Vol 42 No 2 March/April 2017

ACOUSTICS
BULLETIN

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The assessment of noise from construction of offshore renewable energy infrastructure

Predicting noise behaviour in building acoustics – a case study example

Institute of **Acoustics**

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Front cover photograph:
Mark Dodd gives the Peter Barnett Memorial Award lecture at Reproduced Sound

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 2017

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

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

21-23 November
Organised by the Electroacoustics Group
Reproduced Sound 2017
Nottingham

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

Dear Members

Mrs May's worker bees in the Department of Business, Energy and Industrial Strategy have been busy setting out the government's vision for the post Brexit UK. The UK education and industry sectors currently have much to think about, with the government's Green Paper *Building Our Industrial Strategy* being published for consultation, while the Higher Education and Research Bill (the Bill) has progressed to the House of Lords select committee stage. Both of these have the potential to influence the future of the acoustics profession – how we learn, research, and develop ideas into real products and services.

The Bill is perhaps most likely to have come to members' attention because it seeks to replace the current research councils with a single body. Universities UK (UUK) is the organisation which represents universities and provides a unified campaigning voice for the sector. UUK is concerned that the Bill, if passed as it currently stands, could affect the freedom of universities to determine their curricula and the standards expected. They are supporting a number of amendments to the Bill, to ensure "standards are clearly defined in the new framework, in a way which protects the principles of a high quality, autonomous sector".

The industrial strategy Green Paper seeks views on 10 pillars for the industrial strategy. The first concerns *Investing in science, research and innovation*, stating that we must become a more innovative economy and do more to commercialise our world-leading science base to drive growth. The pillar on *Developing skills* ties in with the Institute's interest in developing an apprentice route into acoustics – it calls for a new system of technical education to benefit those who do not go to university. It also identifies a need to boost STEM (science, technology, engineering and maths) skills, which could help increase the pool of potential acousticians.

The pillar on *Cultivating world-leading sectors* gave me pause for thought. This states that the UK must build on areas of competitive advantage, help new sectors to flourish, and challenge "existing institutions and incumbents". What parts of acoustics are out there which might fall into this category and how do we encourage our research institutes to find and investigate them? Should we as an Institute help industry to access research findings so that they can exploit them, and how would we go about that? What should we challenge and by doing so what positive outcome do we seek? We seem to live in a time dominated by questions; as a community of technicians, scientists and engineers we are well placed to assist in finding answers, albeit we may need a funding stream to help. UK government investment in research is consistently lower than the OECD average. The Green Paper states that it is likely that there would be increased funding for research, and commercial development and exploitation of ideas – around a 20% increase. If we're going to meet the government's stated aims, EU funding, from which the UK has benefitted by £1 billion a year, will need to be replaced and added to.

As a strategic piece, the Green Paper has the potential to offer much to our profession. Perhaps, if the political will is there, and is backed by the necessary funding and encouragement, we could see positive change. As an Institute we should engage, where appropriate, and lend our skills to encourage positive change. To that end we will prepare a response to the consultation; please send any contributions you would like to make to the Institute Head Office by the end of March. I would also encourage members to respond to the consultation as individuals, and ask their employers to join in the process by putting forward their own ideas (https://beisgovuk.citizenspace.com/strategy/industrial-strategy).

Jo

Jo Webb, President

Reproduced Sound 2016: 'very busy and intensive programme'

Full conference round-up

By Bob Walker

Reproduced Sound 2016, organised by the Electroacoustics Group, was held on 16-17 November, with informal demonstrations on the evening of the 15th to allow delegates to "meet and greet". There were also visits to Southampton Solent University on the 17th and to the Institute of Sound and Vibration Research (ISVR) at the University of Southampton on the 18th. This year the conference was held in a new venue, the Holiday Inn, Southampton.

The Institute's thanks and appreciation go to Keith Holland for chairing the organising committee, to all committee members for their contributions and to Linda Canty, the event organiser. Thanks also go to the hotel staff, always friendly, helpful and co-operative, for ensuring the smooth running of the conference. And finally they must go to the many staff and students of the two universities who went out of their way to present their work and facilities in an informative and friendly manner.

The meeting room had been equipped with an advanced audio-visual system. This had been organised and managed by John Taylor of d&b audiotechnik, assisted by Hansa Metger, and student volunteer, Jamie Scanlan. The organising committee gratefully acknowledges the effort put in by many people in arranging, setting up and managing the technical support. Thanks also go to d&b audiotechnik for the use of their equipment, including the audio system, the large screen and the projector.

The contributions of the exhibitors to the success of the conference are also gratefully acknowledged. Several exhibitors also included sponsorship as part of their exhibition package. Those were valuable and much-appreciated contributions to the conference budget.

The conference meeting room was also used for the conference dinner. The venue facilities fitted the conference requirements well, with a private bar and lounge providing space for informal evening breaks.

The conference theme continued from previous years with its focus on developments in spatial acoustics, electroacoustics, room acoustics and intelligibility. This year the main focus was intended to be the relationship between audio and video, as suggested in the conference sub-title *Sound with pictures – time is of the essence.*

In addition to the Peter Barnett Memorial Award paper, 23 technical papers were presented in eight sessions. This made for a very busy and intensive main programme, fully occupying both days from 9am until 6pm. There were also two poster presentations.

The conference was well attended, with 97 registered delegates, of whom 22 were registered as students and five exhibitors. The committee was again pleased to see a number of new faces.

The delegates certainly appeared to have had an enjoyable and worthwhile conference. Overall, the organising committee was very satisfied with the response to the programme and the smooth running and friendly atmosphere. The 2017 event is planned for 22-23 November, with the usual preliminary gathering on the 21st. It will be held at the Nottingham Conference Centre and is set to include a visit to the University of Derby.

The conference programme

The programme began on the 14th with an evening workshop and


Keith Holland opens the conference


Mark Dodd


Raising a point from the floor


Sarah Wakely receives the IOA Diploma prize from Jo Webb

discussion entitled *Workshop on 3D audio and sound field control.* Marcos F Simón Gálvez of ISVR had set up a demonstration of their binaural presentation over loudspeakers using a line array of 28 small loudspeakers. The system also used a small camera and video image tracking to "steer" the response towards the listener's position. There was a lively discussion amongst the 40 or so delegates present, with much audience participation. Marcos and his colleagues had put a great deal of effort into setting up the equipment and making the presentation, which was much appreciated by those present.

The second part of the workshop consisted of a demonstration of binaural object localisation with headphones presented by Dylan Menzies-Gow, also of ISVR. The system included sound source localisation by intensity panning and head orientation compensation using a head-tracking helmet. The whole session was very successful, with many staying late taking turns with the headset.

The effort put into these sessions by Marcos and Dylan and their colleagues was greatly appreciated and the committee thanks them for it.

Following the demonstrations, James Allen representing the IOA Young Members' Group invited the younger delegates to an informal gathering in the bar.

The conference was formally opened on the 16th by Keith Holland, who presented a brief history of Reproduced Sound and noted the opportunities offered by the conferences for networking. He welcomed the delegates to the venue and said that the conference had been well supported, with many papers submitted and good attendance numbers.

The welcome address was followed by the presentation of the Peter Barnett Memorial Award to Mark Dodd (GP Acoustics (UK) (see page 22). That was followed by the remaining technical sessions of the day. Thanks go to Chris Barlow of Southampton Solent University for recording the award lecture for YouTube.

After the day's sessions, the Electroacoustics Group AGM was held. This was followed after a short break by a reception and the conference dinner.

After the dinner, the Institute President Jo Webb presented the Institute's annual prize for the best student in the 2014-15 Institute Diploma to Sarah Wakely of Basildon Borough Council. Her project entitled *Railway noise – comparison of predicted and measured noise levels and its subsequent effect on health* was also presented at the conference as a poster.

After Keith had thanked everyone involved in the conference organisation Bruce Wiggins (University of Derby) presented a talk entitled *Head tracked audio for all – the 3D audio VR revolution* in which he discussed the technologies involved in 3D audio production for VR using head-tracked binaural decoding. He began with a review of how YouTube, Facebook and similar applications had resulted in a resurgence of interest in immersive sound, and especially ambisonics.

The second day started with further technical sessions which continued until the last paper of the conference. That was followed by the visit to Southampton Solent University where delegates were shown the facilities, especially those for the media courses. They were then treated to a full presentation of a recent release of an "action film" to demonstrate the impressive capabilities of the Dolby Atmos system.

The visit to ISVR included a tour of its many acoustic facilities, including the large anechoic chamber and the acoustic transmission suite and reverberation chambers. Of great interest was the large, hydraulically-controlled "shaking table" capable of supporting heavy objects, including large fractions of motor cars, and shaking them at frequencies of up to 50Hz. For many, if not most of, the visitors that was quite outside their normal experiences, and resulted in much interest and many questions for those giving the presentation.

Technical Sessions, 16 November

The day started with the presentation of the Peter Barnett Memorial Award to Mark Dodd by Institute President Jo Webb. The following lecture was entitled *Developments in wideband transducers and transducer arrays with single source characteristics.* In the lecture, Mark spoke about the long history of loudspeaker development and his own involvement. He suggested that simplifying the design always resulted in improvement of the sound and that A-B testing put too much emphasis on the technical P8


Bruce Wiggins


Wolfgang Ahnert


A session gets under way


Alistair Meachin (left) and Eric Magloire

◀ P7

aspects and tended to obscure subtle musical effects.

He reviewed in some detail the development of a successor to the well-known BBC LS3/5A. He continued by reviewing the development of a large compression driver with a much larger diaphragm than was usual and the efforts made to raise the fundamental resonance to at least the extreme upper end of the working range.

The lecture was followed by a substantial number of questions from the delegates. Sam Wise asked about durability and lifetime testing. The reply was that the solution was to use accelerated life tests and not to use problem materials. Keith Holland asked about metal fatigue. The answer was to keep deformations below the fatigue limit. Another question raised was on controlling the thickness of the metal deposition for the diaphragm. The reply was that it would be sufficiently rigid in use if it was strong enough to resist handling during assembly.

Session 1, PA systems: management and design
Chairman – Helen Goddard

Session 1 began with *Ultrasonic surveillance monitoring of PA systems - a safety feature or audible hazard?* by Peter Mapp (Peter Mapp Associates). The presentation discussed the implications of the current practice of using nominally inaudible monitoring signals to verify the continuing operation of audio alarm systems. These could be dc, very low frequency or ultrasonic. Each involved difficulties and lack of measurement precision, with very large scatters of results. A code of practice was required.

The session continued with *Stadium sound systems and FIFA regulations* by Wolfgang Ahnert (ADA Acoustics and Media Consultants, Germany). The paper described the history of stadium sound system development, beginning from 1904 up to the present. Not until 2006 was there any mention of FIFA standards and then it was only a single sentence. Only in 2011 were actual performance numbers introduced. The latest standards, for 2014, set numerical values that were clearly nonsensical. The audience reacted to the quoted numbers with mixtures of scepticism and derision.

The final paper of the session was *Specifying performance targets of acoustic enhancements systems* by Ron Bakker (Yamaha Commercial Audio Systems Europe, Germany). Ron presented a review of factors contributing to an overall impression of Basic Audio Quality. He described a system incorporating the enhancement, cinema and sound reinforcement systems into a single integrated system. The system was organised so that users could add their own input signals but were unable to alter the basic system parameters.

Session 2, Auralisation and 3D audio
Chairman – Robin Cross

After the lunch break, the programme continued with *Object* P10 ▶


Peter Mapp


Ron Bakker


Helen Goddard


Dylan Morgan


Gavin Kearney


Alexander Vikaitis

◀ P8

based spatial and audio technologies for live and entertainment by Wil Stam (Vanmunster BV/Astro Spatial Audio, The Netherlands). The presentation described the development of a Wave Field System to make it artistically and aesthetically acceptable in the marketplace, though without very much technical detail.

The next paper was R*oom acoustics and virtual reality: an implementation of auralisation and 360 degree image techniques to create virtual representations of spaces* by Alexander Vilkaitis, Mark Dring, Charles Middlicott, Bruce Wiggins and Adam Hill (University of Derby). The presentation was started by Mark, who described the concept of bringing together spatial audio and virtual reality using measured impulse responses. Alexander continued by describing how YouTube had simplified the implementation of binaural rendering using ambisonics and that a minimum of four channels was required. The presentation was followed by a large number of questions from the audience.

That was followed by *Multiple listening position evaluation of two-channel and three-channel OPSODIS with applications to virtual rendering of multi-channel surround sound* by Dylan Morgan, Takashi Takeuchi and Keith Holland (ISVR). The paper was presented by Dylan who described the development of a system for off-axis cancellation for multiple listeners. Experimental data was compared with the theoretical predictions. A three-way system had been developed and the plan was to continue the development of a four-way split.

The session was completed by Gavin Kearney (University of York) presenting *Auditory height perception in cross-talk cancellation using low order HRTF approximation*. The initial motivation had been the recognition that existing 5.1 systems were not very convenient domestically. Current systems using cross-talk cancellation and loudspeakers located close to the television screen relied on reduced-resolution impulse responses for speed and efficiency of calculation. The issues of height perception had not been investigated. The project objective was to investigate the potential order reductions in the context of height perception. The reduction methods assessed included IIR approximations to FIR responses, parameterisation of responses and binaural simplification using frequency bands. Only the first had been investigated in detail, so far. The presentation was followed by a number of questions and further discussions.

Session 3, Intelligibility
Chairman – Paul Malpas

The first paper of the session was *Investigations into the impact on STI of changes to the specified male speech spectrum* by Glenn Leembruggen, Jan Verhave, Peter Mapp, Stefan Feistal, Ludger Holzem, Hiroshi Sato, Thomas Steinbrecher, Sander van Wijngaarden and John Woodgate (STI Maintenance Team). The paper was presented by Glenn. He described the investigation of proposed changes to the low-frequency part of the test signal spectrum because the current test signal was very demanding for small transducers at low frequencies but their contribution to the overall result was small. The potential implications of a change had been exhaustively tested and assessed, with more than 1.6 million simulations. The work had resulted in a proposal for a revised spectrum, which has yet to be ratified.

The second paper of the session was *Turning up the background noise: the effects of salient non-speech audio elements on dialogue intelligibility in complex acoustic scenes* by Lauren Ward, Ben Shirley and William Davies (University of Salford). The paper was presented by Lauren, who began with a comment about the large numbers of hearing-impaired users. Significant improvements in word-recognition could result from the addition of context-sensitive non-speech effects. In a question, Glenn Leembruggen asked about the loudspeaker used and suggested that some of the improvement might have resulted from the use of a better loudspeaker. Lauren replied that future work might include the simulation of a more realistic test environment.

