Vol 41 No 6 November / December 2016

ACOUSTICS BULLETIN

in this issue… **Acoustics 2016**

plus… **Gyms – noise and vibration**

Measurement and analysis of mechanical noise in wind turbines

Considerations in modelling freight rail noise

Call for more green building façades to cut city noise

Institute of **Acoustics**

Contacts

Editor:
Charles Ellis

Contributions, letters and information on new products to:
Charles Ellis, Editor,
Institute of Acoustics,
3rd Floor St Peter's House,
45-49 Victoria Street, St Albans,
Hertfordshire, AL1 3WZ
tel: 01727 848195
e-mail: charles.ellis@ioa.org.uk

Advertising:
Enquiries to Dennis Baylis MIOA, Peypouquet, 32320 Montesquiou, France
tel: 00 33 (0)5 62 70 99 25
e-mail: dennis.baylis@ioa.org.uk

Published and produced by:
The Institute of Acoustics,
3rd Floor St Peter's House,
45-49 Victoria Street, St Albans.

Design and artwork by:
oneagency.co London
81 Rivington Street
London, EC2A 3AY
e-mail: london@oneagency.co
web site: www.oneagency.co

Printed by:
Newnorth Print
College Street
Kempston
Bedford MK42 8NA

FSC www.fsc.org MIX Paper from responsible sources FSC® C023802

Annual subscription (6 issues) £120.00
Single copy £20.00

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Front cover photograph:
Rupert Thornely-Taylor delivers the Rayleigh Medal Lecture at Acoustics 2016

Institute of Acoustics

The Institute of Acoustics is the UK's professional body for those working in acoustics, noise and vibration. It was formed in 1974 from the amalgamation of the Acoustics Group of the Institute of Physics and the British Acoustical Society. The Institute of Acoustics is a nominated body of the Engineering Council, offering registration at Chartered and Incorporated Engineer levels.

The Institute has over 3000 members working in a diverse range of research, educational, governmental and industrial organisations. This multidisciplinary culture provides a productive environment for cross-fertilisation of ideas and initiatives. The range of interests of members within the world of acoustics is equally wide, embracing such aspects as aerodynamics, architectural acoustics, building acoustics, electroacoustics, engineering dynamics, noise and vibration, hearing, speech, physical acoustics, underwater acoustics, together with a variety of environmental aspects. The Institute is a Registered Charity no. 267026.

Conference programme 2016/2017

15-17 November 2016
Organised by the
Electroacoustics Group
Reproduced Sound 2016
Southampton

23 November 2016
Organised by the
Environmental Noise Group
Defra research – synopsis of recent publications
London

7 December 2016
Organised by the
Environmental Noise Group
ETSU-R-97 – Time to move on?
(including AM update)
Birmingham

12-13 December 2016
Organised by the
Underwater Acoustics Group
Acoustic and environmental variability, fluctuations and coherence
Cambridge

14 March 2017
Organised by the
Measurement and
Instrumentation Group
Sound transport modelling
Manchester

23-27 July 2017
Organised by the IOA on behalf of the International Institute of Acoustics and Vibration
24th International Congress on Sound and Vibration
London

Please refer to **www.ioa.org.uk** for up-to-date information.

Dear Members

You may have read in October's *Acoustics Update* that the National Physical Laboratory is withdrawing from airborne acoustics work, including calibration services. We are very concerned about the loss of the UK's primary and secondary standards which are currently held by NPL. We have had an initial meeting with NPL, which is keen to engage in discussion regarding future possibilities with respect to these standards. We hope to have further exchanges with NPL, and to facilitate discussion with other bodies to explore what options there might be for the retention of one or more of the airborne standards.

Acoustics 2016 provided papers on fascinatingly varied subjects, as you'll see from the articles in this edition. It was a good reminder of how enthusiastic our profession is in seeking answers to those questions which we regularly confronted. Many members clearly carry out research in their own time and within their companies to further knowledge in our discipline. Their readiness to share this with their peers, and to seek challenge and input from others, demonstrates the maturity of our profession. Several of our medal and award recipients have shared their knowledge or time freely within the profession, or with those who may join it in the future. Reading the citations for award and medal winners at the conference was a humbling experience.

The work of one of our medal winners in helping young people to see physics and acoustics as exciting subjects led me to think about what the building blocks are for a career in acoustics. Perhaps first there is something which catches our imagination as children. Then we need support through the education system to gain qualifications that will enable us to get the employment we seek. But who provides that spark of interest, and where do we get that support from? I was lucky enough last month to hear a talk by the Social Mobility Foundation which highlighted the difficulties teenagers from low-income families encounter in realising their potential. If your company offers work experience, check out the Foundation's One +1 scheme. The scheme helps companies offer work experience to bright students who don't have connections in science and engineering. Or if you have colleagues who have recently come through university, perhaps you might encourage them to become a mentor through the Foundation and offer support to a student who has no family background in higher education.

For those already working in acoustics, and for our current students, 2017 offers a great opportunity to present a paper or poster at a premier international conference. The Institute is providing the organisation for ICSV24, which is being held in London and will replace our annual conference next year. It's a fantastic opportunity for the UK and Ireland to showcase our research and professional skills – so do submit your abstract as soon as possible.

Shortly after the Bulletin goes to press, the Reproduced Sound conference will be held in Southampton. In addition to a great mix of electroacoustic-related papers focussed on sound and pictures, the conference includes workshops and visits to ISVR and Southampton Solent University's facilities. There's a huge amount packed into the programme – so much so that the first workshop will take place on the Tuesday evening, before the first full day of papers on the Wednesday. I look forward to presenting the Peter Barnett Memorial Award. I miss the robust but friendly challenge of a debate with Peter at a Reproduced Sound conference, but I am confident that there will be colleagues following in Peter's footsteps. It will be interesting to see whether the hotel bar staff's ability to keep serving until the early hours of the morning after the conference dinner will be as enthusiastically tested as at Kenilworth for Acoustics 2016.

I hope that you'll take inspiration from the papers described within this Bulletin, and consider providing an article on work or research that you've been carrying out for a future edition.

Jo

Jo Webb, President

Acoustics 2016: more than 200 flock to 'relaxed and enormously enjoyable event'

Full conference round-up

Acoustics 2016 maintained the Institute's proud tradition of staging highly successful annual conferences, attracting more than 200 people, 175 of whom stayed for both days.

The event, at Chesford Grange, Kenilworth, offered sessions on building acoustics, environmental noise, measurement and instrumentation, musical acoustics, physical acoustics and noise and vibration engineering as well as poster sessions.

The first day's sessions were followed by a reception and the conference dinner, during which a number of awards were made. (See pages 15-17 for full details)

Martin Lester, conference chairman, who opened the proceedings, said: "Walking round at any time, there were always groups of people in animated discussion – the feeling I got was that people really wanted to be there: they were relaxed and were enjoying themselves enormously."

Because the Institute's main focus in 2017 will be organising the 24th International Congress on Sound and Vibration in London (23-27 July), there will be no main IOA conference in 2017 – the next one will be in spring 2018.

Building Acoustics

By Roger Kelly

No building acoustics conference would be complete without a presentation from Jack Harvie-Clark of Apex Acoustics, who is also the new Chairman of the Association of Noise Consultants (ANC). Jack ably started the day sharing his knowledge on the design and commissioning of schools to meet the 2014 revision of Building Bulletin 93. The two main changes to BB93 concern indoor ambient noise levels and reverberation time. Both changes lead to difficulties in design and commissioning of schools and the presentation discussed what these possible pitfalls might be.

Nick Conlan, also from Apex Acoustics, discussed one of the industry's main hot topics – flanking paths through curtain walling systems. Nick had done an in-depth study into current academic research and provided recommendations into methods of improving the sound insulation of these systems by controlling the flanking paths.

Finishing the morning session was Andy Parkin of Cundall Acoustics, the immediate past Chairman of the ANC. He kindly stepped in at the last minute after a late cancellation and talked in detail about how the acoustics of offices can directly affect the health, wellbeing and productivity of the occupants. He used the open plan Cundall offices in London and Birmingham as case studies. He predicts that the design of good acoustics in office buildings will become more important in the coming years, especially with the emergence of the WELL building standard and other such guidance.

The first talk after lunch was by Nikhilesh Patel from the University of Salford who has been researching if acoustic cameras can be used to detect air leaks in a structure. The method seemed to be effective but only at certain higher frequencies. There appeared to be a similarity in the results of thermal and acoustic imaging at 2kHz which has given further research opportunities with Salford's Energy House team.

The remainder of the afternoon was filled with talks about ventilation and the fine balance between getting enough fresh air into a building without letting in too much noise.

Anthony Chilton was representing the ANC Acoustics, Ventilation and Overheating Group which is aiming to provide guidance on acoustic conditions and design when considering both the provision of ventilation and prevention of overheating. The design guide will clarify the relevant definitions of ventilation and overheating for residential development to act as a reference for acoustic designers. It will also give quantitative guidance as to

Martin Lester opens the proceedings

Jack Harvie-Clark

Nick Conlan

Andy Parkin

The conference gets under way

Nikhilesh Patel

Michael Barclay

how to assess internal noise levels in the situation where windows are open or other means of controlling overheating is provided. This group is another example of how volunteers work tirelessly to provide help for the rest of us.

Before afternoon tea Grant Waters of Hoare Lea Acoustics talked about the feasibility of incorporating active noise control technology into ventilation openings to reduce external noise ingress during periods of overheating. Whilst providing encouraging results at low frequencies, more work needs to be done to provide a commercially viable product.

Michael Barclay of the University of Wales Trinity St David talked us through how noise mapping and dynamic thermal building modelling can be used to investigate how to optimise the energy consumption of a building whilst maintaining acceptable internal noise levels.

The normal method of letting fresh air into a building is to open a window, except that how it opens and the direction in which sound is incident on the window can hugely affect the internal noise levels. Chris Jones of Mach Acoustics presented how the window type (sash, top hung, side hung etc..), and many other aspects can affect the sound insulation performance of an open window and that the rule of thumb 10-15dBA should not be used.

To finish Barry Jobling of Hoare Lea Acoustics and, using the miracles of modern technology, Diana Sanchez (nearly live from Japan) presented an alternative way to assess the health implications of excess heat and noise in homes. By estimating the economic cost of these effects, they hope to be able to influence fundamental design considerations both at a policy level, and on a day-to-day basis demonstrate to developers, designers and builders that their contribution to the built environment matters on a significant scale.

And so our session came to an end. Thanks to the welcome return to the two-day format, we were later able to enjoy a conference meal and entertainment, which allowed us all to get to know newcomers and to renew old acquaintances.

Environmental Noise

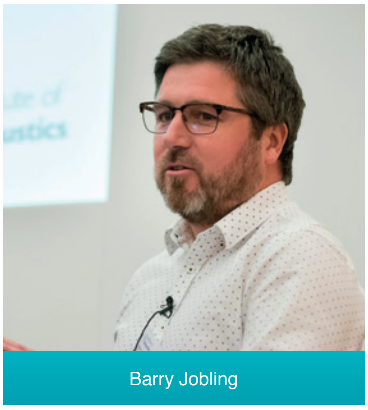
By Richard Perkins and David Waddington

The first session focussed on construction noise and military noise. The first speaker was David Nicholls from Addiscombe Environmental Consultants, who spoke on construction noise and vibration monitoring systems, past, present and future. Having worked for the past 20 years on projects such as Channel Tunnel Rail Link, Crossrail, DLR extensions and Thames Tideway, David was responsible for the noise and vibration elements of these projects. Over that time he explained how he had implemented a number of noise and vibration monitoring systems, and talked us through how the technologies have developed in terms of the instrumentation available, its connectivity and the presentation of data. He went on to describe how legislative and contractual requirements had developed in line with the available technologies, and included a case study of systems currently in use on construction projects and his views on where monitoring systems may progress in the future.

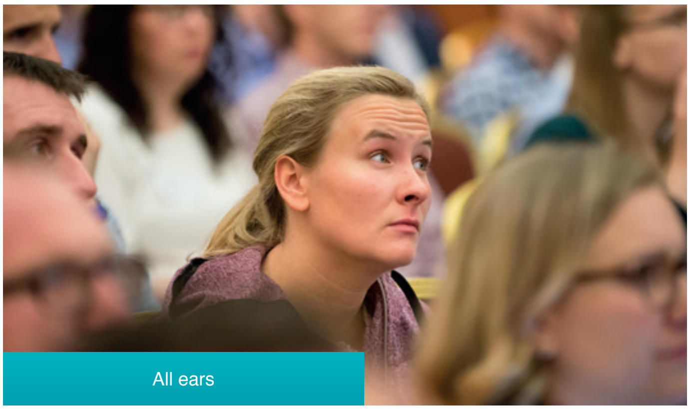
Martin Butterfield from Arup talked about his role as the Employers Delivery Team leader on the Forth Replacement Crossing (to be officially known as Queensferry Crossing). Scotland's biggest transport infrastructure project in a generation, the crossing will be open to traffic in May 2017. He explained that the scheme was 22km overall including a 2.7km cable-stayed bridge with three single column towers, wind shielding, a single deck carrying two general lanes of traffic, and hard shoulders in each direction.

Martin highlighted that the project had been delivered through the Forth Crossing Act (2011), the first time in Scotland that a large infrastructure project has had such legislation. This fundamentally changed how the noise and vibration from the construction was managed to control the effects on people and wildlife. He then went on to explain the parliamentary process; how the significance criteria were derived and agreed; the practical implementation of construction noise and vibration management, and the formation and interactions of the project team with the Noise Liaison Group and Code of Construction Practice. He noted that close liaison with the local authorities and residents had reduced the number of complaints to a minimum, and left a positive lasting legacy on the surrounding area from the process.

The third speaker was Ian Hepplewhite from Amec Foster Wheeler, whose talk was titled *Experience and lessons learnt from large military infrastructure projects*. Ian described how the P8


Barry Jobling


The conference dinner


All ears


Huw Myles raises a question

◀ P7

noise assessment work for military infrastructure can be highly technical and often subject to bespoke criteria. He explained the key stages of engagement such as trust building and how to manage the process of accessing the necessary information amongst military restrictions on what is sensitive, and not in the public domain. Thus the process of undertaking noise and vibration assessments on military sites was often more complicated involving more stakeholders, and more internal approvals than similar projects for other private clients.

Ian then went on to describe a number of case studies to illustrate the problems encountered. One such project for the Defence Infrastructure Organisation was a proposed transformation of the former RAF base at MOD Lyneham into a new Defence College of Technical Training. The conversion involved the creation of various training areas within the curtilage of the base including a refurbished 25m firing range; platoon training (blank firing) areas and vehicle and aircraft testing areas (for post maintenance training). He explained how "standard" environmental noise criteria were unsuitable for this situation, and how early engagement with the local authority was vital to agree the methodology and levels of acceptability to enable a satisfactory outcome to be achieved. Ian also demonstrated how working closely with project design teams was important to determine the final choice of noise control measures since the best environmental noise control measures can often conflict with the requirements of the end users. He then showed how detailed modelling techniques could be used to provide validation of the environmental noise criteria.

The final talk of the session was given by a trio of Phil McIlwain from Westminster City Council, Tom Whatling from Taylor Woodrow, and Caroline O'Connor from BAM Nuttall. Demonstrating the benefits of working together, they took it in turns to explain the collaborative working that resulted in a successful management of a construction project for London Underground at Victoria Station. They explained that the project to upgrade the station has been under way now for six years in an area of Victoria which is undergoing significant regeneration, and is therefore surrounded by other construction projects.

The project was subject to a rigorous Section 61 process which included an open public and third-party stakeholder consultation, but that was only the start of the noise management process. A number of protocols and systems were detailed that had been developed between the main contractor, and the Council that were captured in a site environmental management plan. They went on to explain how the contractor implemented their "internal" management systems to actively monitor, check and enforce the Section 61 consent in line with the requirements agreed for the project, the lessons they learnt along the way, and how this resulted in an exemplar noise management system for all to follow. The talk was rounded off by Phil McIlwain who alerted attendees to the recent publication of the new Code of Construction Practice published by Westminster City Council which is now in force. The key theme running through all of the morning session was the collaboration and partnerships between the developers and the local authority, and how successful these partnerships had been in controlling construction noise and vibration to residents.

The second session had an emphasis on wind farm assessment and was well attended, probably reflecting the consultancy interest in this area. The first paper was a review of research into human response to the amplitude modulated (AM) component on wind turbine noise and concerned the development of a planning control method for implementation in the UK. Richard Perkins presented the work by WSP | Parsons Brinckerhoff commissioned by the Department of Energy and Climate Change (DECC), providing an overview of the literature review, the key findings of the review in relation to the state of knowledge of AM, and the dose-response relationships that exist. Also described were potential methods to control AM, the recommended method suggested to DECC, and how that condition may be written in accordance with UK planning policy. An attentive and clearly informed audience raised questions concerning cumulative responses, an area that appears to require further fundamental research.

David Robinson of Cirrus Research then presented a paper about windshield design approaches for noise measurement in high wind environments. Data acquired from the use of a spinning bar approach to wind testing, as opposed to low-noise wind tunnel facilities, was presented for a variety of dual-screen windshield designs. Discussion concerned the differences and validity of simulated outdoor wind environments, and the possible requirement for standardised methods of testing windscreens in laboratory and/or real-world conditions.

Next, James Mackay of TNEI considered some of the key decisions acousticians need to make when undertaking proxy measurements to determine wind farm noise compliance, in particular where measurements should be taken and how data from proxy locations can be extrapolated to receptor locations further away. Questions from the audience raised the topic of uncertainties, an area that has occupied entire conference sessions in the recent past.

With delegates' minds turning to lunch, Clive Bentley of Sharps Redmore finished the session by presenting a fascinating paper on the assessment of tranquillity and noise impact on areas of quiet character. Firstly the TRAPT index was considered, then two additional indices (known as PONS and NAMM) were introduced to consider how noisy behaviour of people (and their dogs, machines etc) might detract from tranquillity. In response to questions, Clive made it clear that the assessment of tranquillity is complex and must consider people's states of mind and the presence or absence of certain indicators as well as simple levels.

Measurement and Instrumentation

By Ian Matthews

The session was chaired by Ian Matthews of Red Twin and delivered by Mark Dowie of Brüel & Kjaer with a presentation entitled *BS 4142:2014 measurement planning and practice*.

Mark presented a practical guide to performing BS 4142:2014 assessments with some comparisons with BS 4142:1997 which was followed with a participatory case study.

Mark outlined some useful techniques, such as how a statistical distribution of LA90 values can be useful in determining the most appropriate background level. He also summarised which other parameters should be measured, with 10 or 25 ms logging P10 ▶

Rick Downham (left) and Dennis Baylis

Checking out an exhibit

◀ P8

and audio recording now important in the assessment of acoustic features. Another key data set is the weather, particularly the wind speed and direction which could be used to exclude unrepresentative data and reduce errors caused by the winds effect on sound propagation.

Mark explained the different methods, and their relative merits, for assessing acoustic feature corrections. A major consideration now is the uncertainty in the measurement. This is not simply about the measurement chain, but requires the engineer to consider the situation and conditions with a view to minimising the influence of the unknowns on the conclusions.

The participatory section was an investigation based on a rural engineering works seeking extended hours. The room was formed into groups and asked to perform a BS 4142 rating calculation with a subjective assessment of the acoustic feature corrections based on audio files. Some lively discussion ensued as to how best to define the residual and specific sound levels, and which background sound level to use in the assessment. As we collected the groups conclusions it was clear that the delegates were generally in agreement as to the assessment method but had some significant differences, 3 to 11dB, on the subjectively assessed acoustic corrections. It was felt this difference was greater than an on-site assessment because the delegates were listening to the recordings through speakers in a sterile environment.

The session was attended by about 70 delegates and prompted much further discussion and positive feedback after it had finished.

Musical Acoustics

By Mike Wright

It was necessary to squeeze six papers covering a wide variety of musical acoustics related subjects into the allotted time. Despite a few technical glitches with the AVA system, this was achieved with a little bit of time overrun!

The sessions opened with a "quartet" of papers presented by four postgraduate research students and visitors working with Patrick Gaydecki, Professor of Digital Signal Processing at the University of Manchester School of Electrical and Electronic Engineering. Mohammed Abdulaal kicked off and presented the "first movement". His paper explored the use of electroencephalography (EEG) techniques to analyse brain behaviour of a sample of participants that listened to samples of an emulated Stradivarius and the sound of raw unfiltered electric violin. Careful attention was taken to ensure that the emulated sampled melodies were consistent — these were well-demonstrated through the AVA system.

Postgraduate research student Jiaxuan Wang described a system in which real-time digital signal processing used image and video data to modulate continuous acoustic signals audio input derived from instrument tones. Visiting research assistant Sheheera Ismail gave an insight into the development of future generation of "intelligent" music surround systems with improved methods of equalisation, cross over filtering and room compensation. She indicated that the system can be integrated with modern WiSA technology for wireless audio data streaming to a "smart speaker".

We returned to the subject of violins with postgraduate research student Thomas Lloyd. He described a listening study in which precise control was exercised over the assessed parameters of various violins including a Stradivarius and a modern quality Johannsson model. This instrument did surprisingly well against the 350-year-old "Italian Master". Also examined was a cheap student model and that raw electric sound demonstrated earlier which, as expected, were not favoured. He concluded with some interesting demonstrations.

The Open University's School of Engineering and Innovation headed by David Sharp, Professor of Musical Acoustics, are regular contributors to musical acoustics sessions and postgraduate research student Richard Seaton presented a work in progress, undertaking experiments to search out reasons for the well-known problem of downward pitch drift in *a cappella* choral singing. These were done with the co-operation of a number of groups with skill levels ranging professional to amateur, and ages from seven to more than 80 years old. The compared choirs ranged from male barber shop groups, chamber and church choirs with choral societies in their various rehearsal venues. He also outlined the problems experienced with the individual choirs during the experiments.

Tim Green, who works with Dr John Prichard at the University of Derby, looked at the quintessential sound of church bell ringing as a call to prayer and clock chimes in an increasingly urban environment. There is no recognised noise assessment methodology or criteria for assessing their impact. He argued that the sound of church bells could be considered as music rather than noise. He further showed that the sound of bells are perceived differently to that of other sources of noise and considered sound exposure levels, the use of BS 4142:2014 against a social survey which he had undertaken with measurements. He concluded combining his findings into a draft measurement and rating method.

As expected, the session closed a bit late in order to take a number of thought-provoking questions that brought about some interesting discussions.

Noise and Vibration Engineering

By Russell Tipping and Malcolm Smith

The morning session was based around all areas of computation modelling. An initial introductory presentation was given by Malcolm Smith of ISVR Consulting, who is also the Chairman of the NVE group. The presentation entitled *Numerical modelling case studies in acoustics dynamics and vibro-acoustics* gave a brief overview of the different forms of modelling techniques including; finite element analysis (FEA), boundary element analysis (BEA), statistical energy analysis (SEA) and ray tracing. This was followed by an example case study for each.

The second talk was given by Carl Hopkins of Liverpool University. His presentation, *Using statistical energy analysis to predict sound insulation in buildings*, began with a useful analogy of SEA modelling in terms of thermodynamics, before moving on to outlining how SEA can be used at the design stage of buildings to determine overall transmissions between rooms.

The third presentation was *Assessing noise and vibration in buildings using finite element modelling: understanding the factors influencing predictions* given by Christos Karatsovis of ISVR Consulting. This presentation focussed on the use of P12 ▶

Aitor Lopetegi (centre) of AMC

Richard Perkins (right) enjoys a joke

◄ P10

FEA analysis of noise and vibration within buildings. The talk was centred around two case studies; the first prediction of vibration in a new state of the art research facility and the second predicting noise and vibration in multi-storey buildings from underground railway lines.

The fourth talk was given by Gaurav Kumar of Siemens Industry Software Limited and was entitled *The application of higher-order adaptive finite elements in vibro-acoustic analyses*. The talk gave an insight into how modifications to the "traditional" FEM process can be made to give the FEM Adaptive Order method which, as his examples showed, can result in reductions in computational time without loss of accuracy.

Following the break, the session continued with four papers on numerical modelling in acoustics. The first of these was given by Ian Rees from Adrian James Acoustics, who gave a very informative presentation on *Common pitfalls in computer modelling of room acoustics*, which outlined the processes required for creating models using the CATT-Acoustic ray acoustics code. The paper provided some common rules of thumb for the generation of valid geometrical acoustic models.

The next presentation was from Rebecca Haunton, University of Reading, who reported her research into detection of obstruction in sewer pipes in a paper entitled *A novel point source method for inverse scattering in waveguides*. The principle of the method is that acoustic waves in a duct are reflected and scattered from the obstruction, and that information from the scattered field may be used to estimate the location and shape of the object.

Erika Quaranta from ISVR Consulting gave the next paper, on the topic of *Application of numerical modelling methods to the design of silencers*. Erika described several case studies in which 3-D numerical models had been compared with 1-D analytical models of reactive marine silencers, and numerical methods had been used in the design of silencers for an aeroacoustic fan test facility. The numerical methods to compute the flow characteristics, back pressure and acoustic performance of all types of silencer are now readily available.

The final talk in the morning session was given by Tom Richards from Dyson, who discussed *Modelling the propagation of rotor stator interaction noise*. The blade passing frequency tones of fans in a vacuum cleaner can be suppressed by ensuring that the acoustic modes in the duct are cut-off, and hence decay exponentially with distance. The presentation described the acoustic FE modelling that had been performed to inform the design process.

Physical Acoustics

By Mike Swanwick

This session began with Alexander Stronach (Open University) presenting a paper on surface waves generated over a periodic rough surface. These surfaces have a regular rectangular section that generate additional slow-moving air-borne waves that can attenuate external sound travelling near the same surface. Evidence of several waves were observed during testing, and time-domain Boundary Element Method and a slit-pore model was employed. The variation of the periodicity and height of the surface undulations has the ability to influence both amplitude and frequency of the surface waves and the effect on attenuation of the external sound source.

