ACOUSTICS 2017 PERTH

SOUND, SCIENCE AND SOCIETY

THE 2017 CONFERENCE OF THE AUSTRALIAN ACOUSTICAL SOCIETY

PAN PACIFIC HOTEL PERTH WESTERN AUSTRALIA

NOVEMBER 19 - 22, 2017

PROGRAM AND ABSTRACTS

Australian Acoustical Society
Western Australian Division

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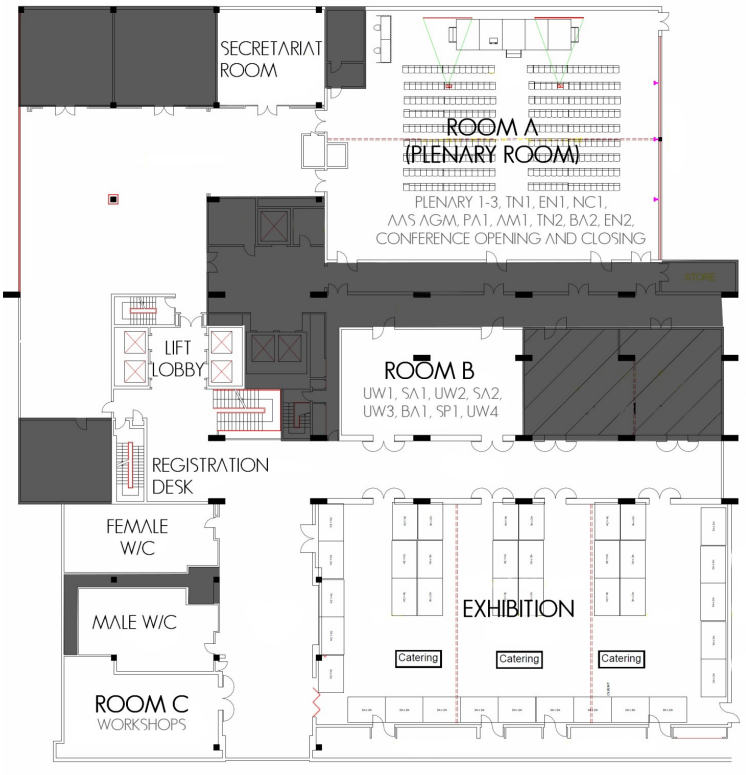

Summary Program

Sunday 19th November 2017, Pan Pacific Hotel, Perth

Time	
1800 – 2100	Conference Registration
1830 – 2100	Welcome Function

Monday 20th November 2017, Pan Pacific Hotel, Perth

Time		Room A:	Room B:	Room C:
0815	Registration (Foyer)			
0900 – 0920	Session S01	Conference Opening (Guest Speaker – WA Chief Scientist)		
0920 – 1000		Plenary 1		
1000 – 1030	Morning Tea (Exhibition Area)			
1030 – 1220	Session S02	TN1 - Railway noise and vibration	UW1 - Environmental	
1220 – 1320	Lunch (Exhibition Area)			
1320 – 1500	Session S03	EN1 - Environmental noise	SA1 - Fluid-structure interactions	
1500 – 1530	Afternoon Tea (Exhibition Area)			
1530 – 1710	Session S04	NC1 - Noise and vibration control	UW2 - Acoustic sensing of the marine environment	Workshop: Latest features of SoundPLAN
1715 – 1745		Australian Acoustical Society AGM		
1800 – 1930		Free Public Seminar: Swan Sound Science: exploring the Swan River through underwater sound		

Tuesday 21th November 2017, Pan Pacific Hotel, Perth

Time		Room A:	Room B:	Room C:
0845 - 1015	Session S05	PA1 - Physical Acoustics	SA2 - Structural acoustics	
0915 – 1015				Workshop: Noise and vibration monitoring with 01dB
1015 – 1045	Morning Tea (Exhibition Area)			
1045 – 1145	Session S06	AM1 - Acoustics of materials and products	UW3 - Underwater Propagation 1	Workshop: Road traffic noise assessment
1150 - 1230	Session S07	Plenary 2		
1230 – 1330	Lunch (Exhibition Area)			
1330 – 1510	Session S08	TN2 - Transportation Noise 2	BA 1 - Building Acoustics 1	
1510 – 1540	Afternoon Tea (Exhibition Area)			
1540 – 1720	Session S09	BA2 - Building Acoustics 2	SP1 - Signal processing, tracking and communications	Workshop: Noise prediction with iNoise
1730 – 1800	Transport available to Frasers Restaurant Kings Park			

Tuesday 21th November 2017, Frasers Restaurant Kings Park, Perth

Time	
1800	Drinks
1900	Dinner

Wednesday 22th November 2017, Pan Pacific Hotel, Perth

Time		Room A:	Room B:	Room C:
0845 – 1035	Session S10	EN2 - Environmental and low frequency noise	UW4 - Underwater Propagation 2	
0935 – 1035				Workshop: Customisation of wall and ceiling panels
1035 – 1105	Morning Tea (Exhibition Area)			
1105 – 1145		Plenary 3		
1145 – 1200		Conference Closing Ceremony		

Full Program

S01 - Plenary 1 Monday 20, 09:20, Room A

7 Vibro-acoustic sources in ground transportation

Arteaga, Ines Lopez
Mechanical Engineering Department at Eindhoven University of Technology The Netherlands

ABSTRACT
Long term exposure to ground transportation (road and rail traffic) noise is, after air pollution, the main environment related health stressor in densely populated areas and compromises the quality of life and, indirectly, the life expectations of millions of people. At speeds up to 130 km/h in road traffic and up to 300 km/h in rail traffic the main source of noise is the tyre/road (respectively wheel/rail) interaction. In this paper the sound and vibration generation mechanisms due to tyre/road and wheel/rail interaction are discussed, focusing on the similarities and differences between the sound and vibration generation mechanisms in these two systems. This perspective is further extended to the discussion of contact force modelling and characterization methods in both road and rail traffic systems.

S02 - TN1 - Railway noise and vibration, Monday 20, 10:30, Room A
Chair: TBA

70 Beyond Industry vs Government: A Partnership Approach to Managing Freight Rail Noise in NSW

Hanemann, Jacinta (1); Hanson, David (2); Howard, Giselle (1); McGuire, Justin (2)
(1) NSW Environment Protection Authority
(2) Transport for NSW, Sydney, Australia

ABSTRACT
The NSW Government manages the shared passenger / freight rail network around Sydney, stretching from Newcastle in the North to Nowra in the South and Lithgow to the west. As well as carrying one million passengers every day this network supports freight rail operations delivering billions of dollars to the state and national economies. The NSW Government, under its Long Term Transport Master Plan, has committed to doubling the rail freight task over the next decade. Noise from freight trains is the primary environmental issue associated with the network, and a major challenge in delivering this objective. This paper provides an overview of how rail freight noise is managed in NSW to protect the health and amenity of the community and support growth in the freight rail business. Key Government agencies are working in partnership with the freight industry, to design and implement appropriate management structures that are focussed on identifying and fixing key noise issues, mitigating legacy noise impacts through a targeted noise attenuation program and ensuring that new dwellings have noise controls built in. This paper outlines the development of these structures and describes how they are applied to manage both current rail freight noise impacts, including wheel squeal and noise emissions from locomotives, and future rail freight noise impacts, including from new rail infrastructure.

115 A measurement campaign for railway-induced vibrations in a building

Kuo, Kirsty (1); Maes, Kristof (1); Germonpré, Matthias (1); Lombaert, Geert (1); Degrande, Geert (1)
(1) Department of Civil Engineering, KU Leuven, Leuven, Belgium

ABSTRACT
In October 2016, an extensive field measurement campaign was conducted at a site in Belgium where a three-storey building with a basement is located 33m from a railway line that is used by both freight and passenger trains. Over a period of eleven days, the dynamic response in the free field and the building was measured simultaneously, resulting in a database of over 500 train passages. Nine measurement locations were used in the free field, and sixteen measurement locations were spread across the four floors of the building. In a second set of measurements, transfer functions were obtained using excitations from an impact hammer at a series of 17 sleeper locations over a total distance of 196 m. The vibration levels within the building are, on the whole, smaller than those measured directly outside the building. There is no clear trend of attenuation with floor height, and although it would generally be expected that mid-span locations would have higher vibration levels than near-column locations, this study shows that this is not always the case.

8 Predicting and managing rolling noise emissions from trains on the Perth metro passenger rail network

Zoontjens, Luke (1); Welsh, Lyndsey (2); Croft, Briony (3)
(1) SLR Consulting Australia, Perth
(2) Public Transport Authority, Western Australia
(3) SLR Consulting Ltd, Canada

ABSTRACT
Noise emissions from individual trains are generally not regulated in Western Australia, and for this reason there has not be a historical driver to reduce noise from the existing passenger network. As an outcome of the Public Transport Authority's recent overall strategic initiatives in noise and vibration management, this paper presents results from an investigation of rolling noise emissions from Series A and B trains operating on the Perth electrified network. The study compared STARDAMP model results with field measurements for both ballasted and slab track, examining scenarios with and without rail dampers.

The study has identified the contribution of track and rolling stock to overall passenger rolling noise emissions. Both the model and measurement data demonstrate that noise from the Perth metropolitan passenger train network can be effectively attenuated using rail dampers. In terms of overall A-weighted levels, a rolling noise reduction of up to 5 dB was predicted and measured for passenger trains on ballasted track. In a tunnel situation with slab track (Pandrol Vanguard), a rolling noise reduction of up to 8 dB was achieved. These benefits are greater than have been observed on the NSW passenger rail network. The efficacy of rail dampers as a noise control measure in Perth is attributed to the Perth rolling stock wheel design and track support dynamic stiffness. This paper presents an outline of the modelling and field measurement approaches taken, and the key factors in forecasting future rolling noise levels. The study highlights the advanced technology now

available in railway environmental impact assessment and noise control methods that could be applied to rail systems elsewhere.

107 **The PiP model and progress in ground vibration from railways**

Hunt, Hugh (1); Hussein, Mohammed (2); Hamad, Waleed (3)
(1) Cambridge University
(2) Qatar University
(3) WSP Group, London UK

ABSTRACT
Vibration in the ground causes problems. At large amplitude vibration causes damage, the most obvious example being earthquake damage. But the ground motion in a damaging earthquake is typically low-frequency (be-low 1Hz) and large-amplitude (above 10mm). At higher frequencies and lower amplitudes (above 10Hz, below 0.01mm) vibration is simply bothersome. Rarely do perceptible vibrations cause damage - the cracks in the plaster of a house near a busy road are most probably due to subsidence, or perhaps due to the kids jumping down the stairs two-at-a-time and slamming doors. Vibrations from man-made sources are arguably preventable and if we are disturbed by them, generally there is someone we can sue. Railway companies are an easy target for litigation so there is clear motivation for keeping vibration levels low. This paper addresses the general topic of ground vibration from railways and some of the common techniques used to control railway vibration and also the predictive tools available to engineers. It is often believed that the environmental concerns of residents near a proposed railway development will be met by putting the trains underground - in tunnels. Even though modern tunnelling methods are now quicker and cheaper than ever before, vibration concerns turn the average "nimby" into a NUMBY (Not Under My Back Yard). The underground-railway problem encapsulates all that is difficult about controlling a distributed source of ground-borne vibration. The paper also illustrates the features of the PiP model (Pipe in Pipe) developed in Cambridge and used to predict vibration levels in the ground near railway tunnels. It will also cover progress with other computational tools including MEFISSTO from CSTB in France, the Elasto-Dynamic Toolbox (EDT) from KU Leuven, FINDWAVE and the MOTIV project in the UK.

