz to some tens of kilohertz. The characteristics of the received noise field depend on the propagation of sound as well as on the source characteristics. Since breaking wave sources radiate preferentially downwards, the steeper rays carry the most energy and multiple bottom and surface reflections are required for contributions beyond a fairly local region. Thus the area of sources contributing to the field at a receiver varies substantially with the reflectivity of the bottom. For a completely absorbing bottom, 90% of the noise energy comes from sources in a circular area with a radius three times the water depth (Cato and Tavener, 1997a). A reflective bottom expands this area substantially, and modelling by Kuperman and Ingenito (1980), Chapman (1987) and Harrison (1996) indicate that the variation in the effective area of sources may vary by at least an order of magnitude. Since bottom reflectivity is frequency dependent, the spectral shapes of the received noise may also vary.

A wide variation in wind dependent noise between locations is in fact observed. Usually the correlation of noise on wind speed is poorer than that of Fig. 1, the slopes of the regression lines vary as do the spectral shapes (there are significant differences between Spencer Gulf and waters off Perth for example: Cato, 1997; Cato and Tavener, 1997b). Some of this variation may be due to the unknown influence of the surface wave properties, some is due to contamination of measurements by other sources of noise, but much is likely to be due to variations in propagation conditions. Better prediction of wind dependent noise requires the development of a model of the source field and matching of this to a propagation model to calculate the received noise field. Since the measurements that we have to work with in the ocean are of the received noise field, we need methods of inverting these measurements to estimate the source field characteristics, thus removing the effect of propagation at the site of measurements. This is a difficult experiment because of the precision of the measurements required in the received noise field and the detailed knowledge of the bottom acoustics needed.

Low Frequency Wind-Dependent Noise

This is the dominant prevailing component of ambient noise at frequencies below about 200 Hz in the Australian region and probably in much of the world, but it does not appear in noise prediction methods from the northern hemisphere. The reason is that the northern hemisphere methods were derived from measurements in waters of high shipping densities so that the high levels of traffic noise made this component difficult to detect. The spectral slope of -3 to -6 dB per octave is similar to that of traffic noise and there is nothing in the characteristics of the noise to distinguish it from sea surface generated noise. Both result from such a large number of sources that any individual characteristics are lost. The lower levels of traffic noise in a Australian waters have allowed us to measure this component by determining the dependence of noise on wind speed (Cato, 1978; Burgess and Kewley, 1983; Cato and Tavener, 1997b). Evidence of this component can be seen in a few North American studies, particularly those of Piggot (1964). Wenz (1962) noted evidence of this component in some of his data, but did not include it in his prediction methods, presumably through lack of data. Examples of the wind dependent noise spectra (with both components combined) measured in Australian waters are shown in Fig. 2 (Cato and Tavener, 1997b).

This is a good example of differences in environmental data between Australian and northern hemisphere studies, even where the actual property of the environment could be expected to be similar. This component causes ambient noise to vary with wind speed by more than 20 dB in Australian waters, but none of this would be predicted using northern hemisphere methods. It turns out that at winds of 15-20 m/s, this component of surface noise is comparable to the high levels of traffic noise in Northern American waters.

While the source of this low frequency noise has yet to be determined, a likely cause is the oscillation of bubble clouds as

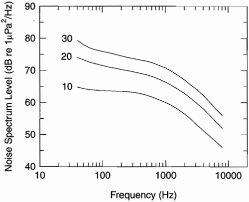

Figure 2. Averaged sea surface noise spectra at the wind speeds shown in knots, measured off Perth.

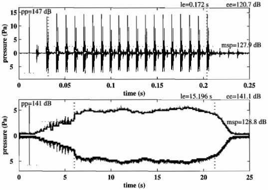

Figure 3. (Top) Call from a fish of the family Terapontidae (McCauley 2001), and (bottom) call from a blue whale (McCauley et al 2001), showing several types of call level descriptors. Note the two orders of magnitude difference in the time scales. Abbreviations are: pp = peak-peak (dB re 1mPa); ee = equivalent energy (dB re 1mPa2.s); msp = mean squared pressure (dB re 1mPa); le = call length (s) as defined by time taken between 5 and 95% of the energy to pass (with these time bounds shown by the vertical dotted lines). Trailing surface reflections are evident in the fish call.

proposed by Prosperetti (1988) and Carey and Browning (1988). Large numbers of bubbles formed by a breaking wave might oscillate collectively, effectively like one large bubble. The cloud has a lower sound speed due to the entrained air and thus lower compressibility, forming an effective large volume source.

3. BIOLOGICAL NOISE

Because marine animals make extensive use of sound, a substantial part of the ambient noise is biological. Individual biological sounds vary from a few microseconds duration at frequencies up to hundreds of kilohertz (snapping shrimps: Everest et al. 1948; Cato and Bell, 1992; dolphins: Au 1993) to 15 to 20 s duration at frequencies as low as 20 Hz (blue whales: Cummings and Thompson, 1971; McCauley et al. 2000a). The sounds of most animals, however, are within the audio frequency range and durations lie between 0.1 to 5 s. Examples of the wave forms of a fish and a whale call, illustrating differences in signal length and measures of signal magnitude are shown in Fig. 3. Individual sounds are detectable as signals by sonars and must be separated from signals of interest. Many animals call repeatedly for hours, causing interference over a long period, both to sonar and presumably, to other marine animals. Some animals occur in such large numbers that, calling en masse, they produce a continuous component of the ambient background noise, referred to as a chorus.

The importance of biological noise was recognised in the earliest studies of ambient noise (Knudsen at al, 1944, 1948), but biological noise is generally not well represented in ambient noise prediction methods developed for the northern hemisphere. In Australian waters, biological noise is so substantial and wide spread that no prediction method would be adequate without the biological noise component. The difference is partly due to differences in the environments — Australian waters are warmer and include a substantial amount of tropical water, and there has been a greater interest in shallow water.

In shallow tropical waters near Australia, biological noise is a major component over most of the frequency band from about 50 Hz to hundreds of kilohertz, and dominates at low wind speeds (Cato, 1980, 1992). It is only during heavy rain that the biological contribution ceases to be important. Biological choruses from large numbers of individuals calling are wide spread in temperate as well as tropical waters, and these regularly cause variations in noise level of more than 20 dB over periods of a few hours or more (Cato, 1978; McCauley and Cato, 2000).

The marine mammals produce the highest source level sounds and are the main sources of transient signals, while fish and invertebrates tend to be the main sources of choruses, though whales also produce choruses. There is, however, no clear dividing line and as transients become more numerous, they contribute significantly to the background noise.

Marine Mammal Sounds

Marine mammals, especially whales, are the main sources of intense transients. Whale numbers in Australian waters have been steadily increasing over the last three decades, and the general increase in the contribution to the ambient noise over this time has been very evident. The rate of increase shows no signs of abating. The main contributors to the ambient noise in Australian waters are humpback whales, blue whales and sperm whales, and to a lesser extent, dolphins.

Humpback whales

Humpback whales migrate annually along the east and west coast of Australia, between the summer feeding grounds in Antarctic waters and the winter breeding grounds inside the Great Barrier Reef on the east coast and on the northwest shelf and Kimberleys on the west coast (Chittleborough, 1965;

Dawbin, 1966; Jenner et al. 2001). Numbers have been increasing at a rate of more than 10% pa for decades (Bryden et al., 1996; Paterson et al., 1994, 2001; Bannister and Heldey, 2001). The population estimates for 1999 are 3,600 (± 440) for the east coast (Paterson et al., 2001) and between 8,200 and 13,600 for the west coast (Bannister and Hedley, 2001). These are still significantly less than the estimated pre-whaling populations, less than half for the east coast stock (Chittleborough, 1965). At the end of whaling in 1962, the east coast population may have been as low as 100 (Paterson, et al. 1994) indicating the substantial recovery that has taken place.

Humpback whales probably also migrate further off shore, since there are breeding grounds near tropical islands and reefs of the South Pacific, but not much is known about these migrations. Off the coasts of Australia, the timing of the migrations are quite predictable, with the time of the peak off Brisbane varying by less that a few weeks (Paterson et al., 2001). At this latitude, half the stock passes within the four weeks of the peak which occurs in late June early July going north and in late September, early October going south (Chittleborough, 1965; Paterson et al., 2001).

Male humpback whales produce a complicated song of repeated phrases within a pattern of themes. Typical song durations are about 10 min, although individuals may sing for hours at a time (Payne and McVay, 1971; Cato, 1991b). About 5% of passing whales sing going north at latitudes of Brisbane (Cato et al., 2001) and about 13% going south (Cato et al., 2001; Noad and Cato, 2001). The effect on ambient noise is now substantial. Two decades ago, humpback whale sounds were detectable occasionally during the migration, whereas today, several singers would be audible at any time. Humpback whale sounds are thus a common cause of transient signals, and are approaching the point where they will form choruses as is observed on the Hawaiian breeding grounds (Au et al., 2000), and was observed off the north island of New Zealand in the late 1950s, before numbers were reduced by whaling.

At any given time a local humpback whale song may contain a repertoire of in excess of 30 individual sound types, structured into a song. These sound types can range through broad band clicks, high frequency whistles to deep bellows or moans of many seconds duration. In general, most of the energy in the humpback song lies within the frequency range 30-2500 Hz, with that of the most predominant sound types in the band 100-500 Hz, though harmonics may range as high as 12 kHz. Some sound types, such as the high frequency whistles, are typically transmitted at low levels, whereas others are transmitted at much higher intensities. McCauley et al. (1996) in a study of humpback song in the 20-30 m deep Hervey Bay in Queensland, estimated that under low ambient noise conditions the higher frequency whistles would have fallen below audibility at ranges greater than about one kilometre, while the more powerful low frequency components would have been audible to tens of kilometres.

Although all humpback whales within a stock sing basically the same song at any time, the songs — both the sounds and the structure — change progressively with time. Such change requires continual copying between individuals. Sounds are so well matched during copying that differences between individuals are little more that those within the song of an individual (Macknight, 2001). Changes are usually detectable over time scales of a few weeks, but the rate of change is variable. Over some years, there may be only minor changes in some of the sound types, while over other years, substantial changes in most sound types and in the song structure occur (Payne et al. 1985; Cato, 1991b; Dawbin and Eyre, 1991). These changes are spread through the stock. Only the broad rules that govern the song structure seem to be fixed, though even these can sometimes break down as in 1984 off the east coast (Cato, 1991b).

Songs separated by thousands of kilometres along the length of the coastal migration paths have been observed to be the same at any time (Cato, 1991b), indicating that, for a particular migration path, the song is basically the same. Song off east Australia, New Caledonia, New Zealand and Tonga are similar, the differences increasing with separation (Helweg et al., 1998), indicating that there is sufficient interchange between migrations separated by open ocean to maintain similar songs even with continual progressive changes in the songs. Migration paths separated by the Australian continent, however, generally have unrelated songs (based on comparisons within the same year for a number of years: Cato, 1991b; Dawbin and Eyre, 1991), even though there is a small interchange between stocks (Chittleborough, 1965; Dawbin, 1966). In 1997, however, the west coast song was heard from a small percentage of singers off the east coast. By the end of 1998, the west coast song had completely displaced the east coast song (Noad et al., 2000). Such revolutionary change appears to be previously unknown for culturally transmitted signals of any animal.

As well as the complex and stereotyped song produced by humpback whales they are also capable of producing a broad range of other sound types, which may be used in social encounters. For example several non-song sound types may be occasionally heard from cow-calf pairs or interacting males. The sound of a breaching whale is audible for significant distances (described as "a rifle shot" by McCauley et al. 1996), and has been likened to the sounds produced by air-guns used in offshore petroleum exploration (McCauley et al. 2000b). In trials approaching whales with a single air-gun in Exmouth Gulf, McCauley et al. (2000b) found that in more than half the trials carried out, non-target whales consistently charged towards the operating air-gun, investigated it, then swam off. They speculated that these were probably male animals who considered the air-gun signal as an indication of nearby breaching or an acoustic event worth investigating.

Blue whales

The low frequency, intense tonal signals of blue whales have been extensively studied in the north Pacific. Similar 20 Hz tones were recorded off New Zealand in the 1960s (Kibblewhite et al., 1967). These were believed to be from blue whales. It has only recently been realised that in some parts of Australia, blue whales can dominate the low frequency ambient noise for months on end. Off Western Australia, what are believed to be pygmy blue whales produce a sequence of three stereotyped signals in a 'song', with dominant energy over 18-26 Hz but harmonics and a secondary source extending up to 100 Hz (McCauley et al. 2001). Each component is approximately 43, 23 and 20 s long respectively, which together run for around 120 s. Sound propagation estimates, indicate these signals may transmit into the hundreds of kilometres along deeper waters off the shelf edge. Up to nine callers have been reported at any given time, and calls are twice as frequent at night as during the day (McCauley et al. 2001).