The second contribution, from Keith Attenborough (Open University), concerned the largely dismissed ability of forests and tree belts attenuating sound propagation, particularly the noise from ground transportation. Several attenuation mechanisms are discussed including the absorption and scattering from acoustically soft ground covering of leaf litter, scattering from hard trunks and branches and the effects of leaves (seasonal for deciduous). In addition to the above, localised meteorological effects can greatly affect the transmissibility, and overall this is a complex problem to model and define in acoustical terms. Experimental evidence is presented along with closely fitting predictions from ground impedance and variable porosity models. A novel feature of the modelling to deal with incoherence is to treat the scattering as an additional frozen-turbulence term. This assumption is supported by the good fitting to experimental data. Periodic tree spacing and sonic crystal effects was also discussed and finally practicable ground transport noise attenuation from trees was proposed.

David Berry (University of Evora, Portugal) presented a paper on the potential use of periodic and quasi-periodic rough surfaces in place of the more traditional noise barrier. This proposed method is able to attenuate noise without the dividing wall that blocks visibility for residents and crossing pedestrians. The use of ground-mounted cylinders and semi-cylinders has been investigated. These low structures are periodically spaced with or without additional gaps to alter sound reflection and scattering effects from the curved surfaces. The introduction of ground surface roughness alters the effective ground impedance which makes the physical hard surface become acoustically softer. This interesting observation can potentially be employed to offer some noise reduction properties for traffic and ground-level receivers such as pedestrians.

Next, we received a presentation on the monitoring of acoustic emission from knee joints presented by Gordon Hunter (Kingston University). The lack of a practicable method for early diagnosis is proposed that is both non-invasive and would not require expensive apparatus such as with magnetic-resonance or X-ray based techniques. The causes of knee conditions such as osteoarthritis are many-fold and common-place. These include, high-impact activities, over-exertion, lack of exercise, obesity and inevitable wear with age. Acoustic emission using a contact microphone can listen to movements whilst comparing force measurements from a floor pad and position of the torso, hip, knee, and ankle of the patient. This sound is produced by a stick-slip vibration set up from a bone to bone grinding where the protective cartilage has been eroded. Albeit that damage cannot be remedied, early diagnosis could retard deterioration of the joint. This is potentially a low-cost, non-invasive method for the diagnosis of joint damage for a large number of sufferers. Further measurement method development work is proposed.

Victor Krylov (Loughborough University) presented a paper on the localised elastic waves and modes in structures of complex geometry. Several cases of this localisation of elastic waves were discussed. This included Rayleigh and plate waves in a solid cylinder, flexural waves in slender wedges and in non-cylindrical shells. The implied possibility of total internal reflection within these structures of complex geometry is said to be often P14 ►

Craig Storey (centre) with James Flitton

Keith Attenborough

Victor Krylov

P12

linked to the presence of lower phase velocities in curved regions than in the flatter surrounding areas or planes. This theoretical wave localisation was also demonstrated by calculations of frequency-dependent phase velocities for the cases listed above. However, these seemingly different cases demonstrated common relationships for wave-guide propagation and classical acoustics in solids and structures.

Next we heard a presentation made by Neha Sharma (University of Salford) on the analysis of a low-frequency muffler based on the “acoustic black hole effect”. This effect is based on acoustic impedance matching and transmission-line theory, but now it is thought to have additional influence from localised shear waves or Rayleigh-Lamb waves travelling over plate-baffles, cylinders etc found in such silencers and similar structures. This study discusses typical mufflers with axisymmetric geometry and sections with varying wall admittance. The baffles in the silencer section play a major role in the attenuation of low-frequency noise. In addition, the data presented showed good agreement with semi-empirical and purely numerical approaches discussed. This theoretical effect can potentially be adapted for practical applications for automotive and aerospace industries.

Tony Kent (University of Nottingham) presented recent developments and applications of Terahertz (THz) sound lasers (SASERS), where acoustic phonons are coherently generated in a similar way to photons with the more familiar LASER. It was shown that a semiconductor stack of alternate layers of Gallium Arsenide and Aluminium Arsenide can be built up in a mesa (table-top mountain shape) using conventional semiconductor processes. In this electrically biased stack, as electrons take a jump in electrical potential from one layer to the next, a localised strain causes a phonon to be released for each jump, as the electrons continue down the mesa mountain side more phonons are released in phase to the original producing a coherent pressure wave front. The resulting SASER diode is exciting development in solid-state semiconductors and provides a low-cost source of phonons. These phonons have wavelengths that can be used to probe nanostructures and can also generate and modulate microwave electromagnetic signals.

In the next presentation we heard Joshua Meggitt (University of Salford) describe virtual assemblies and their use in the prediction of vibro-acoustic responses. “Virtual assemblies” is a term used in vibro-acoustic modelling and virtual (computer-aided) prototyping of physical mechanical assemblies. A method for characterising a component as a source (a pump in this case), a transmission path (resilient mount) or as a receiver (plate/base structure) was discussed as a case study. Construction of virtual assemblies in vibro-acoustic modelling is a useful concept for characterising individual components within a system for free-mobility, dynamic stiffness or blocked force (the independent source characteristic) as appropriate. The matrices of dynamic sub-structure data is simplified using Boolean algebra, and the coupling of individual components are characterised by the summation of acoustic impedances. The resulting virtual assembly is able to predict system response and can potentially save on physical prototyping during new product development.

Concluding the session, Chris Youdale (University of Salford) presented his paper on the perceptual evaluation of the BS 4142:2014 penalty method for multiple sound characteristics. This standard is widely used for rating and assessing industrial and commercial sound. However, it can be open to user-interpretation and can often lead to large variance in applied penalties and conclusions. The aim of this paper was to design a noise matching experiment whose results could be compared to responses from participants. The experiment used several noises including a broad-band industrial fan with a superimposed protrusive 500 Hz tone, a pneumatic hammer, and a string of interrupted broad-band bursts of noise. This was accompanied by a questionnaire of how a user would apply the standard and deal with penalties for character. Unfortunately, the results were statistically insignificant. However, the subjective nature of noise annoyance combined with overall level, impulsivity, intermittency and frequency characteristics was a useful observation and it was proposed that further work is required in this debate.

Rayleigh Medal Lecture

By Martin Lester

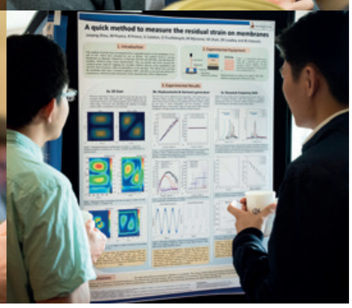
Having been presented with the Rayleigh Medal for 2016 by the outgoing IOA President, William Egan, Rupert Thornely-Taylor gave a most interesting and informative presentation on underground acoustics.

The first fact is that there are some ten significant differences between working with airborne noise, and ground-borne vibration, and Rupert talked through each of these in some detail, including the fact that Rayleigh waves don’t exist in real life (as they only occur where there is a vacuum to elastic half space).

Rupert then went on to talk about the generation, propagation, and reception of vibration, where the reception is dictated by coupling of the soil to the structure, the dynamic building response, the coupling of structure to the human body, and the coupling of structure to the air. He then went on to show visual examples of such propagation by means of the Findwave numerical modelling package that he has developed, including showing the interaction between the vibration from a train in an underground tunnel, to the final radiation of sound within a building above.

A lot more technical detail was presented in the talk. For the first time the Rayleigh Medal Lecture was videoed and it will be available for download in the near future via the Institute website.

Networking



Honours for Institute award winners presented at Kenilworth conference

Presentations were made to six Institute award winners at Acoustics 2016 in Kenilworth. Here are summaries of the citations.

Geoff Kerry

Geoff Kerry Distinguished Service Medal

Geoff Kerry joined the Institute at its foundation in 1974 and has served in many roles, including as President from 2002-2004.

He gained a BSc in applied physics from Salford University in 1967 while working at Hawker Siddeley Aviation at Woodford, where he often took to the air armed with a sound level meter, having successfully completed the flight observer course at RAF Boscombe Down.

In 1969 he joined Peter Lord and colleagues at Salford University as Scientific Officer in the Department of Applied Acoustics. Geoff was a founder member of the Institute's North West Branch and of the Industrial Noise group (now the Noise and Vibration Engineering group), and was elected a Fellow of the Institute in 1981. Through the early years of the Institute's development Geoff played a major role both regionally and nationally.

At Salford, working with Peter Lord and later with Peter Wheeler, Geoff oversaw the design, construction and commissioning of three successive generations of acoustic test facilities, taking responsibility for UKAS accreditation and the numerous commercial and governmental research and development projects awarded to the department, and helping to build its international reputation for teaching, research and consultancy. He has always been active in British and International Standards development, and since his retirement from the university he continues to act for UKAS as a specialist assessor.

In 1994 Geoff gained Chartered Engineer status through the Institute and was also awarded CPhys through the Institute of Physics.

Geoff has served the Institute tirelessly for many years as a member of the Membership Committee and as Treasurer from 1990 until 1998. He was elected President for 2002, serving through a key period in the development of the Institute. He took on the role of Vice President, Groups and Branches from 1985 to 1990, then again from 2011 to 2016, the period which saw P16 ▶

Geoff Kerry with his award

◀ P15

the inauguration and early years of the Senior Members' Group. During this period Geoff also provided the impetus to ensure that the IOA history book was collated and published.

In 2008 Geoff was awarded an Honorary Fellowship of the Institute, an award restricted to extremely distinguished individuals in the field of acoustics who have made an outstanding contribution to the art and science of acoustics and have given outstanding or exceptional service to the Institute.

In recognition of his long and distinguished service to the Institute and his valuable contribution to the development of acoustics as a profession, the Institute is delighted to introduce a new medal to be known as the Geoff Kerry Distinguished Service Medal and to award it to Geoff as the first recipient.

Dr Jon Hargreaves

Tyndall Medal

Dr Jon Hargreaves is an outstanding academic who excels in both teaching and research. His main research focuses on developing novel acoustic simulation algorithms for airborne acoustics. For example, his doctorate extended time domain Boundary Element Methods for Schroder diffusers. He is also adept at practical acoustics and experimentation, working on activated carbon, wind turbine noise and SODAR. Not only has he excelled in advancing science, he has also been successful in bidding for research grants, organising an international workshop and conference sessions.

John Tyndall was remembered primarily as "one of the world's most brilliant scientific lecturers". The quality of Jon Hargreaves teaching is one reason he is a very appropriate recipient of the award. He is a reflective practitioner, and always received very positive feedback from students. One student commented that Jon was, "the best lecturer he had encountered during his entire time as an undergraduate".

Jon has worked on public engagement lectures, including presenting a show on the science of singing for the Royal Society Summer Exhibition. More recently, he has delivered numerous acoustics based CPD days for physics teachers for the Princes Teaching Institute. He has also been involved with several TV programmes, including an appearance on National Geographic Channel's Engineering Connections with Richard Hammond.

Jon is always thinking about the broader needs of colleagues, students and the field of acoustics. One example is his organisation of research seminars at Salford University. He recognised the seminars were not working, initiated the revitalisation of the seminar series and then single-handedly organised a fascinating range of external speakers to the benefit of his colleagues.

For his outstanding research and teaching that bridges mathematics and physics, it is a pleasure to award the 2016 Tyndall Medal to Dr Jon Hargreaves.

Carl Hopkins

Engineering Medal

Professor Carl Hopkins is Head of the Acoustics Research Unit at the University of Liverpool. He is a Chartered Engineer and a Fellow of the Institute of Acoustics.

Carl's major contribution to the advancement of knowledge and understanding in acoustics is his monograph *Sound Insulation*, published by Butterworth-Heinemann in 2007. The book draws on his government-funded research on sound transmission, during his 12 years at the Building Research Establishment. This substantial monograph (622 pages) rigorously considers the limitations of prediction models and measurement methods to demonstrate that often the most useful information is in a combination of the two. The book has been well reviewed in acoustics journals and is currently referenced in seven International Standards on the measurement of sound insulation.

During his period at BRE, Carl conducted research into low-frequency sound insulation between dwellings, and developed more repeatable field measurements of sound insulation in the 50, 63 and 80Hz one-third octave bands.

As technical advisor to the Office of the Deputy Prime Minister and Department for Education and Skills, Carl co-edited two government guidance documents: (a) *Building Regulations - Approved Document E - Resistance to the passage of sound (2003)* (b) *Acoustic design of schools – a design guide, DfES Building Bulletin 93 (2003)*. These documents significantly increased the profile of building acoustics in the UK, and led to the growth in the UK acoustic consultancy sector, as well as in manufacturers and suppliers of acoustic equipment and building products.

Since his appointment at the University of Liverpool in 2007, Carl has developed sampling strategies to determine the spatial average sound pressure level in rooms. His government-funded research into thresholds of information leakage provides a new approach to speech security in spaces where a covert listener might extract confidential information.

His recently completed work has focussed on how people with a hearing impairment, particularly children, can rehearse and perform music with others. He was inspired by Dame Evelyn Glennie, the highly-renowned percussionist, who is profoundly deaf and relies on tactile feedback from the vibrating floor. His research facilitates group performance by simultaneously transmitting different vibration signals to each participating performer.

This work was recognised in the Research Councils UK "Big ideas for the future" in 2011 and was shortlisted for Research project of the year 2013 in the Times Higher Education Awards.

Carl's contribution to the field of engineering acoustics makes him a worthy recipient of the Engineering Medal.

Jon Hargreaves receives the Tyndall Medal from Jo Webb

Carl Hopkins receives the Engineering Medal from Jo Webb

Alistair Somerville

Honorary Fellowship

Alistair first began his career in acoustics more than 30 years ago when he worked in the noise and environmental assessment sections of the City of Edinburgh Council. He later went on to manage both sections.

In 1985 Alistair began lecturing on the Royal Environmental Health Institute of Scotland (REHIS) Noise Course for Environmental Health Officers. This was an extremely popular course. However, following an approach by the IOA, he facilitated the introduction of the Certificate of Competence in Environmental Noise Measurement (CCENM) to Scotland by providing it as a joint REHIS / IOA award, delivered at what is now the University of the West of Scotland (formerly Bell College). The CCENM has run there ever since, and Alistair continues to deliver it there, having done so every year since the start. He also helped develop and continues to deliver the IOA Certificate of Proficiency in Antisocial Behaviour Noise Measurement course.

Alistair completed his Master of Science Degree in Acoustics, Vibration and Noise Control at Heriot-Watt University in 1988, with his thesis on *SEA modelling of sound transmission through a wall mounted speaker bracket*. He went on to assist in the organisation of numerous IOA conferences and meetings, presenting papers and delivering practical workshops at many of them. Several workshops resulted in data findings being the basis of papers jointly published with Professor Bob Craik, his Masters dissertation supervisor.

In addition to chairing the IOA Scottish Branch since 2005, Alistair has contributed to the work of the IOA on a national basis. He has served on Council for many years and on the Executive as Honorary Treasurer. He currently serves on the Education and CCENM Committees and was previously on the Building Acoustics Group Committee.

Alistair has been instrumental in getting the Institute more involved in Scotland and started the Scottish Centre for the IOA distance learning Diploma at Heriot-Watt University. He continues to be involved in the delivery of the Diploma which is now run at Napier University in Edinburgh. As a part-time lecturer at Heriot-Watt University, he wrote and examined the environmental noise and vibration module for its Master of Science degree in acoustics and delivered the acoustics modules for undergraduate and post-graduate mechanical and building services engineering courses.

Alistair also developed a courses coordinator role within P18

Alistair Somerville receives his Honorary Fellowship from Jo Webb

◄ P17

REHIS and, as part of this, introduced and organised regular "Noise Update" conferences. He used his numerous IOA, academic and local authority contacts to provide high quality speakers and workshop organisers. These three day conferences were extremely popular with both REHIS and IOA members and in 2002 he organised the Noise Update as a joint REHIS / IOA Conference.

Alistair has represented the IOA and REHIS on the Noise Council, British Standard committees and working groups for the development and drafting of noise and vibration guidance and standards documents. These include previous reviews of both BS 4142 and BS 6472 and the working groups which produced both the Control of Noise at Concert Events and Guidance for the Control of Noise from Pubs and Clubs.

There can be few individuals who have committed and contributed as much to our Institute, over such a period of time. Due to the significant contribution Alistair has made to this Institute, to acoustics in training and education and to his many years of service and dedication, the Institute is delighted to present him with this Honorary Fellowship.


Vicky Stewart recevies her award from Jo Webb

Vicky Stewart

Award for promoting acoustics to the public

Vicky joined Atkins in 2001 as a placement student from Salford University. She re-joined on a permanent basis in 2003 as a graduate and by 2013 she was looking after her own team of acousticians. Vicky has mainly worked on environmental projects during this time, including projects in the UK, Europe and the Middle East.

She has been an active member of the IOA London Branch Committee for around five years, and sits on the Atkins committee for the Women's Professional Network.

Vicky started volunteering in 2008, and because of her STEM work, in 2013 she was awarded a Sir William Atkins Medal for her outstanding contribution and dedication. Three years ago Vicky started the Epsom STEM Hub to organise inductions and events for volunteers in her office. She supported a huge number of events, as well as attending at least five events each year herself.

At the start of 2015 Vicky became the National STEM Coordinator for Atkins, and has been working hard on developing and supporting smaller offices and national initiatives.

In 2015 Vicky was a finalist for the STEMNET most dedicated ambassador award and in June 2016 she was listed in the *Daily Telegraph* as one of the Top 50 Women in Engineering.

William Egan presents the Rayleigh Medal to Rupert Thorneley-Taylor

Rupert Thornely-Taylor

Raleigh Medal

Rupert Thornely-Taylor started working in acoustics in 1964 and in 1968 established his own practice. He has advised private and public sector clients throughout the world in the fields of: environmental assessment, industrial noise and vibration, transportation noise and vibration, groundborne noise, groundborne vibration, construction noise and vibration, community noise, architectural and building acoustics and noise control in product development.

The scope of his work includes writing, at the age of 24, the Pelican book *Noise* in1970 which made the subject more accessible to a wider audience. He is also named as inventor in a number of patents concerning diesel engine noise.

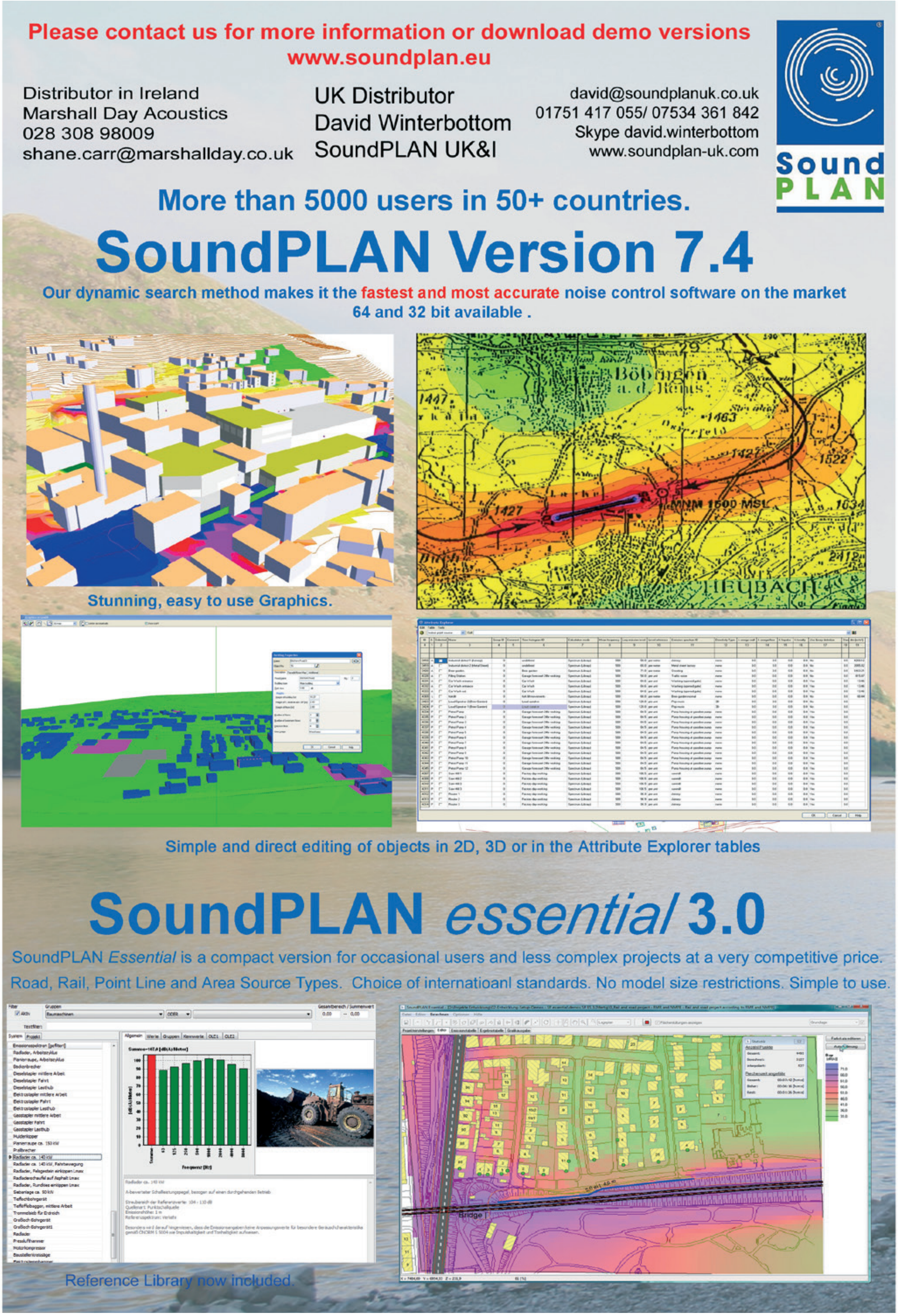
Rupert served a term on the Council of the British Acoustical Society and was a founding officer of the IOA (as the Treasurer during its early difficult financial years) and also a founder member of the Association of Noise Consultants (of which he was latterly President). He is also a Member of the Acoustical Society of America and the International Institute of Acoustics and Vibration and INCE (the Institute of Noise Control Engineering).

He has been unstinting in giving time to IOA conferences and workshops and also his encouragement and enthusiasm for careers in acoustics.

Rupert is a world leader in the field of vibro-acoustics of railway structures and tunnels and was one of the first noise consultants to embrace vibration matters. His FINDWAVE system which he developed not only permits the prediction of vibration using a range of indices but can also predict sound pressure level and output a wav file to provide auralisation, a facility that has now become more commonplace. Rupert is also well known not only for his undoubted technical expertise but also for his ability to provide a clear explanation of technical matters and those skills have led to his well-known role as an expert acoustic witness in which capacity he has appeared in many forums, not only in the courts and public inquiries but before Select Committees of both Houses of Parliament.

He was for 10 years a member of the Noise Advisory Council chaired by the Secretary of State for the Environment, and was chairman and deputy chairman of two of its working groups; he was a member of the Scott Committee, which drafted the basis of the noise section of the Control of Pollution Act 1974. He has carried out wide-ranging noise research projects for DEFRA and has also served on a number of peer review working groups.

Rupert was also Chairman of the working group of the ANC that produced the guidelines on the *Measurement and Assessment of Groundborne Noise & Vibration* and a member of an ISO working group on vibration standards.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Engineering Council registration can bring you huge professional benefits

By Blane Judd, Engineering Manager

This is the first of what I hope will be many reports from me on the work of the Engineering Division and the Institute's support of members to take the important step of becoming professionally registered with the Engineering Council. Professional registration at CEng or IEng is internationally recognised and demonstrates to the rest of the engineering community that you have an externally accredited level of professional competence and ethics expected in today's society.

The team here at the Institute is dedicated to providing the necessary levels of support to assist members through the process, which, as one member recently said, "...looks like a tough process – but then anything worthwhile usually is". In the past I have had people say that they do not think they have gained anything by becoming registered. By the same token, no-one has ever said to me that being registered has hampered their career; indeed the vast majority are of the opinion that it has been wholly beneficial.

We have completed two rounds of professional review panels this year with a third one in October. The team is working with a number of candidates to prepare their paperwork in time for the next set of interviews in spring 2017. We can offer face-to-face interviews here at head office as well at other UK sites or by video link. If you are interested in taking the next step to becoming a professionally registered engineer, contact us on **acousticsengineering@ioa.org.uk**

The requirements for academic qualifications for CEng and IEng changed in 1999. Pre 1999 an Honours Degree at 2:2 or above was required for CEng or a Higher Diploma/Certificate for IEng. Post 1999 this changed and for CEng a Master's Degree was required or an ordinary degree for IEng.

There are two routes: standard route if you have the appropriate EC-accredited qualification in acoustics and the individual route, which requires further preparatory work from you before submitting evidence of your competence. Remember we are here to help you get through the process and advice and support is offered to every candidate.

The election process is overseen by the Institute' s Engineering Division Committee, which is made up of volunteers from the membership, to whom we are extremely grateful. They represent the 300 or so members holding EC registration. They provide the essential peer review process that affirms that you are at the appropriate level for recognition as an Engineering Council Registered Professional Engineer.

For the individual route, the Institute accepts a number of courses in relevant subjects , such as audio technology, from certain academic centres, as being equivalent to accredited courses for the purposes of EC registration, without the need for further assessment.

The Institute recognises the IOA Diploma and the several Masters courses linked to it as providing evidence if you are looking to gain CEng registration. You could also offer a PhD qualification, depending upon the content of the associated taught element. We can also offer support for registration via a "technical report" route, if you do not have the relevant qualifications to help you demonstrate you are working as a professional engineer in acoustics.

