Acoustics 2002
Innovation in Acoustics and Vibration

The Australian Acoustical Society Annual Conference

13–15 November 2002, Hotel Adelaide International, Adelaide, South Australia

BOOK OF ABSTRACTS

Published by:
Causal Productions Pty Ltd
www.causal.on.net
info@causal.on.net
## Table of Contents

<table>
<thead>
<tr>
<th>Page</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Keynote</td>
</tr>
<tr>
<td>3</td>
<td>Active Noise Control (1)</td>
</tr>
<tr>
<td>4</td>
<td>Underwater Acoustics (1)</td>
</tr>
<tr>
<td>5</td>
<td>Environmental Noise + Musical Acoustics (1)</td>
</tr>
<tr>
<td>6</td>
<td>Underwater Acoustics (2)</td>
</tr>
<tr>
<td>6</td>
<td>Musical Acoustics (2) + Aeroacoustics</td>
</tr>
<tr>
<td>7</td>
<td>Marine Bioacoustics</td>
</tr>
<tr>
<td>7</td>
<td>Underwater Acoustics (3)</td>
</tr>
<tr>
<td>8</td>
<td>Underwater Acoustics (4)</td>
</tr>
<tr>
<td>9</td>
<td>Active Noise Control (2) + Electroacoustics</td>
</tr>
<tr>
<td>10</td>
<td>Architectural Acoustics</td>
</tr>
<tr>
<td>10</td>
<td>Acoustic Inversion Techniques</td>
</tr>
<tr>
<td>11</td>
<td>Audio Engineering + Structural Acoustics and Vibration</td>
</tr>
</tbody>
</table>
Uncertainty and Variability in Ocean Acoustics: How do We Cope?

David M.F. Chapman, Ronald T. Kessel; Defence R&D Canada - Atlantic, Canada

Our understanding of ocean acoustics has advanced considerably over the last century. The physics, the mathematical analysis, and the computer models have matured to the point that – given sufficient and valid inputs – we can predict and interpret an ocean acoustic field with great precision. The constraints on computer power and time have eased, and we can readily calculate acoustic fields of great complexity. However, the actual oceanographic and geophysical environment is highly variable (both in time and in space) and our knowledge of the environment is uncertain. How can we bridge the gap between (1) the precision of the physics, mathematics, computation, and measurement of acoustic fields and (2) the inherent variability in the governing environmental parameters and our uncertain knowledge of them? Some insight is provided by analysing the following case: in a weakly range-dependent shallow-water environment, adiabatic mode theory is a reasonable model of the acoustic field. Both the mode functions and the mode wavenumbers vary somewhat with range, but the resulting multimode interference pattern is acutely sensitive to variations in mode phase. (To be more precise, it is the relative phase differences between pairs of modes that is important.) In the case of a nominally range-independent environment with stochastic spatial variability, how sensitive are the mode phase differences to the environmental variations? The mathematical physics suggests that we need a combination of (1) a proper understanding of the parameters that “matter” to the wavenumber, and (2) good statistical knowledge of the true environmental parameters and their correlations in Nature. Although couched in the terminology of underwater acoustics, the coordination of these aspects may be of interest in other disciplines facing similar dilemmas in wave propagation.

Active Noise Control (1)

Xun Li, Colin D. Kestell, Xiaojun Qiu, Anthony C. Zander, Colin H. Hansen; University of Adelaide, Australia

Tonal noise radiated from an exhaust stack of a spray dryer system used to make powdered milk has been the source of unwanted community noise. The tone is characterised by a frequency above the first mode cut-on frequency of the exhaust duct and it is not steady in either amplitude or frequency. Passive silencing of the exhaust is a very expensive and inconvenient option and for this reason the feasibility of using active noise control was investigated.

Zander and Hansen developed a theoretical model for analysing the effect of active noise control on higher order rectangular duct modes, and used it to evaluate the effects of source size, location and strength. It was shown that the total acoustic power reduction was dependent on the relative locations of the control sources. More recently this work was applied to the practical example of a cylindrical spray dryer exhaust stack to determine the most suitable location and number of control sources and error sensors. Prior to installation in the exhaust stack a half scale model was constructed to test the theory.

Here, the effect of the error sensor locations on the active control on higher order acoustic modes propagating in the half scale circular duct is investigated experimentally using real time control with a multi-channel feedforward controller. A tacho meter signal at each bladed pass frequency (BPF) was fed into the controller as the reference signal for the feedforward control. Two configurations of error sensors on the duct wall were tested to evaluate how the error sensor locations affect the control performance, which was evaluated in the far field of the duct outlet.

Acoustic Absorbers for Noise Control: Optimal Design Aspects

Richard C. Morgans1, Ben S. Cazzolato1, Anthony C. Zander1, Colin H. Hansen1, Steven Griffin2, Steven Lane3,1University of Adelaide, Australia; 2Boeing-SVS Inc., USA; 3Kirtland Air Force Base, USA

Passive vibration and acoustic absorbers, called vibro-acoustic devices (VADs), have previously been used to minimise the transmission of low frequency rocket motor noise into structures that represent launch vehicle fairings. This unwanted noise can damage or destroy the payload, and has been blamed for many first day satellite malfunctions. The work described in this paper is the first stage in the development of analytical models of VADs with the intention of producing “optimal” designs. A simple model of an acoustic resonator coupling to a single acoustic mode was used to give analytical results for the reduction of the acoustic mode amplitude in terms of the non-dimensional coupling parameter, and can be used to provide approximate analytical solutions for an optimal broadband acoustic absorber. The feasibility of constructing these optimal acoustic absorbers was then investigated, using three different types of resonators: namely loudspeakers; Helmholtz resonators; and a membrane resonator. The techniques presented in this paper are general, and can be applied to passive noise control of interior spaces, as well as to the design of optimal acoustic absorbers.

Virtual Sensing: Open Loop vs Adaptive LMS

Jacqueline M. Munn, Ben S. Cazzolato, Colin H. Hansen; University of Adelaide, Australia

Virtual sensors using the forward-difference prediction algorithm have shown great promise for remote sensing in active noise control systems. These virtual sensors use linear arrays of microphones containing two or more microphone elements. Under certain circumstances the accuracy of these virtual sensors has been disappointing due to inherent errors such as phase and sensitivity mismatches as well as uncorrelated noise between the microphone elements. The open loop sensing microphone weights are determined without accounting for these errors, which can lead to inaccurate pressure estimates at the virtual location. It is hoped that an adaptive LMS algorithm will overcome these difficulties by using the algorithm to adapt the weights used to modify the signals from the sensing elements which form the array. The algorithm adapts the sensing microphone signal weights until the weighted sum of the sensing microphone signals produces the same signal as the microphone at the virtual location. Once this has been achieved, the sensing microphone weights are fixed and the microphone at the virtual location is removed, thus creating a virtual microphone.