Sperm whales

Sperm whales produce intense clicking sounds with most energy over the frequency band of 1 to 10 kHz. Recent measurements have estimated the mean square source level to be 233 dB re 1 μPa at 1 m (Møhl, 2001), the highest source level of any marine animal. Sperm whales were one of the main targets of whaling, but were so plentiful that the effect of whaling was less devastating than it was for some of the large baleen whales, such as the blue, right and humpback whales. Sperm whales are often found in large schools (Paterson, 1986), many whales producing the intense clicking sounds and making a substantial contribution to the background noise.

Fish Sounds

The significance of fish sounds to ambient noise was recognised in early studies (Knudsen et al., 1984) where it was found that fish commonly known as croakers (Scianidae) in the United States produced choruses. It became apparent in the many studies that followed, that many species of fish produce a wide variety of sounds, usually over the frequency band from about 50 Hz to 4 kHz (Fish, 1964; Tavolga 1964 & 1967, Winn 1964; Moulton, 1964; Fish and Mowbray, 1970 ; Fish and Cummings 1972).

There is a similarly wide variety of sounds from fish in Australian tropical waters, from harmonic sounds like fog horns to knocking and drumming sounds (Cato, 1980; McCauley and Cato 2000; McCauley, 2001) and these produce a substantial component of the back ground noise in tropical waters at low winds speeds, and in the absence of heavy rain. Almost all of the fish groups studied for sound production have shown daily, lunar, seasonal and spatial patterns in their sound production.

For example in northern Australia, nocturnally active fishes have been reported to consistently raise ambient noise levels by an average of 15 dB above normal levels over the frequency range 300-900 Hz about coral reef systems (McCauley and Cato, 2000; McCauley, 2001). On occasions, usually associated with new moon periods over summer months, choruses of these fish have been measured up to 30 dB above normal ambient levels. These choruses are regular, persistent and cover a huge geographical extent, indicating their importance to ambient sea noise predictions and to the fish concerned.

Invertebrate Sounds

The best known and most ubiquitous invertebrate sound is that of the snapping shrimp, which abounds in shallow warm waters, (Knudsen et al., 1948; Everest et al., 1948). It has been known since the earliest studies (Brown Goode, 1878) that the sound is produced when the shrimp snaps an oversized claw, but it has only recently been shown that the source of the sound is actually the collapse of a cavitation bubble formed in the wake of the snapping claw (Versluis et al., 2000). These shrimps abound in such large numbers that the snap sounds form a continuous crackling background noise, evident in Australian shallow waters at all times of day (Cato, 1980; McCauley, 1994; Readhead, 1997). An individual snap is about 10 ms duration, and the noise extends from about 1 kHz to beyond 300 kHz (Cato and Bell, 1992).

Biological Choruses

When large numbers of animals call en masse, they produce a sustained component of the ambient noise known as a chorus. Knudsen et al. (1948) and Fish (1964) described choruses from a number of sources, including shrimps, fish and sea urchins. Choruses from most species occur for a few hours of the day, usually the same hours each day, in contrast to that from snapping shrimps which show only a small diurnal variation.

Ambient noise studies around Australia have shown that choruses are widespread in both temperate and tropical water (Cato, 1978; McCauley and Cato, 2000; McCauley 2001). In shallow and shelf edge waters, an evening chorus, occurring for a few hours between sunset and midnight is almost always observed, and is usually so regular as to be highly predictable. In some locations, there is an early morning chorus in the few hours before dawn. The noise level rises to levels of 20 dB or more above the background during the chorus, and at the height, there are so many sounds that they merge into a nondescript roar. These choruses are from fish and invertebrates, some apparently related to feeding and have most energy between 500 Hz and 4 kHz. Fish also produce choruses in more complicated diurnal and seasonal patterns, related spawning behaviour. The season and time of day of calling varies with species (McCauley, 2001). In a study area where up to four chorus types may have been potentially heard at the same time, the displacement in time of choruses or time of maximum calling rate, appeared to limit competition for the 'sound space' (McCauley, 2001).

While the evening chorus has been observed in deep water at a number of locations, these have been within 6 km of shallow water, so may have been from animals in shallow water habitats. Fish choruses in which individual sounds were detectable have been observed in deep water large distances from shallow water (Cato, 1978; Kelly et al., 1985).

Sperm whales are common sources of sustained choruses in deep water, with frequency band extending from 500 Hz to beyond 5 kHz (Cato, 1978). While these have a similar spectrum to the evening chorus, the characteristic clicking sounds are always clearly detectable, and although there may be many clicks per second, a rhythmic beat of a half second period is often evident. Sperm whale choruses are not so regular as fish and invertebrate choruses, the locations depending on the movements of the whales in search of prey, though there appear to be preferred feeding areas, such as the deep waters off Kaikoura, New Zealand, where there is a whale watch industry. These choruses may continue for many hours at a time.

CONCLUSIONS

A wide variety of sounds from many different types of sources contribute to the ambient noise in the ocean. The area of sources contributing is large because of the good propagation of sound in the ocean and noise levels vary widely as conditions and the behaviour of the sources change. This causes substantial variation in sonar performance and provides a challenge to those who need to predict the effects on this performance. The pioneering studies of ambient noise in waters around North America and Europe provided the basic knowledge of ambient noise, but the significant environmental differences in Australian waters have required substantial research to adequately characterise the ambient noise here. This research has covered a range of disciplines from fluid dynamics to animal behaviour, addressing sources such as wave breaking at the sea surface and marine animals. While much of the work has been driven by the need to operate sonar effectively in our waters, it is apparent that the noise can be used to learn more about physical processes such as wave breaking and rain on the sea surface, and biological processes such as marine animal behaviour, movements and abundance. For example, whales can be heard at much greater distances than they can be seen, so acoustics is turning out to be a useful tool in studies of behaviour and abundance. The increase in whale numbers over the last two decades has substantially increased their contribution to the ambient noise. There are still many unknowns about ambient noise and limitations on our ability to predict and forecast the noise. Some sounds, apparently from marine mammals, have yet to be identified.

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AN INTRODUCTION TO SHIP RADIATED NOISE

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ABSTRACT: Radiated noise from ships is important for naval vessels, hydrographic survey ships and oceanographic ships. This article provides a broad overview of the major sources of radiated noise, transmission paths, and noise reduction methods. Its principal objective is to introduce the reader to the topic of radiated ship noise. Many of the procedures for estimating the radiated noise form ships have been derived empirically. This paper is written to provide a general overview of the topic, rather than a detailed technical discussion.

1. INTRODUCTION

Ship noise is a major part of the field of underwater acoustics. In naval operations the radiated noise is an important source of information, ie signal, for passive listening systems. Radiated noise is an important contributor to ocean ambient noise, and is a factor in oceanographic research and geophysical exploration. Ship noise reduction and control is an important factor in the performance of underwater acoustic systems and in the habitability of the vessel for the crew and passengers. Underwater radiated noise is also critical to many naval activities.

Seismic survey and oceanographic research vessels require low acoustic signatures, while many commercial vessels are subject to environmental legislation. In underwater warfare the increasing capability of the detection systems of modern weapons such as mines and torpedoes plus the improved performance of passive sonar systems is leading to stringent requirements as to ship radiated noise signatures. Specifications describing the permissible levels of underwater radiated noise and self-noise are important requirements in the acquisition of any major vessel.

This paper provides a brief introduction to the subject of radiated ship noise. It describes the major sources of radiated noise, transmission paths and noise control measures. It is written to provide a general overview of the topic, rather than a detailed technical discussion.

2. RADIATED NOISE

The four principal groupings of radiated noise sources are: machinery vibration caused by propulsion machinery and auxiliary machinery; propellers, jets and other forms of in-water propulsion; acoustic noise within compartments below the water line; and hydro-acoustic noise generated external to the hull by flow interaction with appendages, cavities, and other discontinuities.

Noise spectra are generally classified in two groupings; broadband noise having a continuous spectrum such as that associated with flow or cavitation; and tonal noise containing discrete frequency or line components, usually related to machinery. In addition to steady state noise, ship noise is also characterized by transient and intermittent noise caused by impact, machinery changes of state or unsteady flow that have particular spectral properties.

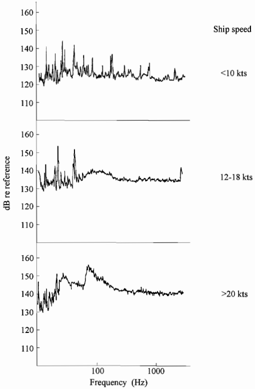

Figure 1. Diagrammatic radiated noise spectra for different speeds.

Generally, at speeds below the cavitation inception speed, main and auxiliary machinery are the principal components of radiated noise. Above this speed propeller cavitation becomes a major source, with discrete frequency components from machinery still being significant. Flow noise and cavitation from hull fittings may add a significant contribution at higher speeds. Figure 1 shows typical radiated noise spectra for different speeds. The approximate frequency ranges of different noise source groups are shown in Figure 2.

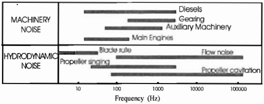

Figure 2. Approximate frequency ranges of noise radiated by ships and submarines.

3. SELF NOISE

Self-noise is the noise or vibration that a vessel produces at its own sonar, thus interfering with and prejudicing the performance of the sonar. As detection requirements become more demanding, the self-noise of the vessel must be reduced to maximize the vessel's own sonar performance.

At very low speeds self-noise is almost entirely due to machinery noise. The background at the sonar is a combination of the self-noise and ambient sea noise, which will vary with sea conditions. The relative proportion of the self-noise increases as the vessel speed increases, becoming dominant at moderate speeds. The turbulence of the vessel wake will be a strong contributor to self-noise on the aft sonar bearings. At speeds above the cavitation inception speed, propeller cavitation noise may be a contributory source, especially on aft sonar bearings and in shallow water. At the same time hydrodynamic turbulent boundary noise (flow noise) due to flow past the hull and sonar dome increases rapidly at higher speeds and tends to become dominant. At speeds above 20 to 25 kts local cavitation, at the sonar dome and hull adjacent to the dome, becomes important. Hull vibration at the natural frequencies of the hull can also be a significant source of self-noise, particularly on submarine flank arrays. The vibration response of the hull to broadband excitation can cause interference on hard mounted sonar arrays.

4. SOURCES OF MACHINERY NOISE

The major machinery sources of radiated noise are diesel engines (propulsion and generation); main bearings; propulsion turbines (steam and gas); turbo generators, forced draft fans; main feed pumps; and motor driven forced lubrication pumps. Other machinery which are lower intensity sources but are still significant are main circulation pumps; extraction pumps; turbo forced lubrication pumps; refrigeration and air conditioning plant; bilge pumps; servo air compressors and high pressure compressors.

Any fluctuation or impulsive force applied to a machinery structure by a working fluid, electrical flux or by motion of the working parts will give rise to noise and vibration. This may be in the form of either airborne noise, or vibration of the machinery mountings and other connection points, structure-borne noise.

The general sources of machinery noise are dynamic unbalance; fluctuating friction forces; journal surfaces not circular and center eccentric; impulsive loading due to impact between components; pressure variations in the working fluid, either periodic or impulsive; disturbances in the fluid flow of lubricating, cooling or working fluids; and rolling bearing noise due to inaccuracies in the races or rolling elements.

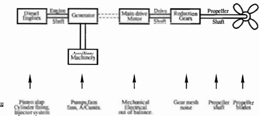

Figure 3. Schematic of machinery components of a diesel-electric propulsion system and associated noise sources (after [1]).

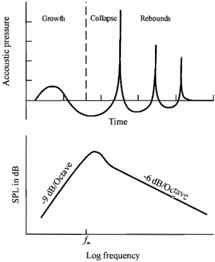

Figure 4. Cavitation bubble generation and collapse (after [2]).

Figure 3 is a schematic of the machinery components of a diesel-electric propulsion system and their associated noise sources. The propeller as a noise source is discussed in the next section.

5. PROPELLER NOISE

There are four main types of noise associated with propellers: cavitation; blade rate; singing and hull vibration.