The final paper in the session was *Measuring the speech transmission index of systems featuring digital voice coding* by Jan Verhave, Margriet Vlot and Sander van Wijngaarden (Embedded Acoustics, The Netherlands). The paper was presented by P12 ▶


Mark Dring


Glen Leembruggen


Bjorn van Munster


Lauren Ward


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◄P10

Sander. He began with an outline of the problem of current test signals not being transmitted by digital vocoder-based systems because the signals were not at all speech-like. A test signal had been devised that was speech-like. It had been assessed with a number of measurement systems. The results had been validated against subjective tests. The conclusions had been that the new signal could be used to differentiate between transmission systems but the absolute values of the results differed from the standard and had to be used with caution.

Technical Sessions 17 November

Session 4, Cinema/TV sound: audio quality
Chairman – Bob Walker

The day started with *Cinema sound and the loudness issue: its origins and implications* by Philip Newell (Acoustics Consultant, Spain), Julius Newell (Electroacoustics Engineer, Portugal), Branko Neskov (Loudness Films, Portugal), Keith Holland. The paper was presented by Philip. He summarised the historical technical developments in cinema sound that had led to the current excessive loudness. He concluded with some suggestions about employing artistically-sensitive means of dealing with the problems.

The second paper of the session was *Cinema sound: how loud is loud?* by Juan Battaner Moro (Southampton Solent University) and Keith Holland and was presented by Juan. He described how this joint project was investigating the increases in current cinema sound levels, mostly resulting from improvements in technology. The main focus of the paper was a study of cinema sound levels in comparison with other forms of entertainment, such as motor racing and live concerts and, for the workers, in the context of the Noise at Work Regulations.

The next paper was *Intelligibility of cinema and TV sound* by Peter Mapp. He began by summarising the current situation with up to 60% of television viewers complaining of poor intelligibility and the reluctance of the broadcasters to acknowledge that there might be a problem. Poor "lip sync" and poor set design were also contributory factors. Some results were presented from simulations of the overall transmission system from soundtrack to listener and measurements of domestic listening conditions showing that typical in-situ responses in the home were far from ideal.

The session was brought to an end by *Improved sound for domestic TV* by Ted Fletcher (Orbitsound). Ted presented a brief history of the development of TV sound, where it had gone wrong and how it might be improved. A number of reasons for poor sound were given, including the limited space for loudspeakers in modern slim cabinets. Poor installations of the standard 5.1 sound were also cited, with the comment that 5.1 was a dying market anyway. The solution proposed was a central main loudspeaker for the sum signal and dipoles for the difference signals.

Session 5, Measurement
Chairman – Adam Hill

The first paper was *Designing an acoustic source of the Stipa Signal: how to build a good talkbox* by Sander van Wijngaarden and Jan Verhave, presented by Sander. He described the difficulties and design compromises for an acoustic source for producing STIPA test signals. He then presented a set of design principles for optimising the accuracy and reliability of a talkbox. These had been incorporated into a commercial product, but the principles could easily be applied to a home-built device. A practical procedure for correcting the transfer function of the device was also described.

The second paper was *Distributed optical fibre acoustic sensors; future applications in audio and acoustics engineering* by Piotr Golacki and Keith Holland (ISVR). Piotr described how optical fibres respond to mechanical forces and how that might be used to sense spatial distributions of sound pressure. He also described experimental evaluations of the effects and the results obtained using optical time-domain reflectometry. Comparisons had been carried between polarisation change, phase change and correlation methods. It was concluded that the current achievable sensitivities were far below what would be useful and that much further development was required.

Session 6, Cinema/TV sound: artistic concepts
Chairman – Mark Bailey

In *Performance change in vocalists with variation in headphone foldback and reverberation levels* by Chris Barlow, Benjamin Ford (Southampton Solent University) and Helena Daffern (University of York) Chris began by describing how performers are affected by their environment and that the key foldback parameters tested were level and early reflections/reverberation. A pilot study P14►


Sander van Wijngaarden


Helena Daffern (left) and Mariana Lopez


Conference reception


Conference dinner

◀ P12

had been carried out using professional, amateur and inexperienced singers. The results showed that longer reverberation led to slower tempo and that level had little effect. Helena presented the results for the long-term spectra. There were no effects for the full "dry" or the fully reverberant conditions but the mid condition did show some differences.

The second paper was *Enhancing audio description: sound design, spatialisation and accessibility in film and television* by Mariana Lopez (Anglia Ruskin University), Gavin Kearney and Krisztián Hofstädter (Anglia Ruskin University). The paper was presented by Mariana who began by quoting the minimum audio description required by law in the UK of 10%. The paper mainly discussed the use of sound design and spatialisation to enhance the basic description track and potentially reduce the need for detailed description. Techniques included spatially accurate rendition of sources, types of shot camera movements camera angles and framing to present audio cues to produce an audio track closer to the film maker's concept.

The final paper of the session was *Listener adaptive binaural reproduction with loudspeaker arrays* by Marcos F Simón Gálvez and Filippo Maria Fazi (ISVR). The paper was presented by Marcos. It was essentially a formal presentation of the informal demonstration given on the 15th as described on page 7. The paper described the development of a system to decompose the crosstalk cancellation filters of a loudspeaker array into gain and delay elements to control the radiation pattern of a linear array of 28 small loudspeakers. Combined with a video tracking system, that allowed position-independent binaural listening using loudspeakers for a single listener.

Session 7, PA systems: loudspeakers and other hardware
Chairman – John Taylor

The first paper was *The effect of performance stages on subwoofer polar and frequency responses* by Adam Hill and Joe Paul (University of Derby). The paper was presented by Adam, who began by describing his own experiences as a mixing engineer for large-scale outside venues and the difficulties caused by the interaction between the low frequency bass loudspeakers and the stage. He also described the principles of dipole loudspeakers and presented the results of many measurements. The conclusions were that placing the "subs" either underneath or on top of the stage resulted in poor directionality and likely failure to achieve the manufacturer's specification. Having either no stage or placing the loudspeakers well in front could achieve around 10 dB of directional discrimination.

That was followed by *Line array modelling with BEM* by Patrick Macey (PAFEC). Patrick described the various different methods that could be used to model a line array numerically. A simple approach, representing the motion at the mouth of the horn as a rigid piston was inaccurate at high frequencies because the directionality was not well represented. A model of the entire system in detail using FEM/BEM would be impractically large. The paper described simplifications to reduce the size of the model in which the transducer and horn were modelled radiating into a half-space. The resulting velocity distribution in the plane of the mouth was then used in a BEM model of the array of enclosures.

Session 8, Transducers and amplifiers
Chairman – Keith Holland

Following the break, the first paper of the session was *Who needs class D? How to make ultra-efficient linear amplifiers. Matching the amplifier to the audio for highly efficient amplifiers* by Jamie Angus (University of Salford). Jamie continued the theme from the 2015 Conference. Class D amplifiers were indeed highly efficient, but not at lower power outputs. Data was presented showing the amplitude distributions of typical programme material and how very rarely the highest levels were actually used. Comparisons were made with Class G amplifiers with different number of switching levels, showing that above two the Class G amplifiers offered efficiency advantages, as well as potentially fewer audio artefacts as they would operate in Class A mode for most of the time. In reply to a question, Jamie suggested that modern switch-mode power supplies might be able to modulate the supply voltage directly rather than having discrete switched supplies.

The final paper was *Room correction for object-based audio* by Dylan Menzies-Gow and Filippo Maria Fazi. The paper was presented by Dylan. He described how traditional room correction systems were unable to address some room acoustic defects and how the introduction of object-based audio provided an opportunity for new correction methods. In particular, it allowed the direct and reverberant components to be processed separately. The paper presented an object-based system where the reverberant properties were parameterised as metadata on which the correction system could operate directly by splitting the time-domain response into direct, early, diffuse and reverberant components.

Posters

Philharmonie de Paris: Sound system integration and calibration by Julien Laval (L-Acoustics). The poster presented the historical background to the design of classical auditoria to provide optimum natural sound rendering to the audience. Modern venues have to be designed to be suitable for both classic and modern music performance. That presents challenges to designers to produce more flexible designs and sound systems capable of hosting amplified concerts. The Philharmonie de Paris has chosen to integrate a well-known commercial sound system in the large concert hall, the Grande Salle, as part of a modular system capable of today's most demanding music agendas. Because of its particular acoustical environment, the project required specific design and calibration processes to use early reflections for the control of sound immersion as well as control of the low frequency range important in modern music. A method using simultaneous multiple microphone locations was used to apply optimum processing to the complete audio chain.

Railway noise – comparison of predicted and measured noise levels and its subsequent effect on health by Sarah Wakely. The poster presented a number of comparisons between predicted and measured noise levels and an assessment of the health implications of high noise levels.

Simon Durbridge

Rebecca Lever with a visitor to to AcSoft stand

Acoustic and environmental variability, fluctuations and coherence

By Peter Dobbins

The Underwater Acoustics Group organised the international conference *Acoustic and environmental variability, fluctuations and coherence* held at the Cambridge University's Møller Centre on 12-13 December 2016. For the uninitiated, these phenomena have much in common with the effect of atmospheric turbulence on light propagation, which causes stars to twinkle.

The Institute last held conferences on this topic in 1999 at Robinson College, Cambridge, and 1986 in Weymouth on the English south coast, both organised by the present author. The scientific aim of this latest conference, as in the earlier meetings, was to bring together scientists and experts from around the world to share the latest advances in this esoteric subject. In this we were successful, attracting some 55 delegates from 10 different countries who presented 37 papers.

A wide range of ideas was covered, including issues such as the variability of ocean environmental parameters, seabed geo-acoustic parameters and surface acoustic scattering; the effects of variability on acoustic propagation; measurements and modelling of acoustic propagation coherence, signal and ambient noise fluctuations, and sonar system performance. The keynote lecture by Chris Harrison (Emeritus, CMRE, La Spezia, Italy) discussed whether this variability is just a nuisance or a potential tool, and the AB Wood Medal Lecture by Yan Pailhas (Heriot-Watt University) examined the often-overlooked information that lies in the phase of an acoustic signal.

As is usual with Underwater Acoustics Group conferences, the meeting followed a single track with no parallel sessions, organised as follows:

Acoustic variability – measured

This was a relatively short session, with just four papers, but covered a wide range of topics. The first was about the effects of dynamic littoral environments, such as estuaries, on high frequency sound propagation. It was intriguing that salinity had a significant effect whereas it is usually of little significance compared with temperature. The next was about communication links in the arctic and how long range (>10 km) horizontal communication signals in the Marginal Ice Zone (MIZ) are affected by the sea-ice cover. The third reported a study of the impact of internal waves on sound intensity, geoacoustic inversion and sound propagation in shallow water based on broadband airgun data, and the final paper covered essentially the same subject but also examined current mitigation practice.

Acoustic variability – modelled

This was by far the biggest session, with some 14 papers (although, as often happens, there were a few dropouts) and it took up the rest of the day. The topics covered once more stretched from low-frequency long-range propagation, where the principal cause of variability is the ubiquitous internal wave, to higher frequency short-range variability due to turbulence, rough surface scattering and other fine scale mechanisms.

The methods employed diverged from random matrix theory via straightforward mathematical wave equation formulations and multi-mode solutions to computer simulations. Likewise, the results obtained came up with fluctuations in particle motion, acoustic scattering, pulse length, arrival time and correlation loss, as well as dealing with both spatial and temporal changeability.

Finally, the causes of fluctuations considered, although largely founded on internal waves, also included turbulence and other fine scale mechanisms and rough surface scattering from both the seabed and sea surface.

Chris Harrison (right) is welcomed to the conference by Peter Dobbins

Sonar performance

This was another short session concentrating, essentially, on how the loss of coherence due to acoustic fluctuations degraded the performance of sonar systems and potential mitigation approaches. The first paper looked at the application of both spatial and temporal (time-varying) weighting to an array and evaluating the performance in the presence of fluctuations by means of Monte Carlo simulations. This was then followed by two papers relating to Synthetic Aperture Sonar (SAS). The first examined estimating the signal coherence from the SAS data and the second looked at optimal acquisition geometries for multiple pass SAS systems employed in bathymetric mapping.

Environmental variability

It is, of course, not possible to understand acoustic variability without understanding the environmental variability that produces sound speed fluctuations and hence acoustic fluctuations – random inhomogeneity is a property of every naturally occurring medium, and the sea is no exception.

The first paper looked at the boundaries in shallow water propagation: the time varying surface wave field and the essentially random variations of the geophysical structure of the sea floor, all of which can influence sound propagation as much as fluctuations in the water column. The third paper continued this theme by quantifying the effect of random sea floor roughness on SAS imaging. The other contributions in the session continued with a simple approach to relating the effect of ocean variability on sonar performance then, finally, an investigation of possible mitigation techniques for decoherence effects in passive sonar based on a scaled tank experiment.

Soundscapes

The concept of soundscapes in underwater acoustics has appeared in recent years, and three papers on the topic were presented at this conference. The first examined the impact of long distance propagated low frequency seismic signals on the soundscape of the Fram Strait, between Greenland and Svalbard, while the second characterised the natural soundscape of the Fram Strait without such impacts, to define a baseline to help clarify the contribution of both anthropogenic and natural noise sources. The third stayed in the same locality but looked specifically at the soundscape of the MIZ, noting that the overall contribution of seismic airgun noise to measured noise levels was minor.

Underwater noise

The final session on underwater noise included four papers on quite different aspects of the topic. The first noted that accurate noise modelling is a vital component of Environmental Impact Assessments (EIAs) and described Gardline's comprehensive sound propagation and noise map model. The next paper reviewed the little existing guidance on over-water noise transmission offshore and compared this with measurements taken during wind farm construction, while the third presented a methodology for estimating shipping noise on a world scale. The final paper of the session and the conference described a series of experiments aimed at measuring the power spectrum and both vertical and horizontal noise coherence in the deep ocean.

Keynote lecture

The keynote speaker was Chris Harrison, who has spent a lifetime in underwater acoustics (and has been known to the present author for much of that lifetime). He spent a good deal of his career at the NATO Centre for Maritime Research and Experimentation (CMRE) at La Spezia, Italy, and this talk described some of the work he carried out there.