The quality of the pressure estimate and the level of control achieved at the virtual location using an open loop algorithm is compared with that obtained using the LMS adaptive algorithm.

An Adaptive Vibration Absorber

Simon Hill, Scott Snyder, Ben S. Cazzolato; University of Adelaide, Australia

This paper considers the design of a vibration absorber to reduce structural vibration at multiple frequencies, with an enlarged bandwidth control at these target frequencies. A theoretical study is carried out using Finite Element Analysis where it is shown that the first six resonance frequencies of the absorber can be moved to a desired frequency.
Active Control of Noise Transmission in a Pipe-Pump System: Theory
Xia Pan, Ross Juniper; Defence Science & Technology Organisation, Australia

CDROM Proc. Page: 42-51

The preliminary theoretical analysis of active control of noise transmission in a pipe-pump system using a fluid-wave actuator is described. The model considered is a long pipe, with one end excited by a pump noise and the other end terminated anechoically. The acoustic and structural coupling in the pipe-pump system is investigated in detail. Acoustic control is achieved using the fluid-wave actuator located on the inside of the pipe wall and downstream of the pump. It was demonstrated that significant reductions of sound pressure levels (SPLs) can be achieved when the sound field consists only of plane waves and is below the first cut-off frequency.

Underwater Acoustics (1)

Modelling Vibrational Noise for Sonar Arrays Mounted to a Cylindrical Platform
Scott Foster; Defence Science & Technology Organisation, Australia

CDROM Proc. Page: 52-63

Low frequency conformal sonar arrays mounted to maritime platform hulls can be expected to experience significant platform induced self-noise. Understanding the noise structure of such arrays must therefore begin with some understanding of the vibrational dynamics of the structure. In this paper we discuss a propagation approach to modelling the vibrational self-noise of a linear array axially mounted to a cylindrical shell. The advantage of this approach over more conventional modal approaches is that it explicitly separates the local dynamics (Green’s function) from the global dynamics. This facilitates heuristic interpretation of spectral features and enables fundamental dispersion relations and local impedance properties to be characterized independently of complicated mode structure. Our formulation is also a natural one for characterizing highly localised noise events, in the presence of large structural damping, when mode structure may not be prevalent.

Predicting the Nearfield Signature of a Ship at One Shallow Water Site from a Measurement at Another
Marshall V. Hall; Defence Science & Technology Organisation, Australia

CDROM Proc. Page: 64-70

The objective is the prediction of the nearfield acoustic signature of a large merchant ship at a shallow water site where measurement of the ship is impracticable, based on a signature that has been measured elsewhere. An empirical method is to tow a point noise-maker along the ship track, repeat this at the impracticable site, compare the measured Sound Pressure Level spectra, and adjust the ship signature spectrum by the difference. An analytic method is to represent the ship by a small number of point sources distributed in space, allowing each source to have its own spectrum and directivity. For each source, the spectrum and directionality would be expressed as functions of frequency and angle. Before obtaining these properties the geoacoustic model (GAM) of the seabed at the measurement site would need to be derived, using inversion of local transmission loss data. To apply the results at the impracticable site would require the GAM at that site, which again would be obtained by inversion of local TL data. The analytic method therefore requires more effort than the empirical method. The performance of the empirical method is examined theoretically, using a ship represented by its propeller, and synthetic seabed environments.

Optimisation of Transmission Predictions for a Sonar Performance Model for Shallow Ocean Regions
Adrian D. Jones, Janice S. Sendt, Z. Yong Zhang; Thales Underwater Systems, Australia

CDROM Proc. Page: 71-80

Recently, the Maritime Operations Division (MOD) of DSTO has been conducting research directed at assessment and improvement of sonar performance prediction tools for range dependent ocean environments. This work has included comparisons between acoustic transmission loss data measured by MOD at shallow ocean sites with range-dependent transmission predictions obtained by Thales Underwater Systems (TUS) based on a geophysical-based seabed database. This task has included an assessment of the potential for an MOD in-situ technique to infer seabed reflectivity at shallow grazing angles and provide input to transmission models for regions where existing holdings of seabed properties are sparse. Examples of comparisons are detailed in this paper. This paper reviews the recent progress in this work in which an MOD algorithm has been used to derive equivalent fluid seabed parameters for the RAM (Range-dependent Acoustic Model) model from in-situ data.

Multi-Ping Integration of High Frequency Sector Scan Sonar Images
Kam W. Lo; Defence Science & Technology Organisation, Australia

CDROM Proc. Page: 81-90

A high frequency sector scan sonar can be used to detect and classify stationary man-made objects located on the sea floor. Sonar images are generated by beamforming the hydrophone data over the region of interest. In a shallow water environment, multipath signal returns cause spurious peaks in the sonar image. These spurious peaks increase the false alarm rate or the chance of misclassification of the object. The sonar detection and classification performance may be improved by multi-ping integration, in which images (or frames) from successive pings are combined after proper alignment that compensates for the apparent movement of the object(s) in the image sequence due to the platform motion. The integration can be either incoherent or coherent, depending on whether each frame of the image sequence represents the output magnitude or complex output of the beamformer. This paper considers multi-ping integration when the sonar operates in the forward-looking mode. The multi-ping integration is implemented in the spatial frequency domain using the fast Fourier transform, assuming that the image from each ping is generated in Cartesian coordinates. Experimental results are presented to demonstrate the potential of using multi-ping integration for improving the detection and classification performance of a high frequency (forward-looking) sector scan sonar, and the advantages of coherent integration over incoherent integration.

Application of PE Method for Shallow-Water Propagation Predictions (Presentation Only)
Dmitry Mikhail; Acacia Research Pty. Ltd., Australia

CDROM Proc. Page: 91-91

High fidelity, full-wave simulations of low frequency sound propagation in shallow water are complicated and time-consuming. The propagation factor is affected by many environmental factors, each of those are either difficult or numerically expensive to account for. More complete description generally increases CPU load. On the other hand, the practical applications of underwater propagation models are time demanding. The requirements of the user interface indirectly result in further increase of the computation time. The paper presents some approaches that help to narrow the gap between the modeling capabilities and the user demands. We consider reciprocity, sampling and interpolation methods, parallel computations, and initial and boundary conditions. The model features desired for the optimal performance are discussed. The results are based on the experience gained from developing a visual tool for analysis of low-frequency sound propagation.
Environmental Noise + Musical Acoustics

**FLULA – Swiss Aircraft Noise Prediction Program**

*Stanislaw Pietrzko, Rudolf Büttiker; EMPA - Swiss Federal Laboratories for Materials Testing and Research, Switzerland*


Aircraft noise prediction methodology based on measured aircraft noise radiation directivity patterns to calculate single event aircraft noise was developed at the Swiss Federal Laboratory for Materials Testing and Research (EMPA) and was first presented in 1988.1,2. Since that time this methodology has been refined; a computer noise prediction program Flulaerm (FLULA) is now available at the EMPA, which is based on a set of directivity data for various commercial and military aircraft. This overview paper deals with the measurement and modeling of aircraft directivity patterns and their FLULA-implementation. After a description of the simulation model FLULA and its unique database of “in-flight” directivity characteristics, the validation of FLULA procedure is presented. It is based on measurements around Zurich Airport, conducted in the summer of 2000. There were 495 departures of various aircraft types measured at 5 locations up to 10 km away from point of takeoff. Using the radar recordings of the flight paths, the noise level-time curves were calculated with FLULA for each measured flight. Average deviations of the Sound Exposure Level (SEL) between calculations and measurements were lower than 1 dB for well-controlled situations. The main causes of variation were (i) the individual power setting of the aircraft and (ii) the accurate modelling of climb profiles. This validation shows that FLULA calculates accurate results. Thus FLULA can calculate all A-weighted values such as Lmax, SEL, Leq and NNI.