The onset of propeller cavitation causes a rise in radiated noise levels of about 20 dB in the 80 Hz to 100 kHz band. As the propeller rotates water vapour is generated along the leading edge of the cavity and collapses along the trailing edge of the cavity. Figure 4 illustrates this process for a single cavitation bubble with the resultant idealized spectrum. There are a number of different forms of cavitation: tip vortex cavitation; hub vortex cavitation and face cavitation, either from the suction face or the pressure face. Cavitation is a function of the blade shape, the operating speed and the wake field.

Blade rate tonals and harmonics result from oscillating components of force or propeller thrust variations as the propeller rotates, caused by circumferential variations in the

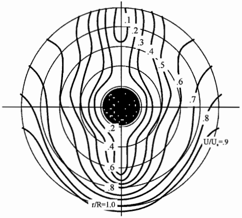

Figure 5. Propeller plane wake velocity contours for a single screw surface ship (after [2]).

wake inflow at the propeller plane. Figure 5 plots contours of equal velocity in the propeller plane of a single propeller merchant ship. The wake inflow speed varies from 10% to 90% of the free stream velocity during the propeller rotation. These velocity differences cause large fluctuations of angle of attack and associated lift forces, which lead to significant fluctuations in thrust and torque during each revolution of the shaft and, in turn, to high level, low frequency hull vibration. The most important design consideration in the uniformity of the wake and the relationship between the harmonic structure of the wake and the number and form of the propeller blades.

A singing propeller results when the vortex shedding frequency matches a blade structural resonance. The vortices are shed in the vicinity of the blade trailing edge, exciting the blade in a twisting mode. The shedding frequency is given by

$$\text{Frequency} = \frac{\text{Strouhal No.} \times \text{flow speed}}{\text{Cross section thickness}}$$

The Strouhal number is the dimensionless frequency, which relates the frequency of vortex shedding to the flow speed and a characteristic dimension, in this case the trailing edge thickness. Typically the Strouhal number is approximately 0.2.

Often the singing can excite the hull, which causes an intense airborne tone within the vessel. Singing is speed dependant, so the tone will only appear in a defined speed range. However, it is possible for there to be a number of tones excited in a number of different speed ranges.

The rotating pressure field exciting the adjacent hull plating causes hull vibration. This is then re-radiated both within the ship structure and into the surrounding water.

Propeller broadband noise is generated by the vibratory response of the propeller blades to turbulence ingestion and trailing edge vortices. In extreme cases this can lead to high levels of radiated noise at a large number of propeller natural frequencies simultaneously. Unlike singing this will occur over a wide speed range, with all frequencies being present at all times, only the relative intensity changes as the speed changes. The broadband excitation can also be transmitted along the shaft and into the hull, causing the hull to respond and radiate noise at its natural frequencies.

6. HYDRODYNAMIC FLOW NOISE

The flow over the complete hull of the vessel and its underwater fittings gives rise to noise, which can be divided into two types; boundary layer turbulence; and large scale irregularities of flow.

For a body moving through a fluid, the region close to the body is known as the boundary layer. It is relatively thin and well defined. It is usually a region of high turbulence; the turbulent eddies causing noise either directly from pressure fluctuations or indirectly through the vibrations excited in the hull plating. The boundary layer over the sonar dome is the most important self-noise source.

Other important noise sources associated with flow around a vessel are: cavitation from items such as sonar domes, shaft brackets, stabilisers etc; and wakes and vortices which are shed from appendages, particularly those whose shape approximates a hydrofoil at incidence to the flow. The associated pressure fluctuations can be detected directly and may also excite panel vibrations.

7. NOISE IN PIPEWORK

The flow of liquid in pipe work can be a significant source of noise. Vibration is transmitted through pipe walls and so care must be taken to isolate pipes and fittings from the main structure. Pressure pulsations are produced by the pumping element of the pump and transmitted through the suction and discharge lines.

Cavitation in pipe systems occurs where a flow restriction increases the flow velocity at the expense of static pressure. If the static pressure falls below the vapour pressure, bubbles form and these later implode in down stream regions with low velocity. Typical sources of cavitation are partially closed valves, orifice plates, rapid changes of direction and low suction pressures.

8. TRANSMISSION PATH EFFECTS

The effects of the transmission along different paths are expressed in terms of transfer functions that relate input at the source location to the output levels at the receiver location. There is usually more than one transmission path for each source; the available paths depend upon the location of the receiver and the type of the noise of interest.

The transmission paths for underwater radiated noise may be divided into three broad categories, dependant upon the medium of transmission; airborne, structureborne and fluidborne. Figure 6 shows the main sound transmission paths for a resiliently mounted diesel engine and figure 7 gives a simplified block diagram of these paths. Paths 1, 4 and 5 may be considered structureborne, path 3 is probably best described as fluidborne, while path 2 is airborne.

Radiated noise from sea-connected pumps can be transmitted via water paths inside the sea-connected pump piping. Also, noise that is generated outside the ship, such as propeller cavitation noise, follows a waterborne noise transmission path from source to receiver.

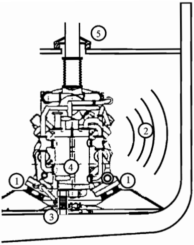

Figure 6. Sound transmission paths for a resiliently mounted diesel engine (after [3]).

For sonar selfnoise, the types of noise transmission paths are similar to those for radiated noise. However, once in the water, the paths for sonar selfnoise lead to the sonar systems and not the far field as for radiated noise. Some sources of selfnoise, such as flow noise at the sonar, do not radiate into the far field. In addition to the three paths above, it is sometimes necessary to consider only structureborne noise that enters the sonar sensors as vibration induced selfnoise.

When dealing with transmission paths it is usually more convenient to divide them up into elements that consist of either transmission within one medium or the transmission of noise from one medium to another. With this approach, transfer functions for transmission in a single medium (eg air, water, ship structure) can be combined with transfer functions that describe the transfer of noise from one medium to another (eg air/hull or hull/water) to construct transfer functions for the transmission of noise from source to receiver.

In Figure 8 some broad outlines for control measures for each path are given.

9. NOISE CONTROL

Noise control procedures may be divided into two categories; reduction of noise at the source and reduction of noise transmission by the different paths. Generally speaking reduction at the source is the preferred solution since it will have the least risk, will cause the least impact on overall vessel design and will normally minimize future maintenance of any noise reduction system. For noise sources that transmit direct to the sea (eg flow noise) this is the only option.

If reduction at the source is not possible or is insufficient to achieve the required results then noise reduction treatments to the transmission path need to be considered. As a broad guide the following measures are most likely to achieve a reduction in radiated noise levels: fitting noise reduction propellers; elimination of propeller singing; design for minimum blade rate noise; resilient mounting of machinery and pipe systems; good seating design; design and manufacture of all machinery for minimum vibration and optimum balance; and attention to hull smoothness and design of underwater fittings.

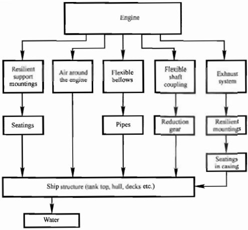

Figure 7. Simplified block diagram of sound transmission paths in Figure 6 (after [3]).

9.1 Noise Path Control Measures

The following factors should be considered in the reduction of structureborne noise transmission:

- Place machinery systems on common, rigid sub-bases or rafts, which are resiliently mounted
- Design machine foundations to maximize the impedance mismatch between the foundation and the resilient mounting
- Avoid cantilever or shelf foundations since moments are readily converted into bending waves
- The impedance of the isolation mounts should be much less than the impedances of both the machinery mounting point and the foundation
- Resilient mounts should be located at nodal points in the machine operational deflection shape.
- There should be no rigid structural paths between mounted machinery and the ship structure
- In two stage or compound resilient mounting systems the weight of the raft should be approximately the same weight as the mounted machinery
- The natural frequencies of the mounted machine in all six degrees of freedom should be well below the lowest frequency of significant excitation (less than half)
- Pipes should be attached with two straight flexible sections separated by a 90-degree elbow.

9.2 Airborne Noise Control

The following factors should be considered in the reduction of airborne noise transmission:

- Fitting of acoustic hoods
- Damping treatment application to machine sections with significant radiated noise

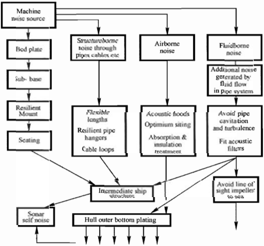

Figure 8. Schematic of transmission path control measures.

- Sound absorption treatment to compartments containing the noise source
- Avoid airborne noise shorts
- Minimise the number of penetrations in bulkheads
- Fit splitter silencers in air intakes or other openings to systems having a high airborne noise level

9.3 Fluidborne Noise Control

The following factors should be considered in the reduction of fluidborne noise transmission

- Fitting acoustic silencers or anechoic termination
- Pipes should be supported on resilient hangers
- Restrict the number of valves to a minimum and design valves to be fully open or closed
- Where orifices are required use cascade or multiple orifices instead of a single orifice plate
- Avoid siting valves in areas of low pressure
- Avoid sudden changes in pipe section
- Avoid ill-fitting gaskets and other projections into the flow
- Use multi-speed pumps to enable reduced load to be matched to reduced flow velocity

9.4 Hull Noise Control

Hull noise is primarily controlled by the initial design stage; however, the quality of hull maintenance can have a significant effect on overall hull noise levels. Aspects of hull noise control include:

- Bow shape – elliptical profiles and waterlines are preferred
- No abrupt change of shape in the vessel waterline
- Uniform flow into propellers
- Minimisation of appendages such as bilge keels, struts, domes etc
- Fairness of hull lines – welds should be ground flush
- Plate distortion should be avoided
- Align fitting with flow
- Hull paint should be as smooth as possible

9.5 Propeller Noise Control

Propeller cavitation, once it begins, will be the dominant noise source, masking other noise sources. All propellers will cavitate if sufficiently loaded. The high load may be due to high installed power, rapid increase in revolutions, crash stops or violent maneuvers. However, proper propeller design will avoid cavitation under normal operation and raise cavitation speed as high as possible. It is important that the propeller remains in good condition, as damage will increase the propensity to cavitate. Important considerations are:

- Optimum loading on each propeller
- Uniform flow into propellers
- Tip shape, and tip unloading
- Adequate clearance between tip and hull, boss and brackets, boss and rudder etc
- Maximizing propeller size for a given thrust
- Selection of blade section and pitch and camber variations to delay the onset of cavitation
- Optimise efficiency versus quietness

Propeller singing usually occurs well below the cavitation inception speed and can persist over a broad range of ship speeds. Singing is usually overcome by putting a sharp trailing edge on the propeller blades.

An alternative is to make the propeller from an alloy with high damping. Unfortunately these alloys have long-term maintenance problems.

It is essential that there is adequate clearance between propeller tips and the hull. Otherwise the strong pressure variations that occur as the blades pass may cause hull vibration. Whilst avoidance of the problem is obviously the most desirable solution, the problem can sometimes be reduced to acceptable levels by damping or isolating the hull plating in this region.

RECOMMENDED FURTHER READING

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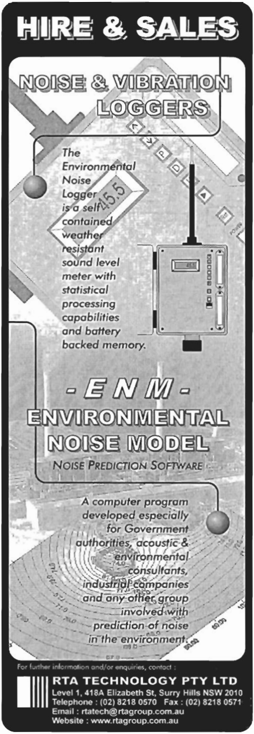
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SEAFLOOR DATA FOR OPERATIONAL PREDICTIONS OF TRANSMISSION LOSS IN SHALLOW OCEAN AREAS

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ABSTRACT; The Maritime Operations Division (MOD) of DSTO is assisting the Royal Australian Navy in its assessment of a sonar performance prediction tool for range dependent ocean environments: TESS 2, prepared by Thales Underwater Systems (TUS). This assessment has included comparisons between acoustic transmission loss data measured by MOD at shallow ocean sites with range-dependent transmission predictions obtained by TUS based on a geophysical-based seafloor database. This task has included an assessment of the potential for an MOD in-situ technique to infer seafloor reflectivity at shallow grazing angles and provide input to TESS 2 for regions for which existing holdings of seafloor properties are sparse. Examples of comparisons are detailed in this paper. This paper also reviews the need for more detailed description of the seafloor for steep angles of incidence, and shows progress of a MOD technique for inference of seafloor properties suitable for short range transmission predictions.