Chris began by pointing out that many man-made sounds from shipping, machinery or sonar are loud enough or persistent enough to be irritating to humans and marine mammals so there is an advantage in reducing them or getting rid of them. He then went on to explain how it is possible to extract information about reflection coefficients and sub-bottom layering from ambient wind noise with a drifting directional array. He also explained that it has been demonstrated experimentally that the same approach can be applied to the detection of a target. This was an informative and interesting presentation.

A B Wood Medal

Peter Dobbins, chairman of the Underwater Acoustics Group, who also read the citation, presented the A B Wood Medal and prize to Yan Pailhas, of Heriot-Watt University (see page 20 for full details). Yan then gave a talk highlighting the overlooked information that often lies in the phase of the acoustic signal.

He explained how the image forming process, which presents the sonar information in a form that human operators can interpret, and most notably the envelope detection processing, suppresses all the information contained in the phase of the sonar signal. During the talk, Yan spoke about the specific issue of phase information, which has guided much of his research on wideband sonar, but also how to exploit the phase by designing coherent multistatic systems such as MIMO (Multiple Input Multiple Output) systems.

Conference dinner

Most of the delegates, some accompanied, came along to the drinks reception and magnificent dinner (the first turkey of the season for some) in the Combination Room at Peterhouse College. Peterhouse is the oldest college of Cambridge University (and possibly one of the oldest functioning buildings in the country), having been founded in 1284 by Hugo de Balsham, Bishop of Ely, and granted its charter by Edward I. For those who watched the excellent *Wolf Hall* television series, it predates Hampton Court, Acton Court and most of the other buildings featured there by some 250 years.

After dinner, some delegates returned to the Møller Centre and bed, while the more robust among us headed for that other Cambridge institution, The Eagle, just a stone's throw from King's College Chapel. This is where James Watson, Francis Crick and their often forgotten colleague Rosalind Franklin spent many hours trying to work out the structure of DNA – eventually succeeding in finding the double helix. Besides that, it is probably the best pub in Cambridge.

Conference feedback

At the end of the conference, the organisers received many comments from delegates saying how they appreciated and enjoyed the presentations, having the proceedings available at the conference, the dinner in Peterhouse and, of course, the opportunity to look round the glorious city of Cambridge. A more formal feedback process has taken place using Survey Monkey and, P18

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although the number of responses was quite small, the results can be summarised as follows:

Delegates were split roughly equally between IOA members and non-members, so it would seem that advertising the event reached well outside the Institute. Everyone felt they were made welcome; nearly everyone thought the meeting covered the topic well, the level of complexity was correct and the quality of the presentations was good or excellent (although these last two are largely down to the individual presenters). In short, the meeting satisfied most people's expectations.

The only point where opinions were more divided was the time allocation for presentations. This is something we discussed at length at the planning stage: it is not possible to allocate times to presentations until the final number is known and we had a dilemma – do we fit a programme of shortish presentations into two days or do we allow three days and a more relaxed schedule, but at a significant increase in the cost of the conference? Your views would be appreciated.

The future

Our fluctuations conferences have so far taken place at roughly ten-year intervals, so should the next one be in 2026? The Survey Monkey results suggest that the venue would still be popular, or should we look for somewhere else in Cambridge – or even elsewhere. Should the format stay the same, or should we introduce workshops, practical sessions, or other experiences besides the conventional presentations? Again, your views would be appreciated.

In the meantime, however, there will no doubt be other fluctuations sessions at various conferences worldwide and, in particular, there will be a session entitled *Acoustic fluctuations and resulting degradation of coherence and beamforming* at the next Underwater Acoustics Group conference and exhibition on the Greek island of Skiathos in September 2017. If you would like to contribute, please get in touch with the author at peterdobbins1@gmail.com

ETSU-R-97 Time to move on? (Including AM update)

By Dick Bowdler and Andy McKenzie

This meeting concerned the future assessment and control framework for wind turbine noise in the light of current knowledge and the latest work conducted by the IOA and the Department for Business, Energy& Industrial Strategy (DBEIS) on the assessment and control of amplitude modulation (AM).

Dick Bowdler ran through the history of wind turbines and wind turbine noise. He described what happened prior to ETSU-R-97 and moved on through the political background, rise of objectors' groups and changes in planning and noise policy and funding regimes over the last 20-30 years. He contrasted the planning, noise, technology and economic situation between 1996 and 2016 referring, in particular, to the increased requirement to describe the impact of a noise to enable a balance to be struck between impact and need.

Andy McKenzie then gave a presentation on *What might an alternative to ETSU-R-97 look like?* This was a joint paper with Andrew Bullmore, first aired at Acoustics 2015. He described some of the challenges posed by ETSU-R-97 and introduced three different approaches: the use of a fixed limit not to be exceeded, with a possible option of varying this depending on non wind-related background noise or noise zones; a noise dose approach, or noise dose change – the latter continuing to require baseline measurements – and finally an approach similar to that of ETSU-R-97 but using either an assumed background noise curve, which could vary depending on different environments, or an average background noise curve based on actual measurements at various locations around the affected area. A fourth approach is to continue using ETSU-R-97 either in its current form, or with modifications in certain areas.

Karen Worthington and Paul Travis from Cornwall Council started with a background to the approach used in Cornwall. Although they had "no real issues" with ETSU-R-97 there were some concerns: the "relative to background" approach resulted in excessively high limits, the controversial night-time lower limiting value (LLV), the lack of clarity over the flexible day-time LLV and the application of financially involved limits. They felt the noise dose approach introduced significant complexity and an assumed background noise curve presented significant opportunity for dispute between the planning authority and the applicant. An ideal approach would provide adequate protection of amenity with minimal time required by Environmental Health.

Krispian Lowe from Innogy thought ETSU-R-97 provided a good and robust framework. He looked at the approaches used in some other countries which could be broadly divided into a single limit value and a value per wind speed. He looked at an imaginary wind farm placed in the Netherlands, Denmark and the UK to see how it would comply with local limits, with the UK appearing to be the strictest. In terms of alternative limits, he felt that excluding wind speed from the limits was a "bad choice". Measuring background noise had the added advantage that the assessor got to meet the people affected.

The discussion on the morning session started with whether the government had any interest in making any change in view of the current state of the industry. There was debate on the requirement for an impact based approach rather than one based on compliance with limits; there was a view that "impact" and compliance with limits could both be addressed as part of an assessment but this would need some kind of IOA guidance. Further guidance/modifications on the use of ETSU (for instance, on changing the night-noise limit) could be provided by the IOA and considered by the current working group.

The conference resumed after lunch for two presentations on amplitude modulation. Gavin Irvine described the final method that has been adopted by the IOA AM working group for its quantification. This is based on an FFT analysis of the time-varying AM signal which is then re-constituted to provide the average peak-to-trough amplitude related to the blade passing frequency for each 10-second period. The level of modulation for a 10-minute period is defined as the AM level exceeded for 90% of the individual 10-second periods. The software necessary to carry out this processing is provided via a link on the IOA website at www.ioa.org.uk/publications/wind-turbine-noise as is the report of the AM working group.

Richard Perkins and Mike Lotinga then talked about the recent publication by DBEIS (see page 41 for more details). The aims of the project were to review the available scientific evidence on human response to AM and to make a recommendation for controlling AM within the UK planning system. Research shows the level at which detection of modulation started is 2 to 3 dB peak-to-trough. The review by the DBEIS group concluded that the RenewableUK penalty scheme is appropriate for modelling human response to AM and mitigating its effect. If the night-time limit is less stringent than that the day-time, an additional correction is required. The action to be taken would depend on the

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judgement of the planning authority as to whether the extent of any breaches of a 3dB criterion required further action.

The two AM papers were followed by a discussion period. There was some concern about the implementation of the DBEIS penalty scheme in terms of compliance testing. Additional issues raised were the reduction of the night time limit when AM occurred, the starting point of the penalty graph and the shape of the penalty graph itself.

The meeting ended with a workshop to explore the various wind turbine noise assessment methodologies proposed and to consider issues around the approach to AM proposed by DBEIS. On assessment methods the view was that fixed limits are simple and testable but do not address the impact. We might need to do background measurements even if a zoning approach was used since noise zones are not defined by the UK planning system. The use of noise dose is complex, requires significant LPA resources and cannot easily be verified. Noise dose change was felt to be like comparing apples and pears and Lden was not felt to be applicable to rural areas. The two variable limit approaches might end up with us being back where we are now. There was a significant feeling, though perhaps not a majority, that ETSU-R-97 is pretty good as it is though some further tweaks might be required.

On AM, the proposed metric works well but that the proposed penalty scheme requires some clarification. A penalty for each 10-minute period and a penalty relative to wind speed both have attendant difficulties. The wording of the recommendations was felt to be unclear. Views were split on whether the 3dB criterion was too lenient or too strict! The extra night-time penalty was thought to be better tackled via a change to the night-time limit.

It was a successful and thought-provoking day. The organisers, and others, will need to put some thought into what the next steps should be.

Dr Yan Pailhas wins the A B Wood Medal 2016

Yan Pailhas (right) is presented with his award by Peter Dobbins

Dr Yan Pailhas of Heriot-Watt University is the winner of the A B Wood Medal 2016. The award, which goes in alternative year to acousticians living in the UK or Europe and in the USA and Canada, is aimed at younger researchers whose work is associated with the sea.

The award was presented to him by Dr Peter Dobbins, Chairman of the Institute's Underwater Acoustics Group, at the *Acoustics and environmental variability, fluctuations and coherence* conference in Cambridge in December. Below is a summary of his citation.

Yan was born in France where he received the early part of his education. Between 1998 and 2002 he studied for his first degree in Paris, where his chosen topic was telecommunications. On completion of his degree he continued his studies to obtain an MSc, with distinction, in signal and image processing. In 2004 he moved to Edinburgh to take up a post as a Research Associate in the Ocean Systems Laboratory in the School of Engineering and Physical Sciences at Heriot-Watt University. In 2009 he decided to extend his education further and registered as a PhD student studying underwater acoustics at the university. He was awarded his PhD, entitled *Sonar systems for object recognition* in 2012. Having completed his PhD he was made a Research Fellow in the department and has been employed there ever since. His work has currently resulted in 12 journal publications, 47 conference papers and numerous contract technical reports.

He is currently carrying out research activities in bioacoustic signals and sensors, signal processing for detection and classification, and numerical simulations. His research focuses on the understanding of the interaction between wideband ultrasonic waves and solid objects. He is currently working on the development of novel wideband signaling systems, detailed analysis and simulation of wideband target echoes for classification and identification from sonar returns, and on the implementation of a low power wideband sonar system for AUVs.

Yan is equally at home with the development of theoretical models and organizing and conducting at-sea experiments to gather data and validate his numerical simulations. His theoretical modelling is always very thorough and robust. His work has included the development of models for imaging sonar such as sidescan sonar and Synthetic Aperture Sonar (SAS) and in more recent times he has been developing models to represent Multiple input, Multiple output (MIMO) sonar systems. This offers the advantage of bistatic and multistatic views of the scene and any targets. Additionally it allows AUV to be fitted with just a transmitter or receiver, thus reducing the power, weight budget.

His development of the wideband sonar system has been based on the bioacoustics signals and geometries that are employed in bats and dolphins. These offer a unique understanding of how these creatures are able to detect and classify targets with extreme accuracy and to discriminate target types when there are only subtle differences. Yan's developments have provided insight into the techniques that are employed by different species and allowed researchers to replicate these techniques in hardware and software. This has led to improved probabilities of detection and correct classification while reducing the number of false alarms. Yan's systems and simulations are able to produce other novel signal types, beamforming and processing schemes to investigate potential improvements.

Yan's recent work in MIMO systems has again seen him using his usual thorough approach and he is one of a few leading researchers in this topic, worldwide. He has presented this work at conferences (including the IOA synthetic aperture sonar and radar conference, Italy 2014) and has published his approach in IEEE *Journal of Oceanic Engineering*. Part of his numerical simulation has demonstrated how the MIMO approach can provide a robust approach to port, harbour and asset protection. In the early part of 2015 Yan was involved in a data gathering experiment with the Canadian government. It is clear that he has collaborated with, or worked in, some of the leading ocean acoustic research laboratories around the world and assisted many commercial companies in the developments of their sonar systems and experimentation. He has been involved in and helped organize over 40 underwater trials.

He was also a co-founder and is the Chief Technical Officer of HYDRASON Solutions. This amply demonstrates that he is able to turn his research into practical systems and market them as commercial products.

The A B Wood Medal is awarded to him for his outstanding contribution to underwater acoustic and sonar development, particularly for his research on wideband sonar, bio-inspired sonar and the interaction of acoustic waves with underwater targets.

Loudspeaker expert Mark Dodd receives Peter Barnett Award 2016


Mark Dodd receives the Peter Barnett Memorial Award from Jo Webb

Mark Dodd has been awarded the Peter Barnett Memorial Award for excellence in electroacoustics. He was presented with it by IOA President Jo Webb at Reproduced Sound in Southampton. Below is a summary of his citation.

Mark Dodd has been working in the loudspeaker industry for more than 30 years during which time he has been responsible for a number of important advances in loudspeaker technology. Mark's work can be characterised by a dedication to the application of science in the pursuit of perfection.

Mark graduated with a BSc in physics from the University of Southampton in 1979, and started his career in audio at Vitavox in 1981. Here he had his first experience in loudspeaker compression driver design. During this time he undertook a part time Masters degree in applied acoustics at Chelsea College London University and was awarded an MSc in 1986. He then joined Tannoy where he developed the Tulip Waveguide phase plug for its coaxial drivers on which he presented his first paper at the 1992 AES convention in Vienna. The Tulip Waveguides are still used in many of Tannoy's current professional and high-end domestic loudspeakers.

In 1994 Mark joined GP Acoustics, a group including KEF and Celestion, becoming Head of Group Research in 2001. At GP Acoustics Mark developed compression drivers for Celestion, was responsible for the concept and HF design of the KEF UniQ loudspeaker drivers, including the Tangerine Waveguide, and pioneered the use of Finite Element Analysis in transducer design. He has presented several papers on loudspeaker driver and enclosure design at AES, IOA and ISEAT conferences.

The Peter Barnett Memorial Award recognises advancements and technical excellence in the fields of electro-acoustics, speech intelligibility, and education in acoustics and electroacoustics, and, although it is mainly the first of these for which Mark Dodd would normally be associated, through his dedication to the application of state-of-the-art scientific methods, his work has had, and will continue to have, impact on many of these fields.