40 **An overview of structure-radiated noise and vibration assessment for elevated rail infrastructure**

Deivasigamani, Arvind (1); de Lacy, Atreyu (2); Toward, Martin (3)
(1) Acoustics, WSP Australia Pty Ltd, Melbourne, Australia
(2) Structures, WSP Australia Pty Ltd, Melbourne, Australia
(3) Institute of Sound and Vibration Research, University of Southampton, U.K.

ABSTRACT
Elevated rail infrastructure has potential to cause structure-radiated noise and vibration concerns during rail operations to the neighbouring community. In this paper, an overview of a structure-radiated noise and vibration assessment method is presented for a box girder design, with elevated station platforms fully supported off the viaduct structure. At first, a simplified method to assess structure-radiated noise levels from viaducts during preliminary design stages of rail infrastructure is explained. The paper also provides a detailed assessment method using a Noise of Railway Bridges and Elevated Structures (NORBERT) model. The NORBERT model is also used to predict force inputs on the structures, which are in turn used in a Finite Element Model (FEM) to predict the vibration levels on station platforms. A brief overview on criteria applicable for such assessments is provided. Sensitivity of parameters associated with rolling stock inputs, rail fastening system and bridge design are also briefly reviewed. The advantages and limitations associated with the assessment technique and modelling inputs are further explored in this paper. This assessment method can be used effectively to mitigate noise and vibration risks associated with rail infrastructure, and develop design solutions to address any relevant environmental concerns.

S02 - UW1 - Environmental, Monday 20, 10:30, Room B
Chair: Miles Parsons

91 **How do impulsive marine seismic surveys impact marine fauna and how can we reduce such impacts?**

McCauley, Robert D (1); Duncan, Alec J (1)
(1) Centre Marine Science and Technology, Curtin University, GPO Box U 1987, Perth 6845, Perth Western Australia, Australia

ABSTRACT
A summary of how petroleum seismic survey sources may impact marine fauna from invertebrates to fish, is presented, along with a discussion of the need for developing and testing alternative seismic sources to reduce biological impacts.

103 **Linked influences of environmental underwater noise and geomorphology on larger mass strandings of Odontocetes (Toothed Whales)**

Hamilton, Les
Defence Science & Technology Group, Data 61 Building, 13 Garden St, Eveleigh NSW

ABSTRACT
The trigger for a few instances of larger mass strandings of odontocetes (toothed whales) involving 10+ animals have been attributed to underwater noise generated by manmade causes. It is believed that a flight response from sounds made by particular sonar devices or underwater explosions caused odontocetes to approach unfamiliar coastal environments, after which a stranding ensued, possibly because the animals were in a panicked state. In comparison to these events the role of natural ambient underwater noise in strandings has received little attention, but it may be a contributing factor in some cases. Perhaps the most obvious is that storm generated noise may mask the presence of coastline wave noise, causing odontocetes to inadvertently approach coasts in difficult conditions. Paradoxically however, the ultimate reason for some mass strandings may be lack of underwater noise generated at shores in times of calms, rather than enhancements. This condition can occur in conjunction with a particular coastal geomorphology which may also act to defeat or impair cetacean biosonar, increasing the risks of stranding. In this case the coastal geomorphology and acoustics are linked. Strandings at other types of sites are related to physical factors

such as high tidal range and bathymetric configuration, and acoustics need not be invoked to explain them, although it may also be a contributing factor.

3 Quantitative analysis on the environmental impact benefits from the bandwidth-controlled marine seismic source technology

Li, Binghui (1); Bayly, Martin (2)
(1) SLR Australia Pty Ltd
(2) WesternGeco

ABSTRACT
A new marine seismic surveying source technology (eSource) has recently been developed based on physical control of the bandwidth of the source elements (Coste et al., 2014). The objective of the new seismic source is to reduce the potential environmental impact of seismic surveying operations on marine life. This new seismic source greatly limits the energy emissions at higher frequencies, while retaining the low-frequency bandwidth output that is crucial to seismic survey imaging.

This paper firstly introduces the new seismic source design considerations based on a literature review, fol- lowed by the eSource signature outputs simulated using the commercial airgun source modelling software package GundalfTM. In comparison with the conventional seismic sources, the potential environmental impact benefits from the new source are analysed in detail under different frequency weighting systems proposed for low-frequency (LF), mid-frequency (MF) and high-frequency (HF) hearing cetacean groups. This quantitative analysis is supplemented with a case study of an array arrangement comprising of conventional/eSource array elements that has been modelled and subsequently implemented for a marine seismic survey within the North West Shelf of Western Australia.

88 Airgun arrays for marine seismic surveys - physics and directional characteristics

Duncan, Alec J
Centre for Marine Science and Technology, Curtin University, Perth, Australia

ABSTRACT
Airgun arrays are by far the most commonly used offshore seismic survey sound sources and, despite ongoing attempts to develop alternatives, are likely to remain so well into the future. Although designed to produce their highest sound levels in the vertically downward direction, these arrays also emit considerable acoustic energy in other directions, thus making them a potential hazard for marine animals. Each airgun array produces a complicated sound field, determined by the array layout (positions and sizes of its airguns), in which both the waveform and spectrum of the signal vary strongly with direction. This paper examines the relationship between the array layout and the directional characteristics of the sound field it produces with a view to providing guidance on how changes in array layout can be used to reduce the environmental impact of an array while retaining its utility as a seismic survey source.

1 On the development of marine seismic airgun array source signature model

Li, Binghui
SLR Consulting Australia Pty Ltd

ABSTRACT
Seismic airgun arrays are the most widely used energy sources in marine seismic explorations. A detailed knowledge of the noise radiation from airgun array sources is essential for the array source modelling, design optimization and the post-processing of seismic signals for marine seismic explorations, as well as for assessing the consequent noise impact on marine fauna species as a result of the seismic explorations activities. Starting from Gilemore's spherical bubble motion theory (Ziolkowski, 1970), this paper reviews and discusses the state-of-the-art airgun array source signature model based on the physical process of airgun bubble oscillation behaviour, with considerations of effects from various physical factors. Subsequently, this study makes an attempt to develop an airgun array source signature model, with the relevant model parameters being optimised against signature outputs simulated using commercial airgun source modelling software package Gundalf™, through genetic algorithm optimization. Case studies concerning specific source array arrangements are presented to illustrate the level of accuracy and the limitations for the signature model developed for this study.

S03 - EN1 - Environmental noise, Monday 20, 13:20, Room A
Chair: Peter Popoff-Asotoff

36 Statistical properties of urban noise – results of a long term monitoring program

Song, Jonathan (1); Lenchine, Valeri (1)
(1) Science & Information Division, SA Environment Protection Authority, Adelaide, Australia

ABSTRACT
High levels of noise pollution in urban areas have a detrimental effect on the health and quality of life of the affected population. Variations in environmental noise levels generally represent a random process affected by multiple factors. Apart from temporal noise variations, substantial differences in the noise pattern may be augmented by multiple factors that can be expected in a complex urban environment. However, there are some generic patterns and statistical characteristics that can be extracted from long term data. This paper analyses common features of sound pressure time histories and frequency spectra using a data set collected over 12 months at different urban locations. It is shown that sound pressure level (SPL) magnitudes do not follow a normal distribution, however several night time samples can be considered "almost normal". A-weighted and C-weighted noise levels were shown to be highly correlated throughout the monitoring period for all monitoring locations. Insights into the frequency content indicate a strong correlation between its neighbouring 1/3 octave levels and with wider frequency groups. Several spectral components were highly correlated with A- or C- weighted SPLs or both. The apparent similarity of noise variations and spectral content between monitoring locations highlights an opportunity to derive a normalised generic spectrum for the

entire area. This can be used for modelling, noise prediction and facilitating effective urban noise planning solutions.

73 Maximising rates of productivity at mine, quarry and construction sites using engineering optimisation and Monte-Carlo simulation

Davis, Dave James
Umwelt Australia Pty Ltd

ABSTRACT
Industrial activities comprised of fixed and mobile noise sources such as mines, quarries and construction sites often operate under environmental noise limitations that can restrict site activity at certain times. The noise immission levels at receptors vary continuously due to unsteady noise emissions of plant and/or because of changes in mobile equipment location and/or orientation and also because of the continually changing attenuation properties of the atmosphere affecting the sound propagation. These sites often want to maximise their production rates utilising as much of their fleet and equipment inventory as possible while still complying with their environmental noise limits. This paper presents a method to maximise the size of the operating fleet within the site's environmental noise constraints, taking into account the inherent variability of noise sources using engineering optimisation and Monte-Carlo simulation.

15 Setting noise objectives for outdoor events at the Sydney Opera House

Parnell, Jeffrey (1); Hartcher, Andrew (1)
(1) NSW Department of Planning and Environment, Sydney, Australia

ABSTRACT
Unwanted music from outdoor events is considered a form of noise pollution which presents a unique set of challenges for regulators when compared to other environmental noise sources. Unlike noise generated by sources such as transport or industry where lower levels are always desirable, there is a minimum level of music below which patron experience will be unacceptable. The challenge for regulators therefore lies in balancing the need for entertainment against the impacts of outdoor music on the surrounding population. Regulators and venue operators of outdoor music events in urban environments are also often required to comply with receiver based noise limits in noise catchments complicated by high levels of extraneous noise from ferries, trains, traffic, pedestrians, restaurants and the like. With this in mind, this paper describes the approach undertaken to review and contemporise the noise criteria for outdoor events held on the steps and forecourt of the Sydney Opera House by adopting Front of House (i.e. at the source) limits rather than receiver based noise objectives.

123 Quality assured implementation of ISO 9613 in software

Hartog van Banda, Sven Erwin (1); Verheij, Theo (1)
(1) DGMR Software

ABSTRACT
Uncertainty in prediction is usually considered to be related to the accuracy of the input data and the accuracy of the prediction method. This paper addresses another very important kind of uncertainty that is related to the (un)clearness of the prediction method and the interpretations software developers are forced to make while implementing ambiguous prediction algorithms. For most noise calculation standards there are no quality requirements and no test cases. The ultimate benefit of quality requirements would be that the calculated results with different software programs, using the same data input, can be expected to show just about the exact same results within a narrow margin, hereby avoiding incorrect comparisons between 2 different software implementations. This all changed in 2015 with the release of ISO/TR 17534-3. Since then the uncertainty when implementing the ISO 9613 method in software according to the quality requirements described in ISO/TR 17534-3, can be strongly reduced. This paper describes the findings of DGMR, member of the ISO 17534 working group, while using the recommendations of TR3 for the implementation of ISO 9613 in software.

54 A low-frequency noise measurement and recording device for occupant operation

Pedersen, Christian Sejer (1); Møller, Henrik (1); Christensen, Flemming (1); Olesen, Søren Krarup (1); Nielsen, Sofus Birkedal (1)
(1) SIP, Department of Electronic Systems, Aalborg University, Denmark

ABSTRACT
There are often several challenges involved with measuring low-frequency noise and infrasound in dwellings. A main challenge is that standing waves make the measurements very dependent on the microphone position. Furthermore, the low-frequency-noise source may be unknown and in some cases, the noise is only present intermittently and maybe worse at night which makes measurements done by consultants or researchers troublesome. In order to deal with these challenges, a low-frequency measurement device was developed. The device is easy to use for the occupants of dwellings, and if they follow simple guidelines they can make representative recordings of low-frequency noise. When the device is connected to the internet, the recordings and pictures of the measurement setup are automatically uploaded to a central server, for further analysis and assessment. This analysis can assist in identifying noise sources and serve as a reference for further investigation. The paper deals with the construction and detailed low-frequency calibration of the device. It has proven successful in capturing low-frequency noise from various sources like heat pumps, cooling systems and wind turbines, and experiences and measurements from some of these cases are presented.