1. INTRODUCTION

For maritime operations in continental shelf zones, for which ocean depths are less than about 200 m, the detection performance of Undersea Warfare (USW) and Anti-Surface Warfare (ASuW) sonar systems may be highly dependent on the specular reflection of sound from the seafloor. At frequencies used for passive sonar (up to about 500 Hz), seafloor interaction is usually significant and the local reflectivity is a critical factor. For higher frequencies, as used by active sonar systems (2000 Hz to 8000 Hz approx.), seafloor reflectivity is significant if the ocean is downwardly refractive. In these circumstances for which sonar signals impinge upon the seafloor, it is essential that the properties of the seafloor are known, so that the acoustic transmission may be modelled with accuracy and the performance of sonar systems may be anticipated with precision.

The TESS 2 system is in the process of being delivered to the RAN as its standard tool for the prediction of the performance of sonar systems for USW and ASuW applications. TESS 2 includes databases describing generic sonar systems, and contains an underwater component (known as "SAGE" [1]) which includes range-dependent acoustic models, plus databases describing the global ocean environment, including geophysical/textural/descriptive seafloor data. These environmental databases, whilst inclusive of the best available data, of necessity contain historical information which may have limitations due to the practicality of extensive surveying. As with any estimate of sonar system performance, the accuracy of the prediction from TESS 2 is dependent, to a critical degree, upon the appropriateness of the input parameters. This present paper reviews an investigation of the degree to which the predictions of acoustic transmission within TESS 2 might benefit from supplementation of the historical seafloor datasets with on-site measurements. This work is a continuation of the joint MOD/TUS work reported earlier [2, 3, 4].

In support of the RAN's desire to have a state-of-the-art sonar performance prediction capability, MOD has on-going programmes of research on testing acoustic transmission models and on the acoustic properties of the seafloor in shallow ocean regions. In a focussed activity which draws on this research, MOD is engaged in the assessment of the TESS 2 system with particular reference to its use within the Australian region. The longer-term research has provided MOD with a considerable body of at-sea data to apply to the assessment of the TESS 2 system, with transmission loss (*TL*) for a number of sites. Further, its research of rapid sensing techniques has enabled MOD to assess the viability of applying a unique method for *in-situ* determination of seafloor specular reflectivity as an adjunct to the TESS 2 system. The technique for *in-situ* determination of seafloor reflectivity is a refined version of that reported by Jones *et al* [5, 6]. This paper describes recent progress in the assessment of transmission predictions obtained by TESS 2 for ocean sites corresponding to MOD's holdings of *TL* data, and presents three-way comparisons of measured *TL*, TESS 2-predicted *TL* and predictions of *TL* based on seafloor properties inferred by MOD's rapid assessment technique. TUS Pty Australia has been involved in these comparisons, so that it is in a position to advise the practicality of implementing recommendations resulting from this work.

2. SEAFLOOR MODELLING

For acoustic transmission modelling, the seafloor is regarded as either an extension of the transmission medium, with layers of material described by appropriate acoustic properties (e.g. Figure 1), or is treated as an impedance discontinuity and is modelled by bottom loss or sound pressure reflection coefficient and phase angle data for each angle of incidence (e.g. Figure 2). The particular form of data required is dependent upon the type of acoustic transmission model, and on the way the wave equation calculations are implemented therein. In

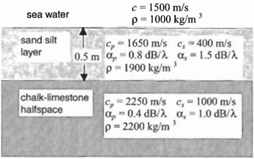

Figure 1: Simulated seafloor with absorptive basement

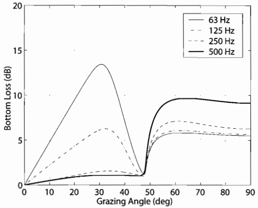

Figure 2: Bottom loss versus grazing angle for simulated seafloor of Figure 1

fact, both these forms of seafloor representation may be shown to be equivalent, and some models, e.g. KRAKENC [7], include algorithms which permit input to be provided in either form. Whatever the form of input data, a practical implementation in an operational model such as TESS 2 requires a dataset descriptive of seafloors in all zones in which operations are relevant. Historical data sampling is of necessity limited in extent and detail, and so some regions may be described with greater accuracy, whereas others are poorly known. A minimum level of description is a single set of parameters describing the seafloor as a uniform half-space for which the reflectivity is frequency-independent. By including detail, such as the nature of a sediment layer overlying a basement of alternate type (see Figure 1), frequency variations in reflectivity may be modelled. For the example of the data shown in Figure 1, the low frequency reflectivity approximates that of the absorptive basement (Figure 2), whereas the higher frequency behaviour approximates the high reflectivity of the thinner sediment.

For operational use, a seafloor model need be only as detailed as is required. For general USW applications, for shallow oceans, range values of interest are such that shallow grazing angles (< 10° approx.) describe effectively the complete seafloor behavior. As is apparent in Figure 2, but not derived here for sake of brevity, an appealing option is to limit the seafloor description to a linear function of bottom loss with grazing angle. However, as may also be shown by analysis, for short range predictions (< 500 m, very approximately), it is necessary to describe either the bottom loss and phase data at steeper angles of incidence, or it is essential to model the sub-bottom as a variation in properties with depth. The SAGE database achieves the latter to some degree, and the MOD *in-situ* inversion technique is based on, and uses, the former approximation, whereas for short-range predictions, a multi-layered description, as obtained by Hall [8] for example, is necessary.

3. ALTERNATE MODELLING OF SHALLOW SEAFLOOR BASED ON *IN-SITU* DATA

As input to TESS 2, TUS Pty Australia has developed a database of seafloor geophysical/textural/descriptive data and has applied algorithms for the inference of reflective acoustic properties. The SAGE global geoacoustic database has been derived from over eighty independent sources in the open literature and includes sediment province data gridded to a resolution of 2 minutes. As reported earlier [2] MOD and TUS have compared *TL* predictions, based on the SAGE database, with at-sea measurements of acoustic transmission carried out by MOD Salisbury. This work was limited in extent, but did show that for a shallow ocean region for which the seafloor was well surveyed, predictions of transmission loss obtained at low frequencies (125 Hz and 500 Hz) matched well the measured *TL* data for both range-independent (along-contour) and for range-dependent (down-slope) situations. This present paper shows how this work has been extended to show the result of using MOD's unique method for inversion of seafloor reflectivity [5, 6], as an alternative to the SAGE data, to illustrate the potential advantage of using the technique for rapid assessments in unsurveyed shallow ocean regions. In particular, this present study has focussed on the ability of the MOD inversion technique to provide a seafloor description which is appropriate for the prediction of underwater signals to long range in shallow ocean regions.

The site discussed in this paper (Site #2 ref [2]) was within the area covered by the Australian Continental Shelf Sediment Series (of the Australian Geological Survey Organisation and its predecessor, Bureau of Mineral Resources), for which the seafloor data available for TESS 2 existed as samples with 10 nautical mile spacing. Sand, silt, clay and gravel percentages, as well as the percentage carbonate, for surficial sediment, then classified the data. The geoacoustic properties installed within the SAGE database were determined using a modification of the Biot equations [9].

For data gathered during MOD acoustic transmission trials, the sound speed profiles for Site #2 are shown in Figure 3, and the bathymetry is shown in Figure 4. Here, Run 5 corresponds with a direction down the continental slope, whereas Run 6 was along the contour of the slope, at a depth approximated for modelling at 195 m. The sound speed data was inferred from temperature data versus depth obtained from

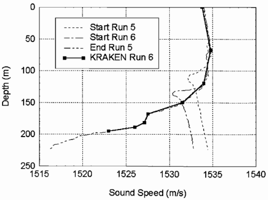

Figure 3: Sound speed profiles at Site #2

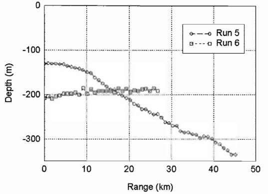

Figure 4: Bathymetry at Site #2

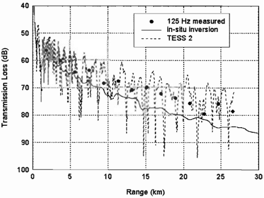

Figure 5: TL measured & predicted, Site #2 Run 6 – range-independent, 125 Hz

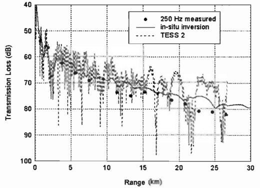

Figure 6: TL measured & predicted, Site #2 Run 6 – range-independent, 250 Hz

AN/SSQ-36 bathythermograph buoys. The ocean depth data was obtained from a 30 second resolution database [10].

MOD transmission loss data was obtained by deployment of small explosive signal sources (SUS charges) at intervals of one nautical mile, with receipt of signals on AN/SSQ-57 sonobuoys for which the output was appropriately attenuated. The received data were processed at MOD using the STAS software [11]. This was achieved by coherent determination of received signal intensity as a narrowband FFT spectrum, and an incoherent summation of intensity in the FFT bins within each one-third octave band, to arrive at one-third octave *TL* values.

4. TRANSMISSION MODELLING AND DATA

Acoustic transmission was modelled at Site #2 using the KRAKENC model [7] (run at MOD) and the TESS 2 version of the RAM model [12] (run at TUS). KRAKENC is a modal model capable of handling a seafloor supporting shear waves in range-independent and range-dependent ocean environments, whereas RAM uses the parabolic equation (PE) method for describing transmission in range-dependent ocean environments with zero shear speed in the sediment. RAM was run with the seafloor simulated as a half-space overlaid by a deep sediment in which the compressional speed increased linearly with depth according to an assumed gradient. KRAKENC was run with the seafloor described by a table of values of acoustic pressure reflection coefficient, and phase, as determined by application of the MOD seafloor inversion technique, which has been outlined in earlier studies [5, 6]. The sound speed profile data used for modelling is as shown in Figure 3. RAM was run using range-dependent data, where this was available; KRAKENC was run assuming range-independence for the along-contour Run 6 and range-dependent for down-slope Run 5.

The measured and modelled transmission data is shown in Figures 5 through 7. In each figure, the measured data is averaged over a one-third octave band for the relevant centre frequency, and is processed by the STAS software. The *TL* predictions obtained by the KRAKENC model have, likewise, been determined phase coherently at single frequencies, and are averaged incoherently over a one-third octave band - the same averaging process as imposed by the STAS software. For the range-dependent down-slope Run 5, KRAKENC was run using the coupled mode approximation. The RAM *TL* predictions are phase coherent determinations at a single frequency, and hence retain the amplitude variability typical of

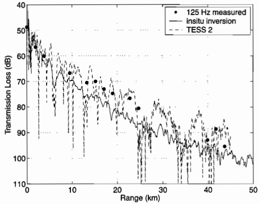

Figure 7: TL measured & predicted, Site #2 Run 5 – range-dependent, 125 Hz

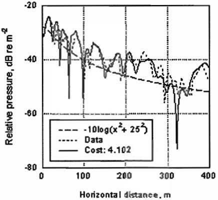

Figure 8: TL measured & predicted, seafloor model inverted using simulated annealing, 251 Hz

shallow water multi-path scenarios.

The data for Site #2 Run 6 show some variation over the frequency range 125 Hz to 250 Hz, but generally, the TESS 2 results, and the predictions obtained by KRAKENC with seafloor reflectivity determined by the MOD inversion, are all close to the measured data, even to 26 km range. In detail, at 125 Hz (Figure 5) the *TL* resulting from the TESS 2 prediction is slightly lower than from the KRAKENC prediction – presumably a result of the effective difference in seafloor reflectivity. At 250 Hz, in Figure 6, the TESS 2 data appears to under predict the measurement slightly, whereas at 125 Hz (Figure 5), the KRAKENC data based on the MOD seafloor inversion over predicts. Overall, both the TESS 2 result and the prediction of *TL* based on the MOD inversion are quite close to measurements for both frequencies and all range values shown. The good result from TESS 2 might be expected, as the seafloor knowledge for the site is extensive. The good agreement with the inverted seafloor reflectivity does suggest that the MOD technique is viable for unsurveyed sites.

For the range-dependent Site #2 Run 5, the RAM model predictions from TESS 2 are close to the measured data, as are the KRAKENC data which are based on the MOD seafloor inversion. As for the Site #2 Run 6 predictions at 125 Hz, the TESS 2 *TL* data are slightly less than the KRAKENC data, possibly a result of differences in the effective seafloor reflectivity implicit in the model input data. This issue is under present investigation.