Let's get the Part-E started?

London Branch report

By Roslyn Andrews

January's branch meeting entitled *Let's get the Part-E started?* was presented by Peter Turner. Following his experiences at the NHBC, Peter presented a series of investigation cases, to question the robustness of Approved Document E (ADE) for the protection of the health and wellbeing of dwelling occupants. As the title suggested, the objective was to get us talking about unresolved noise issues in ADE-compliant domestic dwellings and how to address them in the future.

Case examples included airborne, impact and structure-borne noise and vibration from domestic and non-domestic sources, clear conversations made through compliant walls and floors, horizontal impact and flanking transmission, poorly sealed (but compliant) entrance doors, bridged SVP pipe enclosures, structure-borne noise from domestic services and WCs, garages and under-croft parking, roof terraces, low frequency impact noise, creaking floors, bridged screeds, continuous screeds, tiled floors, wind noise, mechanical ventilation, external noise and the effects of long reverberation times.

In many instances, very low levels of background (masking) noise exacerbated the issue. This was sometimes caused by over-specification of façade elements, or the remote location of the property, away from environmental noise sources such as road traffic.

Unclear guidance and ambiguous wording in ADE sometimes clouded decisions regarding compliance with the Requirements. The appropriate use of referenced standards such as BS8233 for use in post-occupation investigations was also unclear.

The effectiveness of the rating system $D_{nT,w} + C_{tr}$ over $D_{nT,w}$ was discussed, along with ideas for measuring in-situ structure-borne transmission, $D_{tr,2m,nT}$ for façade insulation and L_{Aeq} or L_{A1} for internal noise.

Peter called for an "holistic" approach, and not merely an increase of the existing performance specifications. A rating system (A to F) for airborne, impact, horizontal impact, façade, structure-borne noise, internal noise and privacy (e.g. $D_w + L_{Aeq}$) to address homebuyer's expectations. Further information for home-buyers moving to an attached or detached property or to a different environment, or those more sensitive to noise (e.g. those with ill health, autism, or those wanting a "quiet life") could also assist decision-making.

Careful utilisation of existing environmental or internal mechanical ventilation noise could help to mask other internally generated noises. For this reason, Peter believes a specification and measurement of façade insulation, as well as measurement of background noise generated within the dwelling or from other sources within the same building or from adjacent buildings, could enable the performance of the whole dwelling to be assessed through one document (i.e. ADE) alone.

Examples were shown of clearly illustrated "Good Practice" guides popular with builders. Suggestions were made for training courses for builders, architects, building control bodies and local planning authorities, as well as public information through the media, to help drive up standards, understanding and awareness. This could in turn increase manufacture of off-the-shelf products such as isolating materials, which are key to many structure-borne issues. A homeowner feedback survey, along with further research into measurement of and subjective response to structure-borne sound is also suggested.

A questionnaire handed out at the end of the talk, asked for both professional opinion and home experiences. Those who would still like to return their questionnaire, please send to peter@assuredacoustics.com.

Since writing this Peter has also presented his talk to Central Branch so look out for possible future opportunities elsewhere in the country if you are interested and missed out this time. Many thanks go to Peter for his presentation which certainly opened up the discussion on the topic. Thanks to WSP for once again providing the venue. We look forward to seeing another packed crowd at our next evening meeting.

Projects titles in the 2015/2016 Institute Diploma

The following are the titles for projects in the 2015/16 IOA Diploma in Acoustics and Noise Control:

University of Derby

- BS 4142 (2014) review
- Sleep disturbance from rail noise
- The use of personal headphones
- Noise measurement methodology for military ranges
- Acoustic suitability of multipurpose halls
- Sound insulation testing and the role of RT
- Isolation pads for speakers
- Use of smartphones as an SLM
- Noise impact from schools
- Use of plenums within a rev chamber
- Environmental noise from stadiums
- Noise control solutions for a farrier
- Engine testing at Birmingham Airport
- Motorsport monitoring methodology for stock car racing
- Noise impact of a driving experience enterprise
- Audible warning alerts in cabs
- Noise from all-weather sport pitches

Leeds Beckett University

- A comparison of predicted airborne sound insulation with measured airborne sound insulation tests
- Investigation into creating adjustable acoustics in multi-purpose venues
- Comparison of noise levels predicted by Defra noise mapping project with onsite measurements
- A comparison of the 1997 and 2014 versions of BS 4142 using a specific worked example
- The acoustic properties of unconventional acoustic ceiling tiles
- Sound reduction indices of different acoustic panels
- An exploration into sound propagation from the piano and the effects on the enclosure on tonal propagation
- A comparative study between the predicted and measured hearing thresholds levels of a noise-exposed candidate
- Review of the shortened measurement procedure for the Calculation of Road Traffic Noise (CRTN) methodology
- Acoustic assessment of a live events venue
- An investigation into gear fault detection through time synchronous averaging
- Measuring the accuracy of manufacturers' sound power level for gardening equipment
- The acoustic characteristics of York Minster chapter house

London South Bank University

- Control of noise from a CNC machine
- Optimum indoor acoustics for European Broadcasting Union newsroom at Elephant Studios
- An investigation into the use and determination of Lmax levels in describing noise levels for construction and demolition activities
- Acoustic study of a control room
- Noise generated by high speed hand dryers in small reverberant spaces
- An investigation into the assessment of noise at the planning stage with particular reference to Blue Light Hub developments
- An investigation into the application of high density infill in a ducted attenuator
- Predicted noise levels compared with noise measurements on construction and demolition sites
- BS 4142:2014. Objective and subjective impulsive sound penalty
- An investigation to determine the applicability of a new method of sound monitoring (the Metro system) at live events
- Cinema and the reverberation time requirements
- Noise impact assessment and strategies to reduce noise complaints from a live music event
- Comparisons of different methods for predicting construction sit noise
- Measurement of impulsive sound from fireworks
- Comparison of BS 4142:1997 to BS 4142:2014
- Town Hall Theatre: measurement and modelling
- Short term variation in background sound surveys for BS 4142 assessments
- A review of the prediction and measurement of ground-borne noise at Victoria Station upgrade
- Services equipment noise within dwellings – prediction and evaluation
- BS 4142 case studies of plant noise in the London Borough of Tower Hamlets

Southampton Solent University

- Case study on code of practice of environmental noise in concerts
- Differences between BS 4142 and Australia's EP Policy 2007
- Determination of absorption coefficients using a micro flown probe
- Motorway traffic noise and central reservation barriers
- Intelligibility in air traffic control rooms
- Assessment of acoustics in a sports hall
- Noise exposure associated with basketball

DL St Albans

- An assessment of a quiet room in providing speech intelligibility and speech privacy in the office
- Comparison of the testing methodology between BS ISO EN 140–Part 4 and BS EN ISO 16283–Part 1
- Case studies of plant noise in the London Borough of Tower Hamlets using BS 4142:2014
- Acoustic treatment of a chiller unit located within a residential amenity
- Comparison of predicted noise and actual noise experienced on construction and demolition sites
- Quantifying quality – the measurable difference between entry level and high end acoustic guitars
- Acoustic problems within a small bedroom / project studio
- Traffic noise in India
- Acoustics treatment for two cooling towers
- Aircraft noise assessment and impact on bystanders at small aerodromes
- Investigation into human perception of tonality across a range of frequencies
- Comparison of real world measurements, predictions from statistical calculations and predictions from a computer model for open plan study spaces in a further education building

DL Edinburgh

- Near-field acoustic holography as a method for assessing maintenance condition issues and gaps in sound insulation
- An investigation into noise from licensed premises affecting residential dwellings in a city centre
- Review and Impact of changes to acoustic feature corrections in BS 4142
- An investigation into the efficiency of prediction based noise limits for the control of wind turbine noise
- The effectiveness of guidance on noise from live music events in rural and urban settings in Sunderland
- Flanking sound transmission through steel-concrete composite floors
- A review and comparison of the differences between BS 4142:1997 and BS 4142:2014. Including reassessment of historical cases.
- Planes, trains and window panes
- The dynamics of a new product
- Post completion performance analysis of refurb works regarding reverberation and background ambient levels in a lecture theatre
- Measurement of the near field acoustic performance of a DIY tapped horn concert subwoofer.
- An assessment of the acoustical viability of turning a music rehearsal space into a recording studio
- Acoustics of modern performing halls: an experimental investigation in arena acoustics
- Can vibration magnitude and phase analysis techniques accurately diagnose high speed machinery faults before failure occurs?

DL Bristol

- An investigation into different procedures for airborne sound insulation tests
- Noise impact of Smart motorway on the M20 J4 to J5
- Measurement of vibration absorbed doses
- Loudspeaker modelling
- Silent flight – an assessment of sound from model aircraft
- Occupancy and acoustics in an open plan office
- Acoustic assessment of a garage for a home studio conversion
- Room to room sound transfer from percussion instruments
- Health effects of noise in our homes on children
- An investigation into the relative performance of a smartphone-based sound level meter application compared with a class 1 integrating sound level meter in the measurement of an environmental sound source
- Assessment of noise exposure levels of city bus commuters
- Small recording studio control rooms for use in schools
- An investigation into room acoustics within open plan office spaces

DL Dublin

- Optimisation of the room acoustics in a scout hall
- Cumulative turbine noise in Irish wind energy planning
- To ascertain the noise impact from the expanded waste recycling centre on the nearest sensitive receptor and contrast the noise levels with the site prior to expansion. Ascertain the suitability of such measures that could be installed at the site to attain the same noise levels prior to expansion. Determining if prevention is better than cure
- Investigation of the use of sine sweeps versus pink noise through simulation and measurement


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Uncertain about uncertainty... A practical approach?

By Tony Higgins

Great, an environmental noise job! In the past we would rush out and deploy meters, secure them in position, and watch over them like mother hens in case it rained or the wind blew. Then the industry provided all weather microphones, and we were saved, we could leave them out in their fancy all weather boxes safe in the knowledge that there were no more blown mics or blanked out screens and we could relax. Indeed, we could go and get a coffee and leave the meter happily ticking away.

That is, until we got back to the office, and downloaded the data and tried to make sense of it. Something was wrong. Something didn't look right, and you'd squint at the data, and try to work out what had happened during the period of unattended monitoring. In short, we were uncertain of our results, and maybe just a little ignorant of the potential uncertainties that could (and probably did) affect our measurements. Fortunately, we all now have a much greater understanding of the possible uncertainties and new standards like the recently re-issued BS 4142:2014 make evaluating and *minimising* uncertainty a critical part of the any assessment. Whilst this article focuses on BS 4142 the discussion is probably applicable to most environmental measurement. I realise in writing this that the Measurement and Instrumentation (M&I) Group has dealt with uncertainty in several recent *Instrumentation Corners*, however, anecdotally, uncertainty and reporting of uncertainty remains the single biggest concern for acousticians as both consultants and regulators. This article aims to provide some practical observations on identifying and reporting of uncertainty.

So, what are those uncertainties? And how can we best deal with the issue of uncertainty when reporting? The principal uncertainties in environmental measurement are:

- Weather
- Reflections and interference
- Absorption (both ground absorption and air absorption).

The magnitude of the various uncertainties will depend on the conditions encountered when monitoring, the location and other site specific factors.

Nick Craven and Geoff Kerry have published a number of papers that evaluate uncertainties in environmental noise measurement and help to provide a method for quantifying uncertainty that will allow acousticians to validate their work (ref: *A Good Practice Guide on the Sources and Magnitude of Uncertainty Arising in the Practical Measurement of Environmental Noise*). http://usir.salford.ac.uk/20640/1/Good_Practice_Guide_May_2007.pdf). Good though that research is, it still doesn't replace proper consideration of the potential uncertainties by the acoustician in a site specific manner. It is not always necessary to consider uncertainties that may be small and unlikely to significantly affect the result, and it is probably worth summarising and making some practical observations on those that have the potential for greatest impact.

Weather

That weather conditions have an impact on measurement is well understood, wind direction and wind speed in particular can significantly affect results to the extent that a noise which is audible in favourable conditions, becoming inaudible in adverse conditions. The M&I Group (Mark Dowie, Brüel & Kjær) held an event in October 2016 entitled *When shall we three measure again — in thunder lightning or in rain...* which helped identify some issues around uncertainty due to weather. Rather typically when they were looking for adverse conditions, the weather was fine, however, Mark, David Waddington and Jon Tofts did produce some data on the effects of wind speed and direction (see fig.1) and the effect of wind speed change on LA90 measurements (see fig.2)

It is clear that distance from source upwind reduces the sound levels record comparative to those measured downwind. David reported that wind speeds above 4m/s seem to show an increase upwind probably because of noise generated by the wind itself. In practice, this means that higher winds will result in wind generated noise that will tend to mask the source under evaluation. More importantly, if the wind is blowing hard, most receptors will be (a) indoors, and (b) have windows closed, and any adverse perception they have of the source will therefore be mitigated.

The LA90 data (fig.2) collected shows the effect of wind speed on short term LA90 results. In general, the results for >5m/s wind speed are as expected, higher than those for <5m/s. The difference between the two visually appears obvious, e.g. around 42dB with wind, 32dB without. BS 4142 requires that we consider a modal average and that would present a problem in the above dataset, where the difference between the two conditions is much less e.g. 41dB for <5m/s. So, which dataset should be believed, and how should we deal with this in practice?

For the data in fig.2; Jon concluded of wind speed that "When it is windier, it is noisier; when it is calm, it can be quieter".

BS 4142 notes that we should:

"*Monitor wind speed at the measurement location, using an anemometer, and record the wind speed together with the wind direction. Exercise caution when making measurements in poor weather conditions such as wind speeds greater than 5 m/s*".

It goes on to suggest that recording data on cloud cover, and temperature at the measurement location are also appropriate. And that, for longer term measurements, a weather station might be required.

From a practical point of view, recording weather conditions whilst monitoring helps provide context to the measurements, by describing the conditions within which the sound is propagating. Weather conditions affect the transmission path of sound through the air, with wind direction being the most obvious concern. Changes in temperature and humidity, and the presence or absence of precipitation will also play a part, but the most significant effects are from wind speed (see fig.1).

We are seeking to monitor when conditions are optimum, and if we are carrying out a BS 4142 assessment, that means meeting the criteria within that standard. So if wind speed is above 5m/s, or temperature is below 5°C those non-conformances need to be reflected *and the effect on the results reported* or the source of uncertainty managed so that the effect is minimised. The most obvious answer is to only use data that complies with the weather data requirements of the standard. If you use data that falls outside of the standard parameter this would need to be reported and the impact on results assessed (see conclusion).