The opportunity is there and we are ready to support you through it.

Below are profiles of some of the recent successful candidates.

Roderick Mackenzie CEng

Soft dB Inc

I began my career as a part-time technician for RMP Acoustical Consultants. I then undertook the IOA Diploma whilst working on my doctorate in acoustical and timber engineering. I then became an acoustical consultant and I also became a Senior Research Fellow within Edinburgh Napier University's Building Performance Centre, where I was responsible for evaluating high-performance sound insulation systems. After gaining my PhD in 2009, I was employed on a three-year knowledge transfer partnership between Napier and Icopal Monarfloor Acoustic Systems, focused on commercialising the BridgeStop and Wall-Cap systems and developing additional noise reduction solutions.

In 2012, I moved to Montreal, Canada, and joined Soft dB as a senior acoustical consultant. At Soft dB, my work has more of a hard engineering focus regarding the control of noise from and within large industrial sources such as oil and gas refineries/tankers, and manufacturing plants. I also sit on various ASTM sub-committees for Acoustics, helping to draft or revise measurement standards.

At this point in my career, I decided to pursue a more formal recognition of my acoustical engineering experience.

The IOA registration scheme for status was particularly relevant for me, as it is essentially awarded by your peers in recognition of your capabilities. Initially I was hesitant to undertake what I thought would be a long process of certification. However after several nights drafting and refining the required evidence of my training and experience, I was ready to submit these for review. The example CPD and training reports provided to me by the IOA during this process were extremely helpful in clarifying what I was expected to provide

Anastasios Pantziarides CEng

WSP Parsons Brinckerhof

I graduated from ISVR at the University of Southampton with an MEng in Acoustical Engineering in 2009. Following several successful placements in the consultancy sector during my time at university, I joined Cole Jarman as an acoustic consultant. In 2013 I moved to work for WSP | Parsons Brinckerhoff in the Middle East, where the size and pace of projects accelerated my knowledge and experience as a consultant. I am currently managing several high profile projects in the region including residential and hospitality developments and large scale railway infrastructure works.

Becoming a Chartered Engineer was on my CPD plan very early on and I looked at fulfilling the competencies at every given opportunity. I believe that becoming a Chartered Engineer is a significant milestone for anyone in our sector, and it acts as a recognition of our expertise. This provides a level of

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assurance both within the organisation as well as with our clients. The support provided by the IOA throughout was excellent, and I would highly recommend anyone in the acoustics community to consider going through the process."

Jon Wilmott CEng

AECOM

I started my career working for SRL during a summer placement for my HND in 1998. I then worked at SRL's Manchester office for a further three-and-a-half years and did the IOA Diploma at the University of Salford. After SRL I briefly worked for Acoustic Design Consultants before moving to AECOM in 2005 and I have worked here ever since. During my time with AECOM I have worked on countless schools and hospitals and other notable projects such RIO 2016 and FIFA 2022.

I pursued the individual route to Chartered Engineer and this meant preparing evidence to show I had the required UK SPEC competencies. The key competency requirements related to engineering however; other aspects such as management, sustainability, CDM, code of conduct required consideration. The professional review interview consisted of an appraisal of the of the project based evidence I had prepared and where necessary I provided further explanation and justification for the decisions I had made. The interview was quite intense but its tone was such that I didn't feel uncomfortable at any point.

Based on my experience I would highly recommend registration. The process is quite time consuming but very rewarding and there's plenty of support from the IOA along the way.

Sixty-eight more applications for membership approved by Council

Sixty-eight applications for membership have been approved by Council following recommendations of the Membership Committee. Of the total, 58 were new applications and reinstatements, the remainder were upgrades.

MIOA

Alexander Arnold	Stuart Cumming	Rory Peliza
Imran Bashir	John Freeman	Gianfranco Quartauroio
Paul Bentley	Jordan Hunter	Rostand Tayong Boumda
Mihalis Bourzoukos	Simon Ling	Jennifer Wilkin
Alexander Brooker	Pamela Lowery	Sebastian Woodhams
Jon Cooper	Alistair Maclaurin	
James Cousins	Graeme Parker	

Technician

Emily Brown
Jason Cartwright
Tom Deering
Kirsty Farquharson
James Heath
Stuart King
Melanie Serghides

AMIOA

Thomas Bonnert	Christopher Ferguson	Ando Randrianoelina
Katarzyna Bosiak	Alejo Garcigoy	Martin Read
Robert Bows	Matthew Gore	Jonathan Riley
Annika Buddenbaeumer	Boniface Hima	Alistair Robinson
John Cartwright	Cath Ibbotson	Jack Rostron
Judith Chan	Dunstan Langrish	Ben Southgate
Sei-Him Cheong	Caroline Low	Antonio Taddei
Sebastian Chesney	Gary Lum	Fraser Thomson
Laura de Azcarate Rodriguez	Matthew Malone	Hsuan-Yang Wang
Mark Dring	Adam Nicklin	Yanko Yankov

Affiliate

Ashlie Carty
Tokeer Hussain
Martin Rawlins
Matthew Rogerson
Guillermo Tomac
William Twigg
Wouter Verwaal

Sponsor

Christie & Grey
Finch Consulting
Hayes McKenzie
Pliteq

A very sound development

Midlands Branch report

By Mike Swanwick

In July Geoff Kerry provided an informative and entertaining presentation on a potted history of acoustics. We travel through time from 1963 with the Wilson report, some 11 years before the launch of the IOA, but before we settled in the 20th century, we travel back to 100 years BC to visit the Roman, Vitruvius.

However, before we can get our togas tidy, we launch forward to the Royal Society in the 1600s, where we meet Boyle, Newton, Hooke and Derham. Wigs dusted off, we speed forward to Victorian times and the Physical Society with Tyndall and Rayleigh (naming our two most eminent medals), and land in WW1, looking

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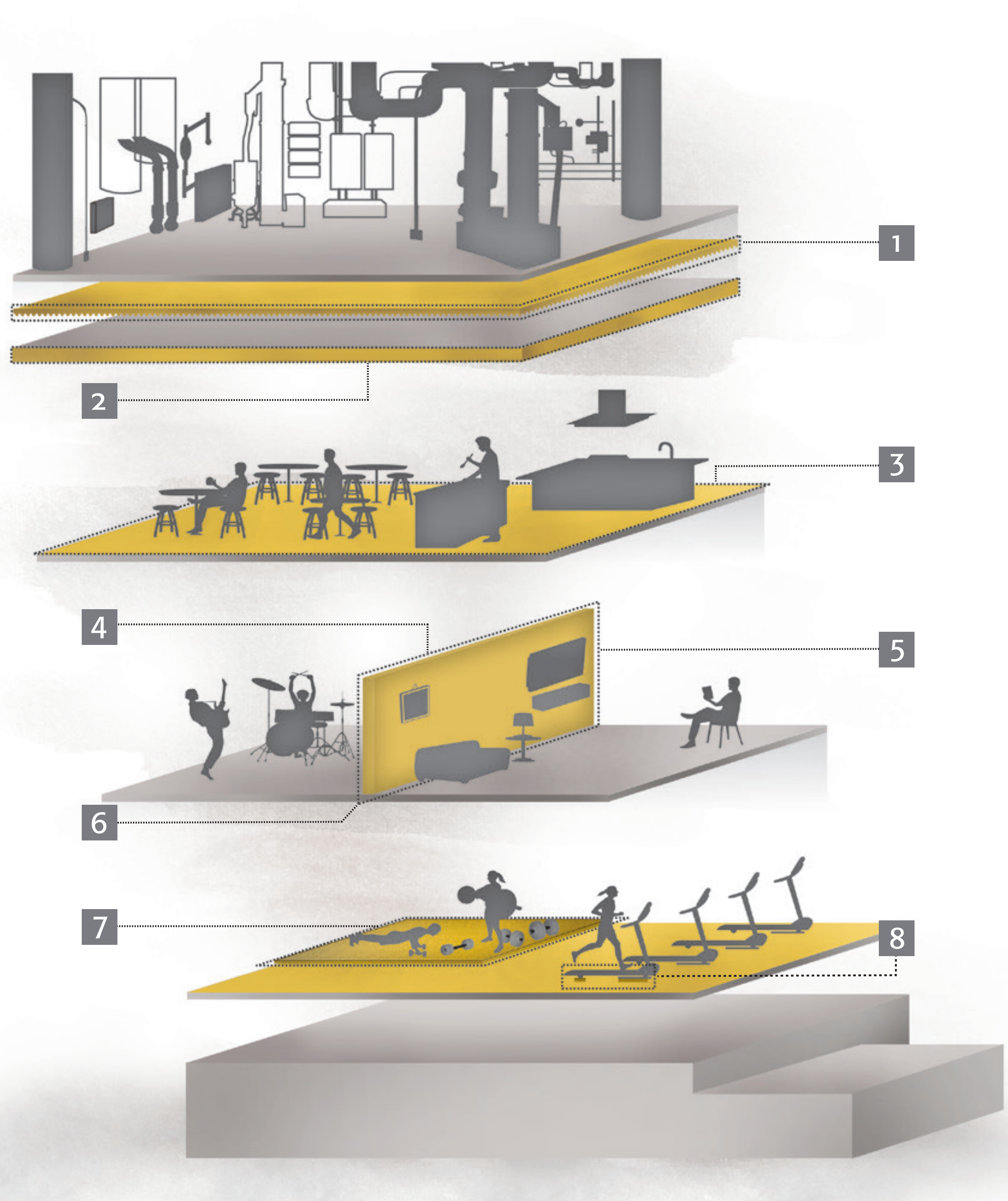

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◂P22
at early SONAR for gun ranging.

In between the world wars, the Institute of Physics (IOP) forms, Sabine introduces room acoustics and the National Physical Laboratory create a division especially for sound. Post WW2, the transportation boom creates noise and more noise, and something needs to be done about this new issue. The Physical Society create an Acoustics Group and eventually amalgamate with the IOP, where emphasis is put on qualifications and professional standards for acoustics, but soon with all these separate groups, acoustics somehow loses momentum.

We arrive back to the 1960s again with the Wilson report and the disparate societies share the concerns but have no clear ownership until the British Acoustical Society forms in the mid1960s and sets a pattern that is similar to the IOA we know today.

In 1974, the IOA was inaugurated and establishes itself as the primary place to go for all things acoustical. The rest of the story is more familiar, especially if you have read the recent history book issued by the IOA to the membership. Through the 40 plus years the IOA has adapted and grown in membership, financial stability and stature as a professional institution.

The message is that the future is ours to mould, strategy and policy, encourage membership involvement, and to inspire young people to consider this profession.

We have arrived in the present day; in a good place where we can carry out important work that benefits all. Modern day acoustics is based on science dating back more than 2,000 years, and we are still moving forward with new technologies and discoveries.

History man: Geoff Kerry

The message from Geoff was with encouragement and enthusiasm, and we carried on with networking over a curry; another tradition carried out by the Midlands Branch but not quite as good a history (yet).

Finally, a big thank-you to Geoff for travelling to Derby and to the University of Derby for hosting a brilliant meeting enjoyed by all.

Instrumentation Corner

'The upper limits...please stand by' – the measurement of airborne ultrasound

By Ben Piper

The measurement of Airborne Ultrasound (AUS) has been a rather niche field in the past, which is to be expected given that the vast majority of acoustic measurements are of sounds that we can hear or things which might affect those sounds. For the purpose of clarity AUS is defined for this article as all sound propagation in air above 17.2 kHz. This is the lower limit of the 1/3rd octave band centred at 20 kHz which is often the first 1/3rd octave band which is not specified in guidelines and legislation regarding noise exposure. There is a growing number of applications of AUS including haptic interfaces, pest deterrents and safety systems. AUS is also the by-product of a number of industrial processes such as ultrasonic cleaning and some types of welding. Further to this there is growing evidence that high levels of ultrasound, whether perceivable or not, can pose a health risk, although the risks are not yet fully understood. In order to make use of, control and understand the effects of AUS accurate measurements are required. In principle measuring AUS is no different from measuring audible sound and should be approached in the same way with consideration given to the measurement environment, the purpose of the measurement and every part of the measurement chain. However, most of the tools available for the measurement of sound are focussed in the audible range to cover the majority of applications.

As reverberation times are very short and air absorption is relatively high measurements of AUS can be considered to be either pressure or free-field. Measurements in a free-field are straightforward and the use of time gating techniques is very effective for isolating the direct sound from its environment, although this requires a repeatable sound. The challenge for free-field measurements comes when the source is unknown. As AUS has short wavelengths the variations in SPL over a small volume can be high. Strategies for scanning the soundfield and identifying an appropriate location to make a representative measurement are required. In both cases care must be taken with the alignment between the microphone and the source. As microphones become more directional at high frequency the impact of misalignment becomes larger. Sound sources also become more directional as frequency is increased which leads to significant wavefront curvature and the need for corrections. An effective approach to alignment is to make use of a pair of laser cross-line levels to ensure that the centre of the microphone is aligned with the centre of the source. In enclosed pressure fields the limitations are largely due to the geometry of the measurement space. Once length and radial modes are present it can be difficult to extract accurate measurements although if the geometry is simple models can be applied to correct for the lower order modes.

Microphone selection and calibration is critical for successful measurements of AUS. The size of the microphone contributes to its upper frequency limit. Table 1 shows common measurement microphone diameters with the range of upper frequency limits found in manufacturer's published data, upper limits specified in IEC-61094-4 and the range of sensitivities typically found. It should be noted that this data is taken from a review of several manufacturers and does not include every microphone on the market. Microphones designed to measure pressure extremes have been excluded.

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Microphone diameter, mm (inches)	Range of upper frequency limits found in manufacturer's data, kHz	Highest frequency specified in IEC 61094-4, kHz	Range of nominal sensitivities, mV/Pa
23.77 (1)	8 - 18	16	47 - 50
13.2 (1/2)	10 - 40	31.5	12.5 - 50
7 (1/4)	20 -100	50	0.9 - 4
3.5 (1/8)	70 - 140	n/a	0.7 - 1

Table 1 - Collated data showing the typical range of upper frequency limits and sensitivities of measurement microphones and the highest frequency specified in IEC 61094-4 for each type.


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Smaller microphones are clearly more suited to high frequency measurement and this is not surprising as accurate measurements require uniform displacement of the microphone's diaphragm. The directivity of smaller microphones is also less and the effect of wavefront curvature will be smaller, meaning the impact of misalignment is reduced. The downsides to using smaller microphones are that the sensitivity and signal to noise ratio tend to be smaller.

Once a suitable microphone is selected consideration needs to be given to the calibration of the microphone. Most manufacturers give sensitivity data for their microphones for frequencies across the specified range of use. These are normally measured using electrostatic actuators and therefore the free-field response of the microphone is based on the use of models to derive the correction needed to the actuator data. Since 2013 Danish Fundamental Metrology (DFM) have been able to apply free-field reciprocity techniques to provide free-field calibrations up to 200 kHz and microphones calibrated using this method are used for research at Physikalisch-Technische Bundesanstalt (PTB). Whether calibrations of this high quality are required or the uncertainty based on the actuator and model method (1-2 dB at 100 kHz) is good enough depends on the purpose of the measurements in question.

When selecting data acquisition hardware for making measurements of AUS the main considerations should be sample rates and whether any filters or gain stages are applied to the incoming signal. The sample rate used should be at least 4 times the highest frequency of interest to give a reasonable degree of accuracy (of course a minimum of 2 times is required due to the Nyquist limit). If there are filters, which may be the case when using consumer grade sound cards, then their response needs to be measured and, if necessary, corrections should be applied to the resulting measurements.

For generated sound fields a broadband amplifier must be used covering at least the highest frequency of interest. Low end audio amplifiers normally have a high degree of attenuation per octave above 20 kHz and should be avoided. Finding a suitable sound source can also be tricky. In order to ensure the repeatability of the measurements, resonances in the source's frequency response need to be avoided and therefore a source with a high first resonance is required. There are a number of hi-fi tweeters on the market which use very stiff materials resulting in usable frequency ranges stretching up towards 100 kHz. The alternative is to use a measurement microphone as a source. The issue then becomes one of signal to noise ratio due to the small SPLs that microphones can generate when used in this way.

As research into both the effects and uses of AUS grows techniques to make accurate measurements are required for a number of different scenarios. Whilst measurements of AUS are in principle no different from measurements of audible sound care must be taken in selecting appropriate equipment and methodology. The free-field calibration infrastructure for measurements of AUS does exist but is currently limited to only two metrology institutes although as demand grows more services may become available.

Further reading

- EMPIR EARS - Metrology for modern hearing assessment and protecting public health from emerging noise sources - http://www.ears-project.eu/empir/ears2.html
- Health Effects of Ultrasound in Air (HEFUA) -https://sites.google.com/site/hefua2/
- Are some people suffering as a result of increasing mass exposure of the public to ultrasound in air? - Leighton, T.G. Proceedings of The Royal Society A: Mathematical Physical and Engineering Sciences, 1-68, doi:10.1098/rspa.2015.0624

Ben Piper *is a co-founder of Acoustic Sensor Networks following several years of research in airborne acoustics at the National Physical Laboratory*

Spider silk microstructure found to have unique acoustic properties

New discoveries about spider silk could inspire novel materials to manipulate sound and heat in the same way semiconducting circuits manipulate electrons, according to scientists at Rice University, in Europe and in Singapore.

A paper in *Nature Materials* today looks at the microscopic structure of spider silk and reveals unique characteristics in the way it transmits phonons, quasiparticles of sound.

The research shows for the first time that spider silk has a phonon band gap. That means it can block phonon waves in certain frequencies in the same way an electronic band gap – the basic property of semiconducting materials – allows some electrons to pass and stops others.

The researchers wrote that their observation is the first discovery of a "hypersonic phononic band gap in a biological material".

How the spider uses this property remains to be understood, but there are clear implications for materials, according to materials scientist and Rice Engineering Dean Edwin Thomas, who co-authored the paper. He suggested that the crystalline microstructure of spider silk might be replicated in other polymers. That could enable tunable, dynamic metamaterials like phonon waveguides and novel sound or thermal insulation, since heat propagates through solids via phonons.

"Phonons are mechanical waves," Dr Thomas said, "and if a material has regions of different elastic modulus and density, then the waves sense that and do what waves do: They scatter. The details of the scattering depend on the arrangement and mechanical couplings of the different regions within the material that they're scattering from."

Spiders are adept at sending and reading vibrations in a web, using them to locate defects and to know when "food" comes calling. Accordingly, the silk has the ability to transmit a wide range of sounds that scientists think the spider can interpret in various ways. But the researchers found silk also has the ability to dampen some sound.

"(Spider) silk has a lot of different, interesting microstructures, and our group found we could control the position of the band gap by changing the strain in the silk fibre," Dr Thomas said. "There's a range of frequencies that are not allowed to propagate. If you broadcast sound at a particular frequency, it won't go into the material."

Spider silk has unique characteristics

Scientists invent new type of 'acoustic prism'

Scientists in Switzerland have invented a new type of "acoustic prism" that can split a sound into its constituent frequencies. Their acoustic prism has applications in sound detection.

Almost 400 years ago, Newton showed that a prism could split white light into the colours of the rainbow, with each colour corresponding to a different wave frequency. Such an "optical prism" relies on a physical phenomenon (refraction) to split light into its constituent frequencies.

Now, a prism exists for sound. Hervé Lissek and his team at Ecole Polytechnique Fédérale de Lausanne (EPFL) have invented an "acoustic prism" that splits sound into its constituent frequencies using physical properties alone. Its applications in sound detection are published in the *Journal of the Acoustical Society of America*.

The acoustic prism is entirely man-made, unlike optical prisms, which occur naturally in the form of water droplets. Decomposing sound into its constituent frequencies relies on the physical interaction between a sound wave and the structure of the prism. The acoustic prism modifies the propagation of each individual frequency of the sound wave, without any need of computations or electronic components.

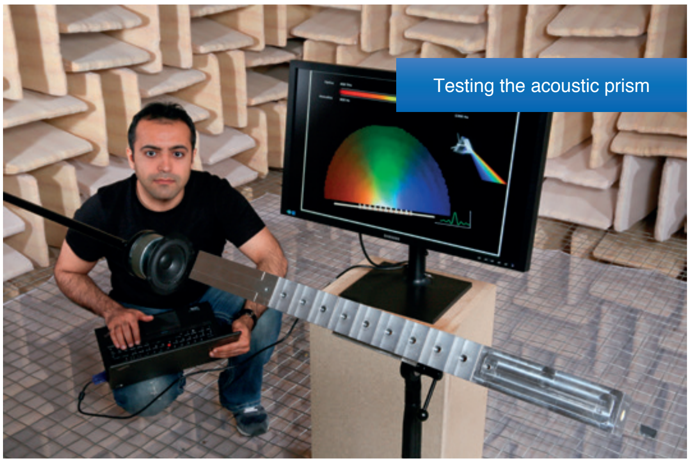
The acoustic prism looks like a rectangular tube made of aluminium, complete with 10, perfectly aligned holes along one side. Each hole leads to an air-filled cavity inside the tube, and a membrane is placed between two consecutive cavities.

When sound is directed into the tube at one end, high-frequency components of the sound escape out of the tube through the holes near the source, while low frequencies escape through the holes that are further away, towards the other end of the tube. Like light through an optical prism, the sound is dispersed, with the dispersion angle depending on the wave's frequency.

The membranes are key, since they vibrate and transmit the sound to the neighbouring cavities with a delay that depends on frequency. The delayed sound then leaks through the holes and towards the exterior, dispersing the sound.

To take the concept a step further, the researchers realised that they could use the acoustic prism as an antenna to locate the direction of a distant sound by simply measuring its frequency. Since each dispersion angle corresponds to a particular frequency, it's enough to measure the main frequency component of an incoming sound to determine where it is coming from, without actually moving the prism.

The principle of the acoustic prism relies on the design of cavities, ducts and membranes, which can be easily fabricated and even miniaturised, possibly leading to cost-effective angular sound detection without resorting to expensive microphone arrays or moving antennas.



Testing the acoustic prism

Researchers probe effect of man-made noise pollution on sea mammals

Researchers at the Universitat Politècnica de València (UPV), Valencia's Oceanogràfic and the University of Alcalá (UAH) have been carrying out a study to analyse the possible influence of anthropogenic or human-generated disturbances on different cetacean mammals in the Mediterranean. Led by the UAH, the study focuses on three areas within the Levantine-Balearic marine region: Cabrera Island, Cape San Antonio and the Columbretes Isles.

Specifically, the researchers are looking at the presence of cetaceans in relation to submarine sound pollution caused by fishing. Another of the project's goals is to control these and other activities in the protected marine areas being studied.

They are using two new SAMARUC units to carry out the acoustic monitoring, designed by researchers at the UPV's Institute of Telecommunications and Multimedia Applications (iTEAM) and the Oceanogràfic. This device detects, records and classifies the calls of the different marine species in the area. Located at different depths, they will record the sounds made by the resident cetaceans and fishing activity.

Compared with the first SAMARUC unit built in 2013, this second version is much more precise, easier to use by biologists and has a longer battery life. It can also incorporate different types of sensors, which increases its feature base and therefore the potential of this measuring device.

"Unlike other devices that act as mere sound recorders, SAMARUC incorporates sound processing algorithms and is able to provide indexed audio files for the different acoustic events detected," said Ramón Miralles, iTEAM researcher. "The system can be programmed to detect and classify the sounds recorded, distinguishing between dolphins, fin whales or human-generated noise from vessels, port installations, etc."

With measurements already taken for Cabrera Island, the team will be submerged a SAMARUC unit inAugust in the area round Cape San Antonio. The second unit was installed on the seafloor near the Columbretes Isles in September.

"Through this project we hope to shed light on biodiversity in these Mediterranean regions. It will help us to detect the movements of cetaceans in this area and establish migratory patterns, as well as isolate the main sources and levels of sound pollution, with a view to establishing possible thresholds for their mitigation," said Juan Junoy, of UAH.


Dolphins are at risk from man-made noise

In a separate European Union study carried out in the North Sea by the Wash, researchers found "significant" displacement of harbour seals during pile driving for offshore wind farms.

The team noted that future environmental assessments around Europe should consider the potential impacts, on seals and other marine mammals, of the short-term displacement that results from pile-driving.

Specifically, they recommend consideration of the pile-driving schedule, especially in places where multiple wind farms are being constructed simultaneously, and mitigation methods such as bubble curtains to reduce sound levels.

Releasing bubbles from an underwater compressor in order to form an air barrier in this way has been established as an effective way of reducing the acoustic impact of pile-driving on marine mammals.

Poor people 'more badly affected by noise pollution'

Poor people are more likely to suffer bad health as the result of noise and air pollution than the wealthy.

This is one of the main conclusions of an in-depth report produced for the European Commission examining the link between the two pollutants and socio economic status.

It recommends the adoption of more sustainable forms of transport and the reduction air and noise polluting emissions, which, it says, would reduce the health impacts for all members of society.

In its summary it states: "Air pollution and noise pollution have a negative impact on all sectors of society, rich and poor. However, it seems likely that some groups of society are more affected than others. These health inequalities may arise as a result of increased exposure to pollution, increased sensitivities, increased vulnerabilities, or a combination of all three.

"Some studies suggest that people in deprived areas are exposed to higher levels of air and noise pollution. These studies are largely focused on specific regions or cities, and on traffic as a pollution source. Other studies provide counter-examples of high-income groups being exposed to higher levels of pollution.

"However, lower socioeconomic status is associated with poorer health in a more general sense. This potentially means that deprived populations are more vulnerable to the effects of noise and air pollution, for instance, through existing long-term health conditions. Health research already shows that people of low socioeconomic status face a greater risk of heart disease, mental health problems and poor sleep. These are also some of the most commonly studied health impacts of air and noise pollution, which could be exacerbated by exposure.