S03 - SA1 - Fluid-structure interactions, Monday 20, 13:20, Room B
Chair: Alec Duncan

23 Meta-material design for middle-low frequency elastic wave mitigation

Shi, Hongyangyang (1); Tay, Tong Earn (1); Lee, Heow Pueh (1)
(1) Department of Mechanical Engineering, National University of Singapore, 9 Engineering Drive 1, Singapore, 117575.

ABSTRACT
In the past two decades, meta-materials have drawn increasing attention from researchers due to their unique properties, including wave attenuation with potential application in acoustic engineering. A number of meta-material designs have been proposed for wave attenuation at different frequencies. In this work, a new configuration of chiral honeycomb meta-material is proposed for the attenuation of middle-low frequency elastic waves. The dynamic characteristics of the new-proposed structure were investigated numerically with band diagram analysis. The results show that the proposed structure is able to create multiple band gaps at middle frequency range. Interestingly, two extra band gaps induced by local resonance effect can be created with reduction of the chiral angle of the unit cell, and one of the bandg aps is located at low frequency range. The wave attenuation performance of the proposed meta-material was also simulated using sound transmission loss finite element analysis, demonstrating the potential of the structure in real applications.

113 Active cloaking of rigid and elastic cylindrical scatterers

Eggler, Daniel (1); Chung, Hyuck (2); Montiel, Fabien (3); Pan, Jie (4); Kessissoglou, Nicole (5)
(1) School of Mechanical and Manufacturing Engineering, The University of New South Wales, Australia
(2) School of Computer and Mathematical Sciences, Auckland University of Technology, New Zealand
(3) Department of Mathematics & Statistics, University of Otago, New Zealand
(4) The University of Western Australia
(5) School of Mechanical and Chemical Engineering, The University of Western Australia, Australia

ABSTRACT
This work presents active cloaking of rigid and elastic cylindrical shells. The acoustic performance using single and multiple control sources and error sensors is investigated for different control configurations. Scattering by a rigid cylinder due to an incident plane wave is initially studied. The scattered acoustic field is actively attenuated using monopole control sources and error sensors located circumferentially around the cylinder. The structural and acoustic responses of an elastic shell due to an incident plane wave are then examined. Active cloaking at the shell circumferential modes is achieved using monopole control sources located in the surrounding fluid. Active structural acoustic cloaking is also achieved using control forces applied directly to the shell.

71 Wind tunnel flow noise measurements using a random design acoustic array

Fischer, Jeoffrey (1); Rowan, Martin (2); Jacquemin, Paul (2); Lamos, Daniel (2); Vargas, Oscar (2); Jones, Malcolm (2); Skvortsov, Alex (2); Doolan, Con (1)
(1) UNSW Sydney
(2) DSTG Melbourne

ABSTRACT

This paper will describe a new aeroacoustic test facility established at the Defence Science and Technology Group (Low Speed Wind Tunnel) in Melbourne. The new test capability utilises a custom 64 microphone acoustic array whose design was optimised for large models. Measurements were carried out on an aeroacoustic model for two flow speeds and for a wide range of pitch and yaw angles. The data were processed using a frequency domain beamforming algorithm assuming monopole sources on the scanning plane. Different noise sources were identified on various parts of the model, notably around the fin and tail regions. Most of the sources were found at mid-frequencies for the lowest flow speed and high frequencies for the highest flow speed. The paper will describe the array design, its implementation as well as the wind tunnel test program.

112 Fast Spherical Filtering in the Broadband FMBEM using a non-equally spaced FFT

Wilkes, Daniel R (1); Duncan, Alec J (1)
(1) CMST, Curtin University

ABSTRACT
The Fast Multipole Boundary Element Method (FMBEM) reduces the O(N2) computational and memory complexities of the conventional BEM to O(NlogN) and O(N) respectively, where N is the number of boundary unknowns. One critical feature of the fast multipole method in the high-frequency regime is the choice of the spherical filtering algorithm used to interpolate and/or filter the multipole expansions between octree levels. In this paper a fast spherical filtering algorithm based on the Non-equally spaced Fast Fourier Transform (NFFT) is presented. The filtering algorithm is implemented in MATLAB via a combination of sparse matrix-vector products and standard FFTs, and is shown to achieve the theoretical algorithmic complexity for this type of spherical filter. Furthermore, the cross-over point at which the present NFFT filter becomes faster than the direct method is shown to be up to a factor of 2 smaller compared to that of other fast filtering algorithms in the published literature. The NFFT algorithm has been incorporated into a broadband Helmholtz FMBEM model. Large-scale acoustic scattering problems are presented to demonstrate the method.

25 **Application of FAMPRADOP ("Far-range Analytical Model for the Pressure Radiated from a Driven Offshore Pile") to the far-range cases of the COMPILE 2014 Workshop**

Hall, Marshall V
Kingsgrove, NSW Australia

ABSTRACT
The cases considered by the COMPILE 2014 workshop in Hamburg defined a pile (length 25 m), a shallow-water environment (depth 10 m), the pile's vertical position in it, and a force waveform on the pile head. It also defined both close-range and far-range receiver positions, at which acoustic Sound Exposure Levels (SEL) and Peak of the Sound Pressure Level (P-SPL) were to be calculated. The organisers published a comparison of results from six participants' pile vibration and far-range propagation models during 2016. Five were Finite-Element Models and one was a Finite-Difference Model; there was no analytical model. For far-ranges, the workshop nominated ranges of 0.75, 1.5, 10, 20 and 50 km. The writer's in-house analytical model FAMPRADOP ["Far-range Analytical Model for Pressure Radiated from a Driven Offshore Pile"] has recently been applied to the far-range COMPILE workshop cases. At 0.75 and 1.5 km, the six participants' results and FAMPRADOP agreed closely amongst each other. At the greater ranges, some participants' results differed from the others, by up to 15 dB at 50 km. The FAMPRADOP results generally lie close to the minimum of the spread in the participants' results, for reasons that will be discussed.

S04 - NC1 - Noise and vibration control, Monday 20, 15:30, Room A
Chair: Jie Pan

18 **Active control of sound transmission through a hole in a large thick wall**

Qiu, Xiaojun (1); Qin, Ming (2); Zou, Haishan (2)
(1) University of Technology Sydney
(2) Nanjing University

ABSTRACT
Holes in walls of enclosures or buildings are often the weak link in the chain of sound insulation. This paper introduces an analytical model to calculate the sound transmission from a baffled rectangular hole based on the modal expansion approach, and proposes to install an active noise control system inside the hole to improve the transmission loss of the perforated wall. Different control source and error sensing strategies are investigated, and it is found that for a 30 cm thick wall with a 6 cm by 6 cm hole, an active control system with 1 control source and 1 error sensor can achieve more than 20 dB attenuation up to 2700 Hz, while that with a compound control source consisting of 4 loudspeakers, the system can achieve similar reduction up to 3900 Hz.

55 **A study on partial enclosures for noise control**

Wang, Shuping (1); Sun, Hongmei (2); Pan, Jie (2); Qiu, Xiaojun (3)
(1) Key Laboratory of Modern Acoustics and Institute of Acoustics, Nanjing University, Nanjing, China
(2) School of Mechanical and chemical Engineering, The University of Western Australia, Perth, Australia
(3) Centre for Audio, Acoustics and Vibration, Faculty of Engineering and IT, University of Technology Sydney, Sydney, Australia

ABSTRACT
Partial enclosures are widely used to reduce noise radiation while keeping ventilation, lighting and easy access through openings at the same time. However, because of the complexity of the sound field around partial sound barriers, no method has been reported on how to design them to achieve the best noise reduction performance. This paper uses numerical simulations to study the properties and performance of partial enclosures. A case study on a simplified model consisting of several separate acoustic panels surrounding the sound source is carried out and some general rules are found which might be useful for optimizing the design. Experiments in the anechoic chamber are carried out to support simulation results.

116 **Tackling the whining noise of a 4WD Bus – A case study**

Law, Harvey (1); Kierzkowski, Marek (1)
(1) Megasorber Pty Ltd, Melbourne, Australia

ABSTRACT
Very high levels of tonal noise were causing great discomfort to passengers, resulting in the whole fleet of 4WD tourist buses being taken out of service while attempts were made to address the noise issue. A comprehensive investigation and testing program was carried out to address a highly unpleasant, tonal whining noise. The effectiveness of each soundproofing treatments, such as vibration isolation materials, vibration damping treatments and air-borne noise reduction applications were investigated. Once each of acoustic treatments were applied, a corresponding on-road noise test was undertaken to determine the effectiveness of the treatment stage. The final results found that the overall noise level had been reduced from an uncomfortable 88 dB(A) to a much more tolerable 74 dB(A). The annoying whining noise was no longer a problem and all buses returned to service. This paper discusses the effectiveness of each treatment with real-life measurements and results.

117 **Car wash noise and EPA regulation – A case study**

Kierzkowski, Marek (1); Law, Harvey (1)
(1) Megasorber Pty Ltd, Melbourne, Australia

ABSTRACT
Car wash business, "Washed", was shut down by the local Council in a blue-chip residential area of Melbourne after numerous neighbourhood complaints about the excessive noise levels being emitted. This paper investigates the impact of Environmental Protection Agency (EPA) regulations on such a car wash operation, in a built-up residential area and the solutions implemented to make the car wash facility

EPA-compliant. On-site noise measurement results are reported for 'before' and 'after' remediation.

51 **Cross-Wind response of cylindrical towers**

Tanner, Kirsty (1); Mackenzie, Neil (1); Moyle, Tom (1)
(1) Aurecon group, Adelaide, Australia

ABSTRACT
The development of Yagan Square (previously referred to as Perth City Square) as a central public place adjacent to the central train and bus stations in Perth includes a 'Digital Tower'. This will be an approximately 60m tall structure formed by series' of steel cylindrical hollow sections (CHS) 'tendrils' extending up from the base. The relatively slender tubular tendrils which are cantilevered can be susceptible to unpredictable wind induced dynamic excitation, otherwise known as vortex shedding. Vortex shedding can be problematic as it can result in fatigue stress and in-service deflection. This paper outlines the method used to determine the effectiveness of strakes to mitigate the cross-wind response of the tendrils.

S04 - UW2 - Acoustic sensing of the marine environment, Monday 20, 15:30, Room B
Chair: Alexander Gavrilov

35 **Passive and active acoustic monitoring of mulloway in the Swan River**

Parsons, Miles James (1); Anning, Justin (2); Parnum, Iain Michael (1)
(1) Centre for Marine Science and Technology
(2) Surrich Hydrographics

ABSTRACT
Passive acoustic monitoring is a standard tool to monitor vocal marine fauna. High-frequency multibeam echosounders have developed rapidly in recent years, with the number of applications for detecting and tracking biological targets expanding significantly. In the Swan River, Perth, mulloway (Argyrosomus japonicus) form aggregations each austral summer. Here, a Kongsberg MS1000 scanning sonar and a CMST Underwater Sound Recorder (USR) were deployed onto the riverbed in 12 m of water. The sonar scanned to ranges of 50 and 75 m (angular resolution, 0.45°), taking approximately 120 s for one full 360° scan. The USR sampled at 6 ksps for five of every fifteen minutes. The sonar detected fish travelling slowly (typically <0.5 ms-1) within its range, while the passive recorder detected the development of an evening chorus, starting with individual calling fish. One example target remained within the field of view of the sonar for over an hour, detected 55 times as it moved ≈100 m. Simultaneously, the USR recorded mulloway vocalisations, with received levels approximating those predicted for a mulloway at the range detected by the sonar. This study outlines one of the first successes of matching passive and active acoustic tracking of vocal fish, as a precursor to using sonar techniques to verify estimates of calling numbers of fish from passive acoustic monitoring.