**Prediction of Long Range Propagation of Peak Overpressure from Blast Events**

*Peter Teague, Stewart Blake; Vipac Engineers & Scientists Ltd, Australia*

CDROM Proc. Page: 100-109

To obtain reasonably accurate predictions of the resultant peak overpressure levels of loud blast events at large distances (> 10km) requires the application of acoustic ray tracing techniques and multi-path propagation models. The variation in vertical meteorological conditions can strongly influence the sound amplification/focussing or dispersion effects.

An extensive noise monitoring program of ordnance detonation and firing has been carried out at the Proof & Experimental Establishment (P&EE) Range at Port Wakefield in SA. Peak overpressure levels have been measured simultaneously at a range of distances (from 10m to 100km) for various blast types during different conditions. The vertical trace of meteorological conditions with height was recorded using a radiosonde balloon (up to at least 10,000m) as well as the variation in ground level weather conditions over distance.

A range of acoustic models and algorithms were used to predict the likely overpressure levels at different sites in different conditions, which were then compared with the measured data in those conditions. The ray tracing algorithms (developed in the US) include vertical meteorological conditions, such as temperature and wind profiles. The models also incorporate the ground topography for a substantial area out to 100km away.

The ultimate aim is to provide forecast estimates of the overpressure levels at different distances/locations and provide the likelihood of causing significant impact (such as high annoyance levels or property damage) for specific sets of forecast conditions.

**Case Study of Tyre Noise: Assessment and Comparison of Different Road Surfaces**

*W. Mior, M.H.F. de Salis; Vipac Engineers & Scientists Ltd, Australia*


This paper presents an investigation of the potential noise impact of a change of local road surface conditions from an asphalt-surfaced thoroughfare with a 50 km/h speed limit to a porphyry setts-surfaced shared traffic zone with a 10 km/h speed limit. The proposed new road surface raised concerns that noise from tyre/road interaction might increase with introduction of the uneven porphyry surface. This might adversely affect adjacent residents, particularly at night. A measurement procedure based on AS2240 was devised to assess noise levels generated by the tyre/road interaction of a light-weight test vehicle at running speeds of 10, 20, 30 and 50 km/h on existing asphalt and porphyry setts road surfaces. Results of the study indicate that noise generated by tyre/road interaction on a porphyry setts surface at or below speeds of 20 km/h would be lower than for an existing asphalt road at speeds of 50 km/h. A comparison and discussion of spectral and overall noise levels generated due to tyre/road noise interaction is also included in the study. Results indicate that noise levels generated due to tyre/road interaction on porphyry setts were appreciably higher than those generated on asphalt for similar speeds, with differences exceeding 9 dB(A) at a speed of 30 km/h.

A Community Noise Burden Approach to Highway Route Selection

*Kym Burgemeister; Arup Acoustics, Australia*

CDROM Proc. Page: 120-126

At the earliest stages of developing a new highway many potential routes are considered and a rigorous 'route selection' process is used compare the routes and enable selection of the 'preferred route'. The constraints on the route options include their effects on flora and fauna, indigenous heritage, visual amenity and noise. The NSW RTA has recently introduced an Environmental Noise Management Manual that provides guidance on noise assessment for the route selection process. This guidance suggests assessing noise using 'Broad Descriptors' rather than by undertaking detail acoustic modelling for each of the routes, which is expensive, and somewhat redundant when put in context with the parcel of equally important constraints. An innovative Community Noise Burden (CNB) approach has been developed based on UK guidance on multi-modal transport studies. This approach has been used to broadly assess 12 route options near a proposed bypass in northern NSW. The benefits include reducing the early study costs, providing a more robust understanding of the relative noise impacts of each of the routes, and allowing the noise impacts to be more reasonably compared and contrasted with the other constraints.

Application of Modal Analysis to Musical Bell Design

*Behzad Keramati Nigjeh, Pavel Trivailo, Neil McLachlan; RMIT University, Australia*


The inharmonic partial frequencies of bending modes of bells can be tuned to a wide variety of frequency ratios. Bells with multiple pitch percepts, polygonal bells, can be designed by tuning partial frequencies to subsets of multiple harmonic series with fundamental frequencies at the required pitches. Bell geometry has been parameterised as capped cylinders of given wall thickness, length and circumference; cones of given cone angle and tapering wall thickness; and more complex forms with wall curvature. A qualitative explanation of the effects of mass and stiffness on the behaviour of particular mode types can be obtained from Finite Element Analysis (FEA) for a range of these geometric parameters is presented. The exact tuning of the bell partials is then achieved by applying shape optimisation algorithms to Finite Element model node positions once an initial geometry has been determined from the qualitative modal analysis. The design process for creating polygonal bells with a second pitch percept at a major 3rd and minor 3rd intervals above the bell fundamental frequency is described in this paper. These bells are compared to European bells containing minor 3rd and major 3rd partials using a range of relevant psycho-acoustic parameters.
Underwater Acoustics (2)

Reflectivity of Bare and Coated Plates and Resonant Scattering from Cylindrical Shells
Z. Yong Zhang; Defence Science & Technology Organisation, Australia

CDROM Proc. Page: 137-146

This paper first examines the reflection of water-borne sound from bare and coated steel plates with either water or air backings. It was shown that steel plates transit from being acoustically transparent at low frequencies to being acoustically hard at high frequencies. Simple expressions that delineate this transition process are given for quick engineering assessments. Coincidence, or trace matching, leads to maximum coupling between the water-borne sound and the plate-borne waves at certain frequencies and incident angles. The effects of absorptive coatings were examined using nominal parameters. It was found that the coating starts to be effective when the frequency exceeds the fundamental longitudinal resonant frequency of the coating layer. Local reflectivity gives insight into the character of specular reflections and this knowledge is then applied to interpret features of resonant scattering from air-filled, cylindrical steel shells. It was shown that interference of circumferential elastic waves around the shell with reflections from the shell surface gives cancellations at low frequencies and reinforcements at high frequencies.