"Studies have shown increased health effects or deaths linked to noise and air pollution in deprived populations compared with wealthier populations, although, again, studies tend to be carried out in specific regions or cities, with a few exceptions at national levels. Thus, while there is not yet conclusive evidence for a 'double burden' of increased exposure and increased vulnerability in all deprived areas of Europe, it is likely that deprived populations living in areas that are exposed to high levels of pollution will experience the worst effects.

"Noise and air pollution contribute to a wide range of factors influencing the health of populations, which include aspects of the living environment to individual lifestyle choices. Although their specific contributions may be difficult to measure, 'multiple risk exposures' are thought to accumulate in deprived populations in a fairly linear fashion. Lower socioeconomic groups thus face a greater risk of poor health for a variety of reasons. Addressing P30

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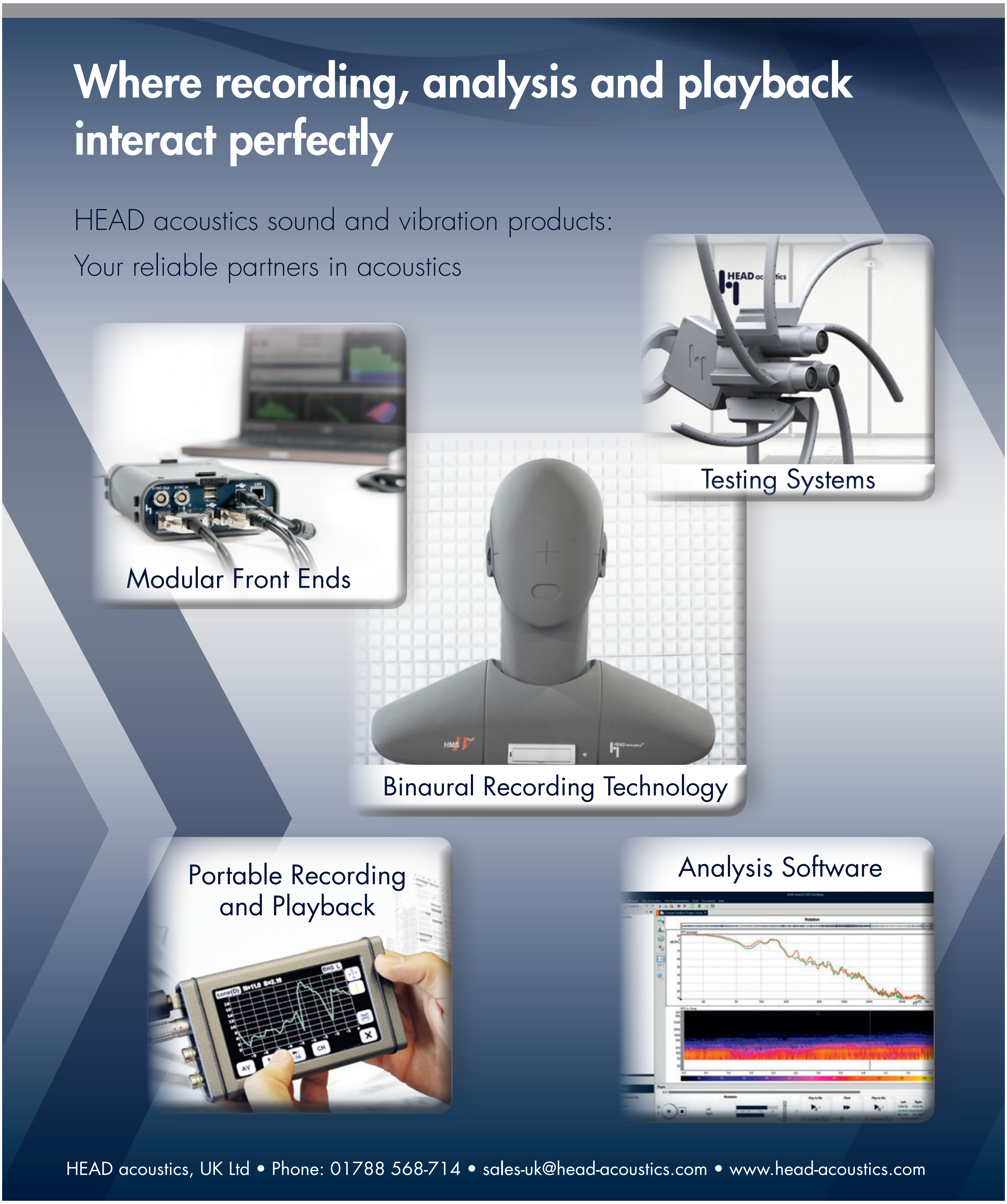

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this socio economic–health gradient is complex since it requires all sectors of society to have access to the same resources and standards of living.

"Further studies directly measuring both exposure and health impacts are needed to explore associations between socioeconomic status and noise and air pollution in Europe. Longitudinal studies – involving multiple rounds of data collection – are required to understand the long-term consequences of exposure to air and noise pollution. Also needed are studies investigating the effects of moving between areas with different socioeconomic characteristics and with different levels of exposure to pollution.

"The existing evidence on this topic should be treated with some caution due to a lack of consistency in study methods. It is currently difficult to compare and contrast results between studies, or to draw wider conclusions about the role of socioeconomic status in exposure to noise and air pollution and resulting health impacts.

"Reducing noise and air pollution will have a positive impact on health for all. Promoting and adopting more sustainable forms of transport could, for instance, reduce both noise and air pollution from traffic, whilst intelligent use of spatial planning tools and data could separate living, working and commuting areas from polluted areas. More stringent limits on both air and noise emissions, including combined emissions, would also reduce health impacts for everyone. In addition to universal measures, targeted measures designed to reduce exposure particularly in deprived populations will help to ensure that the poorest in society do not suffer the greatest health consequences related to noise and air pollution."

The full report can be obtained at **https://goo.gl/kF2OFW**

Noise pollution 'affects poor more'

Study suggests mental health problems may be linked to annoyance from noise

People who are annoyed by environmental noise are also more likely to suffer from depression and anxiety, a new, large-scale study from Germany suggests.

The results do not prove that noise causes mental health issues but suggest a possible link, which the study's authors are exploring further. Of all the types of noise considered in the study, aircraft noise was reported to be the most annoying.

In addition to investigating whether there is a link between noise annoyance and depression and anxiety, the study by a team from Johannes-Gutenberg University of Mainz explored the annoyance levels caused by different sources of noise.

The researchers analysed questionnaires completed by 14 635 residents, aged 35–74, in and around Mainz, between 2007 and 2012. Part of this area is in the flight path of nearby Frankfurt Airport, one of the busiest airports in the world.

The questionnaires asked the residents how annoyed they had been in recent years (rated on a five-point scale, from not annoyed to extremely annoyed) by six different types of environmental noise: road traffic; aircraft; railways; industrial/construction; neighbourhood indoor noise; and neighbourhood outdoor noise.

The results show that 20.7% of participants reported no annoyance to the sources of environmental noise, 26.6% slight annoyance, 25% moderate annoyance, 17.3% strong annoyance and 10.5% extreme annoyance.

Of the six types of noise considered, aircraft noise was the most problematic. Nearly 60% of the population reported being annoyed by it to some degree, and 6.4% were extremely annoyed by it.

They asked the participants to indicate whether they suffered symptoms of depression and anxiety, and the researchers assigned a score for each condition. Participants were also asked if they had ever received medical diagnoses of depression or anxiety.

They found that indicators of depression and anxiety increased steadily with levels of annoyance to the noise. Average depression scores increased from 3.5 (out of a possible total of 27) among the "no annoyance" group, to 5.1 for the "extreme annoyance" group. The percentage of each group with a depression score of 10 or more (a 'clinically significant' level of depression) increased from 6.1% of the "no annoyance" group through to 12% of the "extremely annoyed" group.

The percentage of the population with medical diagnoses of depression was also higher with each level of annoyance, for

Aircraft noise is 'the most annoying' of all noises

instance, 10.1% of the "no annoyance" group and 14.8% of the "extremely annoyed" group had been diagnosed with depression by a doctor.

Average anxiety scores steadily increased from 0.7 (out of a possible total of 6) in the "no annoyance" group, to 1.1 among the "extreme annoyance" group.

The percentage of each group with a clinically significant anxiety score of 3 or more increased from 4.5% of the "no annoyance" group through to 10% of the "extreme annoyance" group. 6.3% of the "no annoyance" group had been diagnosed with anxiety disorders, but the figure was 9.9% for the "extreme annoyance" group.

The study did not assess actual noise levels, just personal responses to noise. It also points out the possibility that people who are already depressed or anxious may be more sensitive to noise and, therefore, report higher annoyance; it is not necessarily the case that noise annoyance leads to mental health issues.

However, the association between annoyance and mental health disorders in these data is very strong and the researchers say their results are "compatible" with the hypothesis that annoyance leads to stress, which in turn can lead to depression and anxiety, or worsen existing symptoms. They are, therefore, conducting regular follow-up assessments with the participants to explore the possible relationship between noise and mental health further.

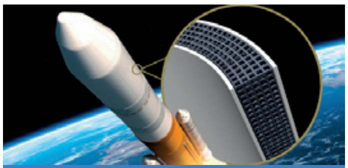
Swiss team's 3-D lattice structure will absorb mechanical vibration

Engineers have come up with a solution to the vibrations in machines, vehicles and aircraft with a new three-dimensional lattice structure that can expand the possibilities of vibration absorption.

The lattice structure can absorb a wide range of vibrations while acting as a load-bearing component, for objects like propellers, rotors and rockets. The structure can absorb vibrations in the audible range, which are the most undesirable in engineering applications.

A team from the Swiss Federal Institute of Technology in Zurich (ETHZ), led by Chiara Daraio, Professor of Mechanics and Materials, is responsible for developing this new technology. The structure has a lattice spacing of around 3.5 mm and is made out of plastic using a 3-D printer. Steel cubes smaller than dice are embedded within the lattice and act as resonators.

"Instead of the vibrations traveling through the whole structure, they are trapped by the steel cubes and the inner plastic grid rods, so the other end of the structure does not move," said Kathryn Matlack, a post-doctoral student in Professor Daraio's group.



The vibration absorbing lattice in a vision of the future. It could be used one day in rockets
Image courtesy of ETHZ

Materials that absorb vibrations already exist in certain machines and household appliances – using mostly soft materials to partially absorb the vibrations – the new vibration-absorbing structure is rigid and can therefore also be used as a load-bearing component, for instance in mechanical engineering or even in airplane rotors and helicopter propellers.

The new structure offers another major advantage. Compared with existing, soft absorption materials, it can absorb a much wider range of vibrations, and is particularly good at absorbing relatively slow vibrations.

"The structure can be designed to absorb vibrations with oscillations of a few hundred to a few tens of thousand times per second (Hertz)," said Professor Daraio. "This includes vibrations in the audible range. In engineering practice, these are the most undesirable, as they cause environmental noise pollution and reduce the energy efficiency of machines and vehicles."

According to the researchers, technically it would be possible to build such a construction out of aluminium and other lightweight metals instead of plastic. This would require a combination of lightweight material structured in a lattice geometry, and embedded resonators with a larger mass density. The geometry of the lattice structure and the resonators would need to be aligned to the anticipated vibrations.

While the vibration absorbers are ready for technical applications, they are limited in terms of 3D printing technology, which is mostly geared toward small-scale production and material properties. Therefore, load-bearing capacity cannot yet match those of components manufactured with traditional methods. Once the technology is ready for industrial use, there are much broader applications for it. For example, it could be used in wind turbine rotors, where minimizing vibrations would increase efficiency, as well as in vehicle, aircraft and rocket construction.

This report is based on one that first appeared in *Electronics 360*.

Innovative monitor to measure wind turbine noise and vibration

Woods Hole Oceanographic Institution (WHOI) in the US has invented a new monitor to control wind turbines. The Multimodal Environmental Impact Monitor (MIM) utilises an all-in-one sensor package that measures flicker, acoustic noise, and vibration generated by wind turbines.

Alone or in combination, data from these modalities may then be used to provide input for turbine control paradigms in order to optimise turbine operations and/or maximise energy production.

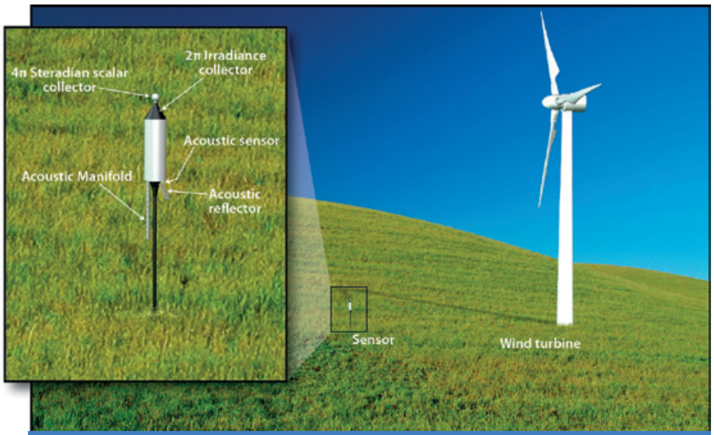
Turbine performance management as well as site and environmental impact assessments for wind turbine developments, are presently hampered by lack of available weather tolerant instrumentation and inadequate sensors.

Thus, appropriate long-term time series assessments are not made, environmental and human health impact is not accurately determined, and output is not optimised.

"Current models for blade shadow flicker don't take into account surrounding reflectors or structures, only topography and sun placement, and such estimates may be inaccurate," said WHOI Senior Engineer and MIME Inventor Paul Fucile.

Mr Fucile also notes that measurement of turbine infrasound generation has become an area of interest in recent years – particularly because of its potential health effects on those living in close proximity – and is something that MIME measures with great accuracy.

Accurately determining the environmental impact and site suitability for new turbine installations allows for responsible planning and building and also allows developers to establish an accurate pre-installation baseline.



The MIME monitor in action

MIME is intended for permanent installation at turbine sites for persistent observation with the option for turbine control, or can be placed on a tripod for short-term studies of multiple sites. It's designed for ease of use. "The goal is to provide something that is affordable and user-friendly," said Mr Fucile.

Acoustic resonator device paves the way for better communication

Researchers at Yale University in the US have developed a high-frequency version of a device known as an acoustic resonator that could advance the field of quantum computing and information processing.

Hong Tang, Yale's Llewellyn West Jones Jr. Professor of Electrical Engineering & Physics, and his team, accomplished this with what is also known as a piezo-optomechanical device.

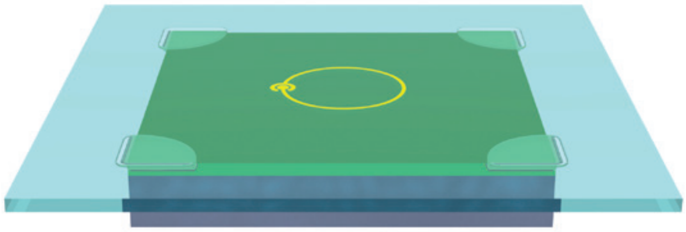
It achieves what is known as "a strong coupling" between two systems: a superconducting microwave cavity and a bulk acoustic resonator system. The results appear in the journal *Physical Review Letters*.

With a strong coupling, the device achieves an exchange of energy and information between the microwave and mechanical resonator systems in a way that exceeds the dissipation – or diminishing energy – of each of the individual systems. That way, information does not get lost.

A unique feature of the system is that it operates at the very high frequency of 10 gigahertz. An advantage of a high-frequency system is that it allows for a high signal-processing speed, noted Xu Han, a Ph.D. student in Professor Tang's lab and lead author of the study. "For example, you can convey the same amount of information or message in a shorter time," Mr Han said.

Another advantage is that the high frequency makes it easier to observe quantum phenomena in experiments. In lower frequency devices, the system has to be cooled to extreme temperatures to overcome thermal noise, which comes from random vibrations from the environment that scramble the signal.

One of the potential applications, Mr Han said, is information storage. "If you have a good coupling and exchange between the systems, then you can store information from the microwave domain in the mechanical domain," he said.



Schematic of the piezo-electromechanical device. A superconducting resonator (in yellow) is fabricated in a niobium titanium nitride film on a sapphire substrate. The resonator is flipped and suspended on top of an acoustic resonator, which consists of a thin aluminium nitride layer (green) deposited on a thick silicon substrate.
Image courtesy of Yale University

Although the experiments were not conducted under quantum conditions, the researchers note that the high-frequency piezo-electromechanical device is compatible with superconducting qubits – the unit of information analogous to digital bits in conventional computing. That potentially could mean an important step towards hybrid quantum systems, which bridge the world between classical and quantum mechanics, they said.

Mr Han said he is currently building on the technology to develop a device that uses the mechanical system to convert information from the microwave domain to the optical.

"If you want to transmit the information signal, you have to use optics, because optical fibre has very low loss over a long distance," he said.

Marine agency probes offshore wind farm noise concerns off Sussex coast

The Marine Management Organisation (MMO) has been looking into concerns about noise off the Sussex coast and the Rampion Offshore Wind Farm.

Officers from the MMO have visited the area where noise has been reported. They are also working closely with the developer to understand and address any relevant concerns.

The work includes constructing 175 wind turbine generators, with the closest turbine being about 13km from the shore.

The wind farm developer, E.On, has made a number of changes to their processes to reduce noise impact. These include:

- installing noise-reducing acoustic panels around pump equipment onshore (which for safety reasons has to run continuously)
- reducing speed of vessels and using anchors so that engines can be turned off
- scheduling maintenance activities where noisy tools are required to be in day time only
- instructing vessels leaving Shoreham Port at night to follow a different route in order to minimise impact on residences at Shoreham Beach.

The developer has also committed to avoiding piling activity overnight when weather conditions mean excessive noise may carry to shore, for example during warm, still nights.

E.On was given a Development Consent Order by the Government to construct Rampion Offshore Wind Farm in July 2014.

This followed consideration of the application and a supporting environmental statement. The statement assessed the potential noise impacts including airborne noise and concluded there would be no significant impact as a result of piling activities to construct the wind farm.

Developments are only licensed when the Government is satisfied they meet legal requirements and any effects on the environment and quality of life are minimised.

Acoustic metamaterial panel absorbs low-frequency sound waves

A team of researchers at the French National Centre for Scientific Research (CNRS) in France has designed subwavelength absorbers specifically for low-frequency sound waves.

As the group reports in *Applied Physics Letters*, recent physical advances showed that the speed of sound can be strongly reduced in a structured medium, while increasing the material's ability to attenuate or reduce the sound. These findings enabled the group to design subwavelength resonators whose total absorption of the sound energy is controlled through simple geometric parameters.

A quarter-wavelength resonator, as its name suggests, is a tube that is closed at one end that resonates when the wavelength is equal to four times the length of the tube.

"In other words, it resonates at f=4c/L, where c is the speed of sound in the resonator and L is its length," explained Noé Jiménez, an acoustician at CNRS. "By reducing the speed of sound in the resonator, both resonance frequency and length of the resonator can be drastically reduced."

In this case, the group manages the reduction of the speed of sound by loading a quarter-wavelength resonator with Helmholtz resonators.

"Our resonator resembles closed flutes with mouthpieces plugged into the holes of the main flute," Mr Jiménez continued. "A decrease in the speed of sound within the resonator lets it resonate at a lower frequency, while the attenuation of the sound wave increases."

To some extent, it behaves in a manner "similar to a heater in which the surface is optimized for thermal exchange," Mr Jiménez said. "These losses are also greatly dependent on the geometry of the loading resonators. The absorption of the whole structure is total – for a thickness that can be 100 times smaller than the incident wavelength."

The group's work shows that a very thin structure made of a metamaterial (synthetic, custom-designed material) can completely absorb very low frequency sound for nearly every angle of incidence – and it largely surpasses traditional acoustic treatments.

"Thanks to the resonances and the losses being produced within the air itself, we expect these subwavelength structured materials to have longer lifetimes than structures made of other subwavelength resonant structures," Mr Jiménez said.

In terms of applications, the group's structure allows a reduction in thickness and weight of acoustic treatments for the absorption of acoustic energy at very low frequencies.

"This is particularly important within the context of highly energy efficient economy in aircrafts, cars, or in buildings and more – generally for reducing carbon dioxide emissions," Jiménez said.

"Broadband and subwavelength absorbers are promising for soundproofing applications," Mr Jiménez noted. "But, on the other hand, the panels we've developed are only designed to work in reflection...so once the transmission is introduced the problem becomes more challenging."

Conceptual view of the thin panel placed on a rigid wall with one layer of square cross-section Helmholtz resonators.
Image courtesy of CNRS

Call for more green building façades to cut city noise

Green building façades can help reduce noise impact

Green building façades have an important role in reducing urban noise and creating a healthier living environment. This is one of the main conclusions of a report entitled *Cities Alive – Green Building Envelopes*, which examines ways in which such façades can improve city life.

Produced by Arup, the 70-page document, which features cases studies from five major cities including London, focusses on three areas: acoustics, air quality and urban heat.

It has five main findings on the acoustical impact of green building façades:

- They could reduce sound levels from emergent sources and traffic noise by up to 10DB(a)
- They do not have a significant impact on noise level reduction close to a noise source
- They have a greater acoustics impact with increasing distance from source up to the point where ambient noise begins to dominate
- They are unlikely to have a noticeable acoustical impact when a neighbourhood's sound environment is dominated by distributed sound sources
- They are likely to have a greater impact at night, when ambient noise levels are lower and the soundscape is dominated by emergent sound sources.

In summing up, the report states: "To shape a better world we must shape better cities. The health and well-being of urban citizens should be the focus of design considerations in the future. Cities are now facing critical issues that significantly affect people's health. These include inner city noise, fine dust pollution generated by the traffic and the development of heat island effects in ever denser urban environments."

It says buildings, as major components of the city, can make a far greater contribution to benefiting their external environment. To this end, building envelope surfaces need to be considered as an essential resource.

"This requires a move away from more traditional and inwardly focussed performance considerations for buildings, instead looking at how envelope surfaces can perform to create healthier environments, better social conditions for people, and resilience to the effects of climate change."

It concludes: "Green building envelopes can contribute significantly and thus become a default design approach for building design. This will require a significant rethink of current design considerations, but if we can make health and well-being a starting point for all building design, we can shape a better world."

Scientists develop 3D holograms crafted from sound waves

Researchers in Germany have found a way of generating acoustic holograms, which could improve ultrasound diagnostics and material testing. The holograms can also be used to move and manipulate particles.

Peer Fischer, a Research Group Leader at the Max Planck Institute for Intelligent Systems and Professor at the University of Stuttgart, normally works on micro- and nanorobots. His lab also develops the nanofabrication methods that are needed to develop such tiny swimmers. Holography was not one of his core interests. "However, we were looking for a way to move large numbers of microparticles simultaneously so that we could assemble them into larger more complex structures," he explained. His research team has now found such a method with acoustic holography, and it has reported the first acoustic hologram in *Nature*. The method promises a number of applications in addition to particle manipulation.

It is well known that holograms in optics offer a means to take photography into the third dimension. Unlike photos that are taken with a conventional camera, holography exploits the information where reflected light reaches its maximum intensity. Physicists talk about the phase of the wave. Upon reflection from a three-dimensional object, the phase shifts and provides information about the spatial structure of the object. This gives holograms their characteristic three-dimensional appearance.

Manipulating the three-dimensional structure of acoustic waves was previously only possible with what physicists call a phased array transducer. This is an ensemble of many acoustic sources positioned side by side that can individually emit sound with varying phase delays. The necessary driving electronics, however, is bulky and expensive. "We can now generate sound in a 3D without this complex technology", said Kai Melde, who conducted the experiments at the institute as part of his PhD. research.

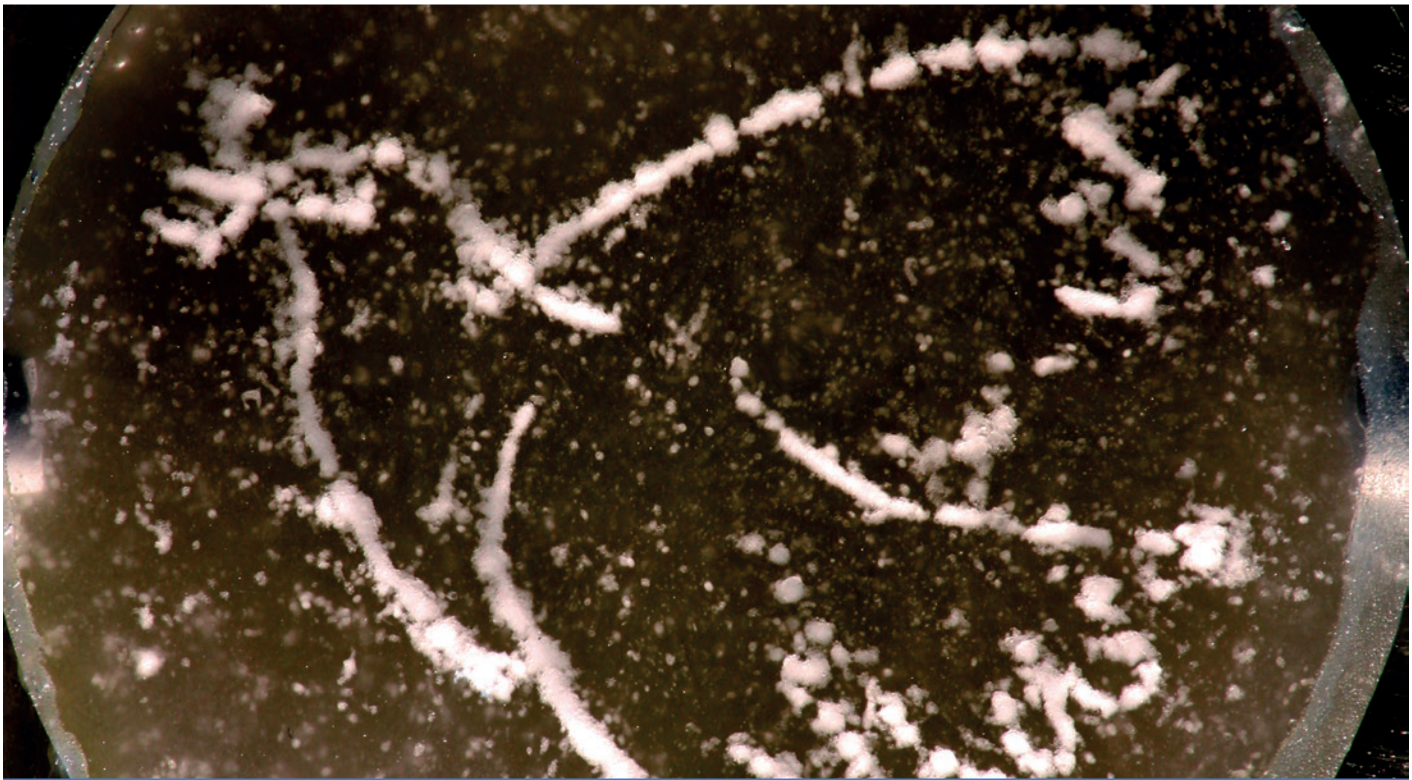
The researchers first demonstrated a hologram that generates sound pressure in the shape of Pablo Picasso's dove of peace. Microparticles suspended in a liquid follow the pattern and form the image. To achieve this, the team first computed where and how strongly the acoustic waves, or more specifically their phases, needed to shift to translate the lines of the dove into an area of increased sound pressure. In this way, they attained a map of the phase shifts. Based on this map, they then fabricated the acoustic hologram: using a 3D printer they created a relief from a plastic that transmits sound faster than the surrounding liquid. The printer applied different thicknesses of material depending on the required phase delay.