66 **Using a multi-frequency echo-sounder to map fish distribution and benthic habitat in Fremantle Harbour, Western Australia**

Salgado-Kent, Chandra (1); Parnum, Iain Michael (1); Landero Figueroa, Montserrat (1); Saunders, Benjamin (2); Parsons, Miles James (1)
(1) Centre for Marine Science and Technology, Curtin University
(2) Department of Environment and Agriculture, Curtin University

ABSTRACT
A multi-frequency echo-sounder and baited remote underwater video systems (BRUVS) were used in May 2016 and March 2017 to identify types and spatial distribution of fish and benthic habitats in the Fremantle Inner Harbour, Western Australia. One of the main motivations for this study is to better understand the distribution of potential dolphin prey. The echo-sounder used was a Biosonics DTX scientific echo-sounder with three frequencies 38, 120 and 400 kHz towed by a 4.6 m vessel. The echo-sounder survey covered the range of the Inner Harbour. Five BRUVS stations were positioned strategically in locations within the echo-sounder surveyed area and those anticipated to have high fish activity. Individual targets and small aggregations of fish were identified by the echo-sounder at locations near the wharf walls and other topographic features. Initial analysis of the BRUVS, identified: weeping toadfish (Torquigener pleurogramma), tarwhine (Rhabdosargus sarba), and western butterfish (Pentapodus vitta) as dominant species. The nest stage of this work is investigated how well the acoustic and video data can be integrated to best understand the fish distribution, and assess the usefulness of this technique for studying potential dolphin prey. ACOUSTICS

67 **Preliminary investigations into the repeatability of multibeam backscatter for seafloor habitat mapping**

Le Sy, Xinh (1); Parnum, Iain Michael (1); Gavrilov, Alexander (1); O'Leary, Michael (2); Siwabessy, Justy (3)
(1) Centre for Marine Science and Technology, Curtin University
(2) Department of Environment and Agriculture, Curtin University
(3) Geoscience Australia

ABSTRACT
Multibeam echo-sounders (MBESs) are one of the most advanced and effective remote sensing systems for marine seafloor habitat mapping, especially for deep and turbid water areas. Despite these advancements in multibeam survey technology, and the key role of multibeam backscatter data in marine habitat mapping and monitoring, there is no standardised way to acquire, process, classify, and interpret acoustic backscatter data for producing marine habitat maps. To have a long-term management strategy for marine habitats, it is important to understand how well multibeam data can be used to monitor marine habitats. However, it is unclear how repeatable or how much change can be detected with such multibeam derived maps. The overall aim of this study is to develop methods for monitoring habitats with MBES, and to determine the level of marine habitat change that can be detected with multibeam data. Initial results examining the

repeatability of multibeam backscatter measurements will be presented. ACOUSTICS

68 **Using recreational echo-sounders for marine science studies**

Parnum, Iain Michael (1); Ellement, Tyler (1); Perry, Malcolm Anthony (1); Parsons, Miles James (1); Tecchiato, Sira (2)
(1) Centre for Marine Science and Technology, Curtin University
(2) Department of Environment and Agriculture, Curtin University

ABSTRACT
In recent years, recreational echo-sounders, such as the Humminbird, Lowrance and Simrad Yachting brands, have become more advanced. These brands now offer models with the ability to log not just depth, but acoustic data from the different transducers. This paper presents methods for converting, processing and visualising data collected by recreational sounders. Examples of visualising fish aggregations and seafloor mapping are given. The examples show both the potential and the drawbacks of using such systems.

101 **Towards autonomous characterisation of side scan sonar imagery for seabed type by unmanned underwater vehicles**

Hamilton, Les
Defence Science & Technology Group, Data 61 Building, 13 Garden St, Eveleigh NSW

ABSTRACT
Surveys by autonomous underwater vehicles fitted with side scan sonar could potentially be made more efficient if they could recognize particular seabed types and modify their search strategy or software use accordingly. A limited scheme to autonomously infer actual seabed type is described. Categories are flat (even textured), sand, rippled, rough, rough periodic (seabeds of unknown type with low wavenumbers and pronounced directionality), unknown, and a class for a collection of types which presently are difficult to distinguish (including seagrass, and gravelly sands with high reflectivity speckle). The scheme has three stages: (1) even texture/rough texture is decided using the GLCM (Gray Level Co-occurrence Matrix) image processing technique, (2) periodicity and directionality are examined with 2-D Fourier and Radon Transforms, and (3) an inference of seabed type for non-rippled seabeds is made using the Gray Level Size Zone Matrix (GLSZM) scheme. The final inference is a consensus of the three stages. Some seabed types as seen in side scan sonar imagery defy categorization by any means, and problems arise from motion artefacts, saturation at higher backscatter levels, uncorrected angular effects, sea surface acoustic returns, and acoustic ambiguity.

S05 - PA1 - Physical acoustics, Tuesday 21, 08:45, Room A
Chair: Alec Duncan

19 **Sound radiation from the open end of pipes and ducts in the presence of mean flow**

Kirby, Ray (1); Duan, Wenbo (2)
(1) University of Technology Sydney
(2) Brunel University London

ABSTRACT
The radiation of sound from the open end of pipes and ducts is a common problem in environmental noise control. Examples include radiation from ductwork in heating, ventilation and air-conditioning systems, noise emissions from exhaust stacks in industrial power plants, as well as radiation from turbofan engines. These open duct terminations represent a relatively simple mechanical structure; however, the acoustics is significantly more complicated and this is especially true when a mean gas flow is present. This article presents an efficient numerical model suitable for analysing sound radiation from an unflanged duct termination, and introduces a method for including a uniform mean fluid flow in the exterior region away from the termination. An example of sound radiation from a turbofan engine is then investigated.

61 **Detecting sound waves generated by leaks in buried water distribution pipes**

Kirby, Ray (1); Duan, Wenbo (2); Karimi, Mahmoud (3); Brennan, Michael (4); Kessissoglou, Nicole (3)
(1) University of Technology Sydney
(2) Brunel University London
(3) University of New South Wales
(4) UNESP

ABSTRACT
It is common to use guided sound waves to detect leaks or cracks in pipelines. Applications include the nondestructive testing of oil and gas pipelines, which normally takes places at ultrasonic frequencies, as well as the detection of leaks and ruptures in water filled pipes at much lower audio frequencies. However, if the pipe is buried then sound leaks out of the pipe into the surrounding medium and this lowers the acoustic energy travelling along the pipe wall. This has the potential to limit the applications of this technology, and so it is necessary to develop knowledge of the acoustic properties of the guided waves in order to optimise detection techniques. Accordingly, this work examines the properties of sound waves propagating in an infinitely long fluid-filled buried pipe, with application to leak detection at low audio frequencies. A parametric study is undertaken to examine the sensitivity of sound propagation to the properties of the internal liquid, pipe walls and of the surrounding medium.

9 **Monte Carlo model of acoustic response from a bubble cloud**

Kouzoubov, Alexei
Maritime Division, Defence Science and Technology Group, Edinburgh, Australia

ABSTRACT
In various sonar applications it is important to model the acoustic response of a bubble cloud to a sonar pulse of different types. In a typical approximate approach, a bubble cloud is modelled as a set of point scatterers. The purpose of this research is to analyse the accuracy and limitation of such a representation. For this, a high-fidelity Monte Carlo model of scattering of an acoustic pulse from a bubble cloud is developed. In this model a bubble cloud is represented by a set of individual bubbles randomly selected from a known bubble size and spatial distribution. The acoustic signals scattered from individual bubbles are coherently summed into a collective response from the bubble cloud. The building block of the model is the forced oscillations of an individual bubble in an acoustic field. In this research we use the state-of-the-art equation of bubble oscillation. We then consider the acoustic response of a bubble cloud to an acoustic pulse in single scattering approximation and compare it with the analytically calculated backscattering cross section per unit volume. A comparison of the results of the high-fidelity model with the representation of the bubble cloud by a set of discrete scatterers is conducted.

58 **Determination of the calibration error of a reciprocal underwater acoustic transducer from standard data obtained in a two-way comparison calibration process using the acoustic reciprocity parameter**

Chambers, Shane (1); James, Ralph (1)
(1) Bioacoustics Research Laboratory, School of Physics, University of Western Australia

ABSTRACT
Hydrophones are more commonly calibrated using the two-way comparison method than the three-way reciprocity method. The comparison method is the most frequent chosen technique for hydrophone calibration due to the time-consuming nature of conducting the free field three-way reciprocity technique. This method is chosen despite the three-way reciprocity method resulting in a more accurate calibration than that of the comparison method due to it being an absolute method of calibration. This paper illustrates how to derive the indeterminate error in a two way comparison calibration using the reciprocity parameter with the limited data supplied from a standard commercial calibration process if the transducer under test is reciprocal. The proposed simple method demonstrates that the determination of this error can be derived whilst examining the reciprocity of the transducer under test and can be performed post calibration using the supplied data consisting of complex impedance (Z) and the measured receive (M) and transmit (S) sensitivities of the transducer under test. This method is advantageous as one does not have to break the measuring circuit to observe other variables such as voltage and current at the transducer terminals to prove reciprocity which is difficult to do during an automated comparison calibration process. It is shown that from this proposed method the actual error (~0.3 dB) of the two-way calibration process was substantially less than the calibration error stated by the manufacturer (1 dB).

S05 - SA2 - Structural acoustics, Tuesday 21, 08:45, Room B
Chair: Daniel Wilkes

65 **Investigations on the total radiation efficiency of ribbed plates floating on water**

Pan, Xia (1); MacGillivray, Ian (1); Trinh, Vinh (1); Forrest, James (1)
(1) Maritime Division, Defence Science and Technology Group, Victoria, Australia

ABSTRACT
The total radiation efficiency of ribbed plates floating on water is often used as a basis on which to represent the sound radiation from ribbed stiffened ship hulls. Investigations of this efficiency of plates are presented in this paper. Two numerical plate models are developed using the finite element programs ANSYS and Actran and compared with an approximate analytical model. Results of experiments conducted in a water tank are compared with the numerical and analytical methods. Good agreement is obtained from all the methods up to 10 kHz. Above 10 kHz Actran and experimental results were not available, but both the ANSYS and the analytical methods agree well until just below the plate critical frequency of about 78 kHz. Above the critical frequency, no comparison is carried out. The results shown provide confidence in the above methods to conduct detailed studies of complex structures, such as ship hulls.

80 **Relative performance of different strategies for wave attenuation by periodic structures**

McMahon, Darryl
Curtin University, Centre for Marine Science and Technology, Bentley, WA 6102, Australia

ABSTRACT
For a periodic structure of symmetric scatterers, such as a ribbed plate or cylinder, Bloch-Floquet waves (BFW) are well-known periodic structure waves (PSW). Conventional wisdom is to attenuate BFW propagation by reflections, energy absorption or stopping bands. Recent theoretical results show that periodic structures with asymmetric scatterers do not lead to BFW, revealing more possibilities for noise reduction through these different PSW. This paper compares the performance of reciprocal and nonreciprocal wave propagation as methods for PSW attenuation. It is found that nonreciprocal wave propagation, such as could be realized with asymmetric metamaterial scatterers, could achieve significantly better attenuation with relatively small deviations from symmetric scatterer properties.

85 **Experimental study of the vibro-acoustics of a beam with periodically attached short bars**

Gong, Zhenglong (1); Dawson, Clancy (1); Zhang, Yanni (2); Matthews, David (3); Sun, Hongmei (1); Pan, Jie (1)
(1) School of Mechanical and Chemical Engineering, The University of Western Australia, Perth, Australia
(2) School of Marine Science and Technology, Northwestern Polytechnical University, Xi'an, Shaanxi 710072, China
(3) Defence Science & Technology, HMAS Stirling, Western Australia

ABSTRACT
Periodic structures have well-known band-pass and band-stop frequency properties in wave propagation and sound radiation. However, little experimental research focusing on the performance of periodic attachments mounted by various interface materials and distributed structural elements has been undertaken. The aim of this research is to experimentally investigate the effects of lumped masses and short bars periodically attached to a long beam with various interface materials on the vibration transmission and noise radiation of the resulting periodic structure. The focus of this paper is to demonstrate that the band-pass and band-stop properties of the vibration and sound in the structure are dependent on the periodic arrangement and local resonance of the short bars, as well as the elastic bounding layer between the short bars and the long beam.