5. SIMULATED ANNEALING INVERSION

To characterise transmission in shallow water environments at short range, descriptions suitable for small grazing angles, only, are not sufficient as significant components of the received signal arrive via steep angles of incidence. It is then necessary to have a geoacoustic model which is representative of the layered nature of the local seafloor. The method developed at MOD by Hall [8] uses received signal versus range data across several octaves to invert geoacoustic parameters (compressional and shear wave speeds, compressional and shear wave attenuations, density) for several layers of material, plus layer thickness, and an underlying basement.

For application to a sound range site, for which ocean depth is 47 metres, the signal from a projector at 20 m depth was received at the seafloor, for tonal frequencies of 53, 63, 125 and 251 Hz, for horizontal ranges out to 400 m. Headwave data from earlier airgun tests were first used to estimate basement compressional wave speed (6100 m/s) and basement depth. The received CW signal data were then inverted to obtain remaining parameters of a geoacoustic model. The inversion algorithm was an implementation of an adaptive simulated annealing method [13]. Here, the cost function used by Hall is the rms of the residuals between measured and computed values for received signal (in dB) as computed with the OASES model [14] over the four frequencies. The performance of the inversion was examined as the number of uniform layers overlying the basement was set to 1, 2 and 3. A best result with 2 seafloor layers was found to be similar to a best result with 3 layers, and was selected for subsequent modelling work. An example of the agreement between measured received signal data and computed data (at 251 Hz) is shown in Figure 8, where comparison is also made with spherical spreading. The very high degree of agreement highlights the necessity of a description of seafloor layering for very short range predictions of signal data. The level of fidelity in such seafloor descriptions is not normally justified for inclusion in performance models such as TESS 2, unless very short range phenomena is of interest in a particular location.

6. CONCLUSIONS

Based on the limited comparisons presented above, it does appear that the TESS 2 system provides predictions of acoustic transmission of good accuracy for shallow ocean regions for which high resolution bathymetry data is available and for which there is a high confidence in the accuracy of data contained within its seafloor database. This brief study has considered low sonar frequencies. Further, it does appear from this work, that if determinations of seafloor reflectivity within operations are feasible using the MOD *in-situ* technique, it will be distinctly advantageous for these data to be selected as input to a sonar performance prediction tool, for shallow water applications in poorly surveyed areas. Lastly, a technique has been demonstrated which may aid effective surveying in some regions for which short range predictions are particularly critical. In any event, if an accurate prediction of acoustic transmission is to be achieved, detailed sound speed data is required.

ACKNOWLEDGEMENT

The authors acknowledge the beneficial suggestions made by Dr. M. V. Hall of MOD, and his provision of Figure 8.

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Letters to the Editor

Business Opportunity

Acousteel Ltd is a British company manufacturing an innovative sound deadened steel product – Acousteel. Utilising automotive laminated steel technology, Acousteel offers reductions in noise of up to 30 dB(A). Whilst the technology is proven the product is for the first time being manufactured in sheet format with gauges ranging from 1mm-6mm, thus making this extraordinary product available for the first time to all areas of industry ranging from Air conditioning to Roofing applications.

After a successful launch of the product within Europe, Acousteel Ltd is now looking for Agents/Distributors of the product within Australia, with the aim of duplicating proven and profitable markets whilst identifying new applications. For more information visit our website www.acousteel.com and/or contact Managing Director Mark Ingram at info@acousteel.com.

Expert Witness

I refer to Ken Scannell's letter (vol 29(3), 132), and endorse his suggestion that AAS might prepare a code of practice for members who may be approached to act as expert witnesses and are perhaps unfamiliar with the (very extensive) literature which now exists on their roles and responsibilities.

I am glad to report that in my own case, relating not to noise exposure but to issues in asbestos exposures and heat stress, none of the lawyers who have approached me have ever suggested a "no win – no pay" payment basis for my professional opinion. This experience relates to opinions requested over a period of some 15 years, and even includes those where my opinion has not been in support of the party on whose behalf it was requested.

The question of payment in advance is, however, a difficult one, or at least has been so in my experience, in view of the sometimes almost impossibility of indicating the time needed for preparation or still less the time which may be spend in court. When first dealing with lawyers for whom I have never previously provided opinion. I have indicated the time based consultancy fee rate it is usual for me to charge and submit accounts accordingly. Usually however the fees for appearances are governed by the practice of the court concerned and I think it unlikely that any arrangement for advance payment is possible.

Nevertheless I agree with Ken that it would be excellent if the AAS can indeed provide a Code to which members can refer as binding on them, as members of a professional society, in assisting the proper decision in any legal proceedings.

Gerald Coles (MAAS, FAIOH)

Expert Witness Reply

I would like to thank Gerald Coles for this reply to my letter (vol 29(3), 132) and his support for an AAS Code of practice for the Expert Witness. While I accept that the final fee for work carried out is nearly always impossible to predict, a retainer based on a minimum estimated fee would very useful. The final payment could be made after the case is completed. This would remove, or at least minimize, any inhibitions the expert may feel that she or he is under from expressing totally frank opinions.

Ken Scannell MAAS

Tales to Share about
Graeme Yates

Marilyn Yates

The request for me to write a short article about Graeme that includes some tales about some of his achievements that are not widely known, has given me the opportunity to sincerely thank the Australian Acoustical Society for inviting me to accept the Fellowship awarded to Graeme. Unfortunately our four daughters were all overseas at the time but Graeme's sisters, Pam and Jill were pleased to have the opportunity to gain an insight into Graeme's professional life and share in the recognition of his contribution to the Acoustical Society. The thoughtful way we were included made it a memorable evening. Thank you.

As you know, Graeme had a long association with the Acoustical Society, so those of you who knew him well will have your own memories of him. I suspect that some of the following are qualities you would also attribute to Graeme. In my eyes he was a man dedicated to science but one with very broad interests that extended way beyond science. He had an inquiring mind and because of his many experiences was a creative problem solver, a person with an incredible number of skills from which many others benefited. Also he strongly believed in social justice, and could put the needs of others, particularly those of his family, before his own. He passionately believed in the value of professional associations and of the need for rolling up your sleeves to get the job done.

Graeme was the second of five children and was fortunate to gain an academic scholarship to Perth Modern School, a fact that contributed to him completing his secondary education. At seventeen Graeme went to work at Plaimar's in West Perth and began studying a night school course in Industrial Chemistry. He had been with them for about eight months and I might add we had just become 'girlfriend and boyfriend' when he was whisked away to work on the development of food flavours in their Sydney laboratory. History demonstrates that the flavour he was assigned to develop for a client didn't knock Coke and Pepsi out of the market. He was twenty-one when he commenced a physics degree at UWA, just after we married.

Marilyn Yates receiving the certificate for Fellowship awarded posthumously to her husband Graham Yates from Terry McMinn at the WA Division Christmas Dinner, 2001

When it came to Graeme valuing 'doing it yourself' his father was a wonderful role model. He was always designing and building a vast range of products made from wood and metal, repairing radios, televisions and motor cars and remodeling the family home. Graeme developed an attitude that all these things happened in or around the back shed. Our courtship involved me helping him strip and spray paint his motor scooter and help him de-coke my Ford Anglia and backyard mechanics drove him to build his own cathode-ray oscilloscope. My memory of the following undertaking when we were about twenty years old, was that armed with the CRO on my knee I was instructed in the mysteries of obtaining information to determine the effect of the addition of twin carburettors to the performance to his brand new Vauxhall Viva. Using a quiet road in Waneroo for our test track, Graeme became convinced that there was a design fault with the engine head causing a problem with the circulation of gases. He informed Vauxhall Australia that there was a problem and when he received a reply to his letter telling him that it was nonsense he wrote to the parent company. His car was recalled for modifications and from memory the reason given was that their tests had demonstrated a problem the internal moulding of what was then an 'innovative' aluminium head.

There was never a dull moment being with Graeme and there are many stories I could relay but another which stands out was when our backyard bore ceased working properly Graeme decided he needed to know what was happening sixty plus feet below ground surface. With me protesting that if he pulled apart a relatively inexpensive camera belonging to one of our daughter's he would never put it back together again, he designed a remote control firing mechanism and lowered the modified 'camera' and was able to determine the level of the water and what was happening to the clap valve. Did he put the camera back together again? Of course not, he had new challenges far more exciting than assembling a camera.

Whether it was building his own colour analyser for developing colour photographs, laying the last brick in the garage he designed and built just hours before stepping on the plane to take up a research post in England, developing a computer controlled system long before any commercial products were available for our budding violinist daughters to learn pitch and timing when practising, Graeme was creating a new challenge. He has provided our family with endless stories to pass on to future generations about a man who could combine a theoretical grasp of knowledge with incredible technical skills to always come up with imaginative and enterprising solutions to everyday problems. The recognition paid by the international scientific community since he died will also be added to our stories of a much loved and respected man.

Book Reviews

Understanding Active Noise Cancellation

Colin Hansen

Spon Press, London 2001, 162 pp, ISBN 0415231922 (soft cover) 0415231914 (hard cover). Distributor DA Information Services, 648 Whitehorse Rd, Mitcham 3132, Australia, tel 03 9210 7777, fax 03 9210 7788, Price soft A$77.11, hard A$200.56

With the rapid development of active noise control in the past decade, this book is a timely addition to the field. In the words of the author who is a leading authority in the field, "this book is intended as a precursor to more complex books available on the subject." Indeed, it is a concise text aimed at providing an overview of the technology.

There are six chapters and two appendices in the book. A brief historical overview of the development of active noise control is given in chapter 1. In chapter 2, physical mechanisms of active noise control are explained, followed by the introduction of feedforward and feedback control systems. Chapter 3 is focussed on the basic building blocks of an electronic control system: digital filters and various algorithms for adaptive control are described, accompanied by a good discussion of practical implementation issues. The next two chapters complete the description of an active noise control system by dealing with control sources and sensors. Various types of acoustic and vibration sources and their implementation are treated in chapter 4. A good exposure of reference errors, error sensors and various sensing strategies including virtual sensing is given in chapter 5. A range of active noise control applications is discussed in chapter 6 and perhaps of equal value is the discussion of various scenarios where applications of active noise control technology are impractical.

In a field that changes rapidly, it is fitting to provide some 192 references which are complemented by a list of useful web sites. As URLs of web sites tend to change quite frequently these days, it is not surprising that 20% of those listed are no longer valid even though this book was published in 2001. Perhaps the author may consider setting up a web page that continues to update and/or add URLs of useful web sites on active noise control.

The book is very well written with very few typos. In addition to giving a good coverage of the work in this field, there are numerous examples drawn from the author's own experience. I have found the discussions on practical implementation issues most valuable. The author has succeeded in explaining some complex concepts in simple terms without excessive use of complex mathematics. The book serves as an excellent introduction to active noise control for undergraduate science and engineering students in their final year, for postgraduate students, engineers and acoustics consultants. It is highly recommended for physics/engineering libraries.

Joseph Lai

Joseph Lai is Director of the Acoustics and Vibration Unit of the University of New South Wales at the Australian Defence Force Academy. He is involved with research, teaching and consulting in a wide range of areas in acoustics.

Auditory Worlds: Sensory Analysis and Perception in Animals and Man.

Manley et al (Editors),

Wiley, Germany 2000, 358pp ISBN 3 527275878 Distributor John Wiley, PO Box 2083, Fortitude Valley BC Qld 4006, tel 1800 777474, fax 07 3252 8923, Price A$156.84+GST

This is an unusual and historic book that deserves a place on the shelves of academics and professionals with an interest, either primary or secondary, in comparative bioacoustics and the link between neurobiology and perception in vertebrate species, including humans.

The book is a compendium of short papers that attempts to summarise the outcome of 15 years of research in the collaborative research centre "Hearing in Vertebrates" of the Deutsche Forschungsgemeinschaft (DFG). This research centre was formed in 1983 by already renowned staff in the Technical University of Munich, the Ludwig-Maximilians-University and the Max-Planck Institute for Psychiatry in the same city.