Ultrasound waves transmitted through the hologram interfered behind the relief plate in such a way that the sound pressure reproduced Picasso's dove of peace. And as soon as they positioned a container filled with water and microparticles in the focal region, the particles were quickly pushed into the shape of the dove. The researchers showed that the technology can also work in 3D by forming a holographic stack with the images '1', '2' and '3'.

"While our technology does not dynamically modify the three-dimensional structure of the sound field, it can nevertheless cause dynamic motion", says Professor Fischer. "We are surprised that nobody has come up with this idea before."

Even if the Stuttgart-based researchers cannot change the acoustic sculptures on the fly, they are able to move particles on defined trajectories. They demonstrated this with a polymeric particle on water: using the sound pressure hologram, they generated a ring-shaped crest on the water's surface which looked as if they had frozen the ripple caused by a stone that was thrown into the water. A particle floating on the water and influenced by the sound pressure quickly swung to the crest of the wave and surfed along the circle until the sound was switched off. "Such contact-free methods to move particles using sound could be interesting as a material transporter for process engineering", says Kai Melde.

Acoustic holograms create even more possibilities for manipulating particles than the researchers originally had in mind. And apart from exposing particles to acoustic waves, holograms could also be used with ultrasound, for example in medicine and material testing. "There's a great deal of interest in using our invention to easily generate ultrasound fields with complex shapes for localized medical diagnostics and treatments", said Professor Fischer. However, it is not yet clear where exactly acoustic holograms will be used. "But I am sure that there are a lot of areas that could be considered."



Shaped with ultrasound: Researchers transmit ultrasonic waves through a bath of water and microparticles. In doing so, they model the profile of the sound pressure with a hologram in such manner that the particles are pushed into the shape of Picasso's peace dove.

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Specifying and designing an isolation system subject to heavy impact is difficult. Most commonly a problem for free weights zones and high energy activities such as CrossFit, the impact energy can be high and easily capable of causing significant disturbance.

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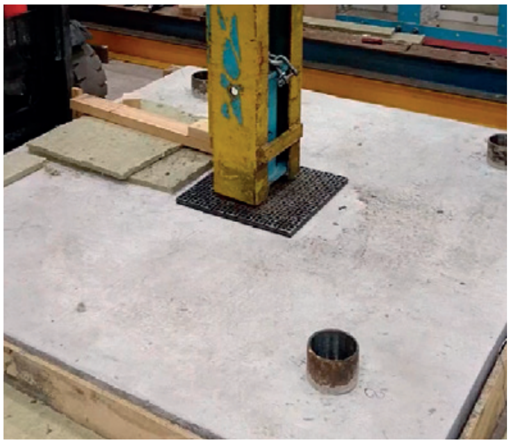
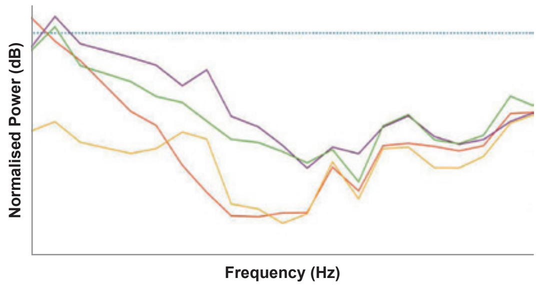
There is no suitable test standard or good quality test data for consultants to specify against. To rectify this, Mason UK tasked Salford University Heavy Structures Laboratory to carry out a range of tests on a specially designed test floor (above right).

The results increase our understanding of how impact energy is absorbed by a floating floor and how it is best controlled across the spectrum by varying the design (below right).

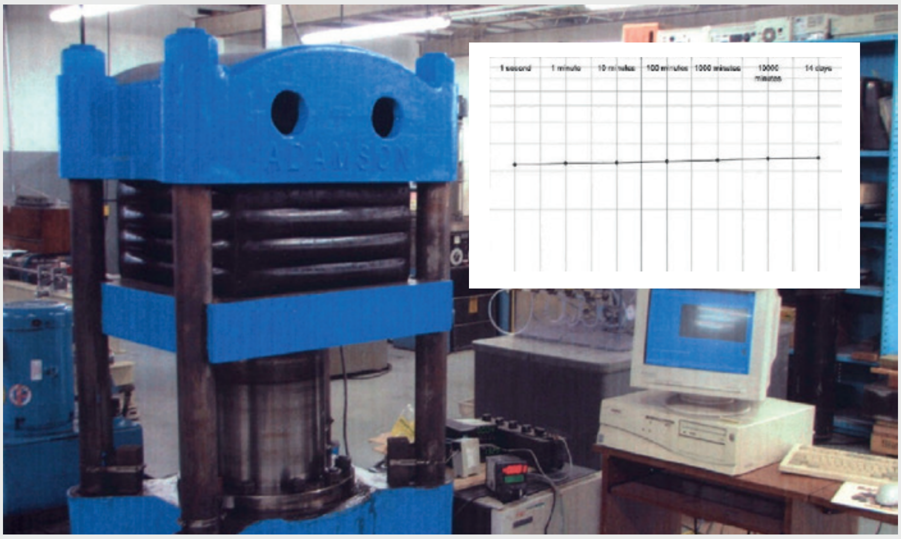
The type of impact, the floating floor and the structure are all part of the same complex system but as with all types of projects Mason UK strives to support industry and produce the best possible solutions.





Mason UK regularly test our elastomers and other products in independent laboratories. As part of the Mason Industries group, we also have access to extensive testing facilities. As well as taking responsibility for our own design and engineering, we often have to fabricate bespoke solutions, some of which require very specific testing and certification.

Whether a standard solution or a problem never tackled before, Mason UK can help.



Bearing creep testing and results chart

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Noisy cattle grids threaten a good night's sleep


Noise from cattle grids can be a major nuisance

Scientists from the Universities of Bradford and Leeds have measured how noisy cattle grids disrupt the peace and quiet of adjacent residential properties.

Their findings, which will be the subject of a technical paper in a forthcoming *Acoustics Bulletin*, enable owners of these devices to implement maintenance and speed control measures that significantly reduce annoyance.

The findings of the study show that excessively high levels of noise can be emitted when vehicles impact cattle grids especially a poorly secured or maintained grid. Measurements revealed that even on well maintained and secured cattle grids closest to residential properties the maximum noise generated significantly exceeded the World Health Organisation's guidelines for night time community noise exposure.

A further finding was that these noise levels reduced with decreasing speed. Hence the recommendation that traffic calming measures should be considered in the vicinity of these installations close to residential properties. Annoyance created by the noise of cattle grids has been periodically reported but this is the first study of its kind to be included in the scientific literature.

"For people living within 100 metres of a cattle grid noise and vibration can be a serious problem that may lead to disrupted sleep patterns and the inability to experience peace and quiet within their gardens. In addition, the noise from cattle grids can compromise the enjoyment of recreation in an otherwise tranquil environment," said Greg Watts, Professor of Environmental Acoustics at the University of Bradford.

The research, which was a response to local concerns and an increasing number of cattle grid planning applications being referred to the Secretary of State, took place over approximately 18 months and was carried out at five sites in West Yorkshire (two on Baildon Moor and three on or adjacent to Ilkley Moor) and two in Cumbria (on the A684 in the vicinity of Sedbergh).

M40 noise barrier installation to ease residents' misery

New noise-reducing barriers will be installed along sections of the M40 motorway in Buckinghamshire, while a worn out section of the motorway will be replaced with a new, quieter road surface in South Oxfordshire in September.

Highways England has been working in partnership with the M40 Chiltern Environmental Group (M40 CEG), Wycombe District Council and South Oxfordshire District Council, to develop proposals to reduce noise along the M40 corridor between Loudwater (near junction 3) in Buckinghamshire and Wheatley (near junction 8) in Oxfordshire.

Noise barriers are planned for sections of the M40 as it passes near High Wycombe, as well as near the Buckinghamshire villages of Lane End, Stokenchurch and Chepping Wycombe.

A 4.3 mile (7km) stretch of the M40 in Oxfordshire, between Adwell (near junction 6) and the A40 Oxford spur (at junction 8), is also being resurfaced, which will significantly contribute to reducing noise. Work is expected to be complete by the end of the year.

Highways England project manager Mark Saunders said: "We have been working hard with our partners to help residents along the M40 affected by noise. I am delighted to announce that we will be progressing a scheme to install noise barriers at the locations where it will make the most difference, in addition to the low-noise resurfacing work we will shortly be carrying out.

"The noise barrier project originally involved trialling innovative, energy-generating noise barriers mounted with solar panels. However, these types of barriers are not currently suitable for this section of the M40 as Highways England would not be able to use the harnessed electricity. In the future, solar panel barriers may be suitable for use at suitable locations on the road network."

Subject to successful completion of detailed design and to funding, the construction of the noise barriers will begin in summer 2017.

Government launches marine noise registry

A marine noise registry (MNR) has been introduced by Defra and the Joint Nature Conservation Committee (JNCC) to collect and display data on noisy activities in the marine area.

The MNR is to record human activities in UK seas that produce loud, low to medium frequency (10Hz – 10kHz) impulsive noise.

Marine licence applicants may be asked to provide additional data about the noise impact of their projects through the MNR.

Where possible data is extracted from current marine licensing processes, however in some band 3 cases it will be mandatory for developers to provide information as a condition of their marine licence. This depends on the type of activity carried out and will be explained within relevant marine licence documents.

For cases that involve impulsive noise impacts but are not band 3, conditions will not be added, but developers will be asked to submit data on a voluntary basis.

When the Marine Management Organisation (MMO) is asked to provide advice on Nationally Significant Infrastructure Projects (NSIPs) which involve relevant types of noise it will recommend to the Planning Inspectorate and the applicant that the MNR conditions are added to the deemed marine licences.

Developers using the MNR to provide information on seismic surveys no longer need to complete the voluntary form to notify the MMO.

Data collected through the MNR will help the UK to assess its ability to achieve "good environmental status" under the Marine Strategy Framework Directive. Information from the register will also be fed into a Europe-wide registry through OSPAR (the Oslo and Paris Convention for the Protection of the North-East Atlantic).

Low resistance car tyres 'can help halve road noise'


A Volkswagen used in the testing
Image courtesy of SINTEF

Fitting cars tyres with very low rolling resistance, combined with the right road surfacing, can provide just as much noise reduction as traditional noise barriers, a new study has found.

"The results show that there is a massive potential for reducing both traffic noise and fuel consumption linked to conventional cars by combining low-noise tyres and the right kind of road surfacing," said Truls Berge, an acoustics researcher at SINTEF, the Norwegian-based research organisation.

His experiments were carried out as part of a joint project between SINTEF and Gdansk Technical University in Poland called LEO (Low Emission Optimised tyres and road surfaces for electric and hybrid vehicles).

The project involved recording a large volume of data using a variety of combinations of road surfaces and tyres, including those specially developed for electric cars, which are known as EV. The aim was to discover combinations beneficial to reducing both traffic noise and CO2 emissions produced by conventional cars, and for extending the range of electric cars.

The winning combination provided a reduction in rolling noise of the order of 10 dB which, to the human ear, represents a noise reduction of one half.

The experiments were carried out on test tracks with a wide variety of road surfacing textures, as well as on ordinary public roads and in the laboratory.

The results showed that the road surfacing texture was very important. However, for four of the EV tyre brands rolling resistance was reduced by an average of 40 per cent. Based on theoretical calculations, this provides a potential reduction in energy consumption of between 12 and 16 per cent at constant speeds of 50 km/h in built-up areas, and between four and six per cent at 80 km/h.

"For example, the measurements showed that a SMA8 surface that was tested in Norway, and which is known to provide minor levels of noise reduction, exhibits a difference in rolling resistance of 23 per cent when comparing an EV tyre manufactured by Continental (standard on electric VW Golfs) with a popular brand manufactured by Michelin," said Mr Berge.

"The results, which demonstrate a reduction in both noise and energy consumption, raise the interesting issue of a technology 'transfer' by which conventional cars could be fitted with tyres developed for electric cars, combined with a re-assessment of what road surfacing textures should be used in heavy traffic areas. This may be of particular relevance in locations where it is impractical to implement conventional measures such as noise barriers," said Mr Berge, who believes that in a few years' time, we will be seeing many low-noise tyre brands on the market.

Gyms – noise and vibration

By Martin McNulty

The growth of the fitness industry has seen an increase in commercial gym facilities throughout the UK. Traditionally, operators would often be situated in out-of-town locations, free to operate without the need to consider impacts on neighbours in adjoining spaces — as there were none. Though such luxuries can still be afforded in certain areas, the rate of growth in this sector is fierce, and gym operators now more commonly seek prime inner-city locations, in order to gain market share.

This expansion has seen a surge of low-price, sometimes 24-hour fitness facilities within office blocks, mixed-use developments and residential areas. Most existing structures are not intended for gym use and in the case of new-build, the original structure was often not designed for the gym-like activities now made available by a landlord to a gym operator at an attractive price. It is also true that while many gym-areas are pre-planned during the design phase of new-build schemes, the implications of gym location and the surrounding structural form are often an afterthought, with the assumption made that modest measures will be sufficient as a means of mitigation.

Noise complaints associated with activities arising from gym use have risen rapidly. These mainly relate to low-frequency structure-borne noise and tangible vibration as a result of treadmill, free-weight or resistance machine use among other impact generating activities, such as dance classes. The absence of acceptable design guidance does not help when seeking to determine appropriate noise intrusion standards and most cases are typically resolved via noise nuisance complaint procedures through the local authority.

It should be made clear that a full assessment of gym-related noise and vibration is a complex process that is unique to each structure and fraught with uncertainty. A broad range of assessment techniques and knowledge of factors affecting transmission mechanisms are required before considering the suitability of a building for gym use.

In refurbishment schemes, it is important to test the receiving structure prior to an operator committing to the space and, provided one is physically able, it is a fairly easy process to drop weights on a range of candidate floor materials and measure the response. However, a drawback to this is that not all the gym equipment concerned is likely to be available to install in a candidate location and, even if it was, the transmission from source to receiver depends on the location of the source. This requires endless permutations within a structure to ensure all modal behaviour is captured in accordance with the fit-out plan.

An alternative method would be to assess via calculation. However, despite there being a number of approaches available, it remains a process not widely used by UK consultancies due to the complexity required. The process is further restricted by the characterisation of the structure-borne source. On this matter BS EN ISO 12354 part 5 acknowledges that '*a choice has been made to use a general quantity in the models, called "the characteristic structure-borne sound power level" of sources, even though there is no practical measurement method available at the moment. This allows the estimation models to have a general form that could be developed and refined in the future*'. Though a number of measures to determine this generalised input value have developed since the Standard's publication in 2009, data for gym-related equipment is not readily available. Consequently, the assessing acoustician would be required to estimate input forces from standard theory. This can become complex for equipment that cannot be well described by lumped parameter systems, requires knowledge of phase relations between different sources, or has multiple points of entry into a structural element. Additional effects of structural response and flanking further muddy the water.

Given the above, this article provides an overview of recent experiences, observations, literature, trends, findings and areas meriting further investigation. It is hoped that useful insight will be offered into key areas in the design of gyms. Focus centres on treadmill and weight-based activities as the underlying principles also apply to similar sources.

Isolation efficiency

When specifying vibration isolating materials, specialist vibration suppliers and acousticians commonly rely on transmissibility charts or calculations to assist in the selection process. Transmissibility is defined as the ratio of input to output forces and a good isolator should be selected such that the transmissibility is as low as possible within the selection constraints.

The general principle behind such selections rests on the assumption that the vibration generating object and the isolating system/mechanism/element can be described as a Single Degree of Freedom (SDOF) system, exhibiting the classical mass-on-a-spring-type behaviour.

Assuming a SDOF system, the isolator selection process requires knowledge of the forcing frequencies associated with the vibrating object (the mass) in addition to the natural frequency of the isolator (the spring) when coupled with the aforementioned mass. The ratio of input-to-transmitted forces is frequency dependent and in the absence of damping is expressed as Equation 1. Values greater than 1 indicate force magnification and values lower indicate frequencies which are isolated

$$T = \sqrt{\frac{1}{\left[1-\left(\frac{f}{f_0}\right)^2\right]^2}} \qquad \text{(Equation 1)}$$

Where
T is the transmissibility
f is the forcing frequency
f_o is the natural frequency of the isolator

In reality, conditions described by Equation 1 do not occur within building structures, as the presence of "large" damping

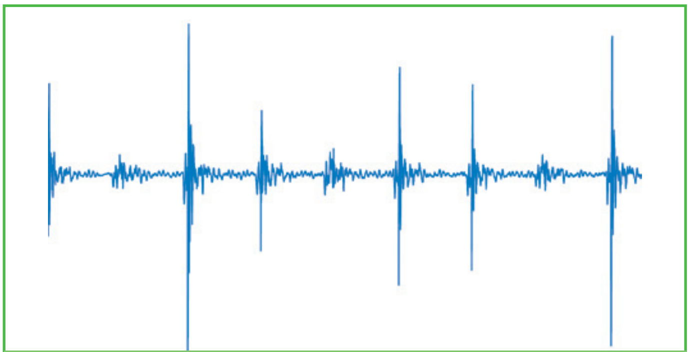

Figure 1 - Typical pulse train at a treadmill contact point with the strucutral floor

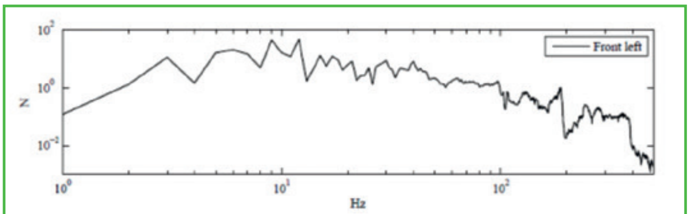

Figure 2 - Spectrum of forces at a treadmill contact point with the structural floor

limits the transmissibility from reaching infinity. The full expression for transmissibility, including the effects of damping is provided in Equation 2 (ψ is the damping ratio ranging from 0 to 1). Again, values greater than 1 indicate force magnification and values lower indicate frequencies which are isolated. It is evident that increasing the damping ratio limits the resonant peak, however this comes at a price in terms of limiting the isolation performance at higher frequencies.

$$T = \sqrt{\frac{1+4\psi^2\left(\frac{f}{f_0}\right)^2}{\left[1-\left(\frac{f}{f_0}\right)^2\right]^2+4\psi^2\left(\frac{f}{f_0}\right)^2}} \quad \text{(Equation 2)}$$

Shock events

In cases where SDOF harmonic or periodic excitation is present, the response is readily described using the considerations highlighted within the previous section. When considering non-periodic vibration excitation, the result sought is not a steady state solution but rather a transient one, and in extreme cases the duration of impact can be less than the time taken for a single cycle of vibration by the receiving structure (i.e. that of its natural frequency).

Shock events are applicable to free-weight drops and it will be argued that they are also applicable in the description of treadmill use. In contrast to harmonic excitation, where forcing frequencies form part of the assessment parameter, shock events are commonly characterised by the maximum response (F_0), over an impact during (T) and the shape of the impact describing the shock event. Below illustrates a typical pulse lasting 5e-4 seconds with a peak force value (F_o) of approximately 6e5N.

Treadmill vibration

When isolating the effects of treadmill use, resilient matting is a favourite of gym operators, and in many instances, the performance observed is less than ideal. Natural frequencies of vibration for supporting pads can be low, typically down to 8-10Hz for single-ply designs. Values lower than this are achievable via alternative means such as floating concrete or timber floors. However, care must be taken as the natural frequency of such systems can match the running rate of a treadmill user, which occupies the region of 2Hz. At these frequencies the isolating floor would exhibit resonant behaviour, severely limiting user comfort.

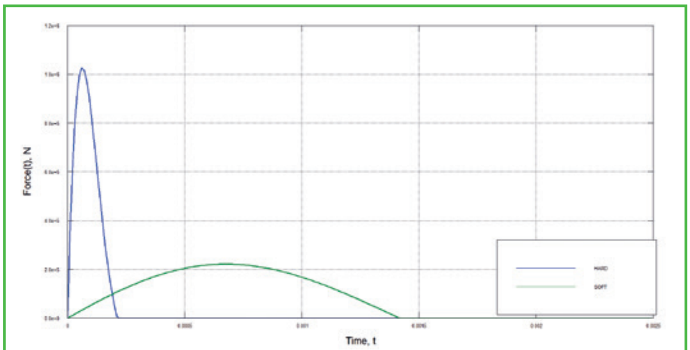

Figure 3 - Force pulse for Hard (blue curve) and soft (green curve) materials

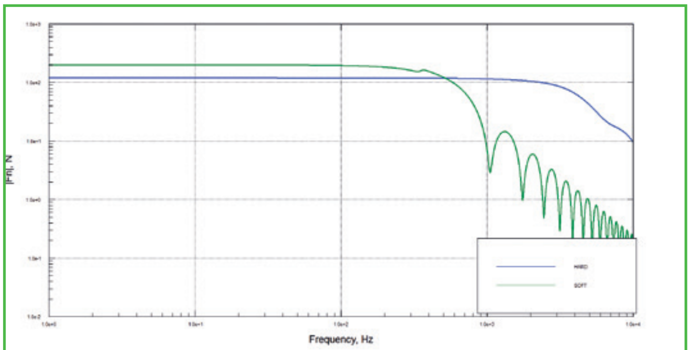

Figure 4 - Force spectra for Hard (blue curve) and Soft (green curve) materials

A common misconception is that the running rate of the treadmill user, coupled with the mass of the user and treadmill, describe a simple-harmonic SDOF system. This is certainly an easy conclusion to reach as all the necessary components of mass (treadmill and user combined), spring (the matting), rigid base (structural floor) and forcing frequency (2Hz) are evident. However, the issue is that the variation of force is not sinusoidal, but instead comprises a train of short duration impulse events (See Figure 1). The input forces into a structure can vary depending on factors such as running style, treadmill dynamics, the mass of the user and treadmill running speed. It can therefore be understood that a high degree of variability can be expected between users, even those of similar weight.

Returning to a harmonically excited SDOF system, selection of an isolator to accommodate a 2Hz forcing frequency is likely to be insufficient, as a well-designed isolator would permit only small deflections. In real terms, the resultant deflections under a large impacting mass would be greater than those prescribed via simple harmonic sinusoidal motion. If the level of deflection required to isolate the impact mass is not available, then the isolation layer will compress under load and change its stiffness profile. Assuming for a moment that the stiffness of the resilient matt (k_1) and structural floor (k_2) can be represented as springs in series, then the effective combined stiffness can be estimated to be (Equation 3) assuming linear behaviour.

$$\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} \quad \text{(Equation 3)}$$

If over-compression of the resilient material occurs, then the Force vs Deflection (static or dynamic) behaviour may increase thus minimising the effect of the k_1 term. In extreme cases, the $1/k_1$ term would tend to zero (appreciating this may now result in non-linear behaviour), leaving only the stiffness of the structural floor. Put simply, if such an instance occurred, the isolation contribution of the pad becomes severely limited in the frequencies of interest and the system would be characterised by the stiffness of the supporting structure. Given the impulsive nature of the treadmill use, this would result in a transmitted force spectrum with wide ranging frequency content, similar to that provided in Figure 2, which illustrates force measurements at a single contact point between the treadmill and a structural floor.

Weight-based activities

Of all gym-based activities, the use of free-weights and resistance machines result in the greatest number of complaints in residential and mixed-use developments. As with treadmills, a similar tranche of lightweight mitigation measures are often favoured with limited results.

By means of illustration, a simplified model is presented describing the force pulse for a typical 'hard' and 'soft' surface. The system is considered to act as a mass-spring-dashpot model proposed by Brunskog, and considers a half-sine load function, with the duration of impact controlled by the contact stiffness of the impacted surface.

An illustration of typical force pulses for typical hard (concrete, blue curve) and soft (resilient matting, green curve) surfaces, derived using the aforementioned methodology are presented jointly in Figure 3.