106 **Simple experiments in vibration and acoustics**

Hunt, Hugh
Cambridge University

ABSTRACT
Sound and vibration are mostly invisible, so no wonder solving noise problems is tricky. Mechanical vibration is taught to undergraduates as if it is a simple science. The mass-on-a-spring, uni-axial vibration of a rod, viscous damping, modal analysis - all these are the bread and butter of vibration science. As for rigid-body dynamics (which this talk will dip into) undergraduate courses remain fixed in 2-D planar motion. But real dynamic and vibrating systems just don't behave simply. There are pitfalls in even the most ordinary cases and some of these will be demonstrated: a tuning fork; a bottle of coke; a bending beam; a turbocharger wheel, a bouncing ball ... and boomerangs. All of these things behave counter-intuitively. The paper describes many practical demonstrations - seeing is believing. All are demonstrations that can be repeated at home and they will be shown live at the conference!

S06 - AM1 - Acoustics of materials and products, Tuesday 21, 10:45, Room A
Chair: Jie Pan

79 **Acoustic Absorption of Porous Materials Produced by Additive Manufacturing with Varying Geometries**

Jiang, Chaoyang (1); Moreau, Danielle (1); Doolan, Con (1)
(1) School of Mechanical and Manufacturing Engineering, UNSW Sydney, NSW, Australia, 2052

ABSTRACT
This paper investigates the sound absorption capability of porous materials produced by additive manufacturing (sometimes known as 3D printing) with different geometrical parameters, where the porosity Φ, hole diameter d0, specimen thickness h and aspect ratio d0 /h are chosen for parametric study. The sound absorption coefficient of the specimens is experimentally measured by using a two-microphone impedance tube and the results indicate that the frequency of the peak absorption coefficient varies with porosity and the peak value is insensitive to the diameter of the holes but strongly correlated to the aspect ratio. Finally, the selection criterion of geometric parameters of 3D printed porous materials is established for achieving maximum sound absorption at a certain frequency.

118 **Benefits of reduced-size reverberation room testing**

Kierzkowski, Marek (1); Law, Harvey (1); Cotterill, Jonathan (1)
(1) Megasorber Pty Ltd, Melbourne, Australia

ABSTRACT
A reduced-size reverberation room (also known as an Alpha Cabin or Test Cube) provides fast and accurate sound absorption measurements in a diffuse-field condition. In addition to this, a sample size of only 1.2m^2 is required, compared to that of the standard reverberation room sample size of 10 m^2 to 12m^2. The reduced-size chamber has proven to be an excellent tool for acoustic consultants, engineers and architects to carry out comparison tests between acoustic materials and 3D systems or structures. However, currently there are no standard methods available on how to derive acoustic indices based on the Alpha Cabin test data. This paper presents the preliminary results of a study to obtain reliable acoustic indices; NRC (Noise Reduction Coefficient), SAA (Sound Absorption Average) and αW (weighted sound absorption coefficient) from such Alpha Cabin data. Utilising a combination of both modelling and testing, the results of three common types of acoustic materials are discussed: (1) homogenous sound absorber, (2) porous sound absorber with flow resistive facing and (3) perforated panel with flow resistive backing. The achieved results are very encouraging and offer a unique tool for assessing single digit values for the overall acoustic performance of sound absorbing materials and systems.

122 **Diffuse field measurements of locally resonant partitions**

Hall, Andrew (1); Dodd, George (1); Calius, Emilio (2)
(1) Department of Mechanical Engineering, University of Auckland, New Zealand
(2) Advanced materials, Callaghan Innovation, Auckland, New Zealand

ABSTRACT
Noise control at lower frequencies is becoming increasingly important with housing densification, as this frequency range is where the threshhold of the human ear is at its highest and sound insulation is the most challenging and expensive. Meta-materials offer a novel approach to achieving sound and vibration management through the use of panels with internal resonant structures with geometries sub-wavelength. These structures can yield significantly greater transmission loss than conventional insulation systems. Numerical models based on networks of single-degree of freedom oscillators were used to understand how the components of the locally resonant structure (LRS) can be manipulated to generate desirable sound transmission loss (TL) performance spectrums. Designs with the targeted TL characteristics were then examined in detail under FEA and plane wave impedance tube testing and samples were fabricated using industry-standard materials and processes. This paper focuses on the acoustic testing of large scale LRS samples at low frequencies under diffuse field conditions. Locally resonant partition wall systems were designed to target frequency regions where poor TL is expected such as the mass air mass region (MAM) and the coincidence frequency region (CF). Samples from between $2m^2$ to $10m^2$ were tested with variations in system arrangements such as mass and geometry. Results are presented here for $2{:}4m^2$ samples which showed significant TL improvements with approximately 20dB improvement above that of a conventional panel over bandwidths in the order of 300Hz. Comparisons were made between, numerical predictions and plane wave experimental results. The resulting systems have the potential to provide significantly higher transmission loss at low frequencies than conventional wall systems of similar size and weight.

S06 - UW3 - Underwater propagation 1, Tuesday 21, 10:45, Room B
Chair: Iain Parnum

76 **The effect of internal waves on underwater sound propagation**

Parnum, Iain Michael (1); MacLeod, Rod (2); Duncan, Alec J (1); Gavrilov, Alexander (1)
(1) Centre for Marine Science and Technology, Curtin University
(2) Maritime Operations Division, Defence Science and Technology Group

ABSTRACT
Knowledge of the undersea environment is critical in estimating ship and submarine performance, estimating own-ship susceptibility, and for tactical planning. A major factor determining the detection range of an active sonar system is the sound velocity profile (SVP). Traditionally, the SVP is measured by deploying an XBT (expendable bathythermograph) and converting the temperature profile to an SVP at the location of the ship. Sonar performance is then predicted based on this SVP. However, the ocean is a dynamic environment, and sound propagation conditions can change with both position and time. This study investigated the effect of the variation in the sound velocity profile (SVP) in a dynamic oceanographic region: the Kimberley shelf, where phenomena such as internal waves are present. Temperature and salinity data collected in the Kimberley region, as part of the Integrated Marine Observing System's National Mooring Network, were used to produce SVPs at a sampling interval of 1 minute. These SVPs were then used in a range dependent sound propagation model (RAM Geo). This paper presents the results of this modelling.

10 **Coherent leakage of sound from ocean surface ducts of nonlinear sound speed profile**

Jones, Adrian D (1); Duncan, Alec J (2); Zhang, Zhi Yong (1)
(1) Defence Science and Technology Group, Edinburgh, Australia
(2) Centre for Marine Science & Technology, Curtin University, Perth, Australia

ABSTRACT
The sound speed variation with depth that defines a surface acoustic duct does not necessarily adhere to the uniform gradient of perfectly isothermal water. Prior consideration of the coherent leakage of sound from a surface duct has almost always been made for an isothermal layer, and not for a realistic duct with a nonlinear sound speed profile. This paper presents the results from a brief study in which the rate of leakage has been obtained by using a normal mode model, for an ocean with various surface duct types for which the sound speed varies nonlinearly with depth. Initial results indicate that the rate of variation of leakage with acoustic frequency is strongly linked to the duct trapping frequency, but that the absolute level of leakage is related to the depth of the duct. The formation of these conclusions is illustrated by results from numerical modelling. Reference is also made to theoretical expectations for ducts of uniform gradients weaker than for isothermal water.

22 **An equivalent fluid representation of a layered elastic seafloor for acoustic propagation modelling**

Koessler, Matthew
Marshall Day Acoustics

ABSTRACT
Modelling range dependent sound propagation over layered elastic seafloors with high shear speeds has proved to be a difficult problem for many widely used under water acoustic sound propagation models. Recent research and numerical developments have shown that it is possible to obtain accurate results for these types of range dependent environments, however these numerical methods are not as yet available for general use. This article explores the appropriateness of using an equivalent fluid approximation to represent the reflection phenomena associated with a layered elastic seafloor. The focus is on layered calcareous seafloors that are typical of the Australian continental shelf. A complex density approximation is used to best match a fluid plane-wave reflection coefficient to an elastic plane-wave refection coefficient in order to determine the equivalent fluid bottom parameters. Synthetic signals are computed using Fourier synthesis to compare reflection from the equivalent fluid bottom and the original elastic bottom. The sound exposure level and peak pressure

level, commonly used for practical purposes, are computed from these synthetic signals to assess the accuracy of the equivalent fluid approximation.

S06 - Workshop: Road traffic noise assessment, Tuesday 21, 10:45, Room C
Chair: J Macpherson

60 **Sound Science for Society? Roe Highway Extension 8 - Western Australia's most noisy road even before it was built**

Chambers, Shane
Bioacoustics Research Laboratory, School of Physics, University of Western Australia

ABSTRACT
The Roe Highway Extension 8 (Roe 8) was likely Western Australia's most expensive and most noise sensitive planned road infrastructure development to date. The building of the road was a highly controversial topic leading up to the 2017 WA State election. The circumstances surrounding the development was likely a major contributing factor towards the largest election loss in history for the incumbent government as there was substantial public opposition to the commencement of building Roe 8 by the clearing of the Beeliar Wetlands, which is a considered a wetland of national and international significance, just 3 months before the election. Significant anomalies identified in the traffic modelling and the subsequent noise mitigation procedures in the Noise Management Plan were first identified early in the environmental impact assessment process but were left uncorrected. The errors appeared to propagate through to the delivery of the final infrastructure plan just before the commencement of clearing. These errors along with the procurement of traffic data from a successful Freedom of Information request indicated significant variances in both total and heavy vehicle volumes projected to 2031 and 2041 to what had previously been accounted for in the Public Environmental Review. These circumstances may have resulted, if challenged, in the re-triggering of the requirement for the proponent (Main Roads WA) and building consortium to deliver a new Noise Management Plan at the 11th hour, at a time where significant environmental and project related financial costs had already been incurred. Additionally, the proponent and building consortium may have, in the worst case, been found to contravene the planning process bringing the validity of the entire project into question and potentially exposing the State to unnecessary liabilities. This talk will discuss the role of assessing noise impact in this project, the problems exposed and the failures in the statutory planning process for noise mitigation. Such failures may have contributed up to $85 million in costs for the WA State Government and the consequential irreparable environmental and cultural damage to the Beeliar Wetlands. Yet despite these costs, solutions to transport problems with respect to the distribution of freight (and consequential noise impact) in the WA metropolitan area are still pending.

S07 - Plenary 2, Tuesday 21, 11:50, Room A
Chair: Alexander Gavrilov

20 **Naval applications of marine acoustics**

Bradley, David
Penn State University

ABSTRACT
Both communities have interests (or requirements) that can be described by the parameters of time and space. The science and technology of Marine Acoustics, dependent on specific investigators and their focus, is not limited in it's interest. Navies, on the other hand, have constrained requirements and most usually, constrained equipments/resources. While there is often coincidence of interest, there is also competition for National resources; the outcome can lead to frustration on all sides. An additional issue has to be recognized; if the Navy believes it has developed an operational advantage by exploiting a particular oceanic behavior, it will (and should) protect that information, which is counter to the needs of a scientist, whose metric for success is publication. Balancing those competing issues can be difficult. From the perspective of Naval needs (requirements), several examples of the juxtaposition of sonar characteristics and Naval Operations onto the "world" of Marine Acoustics will be given, with an emphasis on ocean physical properties.