Reflections and interference

Reflections from surfaces in close proximity to a microphone will increase the measured sound levels. It is normal for acousticians to minimise these influences, by careful selection of monitoring position. The "accepted" method to minimise uncertainty stated in BS 4142, is to measure at least 3.5m from a reflecting surface and at least 1.2m above the ground. Where measurements are taken at 1m from the façade, a correction of 3dB is made to account from the reflections. This would need to be adjusted where the distance from the façade varies. Interference on the other hand could be more complex and might be overlooked.

Wind speed	Total	0-2 m/s	2-4 m/s	4-6 m/s	6-8 m/s	8-10 m/s
LAeq 100m Downwind(1)	62.4	62.9	62.3	62.2	62.6	63.5
LAeq 100m Upwind (1)	50,0	49.3	49.6	51.0	53.5	56.7

Fig.1 Upwind and downwind variability vs wind speed for a shooting range
Ref: David Waddington, University of Salford

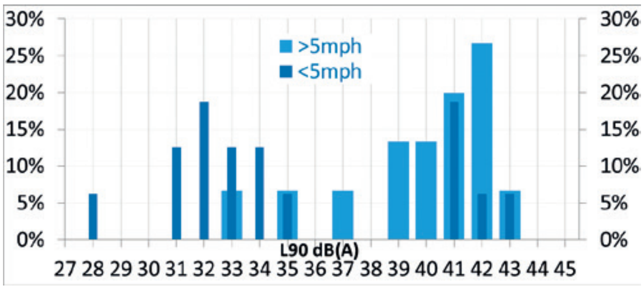

Fig.2 Effect of wind speed on LA90 measurements
Ref: Jon Tofts, Environment Agency

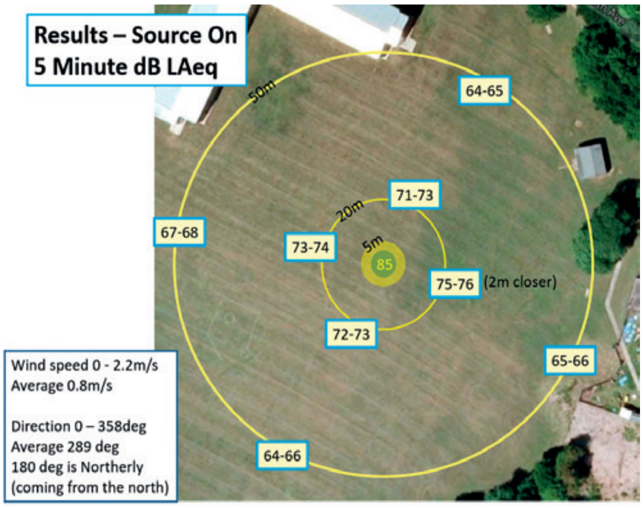

Fig.3 Variance in sound levels recorded during the "When shall we three measure again…" meeting
Ref: Mark Dowie, Brüel & Kjær

It is often the case that measurements at receptor locations are influenced by local residual sound levels, BS 4142 requires that residual sound should be deducted from ambient sound (with the source included) so that a specific level for the source can be determined. This acoustic correction can be misleading if the sound source is at the same level as the residual and the only way to establish a residual is to perform monitoring in similar location.

Results from the October 2016 meeting show a potential variation in levels even where monitoring is carried out at comparatively similar locations, fig.3 shows the variance found during the October meeting:

If we consider the potential differences in relatively static monitoring conditions, for similar locations of monitoring it is clear that variability in measured sound can occur, even more so where residual and specific sources vary over time. P28

◀ P27

Interestingly, the variation in the results noted in fig.3 was identified by the acousticians present to be mainly the rustling of clothes from the acousticians themselves with only a very slight wind effect. This raises another key issue around uncertainty, measured levels at the receptor can be heavily influenced by unexpected sources local to the microphone. This might be a particular problem where unattended measurements are carried out.

Uncertainty can be minimised by measurements taken closer to the source (ensuring that the specific noise is clearly dominant and residual impact limited) and then using calculation to estimate a level at the receptor location, this would also have the benefit of avoiding potential variation in residual noise measurements and may be more accurate and *reproducible* than measurement directly at the receptor. This form of "modelling" may also negate the influences of weather conditions on measured specific sound levels. Additionally, longer duration measurement might provide a more robust data set for evaluation that would "average out" any short-term anomalies.

Absorption

Air

Whilst not a significant concern for most urban locations (distances between source and receptor are short), in rural areas, ground, and sometimes air, absorption can be an issue that affects the propagation of sound. Distances over several hundred metres can reduce sound levels and change the perception of the sound at the receptor. Moderate and high frequency sounds tend to be absorbed better over distance, whilst low frequency sounds will propagate much greater distances, and diffract around barriers or other obstacles. The results of absorption over distance can therefore result in a significant change of perception of the sound, which in turn has implications for BS 4142 assessments. Numerically absorption through the air for a frequency of 1000Hz for reference conditions 101.3kPa, 20°C and 70% humidity is approximately 0.5dB/100m. Decrease in temperature to 5°C reduces this to 0.38dB/100m and 0°C shows absorption to be approximately 0.46dB. Similar variances occur where humidity changes, with 100% humidity increasing absorption to 0.54dB/100m and 50% humidity reducing absorption to 0.47dB/100m. Variance in atmosphere pressure has little effect.

(source NPL Acoustics: Calculation of absorption of sound by the atmosphere http://resource.npl.co.uk/acoustics/techguides/absorption)

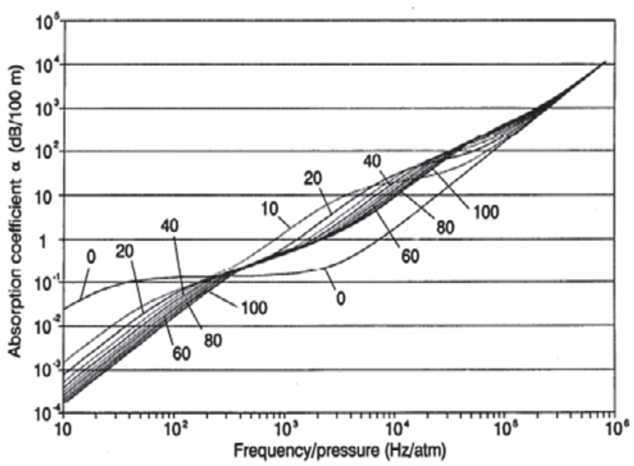

Fig. 4 Sound absorption coefficient in air (db/100) versus frequency for various relative humidities at 20°C
Ref: J. S. Lamancusa Penn State 7/20/2009 Noise Control, Chapter 10.3.1 Outdoor sound propagation

Ground

Absorption into the ground is potentially more significant than air absorption, but is dependent on the hardness and roughness of the ground, hard smooth reflecting surfaces (concrete, tarmac, bodies of water etc.) will not absorb significant sound, whilst grassland, woodland etc. will have a measurable effect. Ground absorption in favourable conditions can produce up to 10dB/100m attenuation, though 3-4dB/100m is more typical. Large barriers or topographical changes tend to negate ground absorption effects, but, like air absorption, the effect is frequency dependent with moderate and high frequency attenuating more quickly. NB: snow can significantly affect ground absorption and enhance the effects of trees and shrubs to reduce noise.

The effects of absorption are mainly of interest when calculating predicted levels. If ignored absorption can tend to overestimate the likely sound level for the source noise. The graph below shows typical absorption values based on research.

Conclusion

There are a large number of potential uncertainties to consider. For a BS 4142 assessment, the uncertainties need to be *managed*.

If compliant with those uncertainties listed in the standard, it should be sufficient to state (and evidence) that compliance.

If non-compliant, then it may be necessary to provide details of the uncertainty, in as far as that relates to the assessment. The details may be simple acknowledgement of the uncertainty and a qualification of the likely impact, e.g. "the monitoring period included light rain, the observed effect was that road increased sound levels by XdB".

More importantly, it is possible that there will be differences in LA90 measurements or a variance in LAEQ measurements. These variances as measured can produce a significant range of potential assessments values. It may be more appropriate to simply quote a range of assessment level results based on the variance in measured levels. E.g. if we have a rating level of 59dB and a background level varying between 42 – 49dB then quoting an assessment level of +10dB - +19dB might be appropriate. Alternatively quoting a "worst case" of +19dB might also be appropriate.

If we do need to quantify the uncertainty more accurately it is possible to by technical means (see Craven & Kerry 2007) and create an uncertainty budget. Such budgets would then be quoted alongside the assessment level, or measured values to show the degree of variance that is possible due to the uncertainties.

Whichever method is selected it is important to describe the effect of uncertainty in general terms in order that the recipient of the report can properly understand the implications and to provide the correct context. ◘

***Tony Higgins**, of Enviroconsult, is a member of the Institute's Measurement and Instrumentation Committee*

Acknowledgement

Mark Dowie and Jon Tofts helpfully shared some useful data and provided comment.

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3. *When shall we three measure again — In thunder, lightning or in rain...* IOA Meeting (see Acoustics Bulletin January-February 2017)
4. Ref: J. S. Lamancusa Penn State 7/20/2009 Noise Control, Chapter 10.3.1 Outdoor sound propagation

Researchers use technology to virtually recreate concert hall acoustics

Researchers at Penn State University in the US are using technology to study individual differences in acoustic design of concert halls and listener tastes.

"In concert hall acoustics, a lot of consultants and musicians know they like the sense of being enveloped or feeling immersed and surrounded by sound in a room," said Matthew Neal, a doctoral candidate in the university's graduate programme in acoustics.

"Despite this fact, there's not a lot of research into what aspects of the sound field make you feel enveloped or how to predict how a given hall is going to sound enveloping."

Mr Neal is working in the College of Engineering's Auralisation and Reproduction of Acoustic Sound Fields (AURAS) facility to measure subjective perceptions by virtually recreating concert hall acoustics.

To collect the data necessary for these virtual concert experiences, he and his fellow acoustics graduate student, David Dick, travelled across Pennsylvania and New Jersey to measure sound fields in various performing arts venues,

According to Mr Neal, advances in acoustics technology have made collecting data in the field easier and more robust.

"With a typical microphone, we can only capture the time and frequency information about a particular room with no spatial information about where in the room reflections and acoustic energy is collected," he said. "Instead, we use a spherical microphone array called the Eigenmike by mh acoustics, which has 32 microphones evenly distributed around a sphere. This tool allows us to collect all three dimensions – time, frequency and space – so that we can virtually recreate the experience of each hall in our facility."

By using the Eigenmike to collect spatial acoustic data in a variety of concert halls, Neal and his fellow graduate students can virtually recreate the sound of each venue in the AURAS facility.

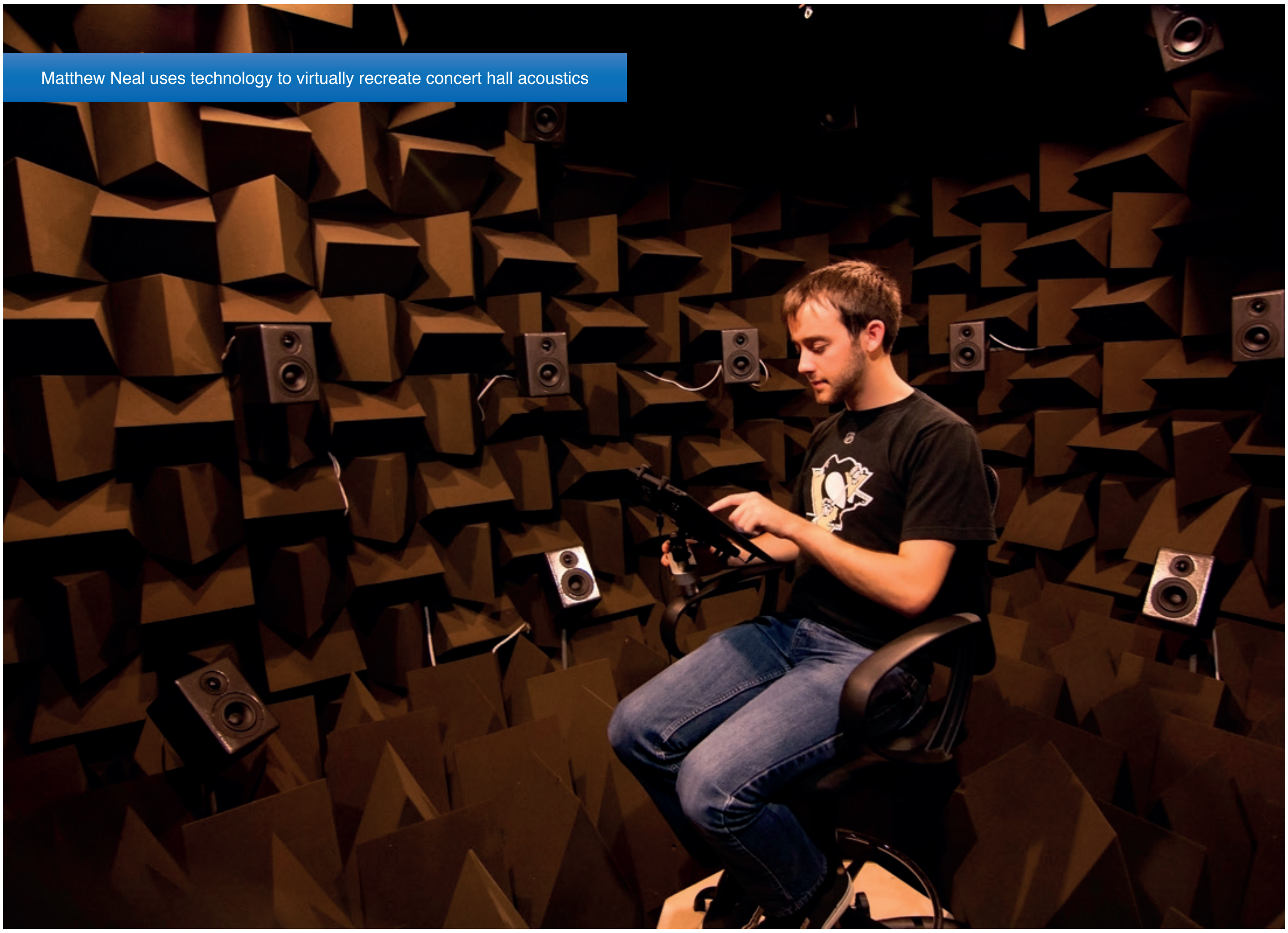
"We can take this microphone array between different halls, place it in a similar seat location and use an identical arrangement of sound sources to create comparable measurements between many different concert halls, "Mr Neal said. "Then we bring all that data back and reconstruct those measured sound fields for listeners."