From inspection, it would seem that choosing a softer material would offer the greater benefit when seeking to limit transmission of vibration and structure-borne noise. However, FFT analysis of the individual pulses reveals force spectra which lead to contrasting conclusions. The resulting force spectra are provided Figure 4, where it is observed that the harder surface (blue curve) exhibits flat response across most areas, whereas the softer P42

P41

material (green curve) results in a roll-off at frequencies above 1kHz. An important observation is that this roll-off comes at a price by elevating the forces within the low-frequency region. It is therefore worth reinforcing the point that in decreasing the stiffness of the floor covering, we must expect an increase in the degree of low-frequency force-transmission and should therefore be wary when reviewing product literature which state reductions in overall A-weighted terms. Though a significant reduction in overall noise may be achieved, low-frequency attenuation may be lacking.

Impedance

Another technical aspect worth considering is impedance, namely the degree in which an object resists forces acting upon it. Impedance terms are used widely in research areas as it provides information on how a structure will react to certain forces, and can also comprise useful expressions to describe SDOF models with a number of input parameters.

Assuming the input forces onto a floor can be derived via calculation or measurement, these can be related through resultant mean-squared velocity by Equation 4.

$$\overline{v^2} = \frac{|F|^2}{wm''\eta S} Re\left\{\frac{1}{Z+Z_a}\right\} \qquad \text{(Equation 4)}$$

Where
$|F|^2$ is the force magnitude,
w is the angular velocity
m'' is the floor mass/area
η is the floor loss factor
S is the area of the floor
Z is the floor impedance
Z_a is the impacting mass input impedance.

The terms of note in the above expression are those of Z (*the floor impedance*) and Z_a (*the impacting mass input impedance*). It follows that for a constant impacting mass input impedance, the velocity level decreases with increasing impedance of the structural floor. This has implications for floor design in new or existing facilities as such values can be modified prior to gym occupation.

Furthermore, the above expression also provides insight into the relative benefits of lightweight vs heavyweight floating floor designs, where it can be inferred that a lighter system would offer a lower performance compared to heavyweight designs. The equation also illustrates that a lightweight option would have a greater sensitivity to variations in impacting mass, as the variation between $Z+Z_a$ term would be greatly affected by heavier sources. By comparison, a heavyweight design would have a dominant structural floor-impedance (Z) value, and would therefore be less sensitive to such changes in excitation via impacting masses.

Structural dynamics

So far, it has been assumed that the vibration isolating material acts as an idealised spring in a SDOF system. However this is not entirely true as the dynamic behaviour of a gym floor and surrounding structure play a key role in the transmission profile.

Returning to pad-based isolators, the lightweight properties of such materials will not restrict deflection of the structural slab underneath, and in doing so, the rigid-base conditions upon which SDOF behaviour is assumed do not apply. Put simply, the system inherits an extra degree of freedom, and can be regarded as a mass-spring-mass-spring arrangement. Additional degrees of freedom become necessary if we consider the effects of additional floating floors and axes of vibration etc. The result of the additional degree of freedom is that the response of the composite system may now be controlled by the resonant frequency of the structural floor, as opposed to that of the isolating material.

Evidence of this can be observed in Figure 5 which illustrates the difference of a treadmill with and without pad isolators upon a structural floor with a natural frequency of 8Hz. Measurements of sound pressure were undertaken in a room beneath the treadmills. Recognising that positive values in the figure indicate that the pad is reducing noise within the receiving room, an increase in noise in over half of the bands in the presence of the pad can be seen. (It is acknowledged that some of these bands are lower than the accepted threshold for hearing, however bands lower than 20Hz were observed to have an associated increase in vibration level.) The most pronounced dip occurs at 8Hz (the structural resonance). In this instance, the pad isolator was suspected of having a natural frequency in the same region, further compounding the poor performance of the system. Notable dips at 16Hz and 32Hz can also be seen, which are likely to be the result of harmonic components.

By further example, Figure 6 summarises the difference in sound pressure level obtained between tests on a standard gymnasium floor and those repeated on a section of padding material. As with Figure 5, a positive value indicates a reduction in noise. A similar pattern emerges to that of treadmill tests whereby the introduction of extra matting results in a worsening of low-frequency values, which from a design aspect, results in a greater potential for disturbance due to noise and vibration.

The implication is that prior to any recommendations for mitigation measures, steps should be taken to ensure the dynamic properties of the structural floor are known. This can be undertaken in existing developments via direct measures. Analysis in new-build schemes will require information from the structural engineer and potentially, assessment via numerical methods. Increasing the stiffness of the structural floor (thus increasing the natural frequency) while keeping the isolator natural frequency as low as possible, will allow the system to tend to the SDOF assumptions, thereby maximising isolation performance.

Floating floor considerations

There are many commercial incentives for specialist suppliers to develop gym flooring in order to control high-impact noise and vibration generating activities. In many cases, especially refurbishment schemes, the cost of retro-fitting floating floors can be significant, often leaving an operator with no choice but to cease trading and relocate to a less commercially desirable space. As such, there is a push to develop lightweight designs capable of meeting onerous noise and vibration demands.

Floating light or heavyweight designs alike are typically suspended via elastomeric pads or helical springs, and there are distinct merits

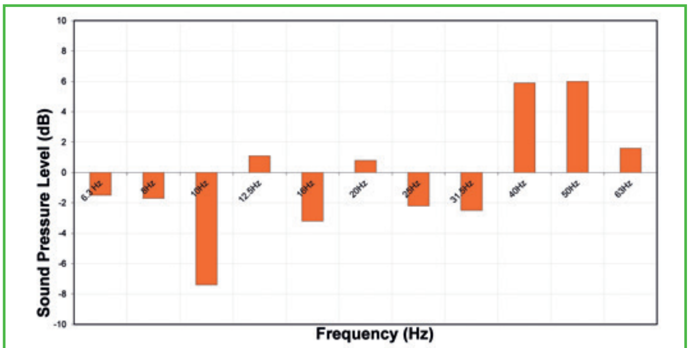

Figure 5 - Effect of pad isolation on treadmill generated noise noise. 8Hz strucutral floor

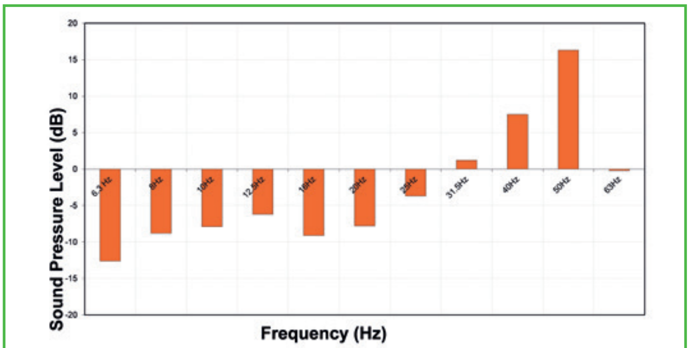

Figure 6 - Effect of pad isolation on free-weight generated noise noise. 8Hz strucutral floor

and disadvantages to both. Helical springs tend to follow predictable linear behaviour if selected correctly, and therefore provide a better fit in any mass-spring based analyses. However, in the absence of the “dashpot” element, helical springs offer little damping and consequently can feel somewhat lively if the excitation mechanism is sufficient to force the floor into a resonant condition.

Elastomeric pads are stiffer by nature and therefore cannot reach isolating frequencies as low as helical spring counterparts, but do have the advantage of offering high levels of damping.

A secondary consideration is the mass-air-mass effect arising from trapped air between the upper surface of the structural floor and the lower surface of the floating element. It has been argued that the resultant stiffness of this pocket of air limits the system’s natural frequency to one greater than the isolation frequency of the spring/pads which support the floor. While there is standard theory to support this hypothesis, research by Mason-UK and Salford University indicates that shock loading of a shuttered concrete floating floor, supported on helical springs, still exhibits maximum power injection into the structural floor at the mass-spring isolation frequency. This, of course, does not mean the air-coupling effect does not occur, but further investigatory work is required to determine whether such effects work in parallel, as opposed to one dominating the other. Notwithstanding, the reality is that a combination of adequate venting and low-frequency floor systems would produce the greatest reduction in vibration.

Though there are other floating-floor considerations, for example, air-gap and void damping, that may play a role in the reduction of power transmission into a structure, perhaps the key factor is the structural floor itself. As was evident in assessments of pad isolation, the flexibility of the structural floor will limit the overall effectiveness of the system. It is necessary to allow a large variation between the floating floor natural frequency (as low as possible) and that of the structural floor (as high as possible) to maximise performance. This would require strengthening works in refurbishment schemes or thicker/stiffer slab arrangements in new-build developments.

Final thoughts

The prediction of noise and vibration from a variety of gym-based sources and activities requires knowledge of the factors affecting transmission. It is recommended that designers consider in greater detail the effects of the supporting structure prior to the recommendation of mitigation measures, as the interplay between the two elements has a pronounced effect on performance.

Impedance of the floor (floating or structural) plays a crucial role, and specialist suppliers are encouraged to look in further detail at how changes in the floating floor dynamics could benefit the reduction of power injection into the main structure. It has been discussed that pad-type materials can often exacerbate issues rather than resolve them.

Further work is encouraged to promote discussion regarding appropriate design guidance and acceptable limits, in order to provide a better means of avoiding noise complaints across a variety of environments.

__Martin McNulty__ is an Executive Acoustics Engineer at Hoare Lea

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Measurement and analysis of mechanical noise in wind turbines

By Miguel Arana, Jorge Machín, Ricardo San Martín of the Acoustics Laboratory, Physics Department, Public University of Navarre, Campus de Arrosadia, Pamplona, Spain

Abstract
The aerodynamic noise component creates the majority of noise emitted by commercial wind turbines. By means of controlled measurements, with acoustic sensors both on the ground and in the nacelle, it is possible to quantify the influence of mechanical noise from the different components that are working in a wind turbine and determine whether they are audible anywhere on the spectrum. Controlled measurements with a 4.5 MW wind turbine helped us to quantify the influence of the mechanical component noise within the total noise. Analysing the results demonstrates that sound recordings can be used to monitor how the mechanical components work.

Introduction
Doubtlessly, the main source of noise in our cities is traffic, causing many disturbances [1] and health issues [2]. It is also true that some works have demonstrated a drop in environmental noise originating from traffic [3, 4]. The number of people affected by wind turbine noise is, quantitatively, much lower. Nevertheless, although road traffic noise is the major source of noise, in general, annoyance seems to be lower than for wind turbines [5]. Persons that easily detect and recognize wind turbine noise are more annoyed than persons affected by road traffic noise [6]. Actually, community annoyance due to noise from wind turbines is often the result of noise character rather than level [7]. Some physical characteristics that play an important role in the annoyance caused by wind turbine noise are the periodicity of the noise [8], the low-frequency content [9-11] and the tonality of the noise [12]. Nevertheless, other non-physical characteristics such as the visual setting [13-15] or the presence of economic benefits [13, 16] are also important.

The noise emitted by wind turbines has a (mainly) aerodynamic and mechanical origin, the latter due to the different mechanisms inside the nacelle: gearbox, ventilators, transformers, hydraulic pumps, etc [17]. The gearbox is still a noisy source, which is often audible on the ground. Audible tones from gearboxes (low-frequency tones) are detected in many modern turbines [18]. Many researches had been carried out on the aerodynamic noise. The dominant noise sources are located on the blade, due to the acoustic waves created by turbulence are reinforced via an edge diffraction mechanism. This is known as trailing edge noise [19] and is the major noise source on a wind turbine [20]. Another cause of noise is the blade-tower interaction, generated by the interaction of the blades with the perturbed flow upstream of the tower. This type of noise (which is probably impulsive noise) remains the least well studied and some controversy surrounds the issue of whether it is a significant noise source [21].

Due to increasingly strict regulations on sound levels emitted by wind turbines, manufacturers are extremely interested in reducing it [22]. The purpose of the part 11 of IEC 61400 [23] is to provide a uniform methodology that will ensure consistency and accuracy when measuring and analysing acoustical emissions by wind turbine generation systems. In this way, standardising the measurement procedures implies the capacity to be able to make comparisons between different wind turbines. This standard also allows tonality to be analysed, or the presence of tones in the noise emitted by the wind turbine. Research has found that the presence of a single tone in audible noise spectra both increases annoyance ratings and decreases human performance. International Standards often include a noise characteristic penalty to quantify the impact of tonal noise characteristics on human response. For example, penalties of up to 5 and 6 dBA are added to account for the adverse subjective response caused where tonal characteristics are audible in Australia [24] and New Zealand [25] respectively. More research of the excitation frequencies within the wind turbine is necessary in order to confirm the source of the tonal characteristic, as well as investigation of the natural frequencies of the drive train and other elements of the wind turbine to determine the path of excitation and any re-radiated structure-borne noise to the environment [26].

This work aimed to study whether it was possible to identify mechanical noise within the general noise emitted by a wind turbine, including aerodynamic noise and background noise.

Materials and methods
By means of controlled activations of the different mechanical components in a wind turbine (pitch and yaw mechanisms, cooling ventilators, etc.) when the wind turbine is stopped (in other words, absence of aerodynamic noise from the actual turning), sound levels were recorded at two positions inside the nacelle and at ground reference points set in the IEC 61400-11 standard. Figure 1 shows both sensors (microphones) located inside the nacelle (one on the generator, R1, and the other in the transformer compartment, R2) and the three on the ground, in reference positions 1, 2 and 4 (R3, R4 and R5, respectively) from the standard IEC 61400-11.

The two sensors inside the nacelle and the ground sensor positioned at reference point 1 formed part of three OPER@ environmental noise monitoring stations – class 1 metrological system designed to continuously measure noise over a long-term period – with the appropriate programming for them to be able to establish a configuration and some measurement parameters. An integration time of 1 s was used, although 0.1 s was used for some parameters. The parameters recorded were: L_{AF}, L_{CF}, L_{AI}, L_{CI}, L_{Aeq}, L_{Ceq} and L_{Cpk}. The spectral analysis was also recorded (every second) in one-third octave bands, from 12.5 Hz to 20 kHz. At points 2 and 4 on the ground, two B&K type 2260 sound level meters were used, timed with the three OPER@ stations. Both sound level meters meet the IEC 61672-1 Standard [27].

A programming list of actions to be performed on the wind turbine was drawn up beforehand to give the greatest possible control and be able to identify each action (afterwards) with its corresponding sound. Previously, the measurement stations and sound level meters had been synchronised with the wind turbine. The wind turbine elements that allow it to work independently from the other mechanical elements are: yaw and pitch mechanisms, opening and closing hatches, P46

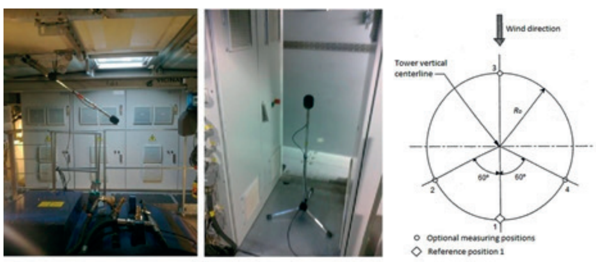

Fig.1 Location of the measurement sensors; two in the nacelle and three (points 1, 2 and 4) on the ground

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activating ventilators and activating pumps. In this way, wind turbine action operations were numbered with the mechanical elements used in this process, the number of these elements and how long each stage lasts.

The entire sequence of actions was carried out when the machine was stopped. Subsequently, the sound levels were recorded (in continuous mode for 15 days) with the two sensors inside the nacelle and the wind turbine in operating mode. The actual machine has sensors to detect when a mechanical element might have been activated/deactivated, making it possible to study the influence of each mechanism on the sound levels measured inside the nacelle, in the presence of aerodynamic noise and background noise. Data was also provided on wind speed and direction, turning speed, power generated, etc.

Results and analysis

Yaw mechanism

The Yaw mechanism is responsible for turning the nacelle to position it perpendicular to the wind when the wind changes direction. Measurements were taken when the wind turbine was completely turned off and only the Yaw was activated. Figure 2 shows the sound level recordings (broadband) in the 5 stations, two inside the nacelle and three on the ground (minimum range of the sound level meter R4 was 30 dBA) . The yaw mechanism started at second 12 and ended at second 178, as can be seen more clearly at the bottom part of the figure. The rotational speed of the yaw mechanism was 0.32 degrees per second. It seems clear that the sound level produced by the Yaw mechanism cannot be detected at the points on the ground, at least in broadband.

When performing the spectral analysis, it was detected that the increase in the sound level was very clear at high frequencies, specifically in the 8 kHz one-third octave band. Figure 2 shows how this changes over time, in this band, for the two stations in the nacelle and one of the stations on the ground (reference point 1).

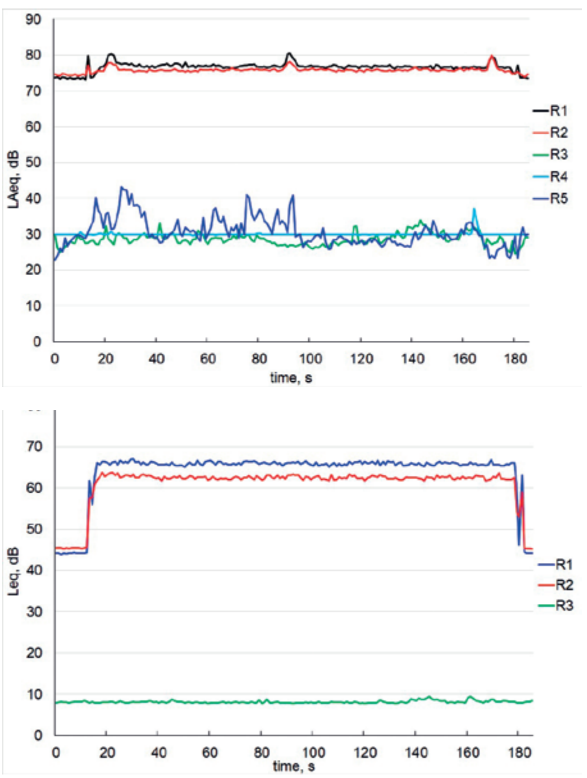

Fig. 2 Sound levels (broadband) generated by the Yaw mechanism. Broadband (top) and 8 kHz one-third octave band (bottom)

Once again, it is clear that this noise has no effect on the ground points. However, sound levels in the 8 kHz band at points inside the nacelle increase by around 20 dB. The mechanisms that allow the Yaw to work are inside the nacelle and are mainly shielded from the outside. On the other hand, air absorption at the 8 kHz frequency (temperature of 20ºC and 50% RH) is 105 dB/km [28]. These two circumstances means that the sound levels from this mechanism are masked at the points on the ground. It is clear that an acoustic sensor inside the nacelle can certainly detect activation and deactivation of the Yaw mechanism. It would be interesting to know whether this is a common result in other turbines or, on the contrary, is specific to this turbine.

Pitch mechanism

The pitch mechanism refers to the blades' capacity to vary the pitch angle. This angle is formed by the blade's string line

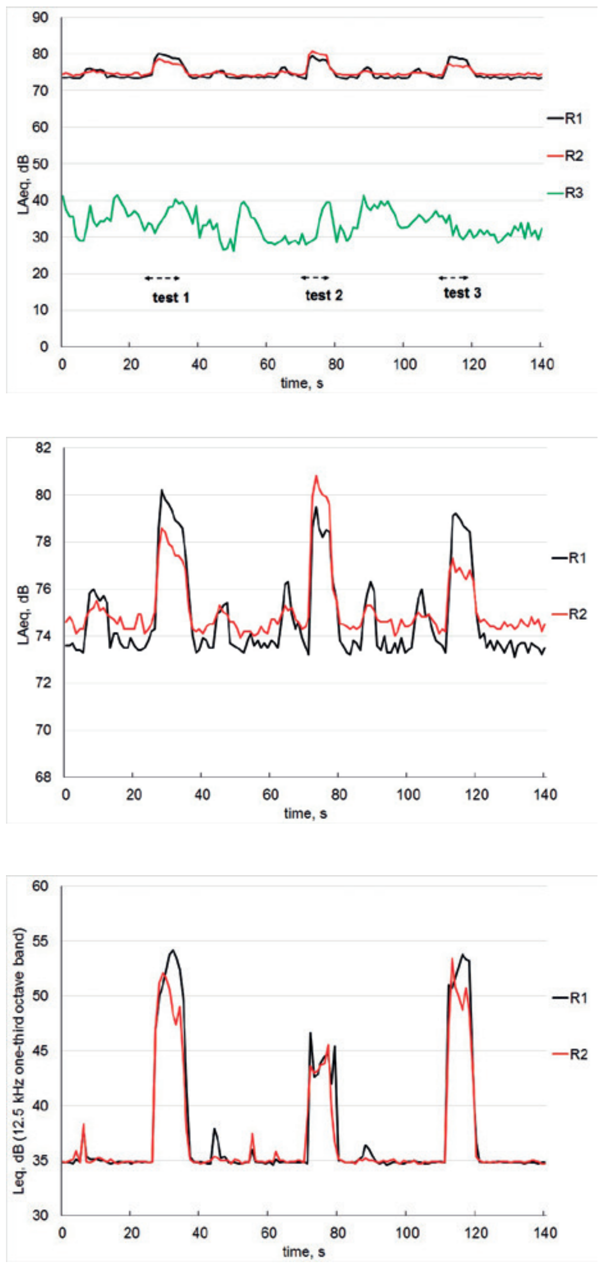

Fig. 3 Sound levels generated by the Pitch mechanism. Broadband (top), R1 and R2 zoomed (center) and 12.5 kHz one-third octave band (bottom)

against the blade rotation direction. The Pitch mechanism is used in power control. The Pitch turns the blades in one direction or another to limit the power generated or adjusts it to the nominal power. Two hydraulic units are used to activate this mechanism.

Figure 3 shows the sound levels (broadband) for three sensors (top part) during three activations of this mechanism. Once again, it is difficult to find a relationship between the activations and the sound levels registered on the outside measuring points. The center part shows (on an amplified scale) the levels in the two stations inside the nacelle. In the first and third tests, the front hydraulic unit was activated to work the Pitch and the rear unit was activated in the second test. When analysing the frequencies, although there are several bands where the sound levels stand out from the background noise, it is the 12.5 kHz one-third octave band where the noise generated by this mechanism can be distinguished most successfully (Fig. 3.bottom). By subtracting background noise in the ground station (reference point 1), it was concluded that the sound levels generated by this mechanism at this point were under 30 dBA.

Cooling fans

There are 12 fans in the cooling system responsible for extracting the heat generated by the other cooling systems. They can be activated depending on the different needs. On running the test, 1, 2, 4, 8 and 12 fans were activated for approximately one minute and subsequently stopped, at both low and high speed.

Figure 4 shows that it is much clearer that these mechanical components have been activated in readings from the ground sensor than from sensors inside the nacelle. This is more clearly demonstrated in the 1.6 kHz one third-octave band. It must be taken into account that these mechanical components are located on top of the nacelle so they are not particularly P48

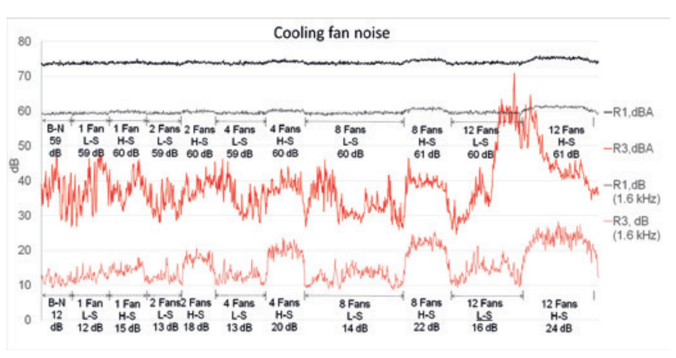

Fig. 4 Sound registrations (broadband, in dBA and component of 1.6 kHz, in dB) for stations R1 (nacelle) and R3 (reference point 1) with activation of 1, 2, 4, 8 and 12 fans (at low and high speed, L-S and H-S, respectively) from the cooling system (B-N: background noise).

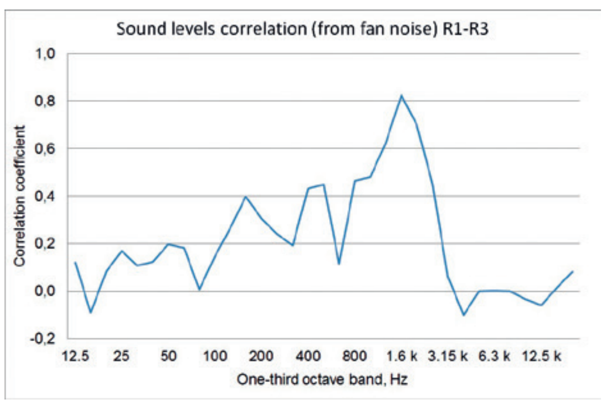

Fig. 5 Correlation between stations R1 and R3 for all frequency bands.

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screened from the ground sensor. This band has been selected because it offers the greatest correlation between the values measured in the nacelle and the values measured on the ground. In fact, Figure 5 shows the correlation coefficients (per band) for the sound levels measured by these two sensors.

In an attempt to look in greater detail at our analysis, we will look at the influence of the different bands on the sound levels measured on the ground position (position 1 of the IEC 61400-11 standard). To do this, we will represent the spectral composition of the noise during OFF periods (background noise) and the activation period for the 12 fans. Figure 6 shows these levels.

The graph shows how this mechanical component influences the level measured in the ground station in components with a frequency between 40 Hz and 2.5 kHz. For these bands, the levels obtained for the signal and the background noise are 51.7 and 36.8 dBA respectively. Considering all bands, these levels are 51.7 and 37.9 dBA respectively. In conclusion, the sound level that can be attributed to the 12 fans in the cooling system working at measuring point R3 does not exceed 52 dBA.