TMA Using Passively Sensed Transient Signals
Dragana Carevic; Defence Science & Technology Organisation, Australia

CDROM Proc. Page: 147-154

This paper considers the problem of target motion estimation using short duration acoustic emissions, or transients, radiated by the target. Range and bearing measurements obtained using passive localisation are non-Gaussian and, also, non-stationary, due to their dependency on the tracking geometry. Moreover, transients radiated by the target are usually observed in clutter, so false measurements are possible. Robust M-estimators are applied to determine the target motion parameters using such measurements. One of the tested procedures defines the weighting function using median of absolute residuals, while the other, denoted as the annealing M-estimator, combines a deterministic annealing procedure into a robust M-estimator.

A Novel Nonlinear Equalizer – Application to Underwater Acoustic Communication
David W. Bartel¹, Langford B. White²; ¹Defence Science & Technology Organisation, Australia; ²University of Adelaide, Australia


The problem of establishing and maintaining reliable and robust underwater acoustic digital communication links may be a severe challenge for the communications engineer, especially in shallow, turbulent water. The presence of time-varying multipath distortion and severe Doppler drift leads to difficulties in channel equalization. By broadening the signal model class to the nonlinear, improvements may be had, but often at the expense of increased computational complexity and algorithm instability. A recently developed type of blind decision feedback equalizer (DFE) incorporating fixed lag smoothing is extended to the class of digital communication channels whose input-output relationship is described by a Volterra series. The computational complexity and bit error rate performance of the equalizer are discussed via simulations of an underwater acoustic communication channel. A comparison is made with a standard DFE scheme, demonstrating the potential performance gain of the new equalizer, with only a moderate increase in computational complexity.

Using a Towed Array to Characterise the Underwater Acoustic Noise Radiated by the Tow-Vessel
Alec Duncan¹, Darryl McMahon²; ¹Curtin University of Technology, Australia; ²Defence Science & Technology Organisation, Australia

CDROM Proc. Page: 165-175

This paper presents the results of a study aimed at determining the feasibility of using a towed array to measure the radiated noise signature of the tow-vessel and to localise the dominant noise sources. The general principle is that by executing a U-turn manoeuvre it is possible to bring the acoustic section of the towed array into an orientation suitable for beamforming back to the tow-vessel. The beamforming process is complicated by the fact that the array is continuously moving and distorting and that the vessel is in the near-field of the array.

The same manoeuvre also provides array geometries that are favourable for determining information about the local acoustic propagation conditions that can then be used to estimate the absolute strengths of the vessel noise sources for input into propagation models appropriate to other environments.

The results of simulation studies and field experiments are presented.

Musical Acoustics (2) + Aeroacoustics

Acoustics of the ‘Arpeggio Series 1’ Set of Bells
Susanne Thwaites¹, Helen Printer²; ¹CSIRO CTIP, Australia; ²Independent Researcher, Australia

CDROM Proc. Page: 176-185

A set of four, novel, bells comprising a major triad and octave has been designed and cast in bronze by an Adelaide bronze artist. The bells have a particularly pleasing strike tone as well as beautiful decoration. To identify the origins of the bell tones, and to assist in tuning, the bells have been modelled using finite element analysis.

Australian Aboriginal Musical Instruments – the Bullroarer
Neville Fletcher¹, Alex Tarnopolsky², Joseph Lai²; ¹Australian National University, Australia; ²University of New South Wales at ADFA, Australia


The “bullroarer”, a simple slat whirled around on the end of a cord and producing a pulsating low-pitched growling sound, is a feature of the traditions of many peoples around the world, and particularly of the Australian Aboriginals. This paper examines the aerodynamics that leads to the rotation of the slat, and also analyses the sound production mechanism. Detailed experiments confirm the theoretical predictions.
**Marine Bioacoustics**

**Observations and Explanation of Low Frequency Clicks in Blue Whale Calls**

Adrian D. Jones\(^1\), Robert D. McCauley\(^2\), Douglas H. Cato\(^1\); \(^1\)Defence Science & Technology Organisation, Australia; \(^2\)Curtin University of Technology, Australia

Recordings of Blue Whale calls are believed to include low-frequency components or "clicks" which are noteworthy for the signal levels achieved (over 190 dB) at such a very low frequency range (about 20 Hz). These features have been observed in calls recorded from Blue Whale aggregations in recent years at locations off the Rottnest trench. These observations are of interest to the Royal Australian Navy (RAN) as, firstly, causes of ocean ambient noise need be understood in relation to interference to the operation of passive sonar systems, and, secondly, it is desirable for RAN vessels to be aware of the proximity of Blue Whales and other marine mammals so that suitable separation distances may be achieved. This paper reports a brief study of the low frequency clicks observed in Blue Whale calls and postulates the mechanism by which these signals are generated. As has been suggested previously, it is concluded that the 20 Hz clicks most likely are the self-excitation of the gas bubble within the lungs by the whale. This is probable, as the wave form has the appearance of the decay of a resonance, and as there are no other conceivable mechanisms which might give rise to a resonance within a whale body at 20 Hz. This is explained with recourse to bubble physics, which are extended to include a treatment of both spherical and elongated bubbles, and to considerations of the effects of various depths at which a whale might call. As is shown, the amplitude of the bubble oscillations required to generate the observed signal levels is surprisingly large.

**Predicting Biological Sea Noise in Australian Waters (Presentation Only)**

Robert D. McCauley\(^1\), Douglas H. Cato\(^2\); \(^1\)Curtin University of Technology, Australia; \(^2\)Defence Science & Technology Organisation, Australia

Many marine animals use sound prodigiously in their normal lives. Invertebrates, fish and whales may all produce regular, intense, transient signals or calls, mostly over the infrasonic to high audio frequencies. Several animals, particularly certain fish species, call *en masse* to produce choruses, where the sound of an individual within the chorus is lost and only a roaring sound is heard. In Australian continental shelf waters biological sources are a normal aspect of the background sea noise. Choruses can routinely raise ambient levels by 10-15 dB and on certain occasions by in excess of 30 dB. Such elevated levels may seriously impact the performance of active sonar systems. In order to predict ambient sea noise levels, the authors have carried out long term detailed studies in selected areas and spot measurements over wider areas. The detailed studies have allowed us to understand the behaviour of sources which can then be translated to wider regions, and verified or refuted by the more geographically dispersed measurements. Almost all sources studied have shown time, space and behavioural influences on their noise production. We are now beginning the process of building these myriad biological factors into noise prediction models for passive sonar performance.