The book is in fact a report for the DFG that signals the ending of the centre and its members took the decision to produce the report in this book form. In so doing they have created an approachable and useful document that gives a clear record of the remarkable breadth and depth of the research carried out during the lifetime of the centre. For the specialist, the book serves as a convenient précis of the work of the centre. For the reader who has what may be only a passing interest in the field, the book is doubly useful. Firstly, because it is a selection of what the authors consider to be their key findings, rather than being a dry and exhaustive list, and secondly, because the vast bulk of the work described has already been published in more detailed form in specialist refereed journals. The book thus provides a convenient and credible source of information, with the opportunity, through the published papers which are listed in the bibliography, to pursue aspects of interest in greater depth.

The book is divided into 9 major blocks around particular themes, ranging from the evolution of vertebrate hearing to the evaluation and rehabilitation of hearing impairment in humans. There is a wealth of interesting data on the acoustics, neurophysiology, and behavioural performance of numerous species; birds, lizards and bats to name a few. Of particular interest is the section on active mechanics and otoacoustic emissions in which much useful data on these processes in man and other animals are grouped together. This section, and the one on models of the human auditory system also contain contributions based on work of the remarkable Eberhard Zwicker, who was the founding chair of the centre and who regrettably died in 1990.

Despite, or perhaps because of, the expurgated nature of the presentation, some parts of this collection will not be easy to digest for the non-specialist reader. Nonetheless the book serves as generally approachable and concise record of a unique era in bioacoustical research and the research projects described are so wide-ranging that there will probably be something for everyone in this volume. Such a book is unlikely to appear again for a very long time.

Don Robertson

Professor Robertson is a staff member of The Auditory Laboratory, Department of Physiology, The University of Western Australia.

Measurement & Assessment of Groundborne Noise and Vibration

The Association of Noise Consultants

6 Trap Road, Guilden Morden, Royston, Herts., SG8 OJE, UK. Fax +44 1763 853 252, http://www.association-of-noise-consultants.co.uk/index.htm. Price 30 UK Pounds plus postage.

The amount of literature available on environmental vibration could probably be counted on one hand. This book goes some way to readdressing the balance. Published by the British Association of Noise Consultants, it gives practical information on the effects of vibration on buildings, and the measurement and assessment of the response of people within buildings. The information in the book goes some way to explaining the ambiguities in the British Standard BS 6472:1992 'Guide to the evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz), which is often quoted in Australian guidelines and criteria.

The guidelines cover a wide range of vibration issues and vibration sources. However, particular attention has been paid to railway vibration and groundborne noise, as a result of the number of major projects under development in the UK (and Australia). Blasting vibration and motion sickness associated with very low frequency vibration are not covered in the main body of the guidelines but are briefly described in the appendices for completeness. Hand-arm vibration is not covered.

The guidelines are not intended as a layman's guide to noise and vibration measurements, but for the use by experienced practitioners. It is assumed therefore that the users will be familiar with the technical terms used in the document.

Ken Scannell

Ken Scannell is an acoustic consultant in Sydney and was a member of the British Standards Committee in 1990 to 1992 for the revision of BS 6472.

Occupational Exposure to Noise: Evaluation, Prevention and Control

B Goelzer, C Hansen and G Sehrndt (Editors)

Federal Institute for Occupational Health and Safety, Dortmund, 2001, 336 p, ISSN 1433-2140, ISBN 3-89701-721-0, Available from Wirtschaftsverlag NW, Burgermeister-Smidt-Str 74-76, DE 27568 Bremerhaven, Germany, www.nw-verlag.de, Price Euro 11 plus postage

This book was published by the German Federal Institute for Occupational Health and Safety on behalf of the World Health Organisation. In September 1995 a group of 19 specialists from 16 countries met to discuss the production of a document on occupational noise. This publication is the outcome and it is intended to be both an introduction and a handbook. It comes in hard copy with a CD including the full document in pdf format.

The book commences in a standard way with chapters on the fundamentals of acoustics and hearing, including sections on the physiology and the pathophysiology of the ear. The criteria for occupational noise exposure are well discussed with due reference to the differing approaches in some countries. There is also a brief discussion of related issues such as infrasound and ultrasound.

The next group of chapters deals with noise sources and their measurement as well as audiometry. The last four chapters cover the aspects of noise management programs and engineering noise control. Each of the chapters has good reference lists and in addition the final chapter lists general reference documents including standards, internet sites, books etc.

Overall this is a very comprehensive document which presents a wide range of information but with considerable depth. It is recommended as a reference for any practitioners dealing with any aspects of occupational noise.

Marion Burgess

Marion Burgess is a research officer with the Acoustics and Vibration Unit of the University of New South Wales at the Australian Defence Force Academy. She has experience with occupational noise assessments and management programs.

Measured Tones: The Interplay of Physics and Music

Ian Johnston

Institute of Physics Publishing, Bristol and Philadelphia, second edition 2002. ISBN 0 7503 0762 5. Soft cover. Price A$76.89.

This is a book by a physicist — the author recently retired from Sydney University — but is directed specifically at musicians and the general public. With this in mind, there are no symbolic equations and very few numbers. Numerous drawings illustrate the text, and fragments of musical scores and instrument fingering diagrams are used where appropriate. The author's aim is to present the basic physics underlying the structure of music and the behaviour of musical instruments, using a historical approach, but keeping the physics clear and accurate. Developments are placed nicely in historical context, with sketches of the contributions of major figures such as Pythagoras, Helmholtz, Stradivari, Boehm, and many others.

While the emphasis is on physical understanding, the story of the development of major instrument families such as plucked and bowed strings, woodwinds, brass and percussion is also outlined, and there are chapters on the human voice, on electronic instruments and on architectural acoustics.

The writing throughout is delightfully clear and easy to read, and the numerous small illustrations break up the pages and add interest. There are few competing books that adopt a similar approach, the nearest being Charles Taylor's "Exploring Music", also published by the Intitute of Physics. Both are excellent books, but I think I would recommend "Measured Tones" as an easier read with more interesting historical and biographical interludes.

This second edition differs in only minor matters from the first. Both have an excellent index and a partly-annotated bibliography of books at a similar level. Another innovation is the establishment of a web site <www.measuredtones.iop.org>. This site includes simple problems, extra explanations, and musical examples. Great idea!

Regrettably, only a few or our University Music Departments or Conservatorium courses include any units on the acoustical basis of music, so that graduates have only the foggiest idea about how their instruments work. This book would provide an excellent basis for such a course, and I am sure the students would enjoy it. Students (and teachers!) not having had the benefit of such a course should certainly buy the book and read it. I also recommend it warmly to the general reader who would simply like to know more about the sounds he or she enjoys.

Neville Fletcher

Neville Fletcher is a physicist and Visiting Fellow at ANU. He also has a wide background in music and has written extensively on musical acoustics

New Members

NSW	
Graduate	Benjamin Lawrence
VIC	
Graduate	Dianne Williams
SA	
Student	Simon Hill
QLD	
Member	Jerome Rivory, Sasho Temelkoski
Student	Robert Ashby

Future Meetings

Acoustics 2002

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

The Conference will be held at Hotel Adelaide International in North Adelaide near park lands and adjacent to a promenade of cafes. It is within walking distance of a wide range of accommodation and entertainment/dining. The conference will start with a tour of the Capri Theatre which is rich in history and music, featuring a gigantic organ, containing a total of 2076 pipes. The opening of the Conference will be held on the Wednesday evening at the South Australian Art Gallery. On Thursday night, all conference participants will be treated to dinner (with special entertainment) at the Hotel Adelaide's restaurant, which offers excellent views overlooking the city and park lands.

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

WESPAC8

In less than a year, 7 - 9 April, 2003, the Society will be hosting WESPAC8 at the Carlton Crest Hotel and Convention Centre in Melbourne, Victoria. As WESPAC8 will be the only major international acoustics conference in Australia for a number of years, the organizers trust that it will be strongly supported by the local, as well as international, acousticians.

The three plenary speakers will be:

- Larry Crum from the USA will with a discussion of acoustics in the medical field (particularly high intensity ultrasonics) and the problems of technology transfer.
- Colin Hansen from Adelaide University will pose the question "Does Active Noise Control have a Future ?"
- Joe Wolfe from the University of NSW, will explore the interaction of information and music.

Other speakers from Europe and the Asian region are being invited to give distinguished lectures and keynote papers. These will cover a wide range of topics, including building and auditorium acoustics, industrial, environmental and transport noise, with sessions on road, rail and aircraft noise, instrumentation, sound quality, speech, music and psychological and physiological acoustics. A committee of over 14 top acousticians from around Australia has already agreed to help organize this very comprehensive and interesting technical program.

Deadlines:

2 August, 2002 for Abstracts submission

2 November, 2002 for full papers for those authors seeking full review

10 January, 2003 for all other papers

Registration for the conference is $650 before 10 January, 2003 then $750. A reduced fee of $400 has been set for additional papers submitted by the same author. The registration fee includes a copy of the CD containing the conference proceedings, admittance to the technical program, opening and closing ceremonies, morning and afternoon coffees, lunches and a barbecue at Emu Bottom (including transport) on the Monday evening. Student fee is $250 by 10 January and then $300. Accompanying person fee is $90. The conference banquet on 8 April will cost $85 per person.

Information from http://www.wespac8.com.

ISMA2002

ISMA2002, Noise and Vibration Engineering Conference will be held in Leuven, Belgium, September 16-18, 2002, This is part of a sequence of courses and international conferences on structural dynamics, modal analysis and noise and vibration engineering, organized by the department of Mechanical Engineering of the K.U.Leuven. It provides a well known forum for engineers researchers and other professionals active in the field of testing, analysing and modelling the vibration and acoustic characteristics of mechanical systems.

The technical program includes 2 keynote lectures; one on large scale experiments for vibration control and vulnerability assessment of bridges and the other on automotive applications. There will be 10 tutorial lectures and about 300 technical papers scheduled into 7 parallel tracks and one plenary poster session. A short course on 'Modal Analysis' and a seminar on 'Advanced Techniques in Applied and Numerical Acoustics' will also be held.

Information from http://www.isma-isaac.be/

Oceans 2002

The Oceans 2002 Conference & Exhibition is being held 29-31 October in Biloxi, Mississippi. This is the annual conference the IEEE Oceanic Engineering Society and the Marine Technology Society. The technical sessions are expected to cover: Advanced Marine Technology, Marine, Ocean and Coastal Engineering, Marine Policy, Fisheries, Information Technology, Ocean Modelling, Integrated Ocean Observing, Communications, Underwater Acoustics, Non-acoustic Signals and Shallow Water Environmental Technology. Detailed information can be obtained at www.OCEANS2002.com.

Ultrasonics Congress 2003

The World Congress on Ultrasonics will be held in Paris, September 7-10 2003. The purpose of this Congress is to provide an overview of current research in ultrasonics, with an emphasis on bringing young researchers to this exciting area. The themes will include: Acoustic Microscopy, Acousto-optics, Biomedical Ultrasonics, Bulk and Surface Acoustic Waves, High Power Acoustics, Laser Ultrasonics, NDE/NDT, Non Linear Acoustics, Numerical Acoustics, Physical Acoustics, Sonochemistry and Underwater Acoustics. The conference will take place in the Biomedical Research Center at the Cordeliers of the University Pierre & Marie Curie. At this site, located in the historical Latin Quarter of Paris, a convent was built between 1234 and 1571, and became a famous school in competition with the nearby prestigious Sorbonne. Today, the convent's refectory and cloister remain splendid vestiges of past.

Further information from
wcu2003@sfa.asso.fr
or http://www.sfa.asso.fr/wcu2003/

NZ Conference

The New Zealand Acoustical Society Conference will be held on November 21st and 22nd 2002 at the Barrycourt Motel, Parnell, Auckland, New Zealand. The theme is "Sound in the Built Environment" and papers are invited on relevant topics including: Environmental Sound, Room Acoustics, Sound Insulation, Structural Vibration, Industrial Noise Control Applications, Rail noise, etc. The Abstracts deadline is July 19 2002.with the full papers by October 18. Further information from www.acoustics.org.nz.

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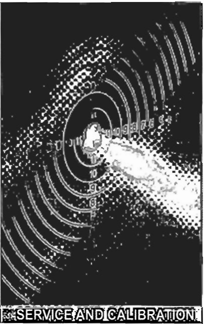

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Meeting Reports

NAL Colloquium

A one day colloquium at the National Acoustics Laboratory (NAL) in Sydney on 23 October 2001 to discuss the Causes and Prevention of Hearing Loss: Global trends in Industrial and Leisure noise, Interactions, Definitions and Strategies. This symposium included presentations by Donald Henderson from, Buffalo, New York on noise standards and new opportunities for inner ear protection, Henrik Dahl on Genetic predisposition to hearing loss, Ramesh Rajan on Protective functions. The symposium convenor, Eric LePage, spoke on evoked otoacoustic emissions and limitations of current testing procedures. Narelle M. Murray, also from NAL discussed the effects of leisure noise and Ross Dineen spoke on hearing aspects for construction workers.