S08 - TN2 - Transportation noise 2, Tuesday 21, 13:30, Room A
Chair: Marion Burgess

108 **Strategic mapping of road traffic noise in Auckland, New Zealand**

Henrys, Nicholas Roy
Resonate Acoustics

ABSTRACT
A model was developed to quantify road traffic noise levels and potential health effects associated with this noise, in Auckland, New Zealand. The model used traffic volume, road geometry and building data as inputs to predict the noise level at the façade of every building in the area of interest. All local, arterial and state highway roads with an average daily traffic volume of 5,000 vehicles or more were included. The results were then postprocessed using 2013 census data to determine population statistics. Established relationships for sleep disturbance and annoyance were used to derive the percentage of people affected within each census area, and across the city as a whole. Based on this analysis approximately 27,600 people are potentially highly sleep disturbed and 48,800 people are potentially highly annoyed due to current road traffic noise. This represents approximately 1.95% and 3.45% of the total Auckland population respectively. There is opportunity to further refine the model, for example by including topography, to reduce uncertainty associated with the results.

5 **Application of statistical energy analysis to rail noise predictions**

Dawson, Bill (1); Mackenzie, Neil (1); Lee, Yong Keat (1)
(1) Building Sciences, Aurecon, Adelaide, Australia

ABSTRACT
Rail transport in Australia is a key component of the push for more people to use public transport and not their own cars, providing a cost-effective and more environmentally friendly means of getting to and from work. This increase in rail infrastructure through the country means that there will be increased train movements, new rail corridors and extensions to existing lines, which require careful impact assessments be undertaken to ensure that the amenity of existing and future receptors is maintained. A key component of these assessments is modelling and assessment of noise and vibration impact from rail movements which needs to be both accurate and fast when applied to the often complex constructions of rail viaducts and train stations, a task which Statistical Energy Analysis (SEA) is perfectly suited for. This paper outlines a summary of an SEA approach to assessment of structure-borne noise from trains, which has been applied to projects including noise impact on the Adelaide Convention Centre plenary hall which is located above Adelaide's railway station, regenerated noise in the new Springfield Station offices located beneath the upper train station concourse areas, and the contribution of structure-borne noise emissions from an elevated rail viaduct to environmental noise emissions.

97 **Regional detailed transport noise modelling - railway methods and outcomes**

Zhang, Sheng (1); Kanowski, Mark (1); Janssen, Neville (1); Greaves, David (1); Tuckwood, Martin (1); Jeffries, Richard (1); Clark, Amanda (1); Worrall, John (1); Hinze, Benjamin (2); Schultz, David (2); Nseir, Bashar (3); Goodfellow, Matthew (4)
(1) Queensland Department of Transport and Main Roads
(2) SLR Consulting Australia Pty Ltd
(3) GIS People Pty Ltd
(4) MRG Environmental Pty Ltd

ABSTRACT
To support the application of the Queensland Development Code (QDC), noise mapping of Queensland road and rail transport noise corridors was conducted. The initial road modelling has been described previously (Zhang et al, 2016). The railway noise modelling of approximately 3 100 km of railway corridor is one of the largest projects of its kind in the world. The project considers attenuation due to terrain, noise barrier and building effects. SoundPLAN software managed the detailed models and calculated noise levels on a 5 m grid. Geographic information system processing of the noise category contours collated the results into a suitable format. The noise category contours present accurate representation of noise impacts for new residential development. Work has commenced on a second stage of rail noise modelling incorporating additional high resolution terrain and building data. This paper describes the modelling and post processing methodology, presents noise contour results, discusses challenges and solutions.

82 **Noise event measures for road traffic**

Brown, Alan Lex (1); de Coensel, Bert (2)
(1) Griffith School of Environment/Cities Research Program. Griffith University, Brisbane, Australia
(2) Waves Research Group, Department of Information Technology, Ghent University, Belgium

ABSTRACT
How should noise events in road traffic noise be measured? This paper reports the performance of a set of algorithms that detect noise events in time histories of road traffic noise in the population of acoustic conditions found near roadways. The latter was obtained through simulation of 500 different road traffic noise time histories using a comprehensive range of traffic flow, traffic composition, and propagation distance, conditions in unshielded locations near roadways. The initial set of algorithms tested was developed by systematically expanding on threshold-based algorithms described in the literature, then excluding those that were unreliable. The finding was that the NA50 and NA55 (detecting when road traffic noise exceeded 50 dB and 55 dB respectively), and the NAL50E10 (detecting when the traffic levels exceeded L50 + 10 dB) can all be considered for practical application as event detection indicators. All apply to measurement of indoor events with the windows of the dwelling open. The primary criterion for selection as supplementary indicators (and others in the same clusters that could substitute for them) was their non-monotonic relationship with the LAeq, The traffic and distance conditions under which these event-based measures could potentially be useful supplementary indicators is identified.

104 **Design, analysis and fabrication of a muffler for a single cylinder SI engine**

Mishra, Sahil (1); Surana, Nitesh (1); Warade, Sumedh (1); Gaurav, Nishant Kumar (1); Suryawanshi, J. G. (1)
(1) Department of Mechanical Engineering, VNIT Nagpur, Nagpur, India

ABSTRACT
The Noise Pollution Regulations demand that the noise generated due to the automotive vehicles should be reduced. The noise in an automobile is primarily generated from the operation of the engine. A majority of these sound waves are carried by the exhaust gases into the atmosphere. The primary way of reducing engine noise is by adding an additional sound attenuating device known as a muffler. The aim of this project is to design a reactive muffler capable of providing a high value of exhaust noise reduction when coupled with a Single cylinder SI engine. Also, the muffler should generate low backpressure so that the efficiency of the engine is not re-duced. The muffler was first designed and analyzed in COMSOL and the theoretical value of noise level reduction was found to be 40 dB. The flow of exhaust gases through the muffler was analyzed in FLUENT and the backpressure was found to be 537 Pa. The muffler was manufactured and coupled with the engine and the experimental value of noise level reduction was found to be 30.2 dB.

S08 - BA 1 - Building acoustics 1, Tuesday 21, 13:30, Room B
Chair: Kym Burgemeister

38 Building a university music facility in a reused printery building

Ottley, Matthew
Marshall Day Acoustics

ABSTRACT
In 2015 Western Sydney University embarked on a project to refit two existing buildings to create a new music precinct. The building housing the recording facilities previously accommodated the University's printery, essentially a lightweight workshop building. The new use required the building to house two studio control rooms, a teaching control room, four isolation rooms, a live recording room, ensemble rehearsal spaces and music practice rooms. At project commencement, there existed a significant incompatibility between the ambitious acoustic requirements in the project brief, the project budget, the size of the building, the number of rooms required and the limitations of the existing building structure. This paper outlines the design process undertaken to reconcile the competing requirements of the project and deliver a high performance, fit for purpose music and recording facility. Key points covered include; stakeholder engagement to derive the true acoustic criteria required; design compromises related to existing structure, spatial allowances and budget; Odeon 3D room modelling of control rooms and comparison with 3D room impulse response measurements on completion.

42 Comparison of ceiling absorption placement configurations in a corridor

Caldwell, Hugo (1); Yadav, Manuj (1); Cabrera, Densil (1)
(1) School of Architecture, Design and Planning, The University of Sydney, Sydney, Australia

ABSTRACT
It is generally acknowledged that speech related noise is a common distractor in many work environments, e.g., open-plan offices. There are many studies and some standards that address these noise related issues, but they generally do not consider sound propagation through corridors. This study investigates how certain spatial arrangements of ceiling absorption affect the spatial decay rate of speech-weighted A-weighted sound pressure levels and speech transmission indices (STI) in a full scale corridor and in a small model tube. Results show that while most of the configurations tested behave similarly, a transverse arrangement of absorptive material has the potential for increased attenuation, especially in the far field, and decreased distraction distance (where STI<0.5, ISO 3382-3 2012). These findings have relevance for design of corridors, not only in office buildings, but for absorptive treatment of elongated spaces in general.

4 Acoustic comfort in a residential apartment subjected to noise from nearby commercial kitchen refrigeration compressor

Sheikh, Mahbub Alam (1); Mitchell, Andrew (1)
(1) Cogent Acoustics

ABSTRACT
With the urban trends towards higher density living and "mixed-use" developments, commercial premises are increasingly being located in close proximity to residential dwellings. Restaurants, cafeteria, bar & bistro and 24-hour gymnasiums below the residential apartments are some common examples of amenities in a mixed-use development that are often a source of noise annoyance. This paper investigates one such scenario where a commercial kitchen is located below a retirement living residential apartment. Sleep disturbance and noise annoyance were key concerns for the resident, even though the measured indoor noise level within the dwelling achieved the acoustic design criteria. Analysis of the measured indoor noise levels and recorded audio showed that a low frequency noise source was cycling on and off periodically every 8 to 10-minutes. This noise source was generating noise levels at least 10 dB higher at 100 Hz than the residual noise in the apartment, and was considered to be the likely source of noise annoyance and sleep disturbance. The noise was traced to a nearby cool room refrigeration compressor associated with the commercial kitchen below. This paper discusses the investigation undertaken and the noise control measures that were implemented.

121 The Philosophy of Acoustic Design Practice: Why it's OK to use the Sabine Equation

Burgemeister, Kym (1); Hough, Cameron (2)
(1) Arup, Melbourne
(2) Arup, Brisbane

ABSTRACT
Acoustic consultants routinely use a range of engineering approaches to provide 'acoustic designs' for projects in the built environment. However, the fundamental engineering design methodology that engineers adopt in approaching their work is rarely formally taught, and is often not well defined or understood by engineers themselves. Koen's Discussion of the Method is used to explore 'what is design' and how it is that engineers go about designing things. The engineering design process is reviewed using the context of an acoustic consultant designing absorptive treatment for a railway tunnel environment. The use and limitations of Sabine's equation for reverberation time (RT) in relation to alternative formulations and contemporary computer modelling approaches is reviewed. It is concluded that, in accordance with Koen's Method, it is always reasonable for an engineer to use the Sabine equation as a part of the acoustic design process to understand the reverberation time characteristics of a space, provided the limitations are understood.

S09 - BA2 - Building acoustics 2, Tuesday 21, 15:40, Room A
Chair: Kingsley Hearne

95 Predicting the performance of hanging baffles in large swimming pools

Raymond, Desmond (1); Camilo, Castillo (1)
(1) Rodney Stevens Acoustics Pty Ltd

ABSTRACT
The need for internal acoustic treatment to public spaces such as swimming pools are becoming a common practice with the increasing need for acoustic comfort from the general public. Selection of acoustic material will need to be based on the acoustic properties, ease of installation, resistant to corrosion and heavy duty. This paper presents the performance of the installed hanging baffles and the limitations of modelling hanging baffles in a large swimming pool with the room modelling software EASE. The predicted reverberation time (RT) in the swimming pool modelling in EASE and the measured reverberation time (RT) post installation have been compared in order to determine the limitations of modelling hanging baffles in swimming pools.

39 Development of a standardised test for comparing pool isolation systems

Murray, Timothy (1); Cosstick, Lloyd (1); Hong, Evan (1); Lourensz, Nicholas (1)
(1) Embelton Engineering Australia

ABSTRACT
Pools in apartments and hotels are commonly isolated from the building structure to ensure noise and vibration from a pool is not transmitted to surrounding spaces. Currently no standardised test exists to compare the effectiveness of isolation systems. Previous testing has measured vibration levels in the building structure with a per-son using the pool. The inconsistent input forces applied to the pool creates limitations to how data from existing tests can be compared between pools. For this paper, vibration characteristics of pushing a barrel into a pool were compared with that of a person bombing into a pool, in order to test the validity of using a barrel to represent the impact of a person in future tests. The variation in vibration levels of each test was also examined, to determine whether a barrel drop produces a consistent vibration response. These tests were repeated in three pools, with a Svantek 958A analyser connected to a tri-axial accelerometer to record vibration levels from various locations. The vibration characteristics of a barrel impact were found to be similar to that of a person, albeit of a larger magnitude. The barrel was also found to produce vibration levels with less variation between tests.