**Australian Research in Marine Mammal Acoustics (Presentation Only)**

Douglas H. Cato\(^1\), Robert D. McCauley\(^2\), Michael J. Noad\(^3\), Tracey Rogers\(^4\), Ken W. Schultz\(^2\); \(^1\)Defence Science & Technology Organisation, Australia; \(^2\)Curtin University of Technology, Australia; \(^3\)University of Queensland, Australia; \(^4\)Zoological Parks Board of NSW, Australia

Australian research in marine mammal acoustics over the last 20 years has found a wide diversity of sounds and acoustic environments around Australia and in the Antarctic. These have included studies of vocalisations from several species of large whales, dolphins and seals. Humpback whale songs over 20 years have usually shown the well structured, evolving song typical of the species, though with some anomalies. Recently, there was a remarkable replacement of the east coast song by west coast song in a way that appears to be unprecedented in animal communication. Research has also included the impact of boat noise and seismic air guns. A large set of sounds have recently been recorded from blue whales off the west coast, and research is continuing. Leopard seals studied in captivity and in the Antarctic have shown a range of vocalisations, including songs from lone animals in the breeding season, and sounds during interaction between individuals throughout the year. Studies of the sounds of dolphins in the wild have included comparisons of whistles between four species and behavioural analysis of vocalisations of the bottlenose dolphin. Research continues in each of these areas and includes studies of the behavioural function of the sounds, the effects of noise and the use of sound as a tool in estimating abundance and tracking movements.

**Underwater Acoustics (3)**

**Background Sea Noise in the Great Barrier Reef (Heron Island)**

Byron Martin; University of Adelaide, Australia

Australia has a long coral reef (The Great Barrier Reef) running along the eastern seaboard. This is a strategic part of our coastline; it is where the majority of the population resides and lies along a key shipping route. This paper presents a sample of the background sea noise along The Great Barrier Reef, measured on one of the many islands forming part of the coral reef. The measurements were made on the lee and windward side of the island in water which has significant coral reefs.

**Relative Performance of Single Scan Algorithms for Passive Sonar Tracking**

Graham W. Pulford; Thales Underwater Systems Pty. Ltd., Australia

Conventional wisdom asserts that more complicated tracking algorithms generally have better performance because they are more like optimal probabilistic filters. While this may be true for algorithms with non-zero look-ahead, this claim needs qualification when only "single-scan" approaches are considered. In the context of passive sonar, we provide a detailed performance study of 5 such algorithms ranging in complexity from a nearest-neighbour Kalman filter to the joint probabilistic data association filter. Somewhat unexpectedly it eventuates that, when automatic track maintenance based on signal strength is employed and all algorithms use identical tuning regimes, the simplest algorithm is more effective than the others except in track loss probability. Some real sonar data examples are also provided.
A new powerful method of solving scattering problems in waveguides, the Multi-Modal Integral Method (MMIM), has been suggested and developed with the author in a series of previous publications. The method is based on a non-standard representation of Green's function. It combines advantages of the integral equation and eigenfunction methods and provides a quickly converging and highly accurate solution. The solution takes into account all the waveguide modes up to infinite order, which allows the method to be used for predicting characteristics of the scattered acoustic field at frequencies close to resonances of scattering objects.

In the current work the MMIM is applied to sound wave scattering by an elastic sphere in a three-dimensional layer filled with an inviscid compressible homogeneous fluid. The boundaries of the layer are impenetrable and parallel to each other. The incident wave is known and represented as a sum of normal modes of the layer. The boundary value problem is reduced to a system of linear equations with respect to Fourier coefficients of a distribution of acoustic sources on the surface of the sphere. Transformation of Green's function is shown to be necessary for completing the solution of the problem. The possibility of applying the MMIM to the three-dimensional scattering by an elastic spheroid is discussed.

Osprey Acoustic Processing Workstation

Chris King; Department of Defence, Australia

Acoustic Analysis of underwater sound recordings for the purpose of exploiting Acoustic Intelligence has traditionally relied on the use of expensive mainframe equipment and inelastic software, contract bound and subject to obsolescence within 3 years. Upgrading from such a system, AJAC decided to manage development internally, specifying a system specific to ADF requirements, PC based, and easily distributable within the organisation. A development-only contract was let to Acoustic Technologies based in Sydney with experience in developing acoustic analysis software. Functionality and specification remains the property of the ADF. The design remains flexible and enhancements can be readily included without contract complications. "Osprey" is a complete acoustic analysis package with onscreen analysis tools, track reconstruction, directional processing for all ADF acoustic collection platforms, and easily integrable with other applications for databasing and publishing results. Osprey can be distributed to other ADF units at a fraction of the cost of alternative, more traditional systems.

Underwater Acoustic (4)

Modelling of Sound Transmission from Air into Shallow and Deep Waters

Z. Yong Zhang; Defence Science & Technology Organisation, Australia

Sound transmission from air into shallow and deep oceans are analysed and modelled to underpin studies in relation to military (the detection and localization of aircraft by underwater hydrophones) and civil (the impact of aircraft noise on marine mammals) applications. The present study includes some environmental complexities that were not modelled in earlier work, e.g., sound and wind speed variations in the atmosphere, sound reflection from Jones, refractions by the changing sound speed profiles, and effects of a wind-driven rough sea surface. It was shown that sound energy transmitted into water via the refracted waves is further affected by refractions within water and by reflections from the seabeds, producing interference structures and convergence zones. The evanescent waves are confined near the sea surface and are therefore little affected by refractions or by the presence of seabeds. Furthermore, it was shown that because sound energy transmits into water within a narrow cone of steep propagation angles, temperature and wind speed gradients in the atmosphere have little effects on the sound field underwater, but they affect significantly the sound pressure field in air.

An Alternative Form of Green's Function for a Three-Dimensional Fluid Layer

Alex Zinoviev; University of Adelaide, Australia

Representation of scattered acoustic field as an integral of Green's function over acoustic sources is a powerful technique, which allows one to solve complex scattering problems. One of the most significant applications of this technique is the Boundary Element Method, commonly used in acoustics. Another technique, where the integral representation of the scattered acoustic field is employed, is the Multi-Modal Integral Method, developed by the author. However, the Green's function of a plane three-dimensional waveguide in its common form is an infinite series of the waveguide's normal modes. Due to slow convergence of the series close to the source, the Green’s function has limited applicability for using in the integral representation of the scattered acoustic field in such a waveguide. The current work shows, that the Green's function of a three-dimensional fluid layer can be transformed into a sum of two quickly converging series. The transformed Green’s function as a whole is demonstrated to be convergent also at infinitely small distances between the source and observation points. This allows inclusion of all normal waveguide modes, including evanescent modes, up to infinite order. The obtained alternative form of the Green's function can be used in integral representations of the scattered acoustic field in the plane three-dimensional fluid layer without restrictions.

Underwater Exhaust Noise

Christopher Norwood, Li Chen; Defence Science & Technology Organisation, Australia

For a conventional diesel-electric submarine exhaust noise from the diesel engine is an important feature of the radiated acoustic signature during snorting. The high frequency region can be dominated by the broadband exhaust noise. DSTO have conducted a series of CFD studies and model scale experiments to investigate the impact of exhaust design on the radiated noise. The results of this work show that structural radiation from the exhaust outlet is an important source as is the noise from the gas exit, while the noise from the rising bubble cloud and surface splash are relatively unimportant. This paper outlines the computational and experimental studies undertaken and presents the results of this work.