Other mechanical components

Other mechanical components have been analysed such as: opening the hatch inside the nacelle, nacelle fans, transformer fans, multiplier cooling pump, generator cooling pump, converter cooling pump and lubrication pump. Although some of these components produce sound levels in a particular frequency that can be detected (against the background noise) in the sensor installed in the nacelle, the sound levels at the ground sensors do not exceed the background noise levels, at least for the wind speeds at which the measurements were taken. However, the nacelle's acoustic sensor can be used to identify when one of them has been activated.

Wind turbine in operation

When the wind turbine is working (automatic mode), the dominant noise has an aerodynamic origin, particularly at the points on the ground. Consequently, these levels increase with the wind speed, around 3 dBA from 8 m/s to 14 m/s, according to our measurements. Beyond this speed, the sound level remains practically constant. In automatic mode, the sound levels with a mechanical origin at the ground points are practically screened by the aerodynamic noise. Figure 7 includes all the results obtained for the sensor fitted inside the nacelle: pitch and yaw mechanisms, nacelle, transformer and cooling fans as well as the background noise and the aerodynamic noise for the two wind speed ranges (8 and 12 m/s). As can be seen in the diagram, the mechanical noise is almost always screened by the aerodynamic noise, even inside the nacelle. However, some of them can be identified in some specific frequency bands, as shown in figure 8 for the yaw mechanism.

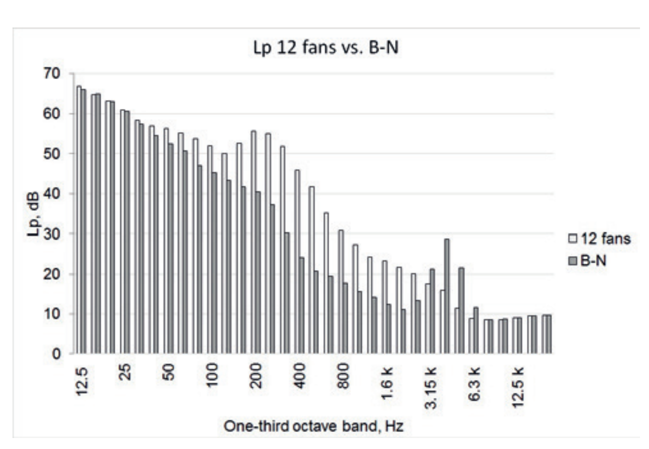

Fig. 6: Spectral analysis of recordings from station R3 with activation of 12 fans in the cooling system vs background noise (B-N).

Conclusion

The mechanical noise in the commercial wind turbine model measured (4.5 MW) is screened (on the ground) by the aerodynamic noise. Only the Yaw mechanism is slightly perceptible at the reference position on the ground and, for that, it is necessary to make a one-third octave bands analysis. Inside the nacelle, it is feasible to monitor some of its components acoustically (particularly the yaw mechanism) thanks to its spectral characteristics. So, for example, levels increase at around 20 dB for the Yaw mechanism on the one-third octave band of 8 kHz and for the Pitch mechanism on the one-third octave band of 12.5 kHz. In the case of the cooling fans (due to their external location) their activation or deactivation is more perceptible from the outside than the inside of the nacelle, especially in some bands (1.6 kHz) as long as aerodynamic noise is not present. ◘

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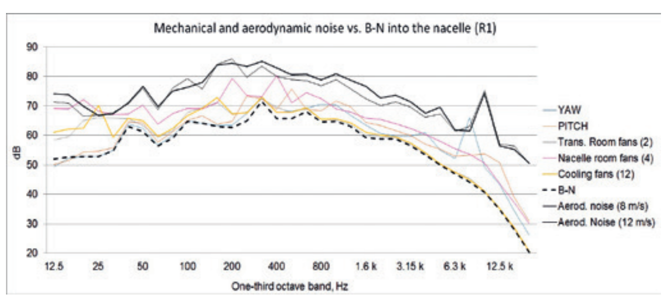

Fig. 7 Spectral analysis of the mechanical noise over the background noise and the aerodynamic noise (wind speeds of 8 and 12 m/s)

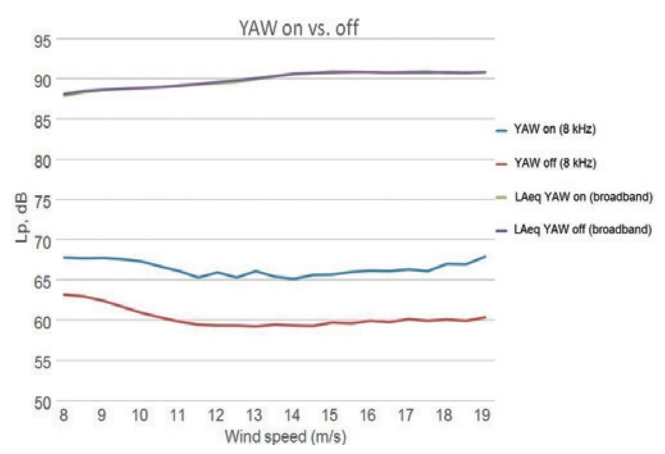

Fig. 8 Sound levels (broadband and 8 kHz one-third octave, in dB) for the Yaw depending on the wind speed.

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Considerations in modelling freight rail noise

By Christopher Schulten of Transport for NSW Infrastructure and Services , Chippendale, NSW, Australia; Conrad Weber of Renzo Tonin & Associates, Surry Hills, NSW, Australia; Briony Croft of SLR Consulting, Vancouver, Canada and David Hanson of Transport for NSW Infrastructure and Services, Chippendale, NSW, Australia

This paper is split into two parts, the second of which will appear in the next issue.

Abstract

An environmental noise model, developed in specialist software such as LimA, SoundPLAN or CadnaA is typically at the core of noise impact assessments for rail projects. These software packages include rail noise modules that account for such variables as train speed and length, and propagation algorithms that allow large scale models to reliably predict noise levels at thousands of receivers neighbouring the track. The ease with which results are generated by these software packages can easily provide a false sense of accuracy however, as the old maxim of noise modelling still applies – garbage in equals garbage out. This is particularly the case for freight rail operations which involve complex noise sources. These include multiple moving noise sources, such as locomotive exhaust noise and rolling noise, that exhibit distinct relationships with train speed. There are localised sources such as crossovers and curve noise which have a particularly annoying character. There are sources that exhibit different characteristics under different operational scenarios. For example locomotive noise can be dominated by the engine exhaust under traction on an uphill grade and ruled by dynamic brake noise on a downhill grade.

This paper presents a discussion of issues to be considered to successfully model freight rail noise. It describes the different noise sources which apply, when they apply and how to incorporate them in a computer noise model. An outline is provided on the most appropriate propagation algorithms to apply and how sources such as curve noise and brake noise, can be accounted for. Attention is also given to validation of the noise model at each stage of its development, including how to make best use of noise measurements to verify model predictions.

Introduction

This paper is intended to summarise the key issues that may need to be considered when modelling the noise impacts of freight railways. It assumes the reader has existing knowledge of one or more specialist noise modelling software packages, such as LimA, SoundPLAN or CadnaA. This paper concentrates on modelling operational freight rail noise on network or main line track. It does not consider issues associated with modelling noise during project construction, or the noise from freight classification yards, stabling areas or intermodal terminals.

This paper describes the process of developing a freight rail noise model, and standard methods and approaches that should be employed to maintain quality and consistency between projects. The context of the paper is modelling rail freight noise in NSW. The paper is arranged in a series of steps corresponding to the stages of model development as follows:

- Modelling accuracy
- Input data collection (databases, measurements, train numbers, speeds)
- Choice of software, rail noise standards, algorithms and assessment settings
- Geometry modelling (terrain, barriers, receivers, ground, model extent)
- Rail noise sources (wheel-rail, locomotive exhaust, idling, curving, turnouts)
- Modelling scenarios (day, night, existing, future, mitigated)
- Checking and review
- Model validation and compliance measurements.

Modelling accuracy

The level of detail required in the modelling of freight rail noise should have a direct relationship with the desired accuracy of the predictions.

If the purpose of the noise model is to establish the likelihood of potential noise impacts at a particular site, then basic information associated with the type of trains, typical speeds, indicative timetable and distance to sensitive receivers may be all that is required. Such models could be implemented within a spreadsheet which includes basic noise propagation algorithms. The source noise levels in such models should be towards the upper end of possible noise level range to capture a "worst case" assessment.

If a detailed noise model is required to optimise mitigation measures and demonstrate compliance with project-specific noise criteria, then a more accurate assessment will be required, taking into account detailed information about the train operations and site-specific features such as ground topography, the orientation and height of buildings and intervening natural or man-made barriers. This type of modelling would normally be undertaken using specialist noise modelling software.

Further guidance on the accuracy of a noise model at various stages of a rail project is provided in International Standard ISO 14837-1:2005 [1]. Whilst this standard is directly applicable to the modelling of ground-borne noise and vibration, the basic principles relating to the type, form and accuracy of a noise model can be directly applied to modelling of freight rail noise.

This paper provides discussion of issues that relate to predicting accurate noise levels using a computer noise model (for detailed design purposes). For scoping models, developed at the earliest stage of a project in order to establish if freight rail noise is likely to be significant, the considerations discussed in this paper can be used to undertake a risk assessment of the potential noise impacts that may exist within the project area.

Data collection

This section provides background on the extent of information required to develop a detailed model for predicting rail freight noise impacts. The information required includes data on train numbers, train types, lengths and number of locomotives, operating speeds and notch settings through the area of interest, as well as data on the geometry of the alignment, curve radii, gradients, the existing ground terrain and receiver locations.

Freight rail noise modelling presents some particular challenges to acousticians, particularly relating to the input data collection stage. Whereas passenger trains commonly follow a defined, regular timetable, freight often operates on a demand basis. Therefore, fundamental model input parameters such as the number of trains, the length of the trains and the number of locomotives can vary from day to day, as well as over a greater time frame.

Train numbers

In NSW, numerical noise criteria are based on the maximum noise levels of train passbys (L_{pAFmax}) and the energy average noise level, evaluated over the relevant assessment period ($L_{Aeq(period)}$).

The number of train movements in an assessment period (daytime, night-time or 1-hour) has a direct impact on the energy average noise level such that a doubling or halving in the number of trains (with the same noise emission level) results in a 3 dB change in noise levels. Maximum noise levels, however, are not affected by the number of trains in an assessment period, but are assessed on the basis of the 'typical maximum' passby level, based on P52

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the 95th percentile (or the level not exceeded by more than 5% of train passbys).

The number of train movements within each assessment period will normally be provided by the project sponsor (or proponent). Care must be taken to ensure that the number of trains modelled reflects the expected number of train movements and the increase in train movements due to a project, rather than the number of train paths available (which will be higher). In the case of existing train operations, the average or maximum number of train movements can be established via long-term noise monitoring and/or operating logs supplied by train operators. For acousticians, long term monitoring commonly means noise measurements over a period of one to two weeks using portable equipment, but this may not provide data on longer term seasonal variations in demand. At some locations, TfNSW now has permanent noise monitoring stations in place that can provide data over months. For a rail upgrade project, often the increase in noise due to the project forms part of the assessment criteria. In this situation, the noise modeler should be aware that assuming higher train numbers for a base case scenario may not be conservative, since this assumption can reduce the predicted increase in noise due to the project.

The project proponent may be a developer seeking to develop land near an existing or future rail corridor. In this case, the approach to determining train numbers depends on the situation and the timing of approvals. If a new rail line (or an upgrade) is approved but not yet constructed adjacent to a proposed development, then appropriate future train numbers would normally be available from planning documents for the rail project. If the development location is next to an existing line, there are several options to determine appropriate train numbers for noise modelling. These include long-term monitoring or operating logs, and also previously published (publically available) planning documents. In some cases, train numbers for a particular line might be available from documentation for a rail project in the next suburb - if the line is the same these numbers are sometimes also applicable in adjacent areas. If there are no forecast train numbers available for a line near a development that will take several years to be constructed, it may be appropriate to add a growth factor to the existing train numbers. This approach enables a conservative approach to account for natural growth in freight demand over several years when assessing impacts on a new development.

Train types

There are a large number of different freight locomotives, wagon types and passenger trains operating on the NSW rail network, each with different operating characteristics and noise emission levels. EPA License 3142 [2] provides a list of locomotives which are approved to operate on the Australian Rail Track Corporation network. The current version of the license includes more than 100 approved locomotives.

A detailed noise model will include an assessment of the train types that are likely to operate within the project area. In many cases, it will not be possible to identify all types of trains and wagons in operation. In order to provide accurate noise predictions, it will be necessary to identify the most common train types that are likely to operate and an estimate of the percentage of each type. This information can be established via long-term monitoring or operating logs supplied by rail operators.

Transport for NSW Asset Standards Authority has established a NSW Rail Noise Database (RND) [3] which establishes the source noise levels of a large number of passenger and freight trains for a variety of operating conditions. Whilst the current version of the database (Stage III) is relatively small, it is intended for the database to be continually updated with additional measurement data to support the improved accuracy of noise modelling and implementation of cost-effective mitigation measures.

Source noise levels from the RND and information relating to the likely percentage of each train type should be utilised to carry out noise predictions. In cases where source noise levels are not provided in the RND (or earlier versions), it will be necessary to establish appropriate levels on the basis of site measurements or existing data. The noise assessment report should clearly document the source noise levels used in the modelling. The source noise levels of 'unknown' train types may need to be set towards the upper end of the possible noise level range to provide a conservative assessment.

Train lengths

The maximum noise level during a train passby will be higher for a long train compared with a shorter train. The noise level difference is a function of the train length and the perpendicular distance between the train and the receiver.

Formulae predicting the change in maximum noise levels for varying train length and source-receiver distances are provided in the RND, based on the Nordic Rail Prediction Method. In most cases, where the source-receiver distance is small compared with the train length, the difference in maximum noise levels between short and long trains is negligible.

In relation to the energy average noise level predictions, the train length is an important factor which directly influences the overall levels. A doubling or halving in the train length (with the same noise emission level for each locomotive or wagon) results in a 3 dB change in noise levels.

In the case of train consists which include locomotives or wagons with different noise emission characteristics, it may be appropriate to model each locomotive type and wagon type separately.

Train speed

The main source of noise emission from many trains is the wheel-rail interaction, normally referred to as rolling noise. At train speeds between approximately 50 km/h and 300 km/h, L_{pAFmax} rolling noise levels are most commonly based upon an N.log(v1/v2) relationship, with N = 30 such that a doubling or halving of the train speed results ▶

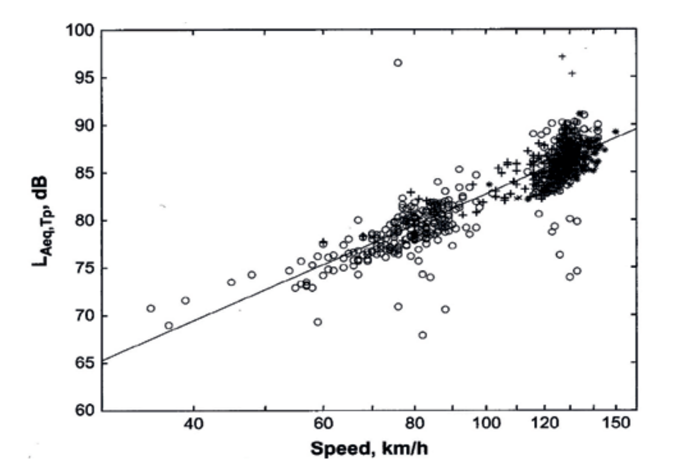

Figure 1 – Example rolling noise relationship with speed (from [4])

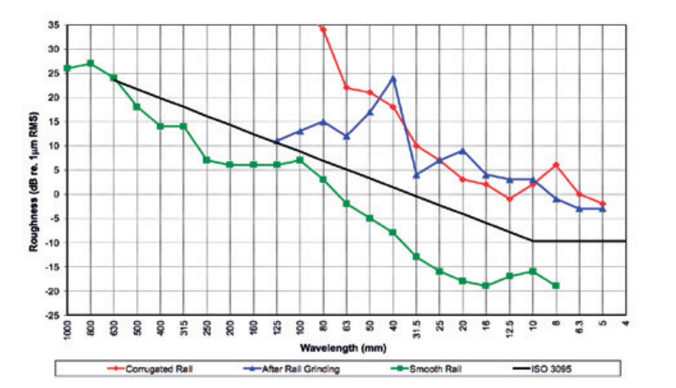

Figure 2 – Rail roughness can differ significantly between sites, as these measurements from the Sydney rail network show. Note that these differences are often not obvious to the naked eye and measurements with a corrugation analysis trolley or other similar instrument are recommended to quantify the rail roughness. Similar differences in wheel roughness are also typical.

in a 9 dB change in the rolling noise levels. Thompson [4] notes that while the speed exponent N is usually about 30, it can vary between 25 and 35. For example, in Figure 1, the linear regression relationship corresponds to N=33.3. For the $L_{Aeq(period)}$ noise descriptor, a speed relationship of N = 20 is commonly applied.

There are a number of other sources associated with train operations which are unrelated to speed. Examples include freight locomotives where the noise emission levels are usually controlled by the engine notch setting, rather than the train speed. The noise emissions from refrigerated containers on freight wagons generate steady noise levels even when stationary. Other sources of noise such as curve squeal and wagon bunching (coupling noise) are also unrelated to speed.

Additional guidance relating to the variation in noise levels with speed is provided in the RND, including the potential influence on modelling accuracy of using alternative speed relationship assumptions.

When developing freight noise prediction models, train speed assumptions can have a remarkable influence on the overall noise predictions. If accurate noise level predictions are required, train speeds should be modelled on the basis of the actual train speeds, rather than the maximum design speeds. In many cases, train speeds will vary throughout the project area and may be different for express and stopping trains. As an example, in the Beecroft / Cheltenham area, freight train speeds ranging from 10 km/h up to 70 km/h were commonly observed [5].

In the case of L_{pAFmax} predictions based on the 'typical maximum' passby (95th percentile), it may be appropriate to model a different (higher) train speed than when predicting energy average levels ($L_{Aeq(period)}$) predictions. If the dominant source of noise is the locomotive engine / exhaust, then it is not necessarily conservative to assume a higher speed for $L_{Aeq(period)}$ predictions, since the locomotive noise then affects any single receiver for a shorter time. The sensitivity of the different model outputs (L_{pAFmax} and $L_{Aeq(period)}$) to speed assumptions should be tested when modelling rail freight noise.

Where the project includes existing operations, train speed information can be established via long-term monitoring or on-board speed data supplied by rail operators. For new train systems, train speed information can normally be generated on the basis of simulations undertaken by (or on behalf of) the rail operator.

Operating conditions

As the noise emissions associated with diesel locomotives are strongly influenced by load and the associated engine notch setting, noise levels can be highly dependent on the track grade. The RND includes data from sites with steep uphill grades, relatively flat grades and steep downhill grades. If operating conditions vary throughout the site being investigated, then the model assumptions will need to vary accordingly.

The location of signals both inside and outside the area of a noise model can affect the train operating conditions and noise levels. In some cases, operating conditions may be different in the daytime and night-time periods. For example, on a shared passenger and freight network where passenger trains have priority, freight trains may be required to stop at signals while awaiting a clear path. If the signal is inside the project area, this may introduce noise from idling locomotives. Even if the signal is outside the project area, a train that has stopped may subsequently accelerate through the project area, at an initially slower speed but higher notch setting than a train that was not required to stop at the signal. This means that during the night-time, typical freight operating conditions and speeds may be different to during the daytime.

Track conditions

The condition of the wheels and track are a key factor in the rolling noise emission level. In relation to the influence of freight wheel defects, the RND found a 12 dB difference in the measured LpAFmax,95% noise levels with and without wheel defects or other noise features, and a 7 dB difference in the measured logarithmic average LAeq(passby) noise level parameter. While wheel condition has an important influence on noise levels, it is factor across the rolling stock fleet. Rail roughness or track condition is a site-specific feature that affects the rolling noise level.

The influence of rail roughness is more important at sites where overall noise is dominated by rolling noise rather than by locomotive engine/exhaust noise. Therefore, if speeds are low at a particular site, then understanding the rail roughness is less important for freight noise modelling than if speeds are high, or if there is mixed electric passenger and freight traffic.

Roughness is commonly reported in spectral form, showing roughness level in decibels at different wavelengths. Figure 2 shows that absolute levels of rail roughness can vary significantly at different sites. However, at many individual locations rail roughness changes relatively slowly over time. For example, measurements on tangent track in Germany did not show a significant change in rail roughness over a two year period [6]. There is evidence that roughness increases gradually over time at some locations, and is relatively stable at others. Measurements taken in the ECRL [7] have shown that short wavelength roughness introduced by grinding decreased over five years of service.

Two situations when rail roughness changes rapidly rather than slowly are when rail grinding introduces a sudden change to a site, or at sites prone to corrugation. After maintenance rail grinding, rolling noise levels are often elevated until the roughness introduced by the grinding machine wears down. If "acoustic" rail grinding (rail polishing) is used the initial noise difference after grinding may be less noticeable, but there still may be subsequent changes over time.

Ultimately, the influence of track and wheel conditions at a particular site can only be determined by measurement at that site. While assumptions about typical rail roughness and wheel condition can be made on the basis of the RND, these assumptions must be validated by measurements specific to the site. If noise measurements indicate levels higher or lower than the RND at a particular location, then measuring rail roughness can help understand the reason for the difference. Asking the rail operator for information as to when tracks were last ground, what grinding process was used, and how frequently rail grinding occurs at a site is also recommended. Then, a judgement can be made as to whether the measured levels are likely to be typical or representative of that site.

Accuracy and availability of input data

The input data and information required to model freight noise is difficult to obtain. The answers to supposedly straightforward questions about train numbers and train speeds can be challenging to establish, yet these parameters are crucial in predicting the noise impact of a change in train numbers or operating conditions. The noise consultant should be prepared to question, interrogate and verify all data provided by others prior to developing a freight noise model.

Choice of software and rail noise standards

Often it is the scale of a project which dictates whether or not noise modelling software is required to undertake a detailed assessment of rail noise. Proprietary noise modelling software programs provide an efficient means of calculating noise levels in situations P54

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where there are a large number of receivers and/or where complex geometry is present between the railway line and sensitive receivers.

Software choice and verification

A number of noise modelling software applications and calculation standards are available for the prediction of railway noise. The choice of software and calculation standards can depend on a number of factors.

In many cases the calculation standard is determined by the railway operator or regulator. Examples include the Schall 03 prediction method in Germany (required by an official act of the federal government) and Harmonoise (required by European Member states to produce environmental noise maps). The use of standard prediction methods and/or modelling software can be advantageous where a rail operator requires information to be presented in a consistent format or where large-scale mapping of a rail network is undertaken.

Local noise regulations may also limit the number of prediction methods that can be used. For example, in NSW, current noise modelling requirements documented in the EPA's Rail Infrastructure Noise Guideline (RING) [8] require an assessment of the maximum noise level (L_{pAFmax}) as well as the energy average noise level ($L_{Aeq(period)}$) during the daytime and night-time periods. There are only a small number of prediction methods available which allow the prediction of the L_{pAFmax}.

Another major factor is the noise modelling software utilised by the acoustic consultant. The investment associated with the capital cost of the noise modelling software, annual maintenance fees and staff training can be significant and it may be cost-prohibitive for a consultancy to operate more than one environmental noise prediction software package.

Whatever software program or calculation algorithm is adopted, the consultant will need to verify that the software is implementing the relevant calculation standards as expected. This model verification process is different to a model validation (which involves comparison of model outputs with measurements). Model verification is required to ensure that the software is giving "the right answer" – that there are no bugs or coding errors.

According to ISO 14837-2:2005 [1], verification is the process of confirming that the mathematical elements of the model are behaving as intended. This will usually involve the testing of all aspects of the noise model predictions, undertaking representative hand calculations and comparing these with the output of the noise model to verify the accuracy of the prediction results.

For rail noise models, all key parameters influencing the predicted levels should be verified. This will include speed dependence, train length, distance attenuation, source corrections, number of trains in assessment period, weather conditions, facade corrections, noise barrier attenuation and reflections. Verification is required when software is initially chosen, and when new software versions are introduced.

NSW requirements

Within NSW, the assessment of airborne noise associated with new and upgraded railway lines is required to be undertaken in accordance with the RING. Two assessment parameters are required to be considered as part of the noise impact assessment. These are the $L_{Aeq(period)}$ (described as the level of average noise energy during the relevant time period) and the $L_{pAFmax,95\%}$ (described as the maximum noise level not exceeded by 95% of individual train passby events).

The $L_{Aeq(period)}$ and L_{pAFmax} noise assessment parameters form part of the noise limit requirements in the Australian Rail Track Corporation (ARTC) and Sydney Trains Environment Protection Licences. Further, the LAeq(period) noise assessment parameter forms part of the internal noise level requirements in Clause 87 of the *State Environmental Planning Policy (Infrastructure)* 2007 (the 'Infrastructure SEPP') [9] and the *Development Near Rail Corridors and Busy Roads – Interim Guideline* [10].

Appendix 8 of the RING provides guidance in relation to prediction models for airborne noise and notes the following:

"Several models are available for predicting airborne noise levels at receptors as a result of railway operations. They include the Nordic Rail Prediction Method, Schall 03 (German), OAL30 (Austrian) and Calculation of Railway Noise (United Kingdom).

All models can calculate the L_{Aeq} level. The Nordic model calculates L_{Amax} in addition to L_{Aeq} and may be advantageous to use. Each model has been essentially developed on the basis of the country of origin's own measurement data on its rolling stock fleet. So there are differences in the propagation calculations between models. It is therefore important that the model or procedure chosen is validated for the project prior to local use."