Once back in the AURAS facility, musicians can virtually travel across the country to hear how a musical composition sounds in varying venues.

Equipped with 30 loudspeakers and two subwoofers surrounding a chair in the centre of the anechoic chamber, the AURAS facility immerses participants in recorded pieces of music from measured concert halls.

Thanks to a tablet digitally displaying each venue and piece of music, participants can easily sift through venues and rate their perception of the room in terms of reverberance, envelopment, overall quality and many other factors.

"Now participants don't have to fly to Los Angeles, New York or Berlin to experience these concert halls," Mr Neal said. "Instead, they can switch between them at the click of a button and hear how a solo violinist sounds playing on a stage."



Matthew Neal uses technology to virtually recreate concert hall acoustics

Graphene thermoacoustic speakers 'sound like the future'

A team of researchers in Korea has developed a simpler way to mass-produce ultra-thin graphene thermoacoustic speakers.

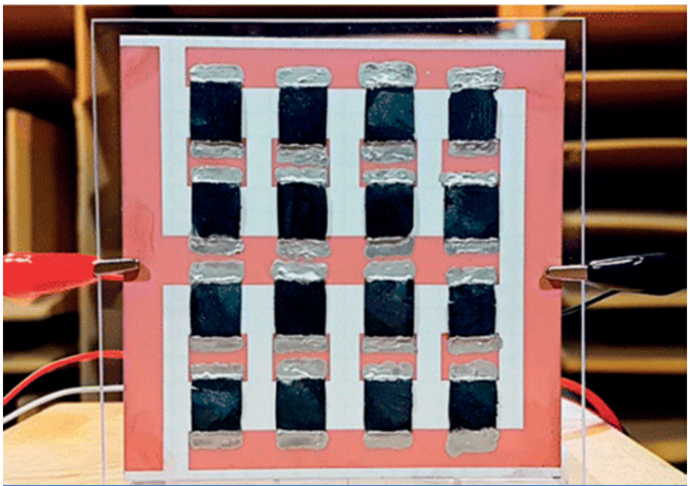
Thermoacoustic speakers generate sound waves from temperature fluctuations by rapidly heating and cooling conducting materials. Unlike conventional voice-coil speakers, thermoacoustic speakers do not rely on vibrations to produce sound, and thus do not need bulky acoustic boxes to keep complicated mechanical parts for sound production. They also generate good quality sound in all directions, enabling them to be placed on any surface, including curved ones, without cancelling out sounds generated from opposite sides.

Led by Professors Choi Jung-Woo, Cho Byung Jin and Kim Sang Ouk of the Korea Advanced Institute of Science and Technology (KAIST), the research team used 3D graphene aerogels to fabricate an array of loudspeakers that were able to withstand over 40 W input power and that showed excellent sound pressure level, comparable to those of previously reported 2D and 3D graphene loudspeakers.

Based on a two-step, template-free fabrication method, the research team produced a N-doped, 3D, reduced graphene oxide aerogel with a porous macroscopic structure.

"Thermoacoustic speakers have a higher efficiency when conducting materials that have a smaller heat capacity. Nanomaterials such as graphene are an ideal candidate for conductors, but they require a substrate to support their extreme thinness. The substrate's tendency to lose heat lowers the speakers' efficiency," said Kim Choong Sun, who is the first author and a doctoral student at KAIST.

Their research results were published online in *Applied Materials and Interfaces*



A thermoacoustic loudspeaker consisting of an array of 16 3D graphene aerogels

Beam me up, Scotty – build a portable acoustic tractor beam at home for less than £70

Researchers from the University of Bristol have shown it is possible to create a simplified tractor beam using readily available parts with a total cost of less than £70.

In the paper, published in *Applied Physics Letters* (APL), the team from the Department of Mechanical Engineering, has shown that it is possible to build a simplified tractor beam using only one electrical signal and a passive wave modulator.

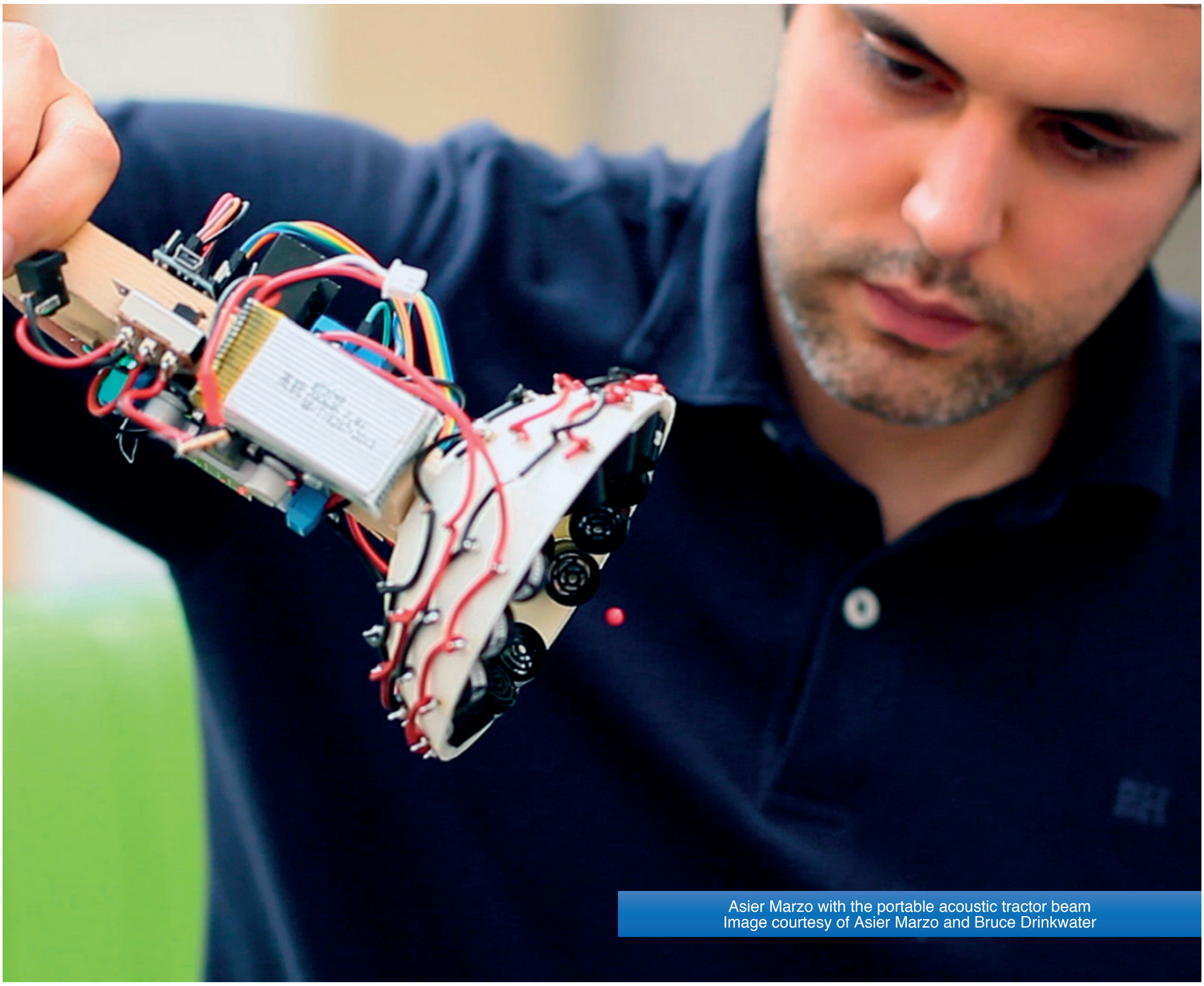
The passive wave modulator is a type of acoustic lens that can alter the transmitted or reflected waves. The research team's passive wave modulator can be made in various different ways. In one example it's a collection of tubes with different lengths and in another it's a carefully contoured surface. In both cases it can be 3D printed using an off-the-shelf printer. Using a single waveform a static tractor beam can be created. If two waveforms are used then up and down manipulation of objects can be achieved.

Asier Marzo, Research Assistant and the lead author, said: "The technique can generate an acoustic tractor beam using only a single electrical signal, this will reduce the cost and complexity of tractor beams making them a more affordable technology for manipulating and analysing levitated samples. With our new research now everyone can have an acoustic tractor beam."

Bruce Drinkwater, Professor of Ultrasonics, added: "The process is so simple that we have released a YouTube video with instructions that show people how they can build their own acoustic tractor beam step-by-step with components that can be bought on the internet for less than £70."

Previous work on tractor beams using sounds waves has opened up lots of applications for contactless handling. For instance, samples of blood could be levitated for visual inspection without any obstruction; chemical compounds could be merged without being contaminated and kidney stones could be removed from the body without the need for incisions.

However, to generate an acoustic tractor beam a phased array of more than 50 channels was required and each channel needs to be composed of a signal generator and an amplifier. These complex electronics have delayed the spread of acoustic tractor beams into the biophysics or medical applications.



Asier Marzo with the portable acoustic tractor beam
Image courtesy of Asier Marzo and Bruce Drinkwater

Tunable sound transmission shapes up

The ability to control fine-scale acoustic waves known as phonons could lead to new sensing and surgery technologies, or even materials that are invisible to sonar.

This pursuit led researchers at King Abdullah University of Science and Technology (KAUST), Saudi Arabia, to describe new phononic crystals whose properties can be tuned to control the propagation of different frequencies of phonons.

Assistant Professor Ying Wu from the university's computer, electrical and mathematical science and engineering division said that the researchers' work was inspired by a phenomenon called topological insulation, which was first observed in electronic systems.

Conventionally, if a material is an insulator, then no part of it will conduct electricity. This logic was turned on its head by the discovery of topological insulators, which have insulating interiors but conducting states on their surfaces that can be manipulated for applications such as quantum computing.

Researchers have extended the concept of topological insulation to materials that only allow certain light or sound waves to propagate on their surfaces. Specifically, these materials may break a physical property called time-reversal symmetry (TRS) to produce a bandgap, a range of frequencies at which no phonons can be transmitted.

"Compared to quantum and electromagnetic systems, acoustic systems did not draw much attention because TRS in acoustic systems is intrinsically conserved," said Professor Wu. "This situation changed in 2015, when several methods were proposed to break TRS in acoustic systems, such as introducing rotating fluids."

The phononic crystal design, proposed by Professor Wu and her PhD student Ze-Guo Chen, involves air flowing around a lattice of ring-shaped waveguides. It could be built from any acoustically-hard material such as steel, with the air velocity controlled by fans. Through numerical experiments, the researchers showed that they could tune the properties of the bandgap by altering either the geometry of the crystal lattice or the airflow itself, thus permitting or blocking different types of phonons from traveling along the surface.

This tunability, which results from the interplay between the TRS and the geometry of the crystal, is a major breakthrough for KAUST and for materials science in general.

"In fact, tuning the phononic band gap itself is not as exciting as tuning the topology or shape of the gap," said Professor Wu. "An interface between two materials with different topological properties in their band gaps would support a special kind of edge state, which only propagates along one direction. A direct consequence is that the edge state is robust and immune to back-scattering, which can be applied in many areas, such as tunable acoustic invisibility from detection."

Tapping into long-lived sound waves in glass

By Jim Shelton

Scientists at Yale University in the US have shown how to enhance the lifetime of sound waves travelling through glass – the material at the heart of fibre optic technologies.

Everyday experience tells us that glass (silica) is highly transparent. In fact, silica is one of the most transparent materials on earth. Light can propagate for tens of kilometres in silica before it experiences any appreciable weakening. This transparency, combined with glass' formability and low cost, is why glass is used in so many of the fibre-optic technologies that shape the information age.

Yet silica also has a mysterious side. At room temperature, silica is an excellent acoustic material. You can demonstrate this by tapping a wine glass with a fork and listening to it ring for several seconds. However, in sharp contrast with most materials, this resonance is quickly muted when the glass is cooled to cryogenic temperatures.

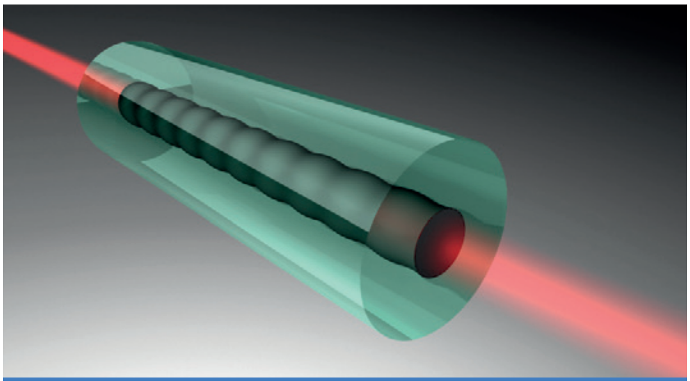
These peculiar acoustic properties are at the heart of long-standing mysteries in glass physics. In the 1960s scientists discovered many perplexing properties of glass: It conducted heat much less efficiently than expected, and it heated up much more slowly than anticipated. These puzzling discoveries were ultimately explained by localized absorbers within glass that interact with sound waves in the same manner that atoms interact with light. To this day however, the true nature of these "acoustic atoms" is not fully understood.

In addition, absorption by these "acoustic atoms" has another consequence that intrigues scientists. At low temperatures the amplitude of a sound wave affects how long it will ring. Roughly speaking, this means you can make your wine glass ring longer by turning on your stereo, which causes the glass to vibrate at altogether different frequencies. Moreover, the duration of the ringing increases as the stereo volume is turned up.

Yale scientists have used this concept to control the lifetime of sound within glass. By shining laser light into fibre optic waveguides made of glass, they were able to probe and generate acoustic waves in the fibre core. By generating an intense acoustic wave at one frequency (i.e. "turning on the stereo") and probing at another ("tapping a wine glass"), the researchers were able to extend the lifetime of a sound wave.

The researchers said that because glass is the backbone of a range of cutting-edge technologies, the findings open the possibility of new forms of high-precision sensing and information processing.