Ocean Acoustics Research in the United States (Presentation Only)

Jeffrey Simmen; Office of Naval Research, USA

Ocean acoustics research in the United States is almost exclusively funded by the Office of Naval Research (ONR). ONR’s Ocean Acoustics Program supports basic research addressing an understanding of the physics of the generation, propagation and scattering of acoustic (and elastic) waves in the temporally and spatially varying ocean environment. The program encourages both theoretical and experimental research efforts in three ocean-acoustic focus areas: high-frequency acoustics, shallow-water acoustics, and long-range propagation.

The purpose of this presentation is to describe some of the exciting research and new directions in each of the three focus areas. Particular emphasis will be given to some of the international collaborations and major multi-institutional initiatives that are ongoing in the program, including efforts aimed at: understanding the anomalous penetration of high-frequency sound into poroelastic media; linking the indistinguishable acoustic arrivals from long-range propagation in the ocean with wave chaos; quantifying the acoustic mode coupling that results from the ubiquitous nonlinear ocean internal wave on the shelf and understanding the behavior of this nonlinear wave; characterizing the acoustic clutter that results from shallow subsea floor buried river channels and understanding the existence of acoustic hot spots; and modeling the impact of sound in the ocean environment on the hearing and behavior of a marine mammal.
Generalizations of the Energy-Flux Parabolic Equation

Dmitry Mikhin; Acacia Research Pty. Ltd., Australia

CDROM Proc. Page: 261-270

Parabolic equations written in terms of energy flux are inherently immune to the problem of energy conservation at vertical interfaces. Mikhin [J. Comp. Acoust. 9 (2001), 183-204] achieved exact reciprocity and energy conservation in a finite-difference PE model following this approach. However, that model used the implicit Crank-Nicolson scheme in range, which requires a small range step for accurate solution. The present work generalizes the exponential propagator of Collins [J. Acoust. Soc. Am. 93 (1993), 1736-1742] to solve the energy-flux PE. The obtained solutions remain strictly reciprocal and energy conserving, while allowing large range steps. The numerical efficiency is improved by one or two orders of magnitude. For some problems the possible range steps exceed those of the existing split-step Padé algorithms. A technique is proposed to calculate the acoustic pressure within the large steps, so the solution combines fast advance in range with dense range sampling. Numerical examples are provided.

Active Noise Control (2) + Electroacoustics

Active Control of Low-Frequency Sound in a Mining Vehicle Cabin

Colin H. Hansen, Daniel A. Stanef, Richard C. Morgans; University of Adelaide, Australia


Accurate finite element models of both the acoustic cavity and the enclosing structure of a mining vehicle cabin have been used together with modal coupling analysis to estimate the benefit of active noise control over a frequency range from 10 to 300 Hz. The model was validated with data estimated using quadratic optimisation and experimental measurements of the transfer function between the control sources and error sensor locations. The finite element model was then used to explore the effect of the number and location of control sources and error sensors on the achievable reduction in both global and local potential energy in the cabin.

Active Vibration Control of an Intermediate Mass: Vibration Isolation in Ships

Xun Li, Ben S. Cazzolato, Colin H. Hansen; University of Adelaide, Australia


The traditional approach for isolating the transmission of vibratory energy from a vibration source, such as a reciprocating engine, to a flexible support structure is to place passive isolators between the vibration source and the receiving structure. The selected vibration isolator must support the static load of the machine and must also have a sufficiently low stiffness so that the translational and rotational resonance frequencies of the machine, mounted on the isolators, are considerably less than the frequencies of the dominant disturbances generated by the machine. A passive isolator capable of adequate isolation at low frequencies can sometimes result in insufficient support stability for the equipment. One promising way around these problems is to use active vibration isolation with passive isolators to reduce the vibratory energy transmission. Ahn et al. proposed a hybrid-type active vibration isolation system using an electromagnetic actuator and air-springs. In their work, the electromagnetic actuator was used as an active element and the air spring acted as the passive element. It was demonstrated that this hybrid control system could provide a better isolation performance than the passive system alone. Gardonio et al. achieved the theoretical effectiveness of various control strategies for active vibration isolation. In their work, the minimisation of the total power transmission through the mounts to the receiver was compared with several control strategies: the minimisation of the axial velocities or forces; the minimisation of the axial power transmission; and the minimisation of the sum of the squared axial velocities and weighted squared forces. It was concluded that the cancellation of the total power transmitted from the source to the receiver through the mounts was the optimal control strategy for the cases they studied.

In this paper, the feasibility of using active vibration isolation to minimise the motion of an intermediate mass of a two stage passive ship engine mount is investigated in the laboratory. The work involved the use of a feedforward controller to cancel the total vibratory energy of the intermediate mass of a test rig simulating one of diesel engine mounts in a ship. The motion of the intermediate mass (a total of six degrees of freedom) was sensed using accelerometers to provide the error signals and several inertial shakers were mounted to the mass to act as control actuators. Both numerical simulation results and real time control results are provided.

A Simplified Method for the Determination of the Quality of an Anechoic Space at the CSIRO National Measurement Laboratory

Bruce H. Meldrum, Anthony Thorley; CSIRO National Measurement Laboratory, Australia


Successful calibration of noise measuring equipment to international standards requires an anechoic space. The CSIRO National Measurement Laboratory in Sydney has a medium sized anechoic room with cutoff frequency of 160 Hz constructed of graded density absorber that has been in use for this purpose successfully for over 20 years. A recent requirement for ISO17025 accreditation has led to a project to revisit the claim to justify that the space is anechoic to the required standards. To carry out such a survey is both expensive in time and equipment. As the NML space is used in a well defined and limited manner, the project adopted a modified approach that has justified the claim of anechoicity for the method of use. The results have demonstrated that it is possible to carry out such a survey in a timely and simplified manner and that the space meets all expectations for anechoicity. The method used and the results will be presented.

High Standards for Australia - A Report on the Recent BIPM Key Comparison for Vibration

Laurence P. Dickinson; CSIRO National Measurement Laboratory, Australia

CDROM Proc. Page: 299-308

In May 2000, Australia’s National Measurement Laboratory participated in an international key comparison that compared the Australian standard for vibration with 11 other National Measurement Institutes representing the leading standards laboratories from around the world. This key-comparison, the first of its kind for vibration, involved measuring to the highest possible accuracy the absolute sensitivity of a Bruel & Kjaer 8305 back-to-back reference accelerometer, and a Bruel & Kjaer 8305 WH2335 end-mount reference accelerometer. This paper summarises the recently released report on this very important benchmark for Australia’s vibration measurement capability, and confirms Australia as having a world-class vibration standard.