In relation to the above, it is noted that across Europe and North America, the $L_{Aeq(period)}$ noise descriptor (over the relevant daytime, evening or night-time periods), is the primary parameter used for the assessment of railway noise. On this basis, several noise modelling algorithms have been developed to enable predictions of the $L_{Aeq(period)}$ noise levels. On the other hand, rail noise assessment on the basis of the L_{pAFmax} parameter is less common, being adopted in Scandinavia, Asia and most of Australia (excluding Western Australia).

Since it is cost efficient to construct a single noise model which predicts the L_{pAFmax} and $L_{Aeq(period)}$ noise levels, the majority of railway noise prediction modelling in NSW has historically been undertaken using the Nordic Rail Prediction Method [11]. In Queensland, the Nordic Rail Prediction Method is the rail noise modelling algorithm and Queensland Rail (QR) requires consultants to use the version implemented by SoundPLAN V6.5 [12].

The Nordic Rail Prediction Method allows the calculation of the L_{pAFmax} in addition to the $L_{Aeq(24hour)}$. Formulae relating to the Nordic Rail Prediction Method are provided in Kilde Report 130 [11] and Appendix B of the RND.

In relation to the reference noise levels which form the start of the noise emission calculations, these are based on typical train operations in Scandinavia (circa 1980). For train operations in NSW, corrections to the standard source noise levels (whichever noise modelling software or calculation algorithms are used) will be required to accurately reflect the rolling stock and operating conditions within the project area. Validation of the source level corrections should be undertaken to confirm that the calculated noise levels at a receiver 15 m from the track centerline (1.5 m above ground on at-grade track) are consistent with the reference noise levels in the RND for a train speed of 80 km/h.

Rail noise assessment settings

Specialist noise modelling software packages include a number of settings which can influence the speed and accuracy of the noise level predictions. Parameters which can influence the calculation speed include the accuracy of the ground topography, the number of reflections and, in the case of noise contour plots, the grid spacing (number of calculation points).

As described in Section 2, the level of detail in the noise modelling (and associated accuracy) will depend on the stage of the project. At the early stages of a rail noise assessment, it may be acceptable to undertake noise contour modelling on the basis of 1 m ground terrain information and a 10 m grid spacing. These calculations may be undertaken in order to identify potential hot-spot locations for a large-scale project.

Where more detailed information is required, noise contour modelling based on 0.5 m ground terrain information and a 5 m grid may be required, supplemented by external point receiver calculations on all levels of each sensitive building.

To ensure that the trade-off between improved modelling accuracy and calculation time is acceptable, a sensitivity analysis of the calculation settings must be undertaken. All relevant calculation settings and input parameters should be validated to confirm that the potential error in the calculation results is within the required range. ◘

This paper first appeared in Acoustics Australia and is reproduced with the kind permission of the authors and publisher. Part two will appear in the next issue. It will cover geometry and terrain modelling, rail noise sources, establishing scenarios and naming convention, checking and review procedures, model validation and compliance measurements and summary.

AcSoft opens acoustic calibration laboratory

AcSoft has opened an acoustic calibration laboratory at its new office in Bedford.

With the first phase of the facility fully operational, the company is now able to offer on-site calibration of its G.R.A.S measurement microphones and pre-amplifiers, as well as perform diagnostics and repairs.

AcSoft has appointed acoustics specialist Alejandro (Alex) Santana to head up the new facility.

Paul Rubens, AcSoft General Manager, said: "We have replicated the excellent calibration set up of G.R.A.S Sound & Vibration in Denmark. Having a dedicated in-house acoustic calibration laboratory backed by Alex's expertise and passion means we can offer market-leading turnaround times and a cost effective service.

"Going forward, we will be expanding the laboratory's capabilities to include accelerometers and a wide range of sound level meters, analysers and dosimeters."

For further information contact Emily Norman at **01234 639550** or go to **www.acsoft.co.uk**

Paul Rubens

Brüel & Kjær provides Heathrow with 50 noise monitors

Brüel & Kjær has supplied Heathrow Airport with50 noise monitors to help with its noise abatement programme.

A mix of permanent and portable terminals are providing unattended sound level monitoring to record, process, store and transmit noise data to the airport's noise and operations management system, ANOMS.

The portable terminals will be used to deliver continuous noise monitoring for shorter-term projects. Both types are specifically designed for continuous outdoor use.

Matt Gorman, Heathrow Director of Sustainability and Environment, said: "These monitors will allow Heathrow and local residents to better understand the impact of aircraft noise in local areas. New monitors, along with other noise reduction steps, like fitting quiet technology to A320s and establishing a voluntary Quiet Night Charter, will help us be a better neighbour to our communities."

Noise monitoring in action

BSRIA to provide acoustic testing on new home builds

BSRIA has agreed to supply all on-site acoustic testing to National House-Building Council (NHBC) clients.

In addition to acoustics, BSRIA can supply Part F ventilation testing during the same site visit or Part L airtightness testing for residential areas and non-residential properties.

Chris Knights, BSRIA Compliance Manager, said: "We are pleased to be forming a closer association with NHBC as we see this arrangement as a perfect fit for BSRIA, NHBC and developers."

Mark Gouldstone, NHBC Product Manager, said: "This partnership will benefit the UK's housebuilders and forms a key element of NHBC's Consultancy and Testing Services."

Armstrong ceiling and wall systems feature in flagship building

Ceiling and wall systems by Armstrong were supplied for an award-winning office building at the heart of one of the largest regeneration projects in the UK.

Armstrong's R-H 200 standard perforated metal hook-on planks with acoustic inlay within a concealed grid, were specified by Falconer Chester Hall Architects for the feature ceiling of the atrium of the £11.4 million Kingsgate building at Birkenhead in Wirral Waters.

They are complemented by Armstrong's W-H 1000 standard perforated metal wall system on the four-storey walls, hooked on in a vertical brickwork pattern to match the ceiling.

The metal tiles in the atrium are complemented by Ultima+ OP Tegular mineral tiles and Ultima+ SL2 planks in the open-plan offices and circulation areas. This ceiling system (and the suspension grid too) is Cradle to Cradle (C2C) certified in line with Kingsgate's BREEAM "Excellent" rating.

Manufactured with up to 64% recycled content, the Ultima+ range is available in three core densities that allow specifiers to engineer sound absorption and attenuation for optimum acoustic performance – standard Ultima+ giving medium density, Ultima+ OP giving low density (both of these variables were used at Kingsgate) and Ultima+ dB giving high density, up to 41 dB.

Part of the Kingsgate building

Chris hits the right note at city centre outdoor concert

How do you stage a big open air concert in the heart of an ancient city while minimising the disturbance to nearby residents?

This was the challenge facing acoustic consultant Chris Selkirk when he was charged with monitoring sound levels at the Hacienda Classical in Lancaster.

Featuring a 40-strong classical orchestra playing to more than 3,000 people, the event was staged in the city's Williamson Park, which has 10,000 homes within a one kilometre radius.

With the help of an Invictus outdoor noise monitor, stationed on site in advance of the concert, and holding an Optimus sound level meter, Chris was free to roam the main "hot spots" that had been identified during the sound check.

"The kit allows me to get readings from multiple locations but also to sign in the sound engineer so he can see the live real time data coming through – it adds to that extra measure of control," he said.

Sounds good: the Hacienda Classical event

School tiles aim to be 'top the class'

The new Burry Port Community School

Troldekt tiles were specified at the first Passivhaus school in Wales, Burry Port Community School.

A design collaboration between Carmarthenshire County Council and Architype architects, the project has united the town's infant and junior schools, accommodating 210 pupils and a 30-space nursery class.

The original school building has been refurbished, while the extended block accommodates four new classrooms, as well as two further teaching spaces, staff and meeting room facilities.

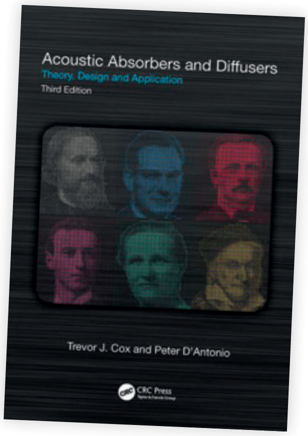
The Troldekt tiles contain 100% natural wood fibres, which boast high sound absorption, high durability, natural breathability, low cost life cycle performance and sustainability documented by Cradle to Cradle certification at silver level.

For more information ring **01978 664255** or visit **www@troldtekt.co.uk**

Acoustic Absorbers and Diffusers Theory, Design and Application Third Edition

By Trevor J Cox and Peter D'Antonio

Review by Mark Howarth of Sandy Brown Associates



Published by CRC Press 2016
ISBN: 9781498740999
https://www.crcpress.com

This is the third edition of the well-regarded reference on absorbers and diffusers. For those who already have an earlier edition, it incorporates significant updates throughout to reflect developments in the field. These include comments on the environmental impact of different acoustic treatments, addition of new products, developments in modelling techniques, and references to new measurement standards.

The section on environmental impact provides commentary on the sustainability of materials used for acoustic treatments. Absorption coefficients are also provided for porous absorbers using natural fibres, green wall systems and vegetation.

Comments on new products include an assessment of the efficacy of "portable vocal booths" used in studios, however, the recent development of inflatable bass absorbers is only mentioned with a brief reference in chapter seven which could have been expanded upon based on available test data and recent applications.

New prediction models are provided for porous absorbers; for reflection modelling using a rewritten Finite Difference Time Domain method; and for diffuser prediction using a time-based Kirchoff solution. MATLAB scripts are added for many of the methods provided in the book.

The book is structured to provide introductions to materials, types and applications of absorbers and diffusers in the first three chapters. Measurement of absorption and reflections (scattering and diffusion) are discussed in chapters four and five. Comments on the poor reproducibility of sound absorption tests between laboratories with reference to round robin tests are sobering reading for anyone advising on the acoustic design of critical listening spaces.

Chapters six and seven provide more detailed comments and analysis of porous and resonant absorbers respectively, while chapter eight discusses absorption and diffusion from other elements, such as seating and vegetation. Chapter nine provides various calculation techniques for predicting scattering of reflections. These are subsequently referenced in analyses of different types of diffusers and hybrid absorbing-diffusers. A guide to the limitations of using absorption, scattering and diffusion coefficients in geometric room acoustic modelling is provided in the penultimate chapter. This has been updated to remove results from models that are no longer in common use. The book ends with a discussion on the use of active elements to achieve sound absorption.

Each chapter is well presented with an accessible style explaining the physics of treatments qualitatively followed by more detailed mathematical modelling techniques. This provides the reader with an understanding of the principles without needing to delve into the modelling.

Overall this is recommended as an excellent reference for researchers and practitioners, particularly those involved in the design of critical listening spaces or acoustic treatments. For those who have copies of previous editions, the updates in this edition are significant enough to recommend purchasing it.

Obituary

Mike Wilson (1949-2016): Distinguished lecturer and research fellow with a great gift for friendship

By Bob Peters, Graham Phillips, John Seller and John Shelton

Mike Wilson was born in Hull but his parents soon moved to south London where Mike went to St Dunstan's School in Catford and then to Cambridge to read natural science and chemical engineering. After attending teacher training college Mike started his academic career as a lecturer in building and environmental science at Tottenham College. The IOA Diploma started in 1978 and within a couple of years Mike and John Seller ran the Diploma course at Tottenham. During this period Mike sat on the IOA Education Committee and served as specialist module examiner for the architectural acoustics module, and his exam questions often reflected his consultancy experience whilst working at Tottenham. Also whilst at Tottenham he studied (on a part time basis) at University College London, for an MSc in environmental engineering and design. In due course he also became a Chartered Engineer, and a member of CIBSE and the Society of Light and Lighting. He was also Secretary and then Chairman of the National Association of Building Science Teachers, a good practice exchange between colleges, polytechnics, universities and BRE.

In 1987 he left Tottenham to become Senior Lecturer in architectural environmental science in the University of North London (now London Metropolitan University). There he remained for 23 years during which time he was promoted to Reader and then Professor.

At London Met Mike's teaching, consultancy and research interests widened from acoustics to all aspects of the science of the built environment and in particular to lighting design and daylighting, integrated environmental design and the science of low energy buildings. He was co-founder of the Low Energy Architecture Research Unit (LEARN) which attracted many research contracts throughout Europe. He developed the MSc in architecture, energy and sustainability at London Met, with, of course, an acoustics content.

Mike Wilson (1949-2016)

During this part of his career Mike's multi-disciplinary activities work continued to have a significant acoustics content, and he contributed papers to IOA meetings on topics such as: acoustic problems in passive solar design; background noise levels in naturally ventilated buildings; studies of the links between thermal and acoustic comfort in buildings and possible adaptive acoustic comfort standards for noise levels in buildings; studies on the effects of traffic density, street width and aspect ratio on traffic noise levels at different heights in "acoustic canyons" in Athens; and his PhD students conducted studies into assessment and control of environmental noise levels from weddings in Algeria, and on aircraft noise, overheating and poor air quality in classrooms in London primary schools.

In 2010 Mike retired from London Met and worked on part time basis for the University of Westminster as Principal Research Fellow in the School of Architecture and Built Environment, and helped launch their MSc in architecture and environmental design.

Mike's health began to decline in 2014, and after periods in hospital he returned home to be with his wife, Helen, and children, John and Emma. He died peacefully at home in Mortlake on 6 September 2016.

Mike was a great communicator and a very outgoing and sociable person and his natural networking skills helped him to develop research contacts through the world. He loved good food, fine wine and foreign travel and it probably not a coincidence that many of his research contracts were in southern Europe. Those who knew Mike will remember him as a person who always enjoyed meeting people and talking over a drink and a meal – his LEARN Christmas lunches were renowned, and his wedding to Helen in Florence and the celebrations afterwards will long be remembered by his many friends who attended.

He will be much missed, both professionally and personally by those who knew him.

Jordi Femenia to spearhead Christie & Grey acoustics drive

Jordi Femenia has been appointed by noise and vibration control specialist Christie & Grey to lead and develop its construction and building acoustics products. He has worked previously on a wide range of projects in Spain and the UK, mainly focussed on the noise and vibration control sector.

Patrick Bergin, Vice President of Engineering, said he saw his appointment as sales/contracts engineer as an important addition to the company in a vital role.

"He will be the point of contact with customers and consultants alike, bringing his enthusiasm, knowledge and experience to our growing company," he said.

Patrick Bergin (left) welcomes Jordi Femenia

Shakin' all over – the new V8900 from Brüel & Kjær

Brüel & Kjær has launched new 80 kN shaker – the V8900.

This is the first air-cooled shaker to combine performance and power, traditionally found in water-cooled shakers, with user-friendly operation, reduced maintenance and low running costs typically found in air-cooled systems.

Shakers are used in a range of applications to test equipment and machines for integrity and durability, ensuring the product can withstand the demanding conditions of the real world.

The V8900 will provide industrial, automotive and aerospace industries with, it says, outstanding performance in several key areas:

- 80 kN sine force for cost-effective testing of complex and heavy payloads
- 3 kNm overturning moment, reducing the need for guided head expanders
- 3 kHz frequency for testing smaller payloads
- 101.6 mm (4 inch) displacement and high velocity combined enhances shock and random test performance.

The shaker has been designed with a high overturning moment, giving it stability when testing irregular and unbalanced payloads, without the need for guided head expanders or intricate mounting assemblies.

For more information visit **www.bksv.com/V8900**

The new V8900 shaker

Good vibrations as B&K launch new vibration monitoring terminal

The new vibration monitoring terminal type 3680

Brüel & Kjær has launched its new vibration monitoring terminal type 3680.

The device enables users to:

- Protect against structural damage risks in construction and mining
- Assess human response to ground-borne vibration from road and rail traffic
- Monitor background vibration to ensure sensitive equipment operates correctly.

The unit provides uninterrupted, tri-axial, real-time ground vibration measurement to help avoid harming buildings. It automatically delivers alerts to avoid breeching set limits and provides reports proving regulatory compliance.

It also assesses vibration impact from traffic. It enables users to conduct background surveys prior to new construction, as well as receive accurate data to evaluate vibration mitigation techniques.

In addition, the system monitors background vibration for organisations such as hospitals, semiconductor manufacturing plants and museums. It helps ensure patient comfort at medical facilities, trusted monitoring of delicate equipment to avoid errors and reduced risk of artefact damage.

It operates stand-alone or with Sentinel for comprehensive, multi-location, vibration compliance monitoring.

Standalone devices come with a smartphone app enabling setup, remote display and operation from anywhere and data transfer to standard post-processing applications.

More information can be found at **http://www.bksv.com/VMT**

AcSoft adds BeanAir wireless sensor technology to portfolio

AcSoft has added turnkey wireless sensor networks (WSN) from Germany-based BeanAir to its portfolio.

The BeanAir Gateway

An alternative to wired sensor networks, BeanAir offers test and time-synchronised, embedded measurement across a wide range of industrial applications, including automotive, railway, aeronautic and naval.

BeanAir can be used for tests on raceway and dirt track, wind tunnel testing, vibration monitoring on train wheels, fault detection, comfort measurement, flight test measurement and underwater test benching.

Other BeanAir applications include structural health monitoring, technical building management, environmental monitoring and condition monitoring.

BeanAir has recently introduced a series of miniaturised wireless sensors with IP66/IP67 rating and 200G shock resistance making them suited to the harsh environments that were previously inaccessible by wired sensors.

BeanAir's concept is based on antenna diversity allowing the optimisation of radio link quality in environments subject to random and diverse disturbance.

For more information contact Paul Rubens on **01234 639550** or visit **www.acsoft.co.uk**

Latest smart vibration monitoring terminal from 01dB

01dB has launched Orion, a smart vibration monitoring terminal.

It has been designed to monitor for all standard and advanced vibration scenarios, from quarrying and construction sites to sensitive machinery or sensitive premises. It is designed to meet the requirements of BS 5228 and BS 7385 with inbuilt tolerance curves and direct measurement of PPV, PCPV, PVS and dominant frequency.

It can also be used to measuring the effects of vibration on human comfort with direct VDV measurements to BS 6472 in parallel with PPV measurements to BS 5228 with one integrated sensor.

Features include:

- VDV, PPV, PCPV, PVS and Dominant Frequency measured simultaneously
- Standards based with built in tolerance curves
- Built-in tri-axial accelerometer
- 3G modem, Wi-Fi and GPS
- Fully waterproof
- Can be mounted horizontally or vertically
- Additional three external channels and one air overpressure channel
- Real time resolution of one second for detailed time histories
- Auto storage of velocity signal and raw acceleration signal
- Log in with any web browser to view real time data and stored results
- Post process acceleration signal for broadband criterion, 1/1 to 1/48 octave & narrow band FFT with the new dBTRAIT Vibration Expert software.

Orion is fully web-enabled and integrated into the 01dB web monitoring platform

For further information call Stephen Thomas on **01550 77925**, **e-mail sales@acoustic1.co.uk** or visit **www.acoustic1.co.uk**

The Orion

New version of Echo Barrier H20 acoustic enclosure

Echo Barrier has launched a new version of the H20 acoustic enclosure.

Feedback from contractors and users indicated that they often needed a mobile noise enclosure with a roof design that allowed for the easy use of larger breakers. As a result of this feedback, the updated H20 enclosure now not only includes a roof but also a window for improved visibility.

The window has been included to improve the safety of those who are lone working inside the tent, allowing them to see out and colleagues to see in. The new roof has been designed to assist those using breakers or other machinery, as the standard roof was proving tricky to manoeuvre inside.

The standard H20 will continue to be available alongside the new and improved version.

The new H20 acoustic enclosure

Cirrus launches wireless App for its doseBadge5

Cirrus Research has launched a new wireless App to enhance the features of its latest personal dosimeter, the doseBadge5.

The doseBadge5 has now enhanced wireless technology to allow the instrument to communicate remotely with the doseBadge5 Wand and the dBLink App.

The doseBadge5 Wand allows instruments to be started and stopped without disturbing the wearer and view measurement information via a mobile phone or IOS or Android controlled device.

If the doseBadge5 is running, the current measurement information can be display, allowing mid-shift readings to be obtained. If stopped, the doseBadge5, any stored measurements can still be reviewed.

The dBLink App for Android allows the doseBadge5 units to be configured, measurement information viewed and measurements started and stopped.

Full configuration of the instruments can also be carried out through the App including the set-up of integrators and measurement timers.

The doseBadge5 has a wide range of new USPs including data-logging facilities that can be specified down to the second, rather than the previous one-minute window.

It also has intelligent charging with the device controlling its own charger to combat overcharging so it can prolong battery life to more than 12 hours, and includes an anti-tamper and vibration device to cut down on anomalies.

The dose Badge5 offering

ICSV24
LONDON CALLING

24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION

23–27 July 2017, London

The International Institute of Acoustics and Vibration (IIAV) and the UK's Institute of Acoustics are pleased to invite scientists and engineers from all over the world to attend the 24th International Congress on Sound and Vibration (ICSV24) to be held in London from 23 – 27 July 2017.

This congress is a leading event in the area of acoustics and vibration and provides an important opportunity for scientists and engineers to share their latest research results and exchange ideas on theories, technologies and applications in these fields.

The congress will feature a broad range of high-level technical papers from across the world: distinguished plenary lectures will present recent developments in important topics of sound and vibration and include discussions about future trends.

THE CONGRESS VENUE: PARK PLAZA WESTMINSTER BRIDGE HOTEL, LONDON

London is an exciting, dynamic and welcoming destination. The congress venue, the grand Park Plaza Westminster Bridge Hotel, is ideally situated on the vibrant South Bank in the heart of London overlooking the River Thames with views across to Big Ben.

FOR MORE INFORMATION, VISIT:
WWW.ICSV24.ORG

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Jens Blauert Emeritus professor, Ruhr-Universität Bochum, Germany
Reading the World with Two Ears

Eric J Heller Professor, Physics and Chemistry, Harvard University USA
The Miracle of Resonance and Formants

Haiyan Hu Professor, President and Vice Chairman of the University Council, Beijing Institute of Technology, China
Advances in Flutter Analysis and Control of Aircraft Structures

Timothy Leighton Professor, Engineering and the Environment, University of Southampton, UK
Climate Change, Dolphins, Spaceships and Antimicrobial Resistance – the Impact of Bubble Acoustics

Andrei Metrikine Professor, Civil Engineering & Geoscience, Delft University of Technology, The Netherlands
Nonlinear Dynamics of Offshore Structures Subject to Marine Currents and Level Ice

Jérémie Voix Dr. Research Chair in Ear Technologies, École de technologie supérieure, Canada
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Committee meetings 2016/17

DAY	DATE	TIME	MEETING
Tuesday	8 November	10.30	ASBA Examiners (Edinburgh)
Tuesday	8 November	1.30	ASBA Committee (Edinburgh)
Tuesday	15 November	10.30	Executive
Tuesday	**6 December**	**10.30**	**Council**
Thursday	12 January	11.30	Meetings
Thursday	19 January	10.30	Membership
Thursday	02 February	11.00	Publications
Thursday	02 March	10.30	Diploma Tutors and Examiners
Thursday	02 March	1.30	Education
Tuesday	07 March	10.30	Diploma Examiners (London)
Wednesday	09 March	10.30	Medals & Awards
Wednesday	09 March	10.30	Executive
Wednesday	**22 March**	**10.30**	**Council**
Tuesday	28 March	11.30	Meetings
Wednesday	05 April	11.00	Research Co-ordination
Tuesday	11 April	10.30	CCWPNA Examiners
Tuesday	11 April	1.30	CCWPNA Committee
Thursday	27 April	10.30	Membership
Thursday	11 May	11.00	Publications
Thursday	18 May	10.30	CCHAV Examiners
Thursday	18 May	1.30	CCHAV Committee
Wednesday	24 May	10.30	Executive
Wednesday	**14 June**	**10.30**	**Council**
Tuesday	20 June	10.30	CCENM Examiners
Tuesday	20 June	1.30	CCENM Committee
Tuesday	20 June	10.30	CCBAM
Wednesday	21 June	10.30	Distance Learning Tutors WG
Wednesday	21 June	1.30	Education
Tuesday	27 June	10.30	ASBA (Edinburgh)
Thursday	06 July	11.30	Meetings
Thursday	03 August	10.30	Diploma Moderators Meeting
Thursday	10 August	10.30	Membership
Wednesday	13 September	10.30	Executive
Thursday	21 September	10.30	Engineering Division
Monday	25 September	11.00	Research Co-ordination
Wednesday	**27 September**	**10.30**	**Council**
Thursday	12 October	11.30	Meetings
Thursday	19 October	11.00	Publications
Thursday	02 November	10.30	Membership
Tuesday	21 November	10.30	CCWPNA Examiners
Tuesday	21 November	1.30	CCWPNA Committee
Wednesday	22 November	10.30	Diploma Tutors and Examiners
Wednesday	22 November	1.30	Education
Thursday	23 November	10.30	CCENM Examiners
Thursday	23 November	1.30	CCENM Committee
Thursday	23 November	10.30	CCBAM Examiners
Tuesday	28 November	10.30	ASBA Examiners (Edinburgh)
Tuesday	28 November	1.30	ASBA Committee (Edinburgh)
Wednesday	29 November	10.30	Executive
Wednesday	**13 December**	**10.30**	**Council**

Refreshments will be served after or before all meetings. In order to facilitate the catering arrangements it would be appreciated if those members unable to attend meetings would send apologies at least 24 hours before the meeting.

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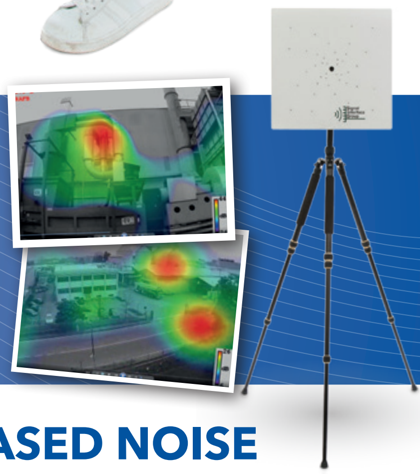

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