The whole day's sessions has been video taped and edited down to one 5-hour tape which is available for $35 per copy (includes GST and postage within Australia). More information and ordering details from http://www.nal.gov.au/

VICTORIA DIVISION

A site visit to the INC Corporation in Oakleigh South was held on Mar 6. This company manufactures acoustic materials, pressure sensitive adhesive tapes, protective barrier fabrics and automotive soft trim components. A tour of the factory was led by Dr Mike Corrigan, John Simmons and Dr Marek Kierzkowski.

The first process to be observed was that of producing DECI-TEX® under licence by the patented Struto process. In it the raw material, an imported polyester fibre, is extruded to form basic 2 m wide bonded fibrous sheets of controlled thickness of from 6 to 43 mm, and surface density of from 200 to 2000 g/m². The heat-bonded nature of this material ('with a weld every mm') means that, because of the resulting low fibre release, the factory is virtually free from fibre dust. This basic material is then cut to size for a range of commercial products. Being difficult to cut, it must be cut by the rotating knives of INC's CNC fabric cutter. Unlike foams, which are naturally stable, Deci-tex when cut is unstable mainly in the lateral direction, but can be stabilized by being faced with 120 g/m² sheet. It is used as an acoustic absorber, an acoustic barrier material at high frequencies, and for thermal insulation. In one form or another, whether as tile or textile, it is being used in numerous building acoustics and automotive applications. Recent developments include corrugated acoustic panels, comprising corrugated perforated metal panels with a thin layer of Deci-tex affixed to the reverse side.

Secondly, the manufacture of adhesive tapes was demonstrated. These, usually with resin adhesives, can be single-sided, or double-sided after a second pass through the machine.

Louis Fouvy

News Items

Changes in BCA

The introduction of the changes in the acoustic requirements in the Building Code of Australia (BCA) for the dividing partitions between residential occupancies is getting closer. The basic change is to increase the minimum required performance in sound transmission loss by at least 5 units.

In February the Australian Building Codes Board (ABCB) distributed the Regulation Document/Regulatory Impact Statement (RD 2002/02) for public comment. This estimates that the proposal to effectively raise the level of sound insulation between dwellings will add an additional cost (to the total construction cost) of 1% for housing and 2% for other dwellings (where floor insulation in addition to wall insulation is required).

The documentation is available from www.abcb.gov.au and follow the links to Whats New.

QLD OHS Legislation

The scale used to measure peak noise in Queensland is set to change with amendments to workplace health and safety laws from February 1, 2003. Division of Workplace Health and Safety General Manager Rob Seljak said the National Occupational Health and Safety Commission changed the National Standard for measuring peak noise levels in July 2000 to improve accuracy. "The subsequent amendment changed the scale for measuring peak sound pressure levels from an unweighted (linear) peak sound pressure level to a C-weighted peak sound pressure level," Mr Seljak said. Queensland noise regulations are based on this national standard and it is proposed that the State's legislation be amended to reflect this change."

The amendment will take effect from February 1, 2003, which will give businesses that measure peak sound pressure levels time to modify or replace existing equipment, if it cannot currently measure the C-weighted peak.

CSR

Bradford Insulation

Excellence in Acoustics Award

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

Winners Award: an inscribed plaque and prize to the value of $2,500.

Finalists Award: gift to the value of $250.00 each plus travel assistance for presentation of final submission.

Who can enter? Any professional, student or layperson involved or interested in any area within the field of acoustics.

Entries are limited to one entry per person or group. Group entries are allowable, however, it is important that should a group entry be submitted all individuals that form that group are nominated on the entry form with one principle to serve as contact. Nomination of all involved will allow for equal recognition in the event that a group receive an award. Should a group entry become a finalist the principle will also act as final submission presenter.

How current does the basis of my submission have to be? Entries need to represent a body of work that is no older than three years old at the time of submission. As this is an award that recognises excellence and innovation it is important that all submissions are representative of up to date technology, creativity and relevancy.

What is required for entry?

An entry form is to be completed with all relevant particulars included.

The submission is to include

- 200 word executive summary. This should describe the essence of the entry, outlining the most noteworthy points with a particular focus on why an award of excellence should be considered.
- submission no greater than six A4 pages, which should be forwarded as electronic attachment to the Australian Acoustical Society General Secretary watkinsd@castlemaine.net

Selection of finalists

The judging panel will select up to 5 finalists. These will be invited to provide a more detailed submission and a verbal presentation.

Timeframe

Entries close 5.00 pm Friday 11 October 2002

Up to 5 finalists will be announced in November 2002 at the Australian Acoustical Society Conference in Adelaide.

Submission of finalists' full presentation: Thursday 20 February 2003 in Sydney

Presentation of Award at Wespac8, April 2003 in Melbourne

Application Forms and more information from www.acoustics.asn.au

WorkSafe WA Update

A new Code of Practice for Managing Noise at Workplaces was approved for use in non-mining Western Australian workplaces on 19 March 2002. The code provides practical guidance for assessing and managing noise which may be damaging to the hearing of people in workplaces. The code is based on the 2000 edition of the National Code but contains up-to-date technical references and cross-references to WA legislation. It is available on WorkSafe WA's website at: http://www.safetyline.wa.gov.au/pagebin/codewswa0222.htm or in hardcopy (for $3.30 plus $1 postage) by phoning (08) 9327 8775.

The exposure standard for peak noise level in regulation 3.45 of the WA Occupational Safety and Health Regulations will change to a C-weighted peak noise level of 140 dB(C) on 1 July 2002. This will bring WA into line with the National Standard, which was changed in 2000 to achieve more reliable results.

Two new case studies are on the website http://www.safetyline.wa.gov.au/. One is about a new much quieter pile driving technique and the other about reducing noise exposures in a night club and a case study on active control of fan noise will soon be added. More case studies are always welcome.

Acoustic Shock is an emerging health issue of concern, particularly to headset users in call centres. There will be two sessions on Acoustic Shock during WorkCover's Injury Management Week (20-25 May). These will include a talk by Dr Rob Patuzzi of UWA on the theory of physiological causes of the symptoms, and a talk by a WorkSafe WA inspector dealing with call centres.

Further information from Pam Gunn at WorkSafe WA, gunn@worksafe.wa.gov.au or tel: (08) 9327 8669.

EU Directive on Vibration

Agreement has now been reached between the European Parliament and the Council of Ministers on the text for the Vibration Directive. In time these changes may filter through to Australia. The significant amendments which were agreed are:

o the whole-body vibration daily exposure action value will be reduced to 0.5 m/s^2 (from 0.6 m/s^2 in the common position).

o transitional periods before the limit values must apply (starting when the regulations are implemented in 2005) will be 2 years for new equipment, 5 years for existing equipment and 9 years for existing equipment in agriculture and forestry.

The common position daily exposure action value and limit value for hand-arm vibration remains at 2.5 m/s^2 and 5.0 m/s^2 respectively.

A full copy of the Common Position text can be found on http://europa.eu.int/eur–lex/pri/en/oj/dat/2001/c_301/c_30120011026en00010013.pdf

Noise Notes on Line

This publication, from Multi Science Publishing, provides an update on noise related issues in UK, Europe and around the world. It is now available on-line for personal subscribers at the rate of UK£39 per annum.

Information Multi Science Publishing, mscience@globalnet.co.uk

Standards Australia

Standards Australia Committee AV-003 has recently published AS/NZS 1270:2002 Acoustics – Hearing Protectors that includes new physical test requirements. This Standard was considered by the Committee as a compromise between the US and European approaches to hearing protection. AS/NZS 1270:2002 supersedes AS/NZS 1270:1999.

AV-003 is now reviewing the four parts of the IEC 60645 Audiometers series. The Therapeutic Goods Association has asked SAI to expedite this series adoption due to current Australian legislation being debated in the House of Representatives. The adoption of the Standards is scheduled for mid-year 2002.

Due to the increasing embrace of wind power as a renewable energy by Australia, a new Committee is currently being formed within Standards Australia. The new Committee objective will be to produce a methodology for the measurement of noise produced from wind farms. IEC 61400-11 'Wind turbine generator systems – Part 11:Acoustics noise measurement techniques', will be considered by the Committee for possible adoption.

Committee AV-004 Acoustics – Architectural is currently planning to publish AS 2253.1 Method of field measurement of the reduction of airborne sound insulation of building elements which is planned to be part one of a five part series for field measurements. Most of Standards in this new series are proposed to adoptions on the upcoming ISO 140 series. AS 2253.1 will replace AS 2253:1979.

Committee AV-004 is also planning to publish AS 1191 Methods of laboratory measurement of airborne insulation of building elements. At present, both standards are scheduled for publishing by mid-year, so that the Australian Building Codes Board may consider the Standards for inclusion in their proposal to change the sound insulation provisions of the Building Code of Australia.

EV-010 Acoustics – Community Noise has recently completed the revision of AS 2377:1980 Methods for the measurement of airborne sound from railbound vehicles. The published Standard should be available for purchasing by May 2002. Due to proceeding being undertaken by NSW EPA for a new rail noise policy, the proposed new Standard Acoustics – Railway noise intrusion - Building siting and construction has been placed on hold by the Committee.

ISO/TC 43/SC1 Noise and ISO/TC 43/SC2 Building Acoustics meetings have been scheduled for the end of May in Paris.

For inquires about the above activities contact Suzanne Wellham at Standards Australia on 02 8206 6821 or at suzanne.wellham@standards.com.au

Environmental Labelling

Standards Australia has announced that it has no involvement with a body called the Australian Environmental Labelling Association (AELA) which is proposing to issue a series of 'voluntary environmental labelling standards'. Standards Australia holds the secretariat of the ISO subcommittee on environmental labelling and has issued a handbook and other standards in this area of environmental labelling.

TAS Feb 2002

Voice response systems

Standards Australia committee IT/22 has been revising AS 4262-1997 which deals with Interactive Voice Response (IVR) systems. Many of these cause great frustration when they are the primary means of communication with government and businesses. New clauses in the Standard will deal with statement phrasing, feedback, error messages and information on how to reach a real person. The committee's next task will be consider adding requirements for IVR systems where the use input is by means of speech recognition.

TAS April 2002

FASTS

The President of the Federation of Australian Scientific and Technological Societies (FASTS), Prof Chris Fells included comments on the following issues in his recent report to societies:

Research Priority Setting

I have written to the Minister to express concerns about the recently-announced research priority areas, and met with Science Minister Peter McGauran to discuss ways that FASTS and the working science community could contribute to the development of national priority areas. While FASTS has consistently supported the identification of national goals, as well as some degree of prioritisation of the research effort towards meeting those goals, we do have reservations about the system as it was announced. Our concerns fall into five areas: process, target, quantum, plurality, and coordination.

In our view, Bill Clinton's science adviser Dr Neal Lane had it right when he addressed the National Press Club in October 2000. When asked how Australia should prioritise its research, he responded: "How do you know what to invest in? You still can't do better than betting on the very best people with the very best ideas."

"Science Meets Parliament" Day 2002

I expect this will be on November 12-13, 2002. This unique event offers a special opportunity for working scientists from across Australia to make the case for science and technology directly to their representatives in Parliament. While the funding initiatives announced in "Backing Australia's Ability" in January last year were a welcome step, Australia is still out of step with other comparable countries in terms of our national investment in S&T.

Working With Departments

I led a team of FASTS' Executive members in meeting with officers from the newly-formed Department of Education, Science and Training. It was a productive discussion on our respective priorities and an exploration of matters where we can contribute to each other's efforts. We discussed matters such as the Prime Minister's Science Council; the Forum we propose holding at the National Press Club in mid-year; the division of responsibilities between the two Ministers with responsibility for science; triennium funding for the government-funded science agencies; the possibility of having another funding round for Major National Research Facilities; and the selection round for new CRCs in May.

The Prime Minister's Science, Engineering And Innovation Council

The Standing Committee (the scientist members of PMSEIC) met on March 8. These meetings set the agenda for the full Council meetings which the Prime Minister and most of his Cabinet colleagues attend. The agenda has yet to be approved by the Prime Minister, but the draft focuses on natural resource issues. The full Committee chaired by the Prime Minister meets on May 17. This is becoming an increasingly important committee in terms of setting national agendas.