A Standard for Time Domain Windows for Fourier Analysis

Byron Martin; University of Adelaide, Australia


ISO is expanding the number of standards into Signal Processing, including Acoustics and Vibrations. This is one of a set of standards aimed at establishing international agreement on the implementation of what might be considered "standard procedure". This paper will present the Draft Standard and the details of arriving at the draft version. AAS through Standards Australia supports this work.
**Architectural Acoustics**

**Speech Privacy Evaluation of Sound Masking in Open Plan Offices**

David Luck¹, John Challen²; ¹Hyder Consulting (Australia), Australia; ²University of New South Wales, Australia

CDROM Proc. Page: 319-326

Speech privacy in open plan offices is an acoustically challenging problem, notably increased speech intrusion. One acoustic treatment, sound masking is a spectrally shaped background noise added to eliminate unwanted workplace distractions. This study assessed the speech privacy performance of sound masking installation using established subjective test methods. Three test scenarios: normal (45-48 dBA), maximum (48-51 dBA) and no masking (43-48 dBA), were evaluated for speech privacy at set distances of 4-7m and 15m from the talker. Speech privacy at 4-7m distance was in all cases ‘Unsatisfactory’, highlighting direct field effects, while at 15m ‘Normal’ privacy was achieved through distance attenuation and sound masking. Sound mapping determined uneven masking coverage near return air grilles and ceiling cable penetrations. The results of the study indicate that sound masking is limited in the absence of an integrated design approach for these spaces.

**Measurement of the Impact Sound Insulation of Walls**

John Laurence Davy; CSIRO Manufacturing and Infrastructure Technology, Australia


The current version of the Building Code of Australia (BCA) regulates the impact sound insulation of walls separating a bathroom, sanitary compartment, laundry or kitchen in one sole occupancy unit from a habitable room (other than a kitchen) in an adjoining unit. A wall satisfies the impact insulation requirement, if it is one of three deemed-to-satisfy walls, has two or more separate leaves without rigid mechanical connection except at their periphery, or is identical with a prototype that is no less resistant to the transmission of impact sound when tested in accordance with Specification F5.5 of the BCA than one of the three deemed-to-satisfy walls. The test method uses a horizontal steel plate, which has to be held in contact with the test wall along its long edge. An ISO standard tapping machine is operated on the steel plate. The proposed revision of the acoustical provisions of the BCA specifies a maximum value of $L_{n,w}$ of 60 dB for a field verification method of impact sound insulation. It also specifies the test method more closely. This paper describes the revised wall impact sound insulation test and presents laboratory results on the three deemed-to-satisfy walls.

**Adelaide Airport Noise Insulation Program**

Ivailo Dimitrov, Neil C. Mackenzie; Vipac Engineers & Scientists Ltd, Australia

CDROM Proc. Page: 337-344

The Department of Transport and Regional Services is overseeing a $63 million federally funded sound insulation program for residential and public buildings surrounding the Adelaide Airport. VIPAC was engaged by the project manager (Clifton Coney Stevens) as the acoustic consultant to design the treatments for the buildings, to oversee the installation of the treatments and to verify their performance. This paper presents a review of the different building types in the area eligible for noise insulation and the noise control treatments utilised. An analysis of the noise reduction gained so far in the program (based on pre- and post-construction measurements) compared to the results of a similar aircraft noise insulation program undertaken in Sydney is presented.

**Acoustic Inversion Techniques**

**Inversion of a Layered Seabed Using Noise Coherence and Simulated Annealing**

Francine Desharnais¹, Matthew L. Drover², Chris A. Gillard³; ¹Defence R&D Canada - Atlantic, Canada; ²Dalhousie University, Canada; ³Defence Science & Technology Organisation, Australia


Ambient noise coherence between two vertically separated sensors can be used to relate the directionality of the noise field and the properties of the surficial sediment. Basic data-model comparisons of the vertical coherence of the noise field can be carried out to determine seabed properties. A model of vertical noise coherence was integrated with an inversion algorithm based on simulated annealing to search the range of model solutions, and find the best estimate of seabed properties. The method was proven successful with a relatively soft seabed approximated by a half-space medium. The technique was taken a step forward by using a one-layered version of the noise coherence model. The inversion was tested on synthetic data to investigate sensitivity to layer thickness.

**The Accuracy of Sound Absorption Measurements**

Fergus Fricke; University of Sydney, Australia


The measurement of sound absorption coefficients of materials in a reverberation chamber is a simple concept. In practice however it is difficult to define the room conditions and measurement procedures which will allow results obtained in one laboratory to be replicated in another. In the absence of funding to carry out a comprehensive assessment of how results can be made more reproducible, or even to determine what the reproducibility of the measurements is, there is a need to evaluate the way in which results are presented. In this paper an analysis is undertaken, using available data on ceiling tiles, to determine approximate confidence limits for results obtained using the Australian Standard AS 1045. Within the accuracy of sound absorption measurements it appears that absorption coefficients, at a given frequency, should be rounded off to the nearest 0.2 and even then there are limits on the frequency range over which the results are quoted. The noise reduction coefficient, NRC, and its ISO equivalent appear to be equally satisfactory. It is suggested that five classifications of absorbers, based on sound absorption performance, are all that is justified from the point of view of reproducibility of results and the use to which absorption data is put.

**Application of Ffowcs Williams and Hawkings Equation to Sound Radiation by Vibrating Solid Objects in a Viscous Fluid: Inconsistencies and the Correct Solution**

Alex Zinoviev; University of Adelaide, Australia


Ffowcs Williams and Hawkings (FWH) equation for the amplitude of aerodynamic sound radiated by a moving object in a fluid is widely accepted in present aeroacoustics. The equation states that the amplitude of the sound wave radiated by a moving rigid object is determined by the normal component of the total velocity of the object with respect to a stationary observer and by the total pressure in the fluid, which includes both viscous and acoustic stresses.

In the current work it is shown that the method of the derivation restricts the application of the FWH equation to the potential components of the pressure and the normal velocity. On this basis an equation, which differs from the FWH equation, is obtained. Both the FWH equation and the obtained equation are applied to the problem of sound radiation by a thin rigid plate, which vibrates parallel to itself in a viscous fluid. It is demonstrated that the FWH equation leads to prediction of a non-zero sound radiation from such a plate, while the obtained equation is shown to prohibit such radiation.

Implications of the obtained equation for active noise control are discussed.
Underwater acoustic propagation models can be used to predict and/or enhance the performance of sonar systems. In order to obtain accurate predictions of underwater sound propagation, knowledge of the geoacoustic properties of the ocean bottom is required. This is particularly true for shallow water applications where acoustic interaction with the seabed can have a significant impact on propagation. In cases where it is too difficult to measure bottom properties directly, these properties can be inferred using geoacoustic inversion techniques. In this paper we use geoacoustic inversion techniques to analyse a range-dependent problem. One approach commonly employed is to find the maximum-likelihood (ML) geoacoustic model using optimization to minimise a mismatch function. However, this technique provides no information on the uncertainties or covariance for the model parameters. To estimate these, a Bayesian formulation of matched-field inversion is used to generate posterior probability density (PPD) distributions, which combine prior information about the model with information from the acoustic data. The mean, covariance and marginal distributions for the PPD are calculated directly using a Gibbs importance sampler. Results are shown for a synthetic test case considered at the May 2001 Inversion Techniques Workshop held in Gulfport, MS.