41 Intra-walker variability of footfall vibration and the effects of walkers' mass and carrying loads

Qian, Jason (1); Miller, Aaron (1); Duschlbauer, Dominik (1)
(1) SLR Consulting Australia Pty Ltd

ABSTRACT
Excessive floor vibration in buildings can make occupants uneasy and many prediction methods of varying degree of sophistication have been developed over the years to assist engineers in the prediction of footfall vibration. Prediction methods categorised as "impulse response" are often applied to relatively stiff floors. For impulse response methods, the predicted footfall vibration is proportional to a nominal walker impulse which is determined by the walker characteristics (such as stepping frequency), as well as the underlying floor parameters (such as modal mass and fundamental frequency). Among the reviewed impulse response methods, the dependence of the mass of the walker on the impulse is not implemented unanimously. This paper examines the influence of walker mass on the response of a relatively stiff floor. Up to 10 walkers of varying mass are considered, with each walker traversing the bay of interest at different stepping frequencies and carrying varying loads within a backpack. For each configuration, the walker traverses the bay at least 10 times to account for intra-walker variations between traversals, which are also explored.

77 What's that creaking noise? An investigation of wind-induced structure-borne noise inside high-rise apartments

McKechnie, Sam
Studco Australia, Melbourne Australia

ABSTRACT
A trend is appearing among a number of tall apartment towers around the globe where residents are complaining of noise annoyance emanating from the internal cold-formed steel wall structures during high wind events. The objective of this research is to uncover what the noise is, which part of the structure produces the noise and what can be done to eliminate it in the future? Over the last two years, research partners Studco Australia, Deakin University, Multiplex and PKA Acoustics have undertaken a detailed study of several buildings with known problems, to establish common attributes among the problematic buildings and to investigate the root cause of the problem. Many important design factors of skyscraper designs are considered and debated within this research including building shape, wind aspects, wind speeds, vortex shedding, geographical location, structure-borne noise transfer, concrete technology, construction methodologies, curtain wall designs, internal partitioning and ceiling systems, traditional acoustic treatments, and resident expectations. Conclusive evidence suggests that although skyscraper infrastructure has changed dramatically over the last 50 years, the way we build our internal wall structures has not and it's to the detriment of the building inhabitants. Notably, generally accepted acoustic treatments failed to rectify the noise annoyance in these buildings. The research includes a case study of a recently completed, 250m tall building that experienced significant noise inside the wall cavity and ceiling plenum during high wind events. A variety of remedial treatments were administered to the internal cold-formed steel structures, including demolishing walls and rebuilding them with entirely new, never seen before building innovations. The end results varied from dramatically reduced noise to no noise. There is no known previous research into this acoustic phenomenon and although research is still ongoing, the conclusions reached so far are already changing the way we build skyscrapers in Australia.

120 **Drop towers and fitness flooring assemblies**

Gartenburg, Paul (1); Golden, Mat (1)
(1) Pliteq Inc, Toronto, Canada

ABSTRACT
Typical practice for quantifying acoustic performance in fitness flooring solutions involves dropping a weight onto a sample and recording the sound pressure level in the receiving room. This causes issues when trying to obtain an apples-to-apples comparison of the different flooring solutions as the 1/3 octave band data is controlled by slab natural frequencies. By instrumenting, with an accelerometer, a known mass dropped from a known height onto a fitness flooring specimen, a force impulse is recorded. This force impulse provides unbiased insight into specimen properties, such as damping, contact time and max acceleration. By using a fast Fourier transform, the impulse can also be examined in the frequency domain, which provides further insight into the acoustical properties. Additionally, repeating this process on the same specimen gives an understanding of how the material fatigues acoustically, which determines the duration of its lifetime.

S09 - SP1 - Signal processing and tracking, Tuesday 21, 15:40, Room B
Chair: Shane Chambers

2 **Target Tracking Using Seabed Based Passive Acoustic Arrays**

Wang, Jimmy (1); Arulampalam, Sanjeev (1); Fletcher, Fiona (1); Steed, Matthew (1); Rose, Vincent (1)
(1) Maritime Division, DST Group, Edinburgh, SA 5111, Australia

ABSTRACT
Passive sonar systems are a key sensor type for anti-submarine warfare, used to detect acoustic energy emitted by surface or subsurface sources. These systems typically provide bearing detections from targets that are loud enough to be detected. Over time, these bearing detections can be associated and fused to generate a track on a target, provided observability criteria are met (usually by manoeuvring the sensor, or having multiple sensors in contact with the target). In this paper, we consider an experimental passive acoustic seabed array sensor system consisting of three line arrays of hydrophones deployed on the sea floor. We use detections from this system to explore the challenges involved with tracking targets using passive seabed array systems. A tracker has been developed using the Cubature Kalman filter for estimation with global nearest neighbour data association. This tracker has been applied to two datasets collected using the experimental seabed array system.

17 **Classification of active sonar echoes using a one-class classification technique**

Nguyen, Binh (1); Kouzoubov, Alexei (1); Wood, Shane (1)
(1) Maritime Division, Defence Science and Technology Group, Australia

ABSTRACT
A typical approach to data classification based on machine learning algorithms is binary classification. This involves the classifier to be trained using representative data sets provided from two object classes. In reality, da- ta from one of the classes may be not well-defined or readily available and so the one-class classification technique is gaining popularity. In this research we apply this method to the problem of classification using active sonar echoes from different classes of objects. A one-class classification research tool was developed in Matlab® to implement several one-class classification techniques found in literature. The tool was applied to three sets of data: simulated, laboratory and at-sea. The performance of the selected classifiers on different data sets will be discussed in this paper.

37 **Performance evaluation of a shock wave-based method for supersonic bullet trajectory estimation**

Lo, Kam W.
Defence Science & Technology Group

ABSTRACT
The supersonic flight of a bullet generates a ballistic shock wave (SW). As the bullet is subjected to both drag and gravity, its speed decreases with the distance travelled and its trajectory is more or less curvilinear. Given the drag coefficient exponent and the ballistic constant of the bullet, its curvilinear trajectory is specified by five parameters. In this paper, these five parameters are estimated using a SW-based method, which utilizes differential time of arrival (DTOA) of SW measurements from an acoustic sensor array and assumes a linear trajectory, a drag coefficient exponent of 0.5, and a known ballistic constant for the bullet. The point of fire is then located by tracing the estimated curvilinear trajectory of the bullet backwards until it intercepts some obstruction on a digital map. The performance of the SW-based method is evaluated using simulated DTOA data for 36 different types of real bullets, which are generated using Doppler radar measured speeds of the bullets with the gravity taken into account. The standard deviation in the estimates of each parameter is compared with the Cramer-Rao lower bound. The effect of using an erroneous ballistic constant on the performance of the SW-based method is studied.

102 **Classification of small arms shock wave data by statistical clustering of actual waveforms**

Hamilton, Les
Defence Science And Technology Group DSTG, 13 Garden St, Eveleigh, Australia

ABSTRACT
Collections of acoustic shock waves generated by small arms fire for 5.56 and 7.62 mm bullet calibre have previously been classified using the two waveform features peak amplitude and duration [Ferguson, Lo, Wyber (2007). Acoustic sensing of direct and indirect weapon fire. ISSNIP 2007, 167-172]. In a very different approach, classification is investigated using unsupervised statistical clustering of the actual shock waveforms. Waveforms are essentially treated as geometrical objects, and are formed into groups with different shapes. Waveforms representative of the central tendencies of groups can then be used to classify other data. For shots fired from the same range in good weather conditions, 5.56 mm calibre waveform peak pressures and durations are less than those for 7.62 mm. However, the clustering revealed previously undetected artefacts which acted to extend some durations, causing each calibre to have two sets of waveforms instead of

one, and leading to overlaps in durations for the two calibres. Clustering was able to isolate the anomalously extended waveforms and other types of anomalies in some cases, and is in principle a better data exploration and classification method for shock waveforms than feature based approaches.

94 Array shape estimation method based on extraction of single normal mode

Lu, Licheng (1); Ren, Qunyan (1); Hu, Tao (1); Ma, Li (1)
(1) Key Laboratory of Underwater Acoustic Environment, Institute of Acoustics, Chinese Academy of Sciences, Beijing 100190, China

ABSTRACT
Accurate estimation and knowledge of array shape is essential for array signal processing in underwater target localization. This paper describes a method to extract a single mode and estimate array shape based on warping transform with an impulse source. One can process the signal received by a vertical array and transform it to another in the wave guide invariant (β) form for warping transform, then extract the single normal mode. By constructing the relation between the vertical array acoustic field phase and vertical array shape, the array shape can be estimated by normal mode phase. There is no source localization information needed in this method, and the simulations in different underwater environment show that the vertical array shape can be estimated effectively.

S10 - EN2 - Environmental and low frequency noise, Wednesday 22, 08:45, Room A
Chair: Norm Broner

26 Predictors of noise exposure in construction workers

Lewkowski, Kate (1); Heyworth, Jane (2); McCausland, Kahlia (1); Fritschi, Lin (1); Williams, Warwick (3); Li, Ian (2)
(1) School of Public Health, Curtin University, Bentley, Perth, WA, Australia
(2) School of Population and Global Health, The University of Western Australia, Crawley, Perth, WA, Australia
(3) National Acoustics Laboratory, Chatswood NSW, Australia

ABSTRACT
Construction workers are exposed to hazardous noise from a wide variety of tools and equipment. This study aims to determine the workplace tasks associated with being exposed to occupational construction noise above the Australian standard (LAeq,8h ≥ 85 dB). The paper also explores the predictors of personal hearing protection use amongst construction industry workers. One hundred construction workers from a range of construction occupations were recruited. Participants wore a dosimeter for a working shift that recorded their time weighted eight-hour equivalent noise exposure levels (LAeq,8h). Interviewers used specialised occupational exposure survey software, OccIDEAS, to collect information about the tools and equipment used during the same working shift. LAeq,8h results ranged from 71 dB to 101 dB with 46% of participants having an LAeq,8h equal to or over the Australian Exposure Standard (85 dB). Results showed that the personal use of planers, sanders and grinders; large machinery; and power hammers were strongly associated with having an LAeq,8h over 85 dB. Only 41% of workers who had an LAeq,8h ≥ 85 dB wore hearing protection all the time they performed noisy tasks.

43 An Open Source Noise Calculation Toolkit for Acoustics

Setton, Philip
Acoustics, WSP, Melbourne, Australia

ABSTRACT
Many Acoustic Engineers today use custom spreadsheets or custom functions to perform their calculations to further enhance the speed and reliability of their calculations. This offers benefits over manually entering tables of data or writing formulas explicitly, both of which can result in human or syntax error. Proprietary software packages have also been developed to perform acoustics calculations. The ongoing development of these packages occurs at a slow pace. Such packages may also encourage a supplier of products whose specification data is included within the software. 'Open source' software refers to any software with editable source code. Open source software offers benefits over proprietary software as new elements can be appended to an existing platform, documentation can be shared for the tool and each piece of code can be checked to ensure it is functioning as intended and documented. In this paper, a new open source acoustics calculation platform, Trace, is presented. The platform is built as a Microsoft Excel Add-In and contains tools for common acoustics calculations, mainly centred around mechanical noise, simplified environmental noise, and basic room acoustics. A collaborative approach to software development and quality assurance will provide the Acoustics Engineering community a more transparent and flexible system than those currently available. By 'crowd-sourcing' the problem, development will not rely on a single person or entity. The most successful platforms are those with a strong community whose collective expertise can be utilised – such a model can be adopted for acoustics engineering for the benefit of all users.