"Our work takes an important step toward engineered sound dynamics in glass," said Peter Rakich, assistant professor of applied physics and physics at Yale and principal investigator of the study.



Laser light generates and probes sound waves in the core of a fibre optic waveguide

Detecting internal tree decay with sound waves

Sound wave technology will make it easier to detect internal decay

A US-based team has established a new method for using a sound wave technology to detect internal decay in trees.

"We don't yet know where internal decay and damage rank as a cause of tree mortality," said Greg Gilbert, Professor and Chair of the Department of Environmental Studies at the University of California, Santa Cruz. "Most of the decay is hidden – the tomography now allows us to see how many apparently healthy trees are actually decayed inside."

The method, known as called sonic tomography, sends sound waves through tree trunks. The longer it takes for a sound wave to traverse a trunk, the more decayed the wood. Based on the velocity of sound, the tomograph (PiCUS 3 Sonic Tomograph; Argus Electronic GmbH, Rostock, Germany) makes a colour-coded image of a cross section of the trunk.

Their methods were derived from measurements on more than 1,800 living trees of 173 tropical rainforest tree species in the Republic of Panama.

Previous use of sonic tomography in forestry has focused on measurements in "typically shaped" trees with cylindrical trunks. However, tropical trees often have large buttresses, irregular trunk shapes, and prop roots that extend up the tree.

The new study, which appeared as a recently published article in *Applications in Plant Sciences*, describes optimum placement of the sensors to avoid aberrant tomography results for the non-model tree shapes that populate the tropics and details how to analyse the tomograms to quantify areas of decayed and damaged wood.

Sound-shaped water droplets may aid drug discovery

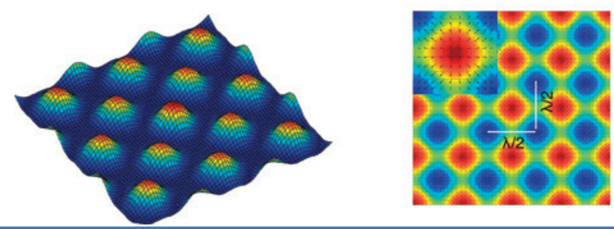
A team of researchers has used ultrasonic forces to accurately pattern thousands of microscopic water-based droplets. Each droplet can be designed to perform a biochemical experiment, which could pave the way for highly efficient lab-on-a-chip devices with future applications in drug discovery and clinical diagnostics.

In a new study published in *Nature Communications*, an interdisciplinary team from the University of Bristol's departments of chemistry, physics and engineering has shown a non-contact method to pattern chemically encoded aqueous droplets into a two-dimensional array under water.

The method uses ultrasonic forces combined with droplet technology to spontaneously create a highly uniform pattern of low surface tension functional water-based droplets. The arrays can be thought of as a new type of highly parallel platform for performing high-throughput analyses in water for drug discovery, clinical diagnostics and protein crystallization. The ability to perform thousands of microscale experiments simultaneously will lead to more efficient lab-on-a-chip technologies.

Current patterning technologies require oil and water mixtures or exposure on a dry surface to achieve arrays of high surface tension droplets. This means that many water-based biochemical reactions are hard to perform. The new method circumvents these problems by patterning the water-based droplets in a water-filled chamber subjected to an acoustic standing wave.

By controlling the composition of the droplets and engineering the acoustic field, the researchers have produced highly uniform arrays of droplets or droplet aggregates arranged in square lattices. The droplet size, spacing and surface-attachment properties could be dynamically controlled and were reversible. The droplets can also be loaded with proteins, enzymes, DNA, polysaccharides, nucleotides, nanoparticles or microparticles, and used in small-scale chemical reactions.



Ultrasonic patterning
Image courtesy of the University of Bristol

Bruce Drinkwater, Professor of Ultrasonics and Head of the Ultrasonics and Non-Destructive Testing (UNDT) research group, said: "As the coavervate droplets are formed they are gripped by the ultrasonic forces and patterned. The uniformity of the droplets is amazing. I'm convinced this technology will have many applications in the next generation of lab-on-a-chip applications."

Professor Stephen Mann, from Bristol Centre for Protolife Research, added: "The acoustic patterning method significantly extends the scope of the current micro-array technologies. We should now be able to develop devices capable of sustaining chemical signals between the droplets as well as enabling spatial and temporal responses to changing conditions in the external environment. This will allow us to exploit the acoustically trapped liquid droplets as a 2D community of spatially organized membrane-free protocells."

Living near busy roads linked to higher risk of dementia

People who live close to major roads face a higher risk of developing dementia than those who live further away – and the reasons are likely to be air and noise pollution, new research from Canada has revealed.

And another study in the UK has found that busy noisy hospitals with changing staff can accelerate mental decline in patients with dementia.

Led by scientists at Public Health Ontario (PHO) and the Institute for Clinical Evaluative Sciences (ICES), the Canadian study, published in *The Lancet*, found that people who lived within 50 metres of busy roads had a seven per cent higher likelihood of developing dementia compared with those who lived more than 300 metres away from busy roads.

The researchers examined records of more than 6.5 million Ontario residents aged 20-85 to investigate the correlation between living close to major roads and dementia, Parkinson's disease and multiple sclerosis.

Scientists identified 243,611 cases of dementia, 31,577 cases of Parkinson's disease, and 9,247 cases of multiple sclerosis in Ontario between 2001 and 2012. In addition, they mapped individuals' proximity to major roadways using the postal code of their residence. The findings indicate that living close to major roads increased the risk of developing dementia, but not Parkinson's disease or multiple sclerosis, two other major neurological disorders.


Hazard: noise from traffic 'increases dementia risk'

"Little is known in current research about how to reduce the risk of dementia. Our findings show the closer you live to roads with heavy day-to-day traffic, the greater the risk of developing dementia. With our widespread exposure to traffic and the greater tendency for people to live in cities these days, this has serious public health implications," said Dr Hong Chen, environmental and occupational health scientist at PHO and an adjunct scientist at ICES.

The UK study, published in *JAMA Psychiatry*, discovered that patients can become acutely confused and disorientated in busy noisy environments such as hospitals, which can prompt delirium.

Delirium, which affects a quarter of older patients, may have long-lasting consequences, including accelerating the dementia process, University College London and University of Cambridge researchers have shown.

The study was based on data from three European observational cohort studies in Finland, Cambridge and UK-wide, in which memory, thinking and experience of delirium had been recorded over 10 years towards the end of their life, and examined brain specimens in 987 people aged 65.

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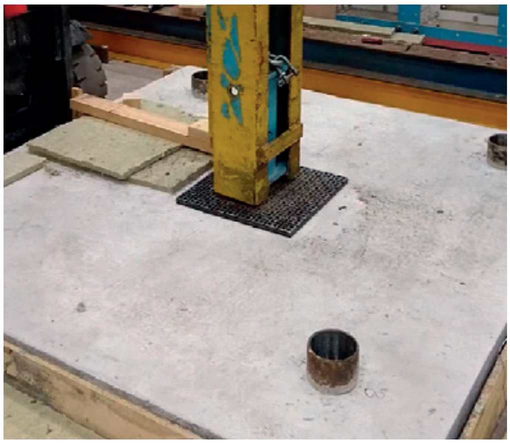
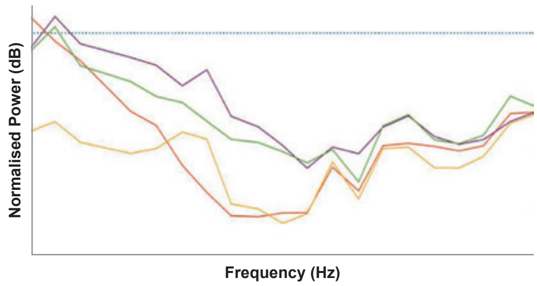
There is no suitable test standard or good quality test data for consultants to specify against. To rectify this, Mason UK tasked Salford University Heavy Structures Laboratory to carry out a range of tests on a specially designed test floor (above right).

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.





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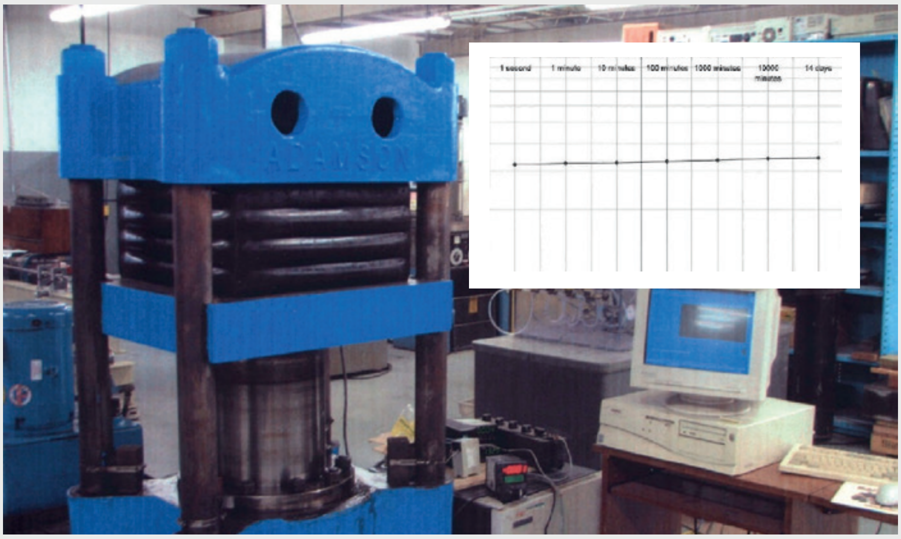

Bearing creep testing and results chart

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Research team improves ultrasound technology with 3D printed lens

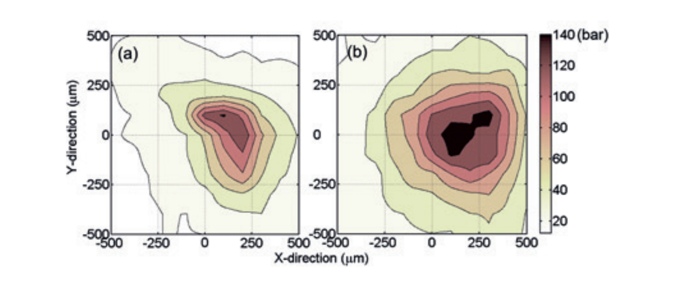
A team at Nanyang Technological University (NTU) in Singapore has developed a 3D printed device that can harness ultrasound technology for surgical and research procedures.

The device, outlined in *Applied Physics Letters*, will enable researchers, surgeons and others to have much more control over laser-generated photoacoustic waves for precise procedures such as surgeries, material analysis and microfluidic research.

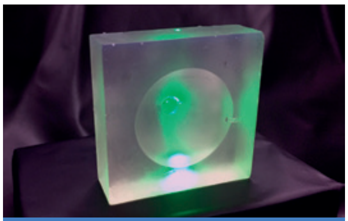
Until now, ultrasound devices could only produce basic acoustic waves called planar waves, which focus to a single point. The devices, called laser-generated focused ultrasound transducers, convert laser pulses into vibrations via a glass surface coated in a thin layer of carbon nanotubes. When the laser pulses hit the glass surface, the heat of the laser causes the coating to expand, generating the vibrations that in turn produce high-frequency, high-pressure acoustic waves.

The main difference between standard ultrasound devices and the NTU device is that instead of glass, the lens, or transducer, is 3D printed with clear photopolymer resin from Formlabs. 3D printing allowed the research team to create lenses in any shape, meaning that they could generate acoustic waves of any shape, unlike glass lenses which are limited to simple planar, cylindrical or spherical shapes. 3D printing more complex lenses allowed the researchers to focus the waves at multiple points at once, as well as to control the phase of the waves and focus them on different points at different times.

"The advantage of acoustics is that it's non invasive," said Claus-Dieter Ohl, Associate Professor and Associate Chair of the School of Physical and Mathematical Sciences at NTU, and co-author of the study. "We have much better control of the photoacoustic wave, and the wave can be even designed such that it serves the purpose of a mechanical actuator."



Positive pressure distribution from the resin (a) and the glass (b) substrate



Nanyang Technological University's proof-of-concept model of the transducer lens
Image courtesy of Weiwei Chan

'Acoustics frequency comb' sounds good

An "acoustic frequency comb", which produces sound at a precise set of frequencies, has been made by physicists at the University of Cambridge.

The device, which is an acoustic analogue of an optical frequency comb, works at ultrasonic frequencies. With further improvements, the device could be used for imaging, metrology and materials testing.

Conventional optical frequency combs emit a spectrum of light made of thousands of discrete peaks at evenly spaced frequencies, like the teeth of a comb. Developed in the 1990s, such combs have been used in a range of applications such as comparing different atomic clocks.

One way of creating an optical frequency comb is to combine laser light of several different frequencies in a nonlinear optical medium. But in the new work, Adarsh Ganesan, Cuong Do and Ashwin Seshia have discovered that a similar effect occurs when ultrasound waves interact in a silicon wafer covered by a thin layer of aluminium nitride, which vibrates when driven by an electrical signal.

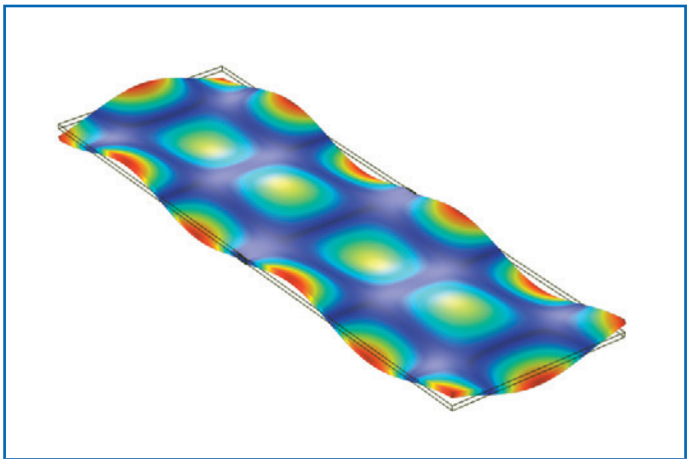
The researchers were initially investigating if such a wafer could be used for sensing applications when they were surprised to see it vibrate at a number of different frequencies when a megahertz signal is applied to it. The gaps between the frequencies all had the same value (about 2 kHz) and the spectrum looked much like a frequency comb. The teeth of the comb extended over a frequency range of about 100 kHz, said Mr Ganesan.