**Underwater Target Tracking Using Signal Subspace TDOA and Differential Doppler**

Kevin B. Smith, Stefanos D. Koutas, Charles W. Therrien; Naval Postgraduate School, USA

This paper presents results of an analysis of transient data reception by a field of distributed sensors. The source is assumed to be moving at a constant speed and depth. Synthetic acoustic data is generated by a full-wave, broadband acoustic propagation model. The data received is then analyzed by signal subspace methods to determine the time-difference-of-arrival (TDOA) between the sensors. This allows for localization of the source position. Additionally, the difference between the Doppler shifts observed at each sensor location can be exploited to estimate the course and speed of the target, thereby providing complete tracking information by the reception of a single transient. A sample data set is examined in an environment based on a shallow water shelf break environment. It is found that the accuracy of the TDOA localization is negatively impacted by the introduction of the Doppler shifts due to the moving source, although localization is still achieved. The source course and speed are, however, determined with good accuracy, within 6° in course and less than 0.5 m/s in speed.

**Propeller Induced Structural Vibration Through the Thrust Bearing**

Jie Pan1, Nabil Farag1, Terry Lin1, Ross Juniper2; 1University of Western Australia, Australia; 2Defence Science & Technology Organisation, Australia

Propeller induced structural vibration through the thrust bearing is an important source for low frequency shipboard noise and underwater sound radiation from a submarine hull. Such vibration is investigated using a scaled experimental model. This research concentrates on the experimental characterization of propeller force, hydrodynamic force of the thrust bearing and vibration transmission through a thrust bearing into the supporting structure. The results of laboratory measurement of the propeller force and the complex hydrodynamic stiffness of the thrust bearing are presented in this paper. The response of the shaft axial vibration and flexural vibration of the supporting structure is also analyzed.

**Distributed Mode Loudspeakers**

Neil C. Mackenzie; Vipac Engineers & Scientists Ltd, Australia

This paper discusses the experimentally measured free-free dynamics of some simple vibration-isolator assemblies. If these dynamics are known, the behaviour of the vibration isolators can be incorporated into a mathematical model of a machine mounted on a foundation via these isolators. Frequency response functions (FRFs) for two single-stage isolators are presented, the isolators comprising two steel endplates and one or four rubber elements respectively. The FRFs were measured with the isolators suspended on a light string and excited by a modal hammer. From these, mode shapes are deduced and natural frequencies and modal damping are estimated. The actual isolator dynamics prove to be more complicated than initially assumed.

**Use of Resonance and Anti Resonance Frequency Shifts to Locate and Size Holes in Pipe and Duct Walls**

M.H.F. de Salis; Vipac Engineers & Scientists Ltd, Australia

The paper describes an acoustic location and sizing technique for small holes in the walls of ducts and pipes. The methodology is based on recent work by de Salis and Oldham, which utilizes shifts in measured resonance and anti-resonance frequencies of ducts to detect, locate and size blockages within the duct. Where a blockage is present in the duct wall the technique reveals its position as the onset of an apparent gradual expansion of cross sectional area in a reconstruction of the duct profile. This expansion may be termed as the effective expansion function and emanates from an initial apparent DC offset from the “equilibrium” line of zero expansion or contraction in the apparent duct profile reconstruction. Where the holes in the duct wall approximate to simple circular holes a simple impedance model can be employed to determine the equivalent radius of the hole thus allowing determination of the size of the hole. Using this equivalent area approach the technique is able to accurately size small circumferential slit shaped apertures in a duct or pipe wall with aspect ratios of up to 1:28.

**Nonlinear Modal Positive Position Feedback for Vibration Control in Distributed Parameter Systems**

Lei Chen1, Fangpo He2, Karl Sammut2; 1University of Adelaide, Australia; 2Flinders University, Australia

Trends in manufacturing technology towards the use of lightweight materials, and the existence of refined structural design methods have made the modern structures more flexible. The dynamic response of such structures is typically charac-
terized by low fundamental modal resonance frequencies, low structural damping, and low stiffness, which may result in severe vibrations under external disturbances. The control of low frequency noise and vibration in such structures has traditionally been difficult and expensive, because of the long acoustic wavelengths involved. A new technique of vibration suppression for flexible structures is investigated in this paper. The technique, called active Vibration Clamping Absorber (VCA), makes use of a quadratic-modal-positive-position-feedback (QMPF) control to design a simple second-order nonlinear controller that can suppress the vibration of structures at various resonant frequencies. The proposed QMPPF strategy uses a nonlinear modal control to transfer the vibration energy from the vibrating system to an artificial sacrificial-absorber so that large-amplitude vibrations in the main structure can be clamped within tolerable limits. The VCA can be constructed by using smart structure technology such as PZT patches excited by a digital signal processor controller. Simulation and experimental results reveal that the proposed strategy is a potentially viable means for real-time control of vibration in flexible structures.

Effects of In-Plane Modes on the Power Flow Characteristics in Ship Structures

Nicole Kessissoglou; James Cook University, Australia

CDROM Proc. Page: 433-442

The inclusion of the in-plane dynamic response in plate-like structures is of practical importance, since many structures consist of plates connected at inclined and right angles. It has been shown that in-plane vibration is significant in built-up structures such as ship hulls, as both the frequency increases, and the distance from the source to receiver increases through several intervening junctions. In this paper, the effect of in-plane waves on the power flow transmission in coupled plate structures is analytically investigated. An exact solution to describe the power flow transmission is presented, including flexural, in-plane longitudinal and in-plane shear waves. Numerical examples are given to display the time-averaged power flow characteristics associated with the built-up plates. The proposed method can calculate higher modes easily and efficiently to ensure convergence of solution, as well as taking into account variations in structural damping.
S
Sammut, Karl .............................................. 11
Schultz, Ken W. ............................................. 7
Sendt, Janice S. ............................................. 4
Simmen, Jeffrey ............................................. 8
Smith, Kevin B. ............................................. 11
Snyder, Scott .............................................. 3
Stanef, Daniel A. ........................................... 9

T
Tarnopolsky, Alex ............................................ 6
Teague, Peter ............................................... 5
Therrien, Charles W. ...................................... 11
Thomson, David J. .......................................... 11
Thorley, Anthony ............................................ 9
Thwaites, Suszanne ........................................ 6
Trivailo, Pavel ............................................. 5

U

V

W
White, Langford B. ......................................... 6

X

Y

Z
Zander, Anthony C. ......................................... 3, 3
Zhang, Z. Yong ............................................. 4, 6, 8
Zinoviev, Alex ............................................ 8, 8, 10