14 Determinants of annoyance from humming sound as indicator of low frequency noise

van Kamp, Irene (1); Breugelmans, Oscar (1); van Poll, Ric (1); Baliatsas, Christos (2); van Kempen, Elise (1)
(1) National Institute for Public Health and the Environment, Netherlands RIVM
(2) Tilburg University, Department Medical and Clinical Psychology, Netherlands

ABSTRACT
The level of concern and health complaints related to low frequency noise (LFN) seems to be increasing, not only in the Netherlands, but also at international level. There is evidence suggesting an association between LFN and symptomatic effects such as annoyance and sleep disturbances. A systematic evaluation of the literature which we recently performed, focusing on epidemiological studies on residential sources of LFN in relation to various symptoms and well-being indicators confirms these findings. However, it is still hard to make a valid estimate of the burden of disease due to LFN. Therefore, based on several Dutch datasets we estimated the prevalence of health complaints due to low frequency noise or attributed to it. The available data only concerned perceived exposure rather than actual measurements of LFN, preventing to link the exposures to these effects. It was concluded that the number of complaints and the percentage highly annoyed has increased.

Large differences were found between cities, regions and in particular neighbourhoods. This paper explored the relation between contextual, situational and personal features with the level of annoyance due to low frequency sounds, based on secondary analysis of existing data.

69 A new clue to infrasound - Experimental evidence supporting osmotic baseline stabilisation in the ear

LePage, Eric Lindsay (1); Avan, Paul (2)
(1) OAEricle Australia
(2) Université d'Auvergne, France

ABSTRACT
This work examines what defines the low-frequency limit of audibility and concludes that because of the way the cochlea has evolved, the definition of infrasound needs to be extended down to zero frequency, viz. static pressures. Auditory frequency analysis is usually modelled using the two-chamber model of von Békésy in which the middle chamber serves no obvious mechanical function. Scala media (part of the endolymphatic duct) is, however, associated with cochlear homeostasis and evident regulation of the transverse position of the basilar membrane. This tiny, sandwiched, vessel sometimes develops enough osmotic pressure to rupture its membranes. A hypothesis is developed that its central function may be to routinely vary its internal pressure to slowly counterbalance atmospheric (ambient) pressure variation delivered to the perilymph, keeping the basilar membrane in the static position required for optimal hearing sensitivity. Two key missing pieces of evidence are needed to support this theory: 1) that cochlear fluid pressures vary in ways influenced by endocochlear potential, and 2) the now well-documented water channels (AQP5s) lining this endolymphatic chamber are gated to control the flow of water down the documented osmotic gradient. We here present the first direct evidence from micropuncture pressure measurements, accessed through of the round-window membrane of living rodents. When appropriately invoked, the data reveal behaviours consistent with aquaporin gating as well as pressure release. It follows that individual susceptibility to infrasound may result from loss of the stabilisation afforded by an ancient form of hydraulic assist.

126 Low-frequency noise from wind turbines

Christian Sejer Pedersen

ABSTRACT
Sources of low-frequency noise and infrasound are found many places in the industrialized world, and it is difficult for the general public to separate fact from fiction, when it comes to the effects that the noise can have on human health and well being. As wind turbines have increase in size, the noise emission has also increased and the noise spectrum has shifted downward in frequency. Therefore, low-frequency noise from wind turbines has become a serious concern. In Denmark this has resulted in additional rules regarding the permitted low-frequency noise from wind turbines, but the question remains as to how well the rules protect the neighbours from potential effects of the low-frequency noise. The presentation will attempt to separate fact from fiction when it comes to low-frequency noise and infrasound. The focus will be on low frequency noise from wind turbines and the potential effect on the neighbours. An assessment of the Danish rules on low-frequency noise from wind turbines will be presented and examples of low-frequency noise measurements from neighbours will be shown.

S10 - UW4 - Underwater propagation 2, Wednesday 22, 08:45, Room B
Chair: Binghui Li

45 An Analytical Study of a Periodic Multilayered Medium for Underwater Applications

Roux, Laetitia (1); Audoly, Christian (2); Granger, Christian (3); Hladky, Anne-Christine (3); Kessissoglou, Nicole (4)
(1) Naval Group Research, Toulon-Ollioules, France; School of Mechanical and Manufacturing Engineering, University of New South Wales, Sydney, Australia
(2) Naval Group Research, Toulon-Ollioules, France
(3) IEMN Institut d'Électronique, de Microélectronique et de Nanotechnologies, ISEN Department, UMR 8520 CNRS National Center for Scientific Research, Lille, France
(4) School of Mechanical and Manufacturing Engineering, University of New South Wales, Sydney, Australia

ABSTRACT
Interest in the use of metamaterials has increased considerably in recent years as these materials exhibit unusual properties due to their internal structure. In this paper, a periodic multilayered medium formed by the alternation of stiff and soft materials is analytically examined, whereby the multilayered medium is modelled as a one-dimensional wave propagation problem. The transfer matrix method is used to determine the reflection and transmission coefficients on the incident and transmitted sides of the multilayered medium, respectively. The effective acoustic properties of the periodically layered medium in terms of the properties of an equivalent homogeneous medium are also derived using the transfer matrix method. These effective parameters, corresponding to the effective speed of sound and effective density, are compared to those obtained using a quasi-static approach. Dispersion curves for the periodically layered medium and results for the transmitted and reflected pressure are presented.

27 Propagation of underwater noise from an offshore seismic survey in Australia to Antarctica: measurements and modelling

Gavrilov, Alexander
Centre for Marine Science and Technology, Curtin University, Perth, Australia

ABSTRACT
An offshore seismic survey was conducted over the western edge of the continental shelf in Bass Strait in 2006. Underwater noise from this survey was recorded on an autonomous sound recorder deployed in the Southern Ocean on the Antarctic continental slope. Sound emission and propagation models were verified by experimental measurements based on parameters and position of the airgun array and characteristics of the underwater sound channel. A parabolic equation approximation method was used to calculate the sound field over the continental slope of Australia and then a normal mode model was employed to account for the transmission loss due to sound scattering by surface waves south of the Polar front.

The numerical predictions are consistent with the measurement results within a few dBs for the sound exposure and energy spectral levels. It is also demonstrated by measurements and modelling that the best coupling of a near-surface sound source with the SOFAR underwater sound channel takes place when the source is located over the continental slope at a sea depth of about half of the channel's axis depth. The model can be used to predict masking effects of man-made underwater noise on the communication environment of marine mammals in Antarctica.

31 **Measurement of radiated noise from surface ships - Influence of the sea surface reflection coefficient on the Lloyd's mirror effect**

Audoly, Christian (1); Meyer, Valentin (1)
(1) DCNS Research, Toulon, France

ABSTRACT
The assessment of ship underwater noise signature is highly important not only to a range of naval applications but for the assessment and mitigation of shipping related noise impact on marine animals. One of the main phenomena affecting ship radiated noise measurement is Lloyd's mirror effect, which describes the interference between the direct sound path and the path reflected on sea surface. Having published a first standard for radiated noise measurement in deep waters for comparison purposes, the ISO committee on underwater acoustics is working towards an objective of correcting the Lloyd's mirror effect. While it is assumed that the surface of the ocean acts as a perfect mirror, this is not often the case due to sea surface deformation. The aim of the present study is to investigate the influence of a non-perfect reflection coefficient on the Lloyd's mirror effect. This is achieved through the use of different models taken from the literature that provide an effective reflection coefficient depending on frequency, grazing angle and sea state. Results are presented in the form of acoustic pressure maps at short propagation distances and of frequency responses at different observation points, for sea states up to 3. Simulations show that the effect is small at low frequencies, and at high frequencies a deviation of up to 3 dB appears. However, these results are dependent on the reflection coefficient model used.

78 **Determination of the source level of underwater noise radiated from marine platforms: effect of surface and bottom reflections on distance normalization**

Zhang, Zhi Yong (1); Zinoviev, Alex (1)
(1) Defence Science & Technology Group, Edinburgh, SA 5111, Australia

ABSTRACT
The concept of source level is often used to characterise the acoustic radiation strength of the platform, and for convenience, is usually referred to a conceptual 1 m distance from the acoustic centre of the platform. Distance normalization is the process where the propagation effects from the platform to the receiver are removed to determine an equivalent monopole source level which yields the same measurements in the acoustic far-field ("back-propagate" from far-field to 1 m). National and International Standards, e.g., NATO STANAG 1136-1995, ANSI-ASA S12.64-2009, ISO 17208-1:2016, have been developed for determination of radiated noise levels. In these standards, spherical spreading of acoustic energy is assumed in the distance normalization, which is equivalent to assuming that sound propagates from the source to the measurement hydrophone by only one direct, lossless, straight path, in particular the effects of surface and bottom reflections are ignored. The latest draft standard ISO 17208-2:2017 considers the effect of surface reflections on the estimation of source levels using coherent reflection coefficients due to sea surface roughness, which does not account for the incoherent energy scattered from the rough surface and also ignored the effect of the near surface bubbles. In this paper, we consider the effect of surface reflections using reflection coefficients fitted to published experimental data, which includes the incoherently scattered energy and the effects of bubbles. We also consider the effect of reflections from seafloor sediments. Based on acoustic modelling suitable for short-range propagation, we propose formulas for distance normalization that accounts for the effects of surface and bottom reflections in both deep and shallow water environments.

86 **Shallow water limits to hydro-acoustic communication baud rate and bit energy efficiency**

Andronis, Nicholas
Curtin University

ABSTRACT
Shallow water hydro-acoustic communication channels are characterised by transient multipath signals which limits maximum baud rate and peak bit energy efficiency. Precision measurements of multiple shallow and deep water environments, using multi-channel direct sequence spread spectrum modems, establish a relationship between maximum baud rate and peak bit energy efficiency as a function of transmit power, communication range, water depth, and ambient noise. Bit energy efficiency peaks at a lower baud rate than the shallow water inter-symbol interference bounded maximum baud rate. Operating multi-channel direct sequence spread spectrum modems at peak bit energy efficiency provides maximum covert performance and minimum battery power consumption with the potential of establishing long range network routed communication links powered by ocean energy harvesting.

S11 - Plenary 3, Wednesday 22, 11:05, Room A

125 **Internal Acoustics of the ISS and other Spacecraft**

Allen, Christopher
NASA Johnson Space Center, Houston, TX, USA

ABSTRACT
It is important to control the acoustic environment inside spacecraft and space habitats to protect for astronaut communications, alarm audibility, and habitability, and to reduce astronauts' risk for sleep disturbance, and hearing loss. But this is not an easy task, given the various design trade-offs, and it has been difficult, historically, to achieve. Over time it has been found that successful control of spacecraft acoustic levels is achieved by levying firm requirements at the system-level, using a systems engineering approach for design and development, and then validating these requirements with acoustic testing. In the systems engineering method, the system-level requirements must be flowed down to

sub-systems and component noise sources, using acoustic analysis and acoustic modelling to develop allocated requirements for the sub-systems and components. Noise controls must also be developed, tested, and implemented so the sub-systems and components can achieve their allocated limits. It is also important to have management support for acoustics efforts to maintain their priority against the various trade-offs, including mass, volume, power, cost, and schedule. In this extended abstract and companion presentation, the requirements, approach, and results for controlling acoustic levels in most US spacecraft since Apollo will be briefly discussed. The approach for controlling acoustic levels in the future US space vehicle, Orion Multipurpose Crew Vehicle (MPCV), will also be briefly discussed. These discussions will be limited to the control of continuous noise inside the space vehicles. Other types of noise, such as launch, landing, and abort noise, intermittent noise, Extra-Vehicular Activity (EVA) noise, emergency operations/off-nominal noise, noise exposure, and impulse noise are important, but will not be discussed because of time limitations.

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