The FASTS' Policy Document

The Policy Committee chaired by Ken Baldwin will be handling the drafting process, and all Member Societies will be invited to comment on draft documents. The 2002 document will have more graphs and diagrams , and reflect changes in the science policy scene with the announcement of "Backing Australia's Ability" and the injection of the ALP's Knowledge Nation proposals.

Meetings With Ministers

In recent months I have met with Science Minister Peter McGauran; Education, Science and Training Minister Brendan Nelson; Shadow Science and Research Minister Senator Kim Carr; and Senator Natasha Stott Despoja as Science spokesperson for the Democrats early in March. These formal meetings are complemented by more frequent informal contacts between our offices, and by phone conversations.

New Products

KINGDOM

SignalStar Vibration Instruments

Kingdom Pty Ltd announced that, in conjunction with Data Physics Corp, it had released a new line of computer controlled permanent magnet and electromagnetic vibrators providing 23 new shakers with Sine force Vibration ratings of from 8.9 N (2 lbs) peak to 35.58 kN (8000 lbs) peak & beyond.

Data Physics SignalStar **Shakers** are built of modern materials using state of the art manufacturing processes. Small shakers utilize permanent magnet fields and damped glass fiber flexure suspensions. Larger units employ a field electromagnet and roller-guided elastomeric suspensions. Automatic pneumatic load-leveling is a standard feature of larger shakers, permitting the full stroke capability of the machine to be used with heavy test objects. SignalStar armature structures are fabricated from magnesium for superior axial stiffness and minimum moving mass. Shaker trunnions are available for vertical, horizontal and inclined operation.

The **Power Amplifier** line provided to drive the vibrators include 20 models rated from 60 VA up to 70,000 VA. They are powered in most cases with a variable supply up to a 280 V mains supply and are provided with Electronic Centering in some cases. All amplifiers are air-cooled and interlocked to integral protective shaker sensors for safe and simple operation.

SignalStar **Slip Tables** simplify horizontal axis tests. Tables are offered with slip plate mounting surfaces from 300mm x 300mm (12" x 12") up to 1000mm x 1000mm (39" x 39"). There are 28 slip tables available in the range providing four types of construction including Minibase (stand alone) with guide or hydrostatic bearings and Monobase with guide and hydrostatic bearings.

The 50 **Head Expanders** available are both of round and square form with half of them providing Vibrodamping. Round head expanders are available as 250 mm diameter for 120 mm diameters armatures and up to 1000 mm diameter for 330 mm armatures. Square head expanders are available as 300 mm square for 220 mm diameters Armatures and up to 1000 mm square for 330 mm Armatures.

SignalStar **Head Extenders** simplify combined thermal/vibration testing. The extender is used to penetrate the test chamber. These can be provided with a companion thermal barrier to protect the shaker from chamber heat.

SignalStar **load bearing platforms** provide external support of heavy objects and increased load table surface. These systems are ideal for modest-level vertical excitation of heavy objects or groups of fixed items.

Acoustic Analyser software

A new version of Data Physics Vibration and Acoustic Analyser includes significant changes and enhancements. It includes ACE, Mobilyzer and DP620VXI. The new features include:

Network Monitoring License (Monitoring) which allows remote users to monitor a currently running analyzer over a network.

Quality Control (QC) package which measures and evaluates product quality based on acoustic, vibration or other characteristics.

Sound Quality - Loudness (SQ) module which offers Zwicker loudness and other sound quality metrics in realtime.

Human Body Weighting is a measurement which applies to all frequency domain measurements and includes a display function to apply hand/arm weighting or whole body weighting.

Information Kingdom Pty Ltd 02 9975 3272

DAVIDSON

Microflown Technologies

Davidson Measurement now represent the Microflown Technologies product range. In place of the pressure microphone these utilise an "acoustic ampere meter". The following measurements, over the range 20-20kHz, are relatively easily performed: 3D sound intensity, 3D sound power, 3D sound energy , 3D acoustic impedance, 3D particle velocity and sound pressure.

Three Microflowns and one miniature microphone are used in an ultra miniature sound intensity probe, just 5x5x5mm. With the half inch PUPPY sound intensity probe a broad band measurement is performed at once and the changing of spacers and recalibration is no longer required. Because the dimensions of this probe are similar to a half-inch pressure microphone, all standard mountings and windshields can be used. Data acquisition can be done with the use of a sound card of a personal computer and Matlab based software is available. The general purpose ICP® particle velocity probe is designed as a general-purpose particle velocity microphone. All kinds of specialised Microflowns can be made on request.

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

ARL

Digital Noise Analyser.

Acoustic Research Laboratories announce the release of the NC10 Digital Noise Analyser from Cortex Instruments in Germany.

The standard package has hardware which includes 2 channel display on a large display screen and 1 GB of memory capacity. The standard software supplied enables the NC10 to display SPL, Octave & third octave data and to perform FFT analysis and data can be downloaded to a PC. It can accept inputs from a variety of sources including microphones, DAT recorders and ICP accelerometers. Accessories include special microphones and calibrators, intensity probes, building acoustics accessories, post processing software – and more.

Information: Acoustic Research Laboratories. Tel 02 9484 0800, www.acousticresearch.com.au

BRÜEL & KJÆR

Odeon

Brüel & Kjær has entered into an agreement to become worldwide sole distributor of ODEON, a professional prediction software tool for indoor acoustics developed at DTU, the Technical University of Denmark. The ODEON project was founded with the purpose of providing reliable, yet easy to use, room acoustics prediction software. Continuous development, immense experience and acoustic know-how have resulted in a software that allows prediction of acoustics in public venues as well as in industrial environments.

ODEON covering room acoustics, noise control, and auditorium acoustics is available in three editions - Industrial, Auditorium and Combined, all running Windows® 95, 98, Me, NT® and 2000.

7836 Auditorium Edition – for calculation of a large set of room acoustical parameters. A number of graphical tools are built-in including a reflectogram, a 3D reflection path display and reverberation curve displays. This edition also provides built-in auralisation features.

7835 Industrial Edition – for environmental acoustics where SPL, SPL(A), T30 and STI are the important results. With this edition you can model point sources, line sources and surface sources, making it possible to model large and complex sound sources.

7837 Combined Edition – includes all the features found in the Industrial and Auditorium editions.

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

BORAL

Firelight™ System

Noise in multi-residential apartment buildings is a key concern for prospective home purchasers. Until recently, combating low frequency noises, often attributed to home theatre and DVD sound systems has been a difficult and expensive process. To overcome this Boral Clay & Concrete has introduced the designed Firelight™ System specifically to provide effective and economical sound insulation for party walls in multi-residential developments.

Extensive testing by Boral has shown that the Firelight™ System can achieve sound ratings of up to R_w67. The Firelight™ System comprises either a double-height brick (11.162FL) or one-and-a-half height brick (11.119FL) made from Boral's lightweight masonry material combined with various walls linings systems including Boral Plasterboard and Villaboard.

What makes the system so efficient, says Mr Maloukis, is the Firelight™ Brick which covers twice the area of a normal brick, but only weighs 50% more. The Firelight™ System also has excellent impact resistance due to the use of independent stud walls which isolates vibrations.

Information: 1300 360 255, www.boral.com.au

CSR

Gyprock Soundchek

Having successfully pioneered the use of Gyprock Soundchek 10mm for residential applications, CSR has now launched Gyprock Soundchek 13mm plasterboard for commercial applications. The high density acoustic plasterboard can be used in non-fire rated systems where sound resistance is important. The product is stronger than standard 13mm plasterboard with improved impact resistance and breaking strength. A single layer is sufficient to meet the Rw 30 requirements for ceiling and ducts in bathrooms and kitchens.

Gyprock Security Wall

Gyprock Security Wall Systems offer very high acoustic resistance with values up to R_w 61 achieved. Steel sheets incorporated into the wall system provide a simple and effective deterrent to intruder entry, whilst the use of light and easily handled components also endure the system is simple and quick to construct.

Information: tel 1800 621 117 or www.gyprock.com.au

WARSASH

Digital Displacement Vibrometers

The VDD series of PC based digital decoding vibrometers from Polytec sets a new standard for resolution and accuracy in non-contact vibration measurement. Its superior signal to noise performance allows direct displacement measurements with picometre resolution at frequencies up to 1MHz. It is the only commercially available laser vibrometer recognized by the German Bureau of Standards (PTB) as a primary calibration standard. Applications include calibration of accelerometers, non-repetitive run-out measurements on precision spindles, investigations on high frequency piezo transducers, MEMS devices, seismic sensors and analog vibrometer systems.

Information from Derek Huxley,
Warsash Scientific, tel 02 9319 0122,
<mailto:sales@warsash.com.au>
sales@warsash.com.au, www.warsash.com.au

Digital Vibrometer Used During World Trade Center Recovery Effort

Polytec's new portable digital vibrometer was used to monitor the stability of World Trade Center Building 4 during the recovery effort at "ground zero". Workers were concerned that heavy-duty equipment being used to remove debris would cause the building to collapse. Professor Jim Sabatier working for the Army on sabbatical leave from the National Center for Physical Acoustics at the University of Mississippi, was flown to the disaster site in a helicopter when it was determined that traditional surveying instruments were generating false alarms and unnecessary interruptions in the recovery effort.

The vibrometer continuously monitored vibrational modes of the building between 1.4 and 11 Hz from a distance of about 50 meters, measuring from columns and trusses between 3 m and 20 m above the ground. After observing these modes for several hours the first night, Dr. Sabatier indicated to the (Federal Emergency Management Agency) FEMA engineers that he thought Building 4 was stable. Monitoring continued for several days in an attempt to provide an early warning to the rescue workers of any impending danger. Dr. Sabatier took turns working 12-hour shifts with two engineers from the US Army CECOM Night Vision and Electronics Sensors Directorate (NVL) located at Fort Belvoir Virginia.

The Polytec PDV-100 is the world's first portable laser Doppler vibrometer with digital signal processing and is available in Australia and New Zealand from Warsash Scientific, sales@warsash.com.au, www.warsash.com.au.

Science & Technology Award

The Ian Clunies Ross Memorial Foundation is pleased to announce that the Clunies Ross National Science & Technology Award 2003 is now open for nominations.

Since 1991 these Awards have honoured sixty-seven people from every state and territory for their successful application of science and technology for the economic, social or environmental benefit of Australia. Award recipients are presented with a silver medal at a formal ceremony and dinner to be held March 2003 in Melbourne.

Nominations close on Friday 26 July 2002. Information from Ian Clunies Ross Memorial Foundation, Tel: (03) 9854 6266
Fax: (03) 9853 5267, info@cluniesross.org.au or www.cluniesross.org.au

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2002

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

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

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

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

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

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

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

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

16 - 21 September, 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

29- 31 October, MISSISSIPPI
Oceans 2002 Conference
www.OCEANS2002.com

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

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

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

2003

7 - 9 April, MELBOURNE.
WESPAC8
Acoustics on the Move
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7-10 July, STOCKHOLM
ICSV 10
Fax: +46 8 661 91 25, icsv10@congrex.se, www.congrex.com/icsv10

14-16 July, SOUTHAMPTON
8th Int Conf Recent Advances in Structural Dynamics
http://www.isvr.soton.ac.uk/sd2003/

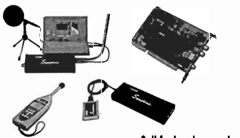
24-27 August, KOREA
Internoise 2003
Fax +82 2762 4946, www.internoise2003.com,
internoise2003@covanpco.co.kr

September 7-10, PARIS
World Congress on Ultrasonics
http://www.sfa.asso.fr/wcu2003

2004

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

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



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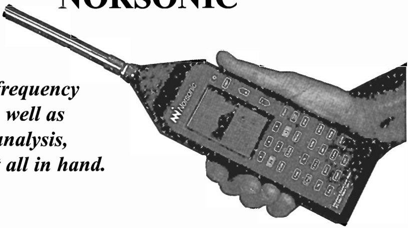
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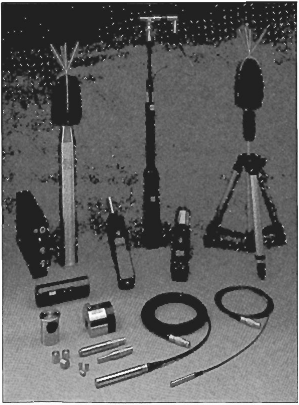

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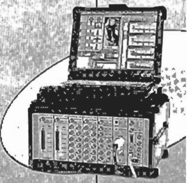

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