Puzzled by their discovery, the trio soon realised that their system is like a theoretical proposal for an acoustic frequency comb made in 2014 by Peter Schmelcher of the University of Hamburg and colleagues. Professor Schmelcher's group modelled the atoms in a solid material as a collection of masses connected by springs that have a restoring force with a nonlinear component.

In such a material, sound waves can interact with each other to create waves at several different frequencies. Mr Ganesan said that while the Schmelcher model does describe some aspects of their acoustic comb, it does not capture the full complexity of the device.

The team is now making more frequency combs and is also thinking about possible applications, which include boosting the accuracy of sensors that operate using mechanical vibrations. Other possible uses include phonon lasers that create phase-coherent sound signals and ultrasonic imaging.

This report is based on one that appeared in *Physics World*.



Good vibrations: the frequency comb was found in a silicon wafer

Researchers use acoustic waves to move fluids at the nanoscale

A team of mechanical engineers has successfully used acoustic waves to move fluids through small channels at the nanoscale.

The breakthrough is a first step toward the manufacturing of small, portable devices that could be used for drug discovery and microrobotics applications. The devices could be integrated in a lab on a chip to sort cells, move liquids, manipulate particles and sense other biological components. For example, it could be used to filter a wide range of particles, such as bacteria, to conduct rapid diagnosis.

The researchers at the University of California San Diego detail their findings in *Advanced Functional Materials*. This is the first time that surface acoustic waves have been used at the nanoscale.

The field of nanofluidics has long struggled with moving fluids within channels that are 1,000 times smaller than the width of a hair, said James Friend, a professor and materials science expert at the Jacobs School of Engineering at UC San Diego. Current methods require bulky and expensive equipment as well as high temperatures. Moving fluid out of a channel that is just a few nanometers high requires pressures of 1 megaPascal, or the equivalent of 10 atmospheres.

Researchers, led by Professor Friend, had tried to use acoustic waves to move the fluids along at the nano scale for several years. They also wanted to do this with a device that could be manufactured at room temperature.

After a year of experimenting, post-doctoral researcher Morteza Miansari, now at Stanford, was able to build a device made of lithium niobate with nanoscale channels where fluids can be moved by surface acoustic waves. This was made possible by a new method Miansari developed to bond the material to itself at room temperature. The fabrication method can be easily scaled up, which would lower manufacturing costs. Building one device would cost $1,000 but building 100,000 would drive the price down to $1 each.

The device is compatible with biological materials, cells and molecules.

Researchers used acoustic waves with a frequency of 20 megaHertz to manipulate fluids, droplets and particles in nanoslits that are 50 to 250 nanometers tall. To fill the channels, researchers applied the acoustic waves in the same direction as the fluid moving into the channels. To drain the channels, the sound waves were applied in the opposite direction.

By changing the height of the channels, the device could be used to filter a wide range of particles, down to large biomolecules such as siRNA, which would not fit in the slits. Essentially, the acoustic waves would drive fluids containing the particles into these channels. But while the fluid would go through, the particles would be left behind and form a dry mass. This could be used for rapid diagnosis in the field.

Study finds noise from fracking could harm human health

Fracking creates noise at levels high enough to harm the health of people living nearby, according to the first peer-reviewed study to analyse the potential public health impacts of ambient noise related to fracking.

"Oil and gas operations produce a complex symphony of noise types, including intermittent and continuous sounds and varying intensities," said study author Seth Shonkoff, a visiting scholar in the US Department of Environmental Science, Policy and Management, an affiliate at Lawrence Berkeley National Laboratory and executive director of PSE Healthy Energy.

For example, compressor stations produce a low rumble; drilling a horizontal well is a loud process that can take four to five weeks, 24 hours per day to complete; and using large volumes of water at high pressure results in pump- and fluid-handling noise.

The study was published in the journal *Science of the Total Environment*.

To understand whether noise from fracking might impact the health of surrounding communities, researchers gathered all available data and measurements of noise levels at oil and gas operations and compared the information to established health-based standards from the World Health Organization and other groups.

They found that noise from fracking operations may contribute to adverse health outcomes in three categories, including anxiety, sleep disturbance and cardiovascular disease or other conditions that are negatively impacted by stress.

UK seas 'exposed to underwater noise pollution'

Shipping is a major cause of underwater noise pollution

Many parts of the sea around the UK suffer from underwater noise pollution, a new study has found. Analysis of underwater noise data from subsea sound recorders located around the coast revealed many sites were exposed to persistent noise from shipping traffic.

Noise was also identified from onshore industrial activities, fishing, and acoustic deterrent devices (ADDs; also known as "seal scarers").

The Defra-funded research was carried out by the Centre for Environment, Fisheries and Aquaculture Science (Cefas), Marine Scotland Science and the University of Exeter. The results were published in *Scientific Reports*.

The study will inform UK policy on underwater noise pollution and form the basis of the UK assessment of underwater noise under the EU Marine Strategy Framework Directive (MSFD), which assesses the status of European seas.

Cefas is currently working in partnership with several UK universities to establish a permanent noise monitoring network, which will become operational this year.

Cefas Principal Scientist and lead author of the paper, Dr Nathan Merchant said: "This is the first time we have had an overview of noise levels around the UK, which means we now have a benchmark against which to measure future changes in noise pollution.

"Ongoing noise monitoring at these sites will allow us to see whether efforts to reduce noise pollution are effective, and if the pressure on marine ecosystems from manmade noise is rising or falling."

Dr Kate Brookes, Renewable Energy co-group leader, Marine Scotland Science, said: "Understanding current noise levels underwater, and the effect these have on marine wildlife is critical to allowing us to develop plans to manage human activities."

Perception and control of amplitude modulation in wind turbine noise

By Mike Lotinga, Richard Perkins and Toby Lewis (WSP | Parsons Brinckerhoff)

Introduction

Wind turbine noise (WTN) has presented some of the greatest challenges to environmental noise specialists in recent times. These challenges have included technical, political, emotional and ethical issues that have tested experts, the courts and lay-citizens, at times fraying relationships and trust in people and organisations.

One of the most controversial acoustic issues has been the reports and perception of the modulation in the amplitude of the noise emitted by turbines. To a degree this is a largely inescapable feature of any rotating sound source relative to a static measurement point. The amplitude modulation (AM) of WTN has been shown to exacerbate the annoyance some people feel in response to hearing it [1], and this may contribute to the greater negative perception of WTN compared with other types of environmental noise at similar exposure levels [2].

This article outlines the background and recent research into perception and response to AM in WTN, a proposed control scheme published by the UK Government, and discusses further issues in relation to its development. All level descriptors refer to A-weighted values.

History

A short timeline of some key events in the roughly 20-year history of WTN assessment and publicised AM issues in the UK is shown in Figure 1. This illustrates that there have been previous attempts to develop a planning control or condition for AM. These have typically been highly technical in nature, either concerned with restricting specific numbers of AM event occurrences that meet a set of conditions [3], or a character-penalty scheme [4]. There have also been less detailed schemes published internationally, such as NZS 6808:2010 [5], which, in addition to proposing an "interim" measurement method, advises a numerical character penalty that could be assigned from subjective assessment.

DECC AM Research Review

In response to growing concern, the Department of Energy and Climate Change[1] (DECC) commissioned a review of AM research in 2015. This project ran concurrently and cooperatively with the separate effort by the IOA's AM Working Group (AMWG) to develop an AM rating method, the final results of which have been recently published [6].

The aims of the DECC project included the following:

- Review available scientific evidence on the effects of human exposure to AM in WTN
- Evaluate the robustness and adequacy of exposure-response relationships
- Work with the IOA AMWG
- Consider the interpretation of AM WTN in the context of policy P42

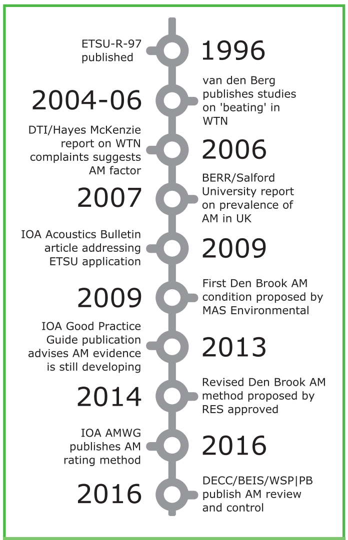


Figure 1: Timeline of key events in UK WTN AM control development

1. Now part of the Department for Business, Energy and Industrial Strategy (BEIS)

◂P41

- Provide a recommendation for an AM control suitable for use in the planning system
- Consider wider implications of possible AM mitigation measures.

The project stakeholders included DECC, Defra, DCLG, PHE and representatives for the Devolved Authorities. The draft deliverable from the research team was reviewed by independent experts in noise and health. The final report has now been published [7], and the results presented at recent conferences, including a day workshop organised by the IOA [8,9]. The discussion points from the workshop raised a number of queries, many of which are discussed in this article. To frame the discussion, a brief summary of the review findings is given below (more detailed information can be found in the reports and papers referenced).

Control scheme for AM

The recommended control scheme comprises the following steps:

- **Instatement:** It would be added within a planning condition attached to a new development consent for large-scale commercial wind turbines (not small domestic turbines).
- **Activation:** The scheme would be considered in reaction to complaints about AM in WTN received by the local authority.
- **Action:** Monitoring of WTN would be required under the scheme, including the specification of equipment suitable for obtaining measurements to produce ratings of AM in accordance with the AMWG Reference Method [6], which gives ratings for individual 10-minute periods.
- **Rating:** The ratings produced would be considered against the penalty scale shown in Figure 2. The corresponding penalty values would be added to the WTN levels derived using the existing methodologies for compliance testing set out in ETSU-R-97 [10] and the IOA GPG [11, 12] for integer wind speeds – implementation of this step is discussed further below.
- **Assessment:** The "rated" levels would be compared with the overall noise limits set out in the planning consent, with the proviso that, if both of the following two clauses are met, the difference between day/night limits at that wind speed will also be added to the rated level:
  1. A higher (less stringent) noise limit is in place for night-time at the wind speed being considered; and
  2. An AM penalty is assigned at the same wind speed (i.e. the AM rating is ≥3 dB).
- **Determination:** Consideration of the implication or significance of any exceedances of the planning condition limits (i.e. a technical breach of condition) remains a matter for the professional judgement of the local planning authority (this might be set out in detail when advising on a condition, or it might not; provided it is deemed to comply with relevant policies – e.g. the NPPF –, the setting and detail of planning conditions is the responsibility of the LPA).
- **Enforcement:** Limit exceedances demonstrating a breach of the condition could be enforced by the LPA, in which case the specific wind speeds in which limits are breached should frame the mitigation requirements (e.g. a breach of the condition at 7ms^{-1} wind speed should not entail action to be taken to mitigate at 9 ms^{-1}, but at 7ms^{-1} – this point is mainly relevant to designing operational mode mitigation strategies, as opposed to engineering solutions such as blade treatments) – this may be formalised by a 'mitigation scheme to be agreed and implemented' clause, or similar, in the condition.
- **Mitigation:** This should address a reduction so that the overall rated level consistently meets the limits; there are two pathways to achieve this: i) reduce AM in the WTN; ii) reduce the overall level of WTN.

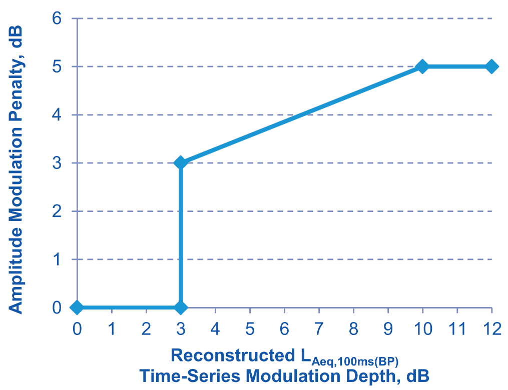


Figure 2: Recommended AM penalty control scheme, from DECC review [7, 8]

In outlining the control, it is also important to state the general principle and aim that will guide its application:

- The underlying principle is that AM increases the annoyance caused by WTN, and that this increase can be characterised by adding a value to the overall WTN level, to equalise it with a negligible-AM WTN sound (in essence this principle is the same as for character adjustments used in other standardised methodologies, including BS 4142:2014 and ISO 1996-1:2016 [13,14]).
- The aim of the control is to reduce the additional impact of AM, i.e. its severity and occurrence; if AM is not reduced, the overall penalised level of WTN must be reduced to compensate (i.e. to meet the limit).

The implementation of the scheme application remains an area that will require further discussion and agreement. In particular, a number of issues are raised within the DECC report:

1. How to add the penalty to the derived WTN levels – this has also been an issue raised with the original ETSU-R-97 tonal assessment penalty, for which two methodologies have been proposed within the IOA GPG [11,12]; it is envisaged that a similar debate must now take place regarding the AM scheme, being careful to avoid a situation where 'averaging of averages' could dilute the effectiveness of the penalty.
2. The determination of non-WTN background noise levels and how this will relate to the penalty scheme implementation in terms of compliance measurements.
3. The extent of any penalised limit exceedances that might be considered unacceptable.

The following section provides views and suggestions on these and other issues, including some interesting points and queries raised at the IOA workshop in relation to the DECC report.

The context for the debate on these issues is referred back to the principle and aim set out above. The DECC report has provided the control framework and presented the supporting evidence. It is now hoped that industry and authorities will take on the role of establishing best practice and developing mitigation, which has proven in the recent past to be a realisable goal. Emerging work, particularly in the aviation sector, has shown that involving affected communities in developing assessment approaches can also be beneficial.

Discussion

Application of the penalty rating

The DECC report confirms that the penalty should be applied to each individual 10-minute period assessed, and the rated levels separated into wind speed integer "bins", for the purposes of comparison with the condition limits. The GPG method [11, 12] requires a best fit curve to be applied to the sound measurements to derive an average WTN level for the relevant period. The rated levels could be analysed in the same way.

One drawback of this approach is that, where some periods have AM (and are penalised), and some do not, this averaging could reduce the overall rated impact. One view that could be taken of this is that this average is a natural representation of the overall impact. On the other hand, it may be considered that this would obscure the impact during periods of high AM by combining it with steadier periods. The latter view implies that the AM-penalised WTN levels might be better assessed separately from the periods in which AM is not apparent or insufficient to attract a penalty. A difficulty that could then arise is that in cases with sporadic AM, insufficient data points might be collected to generate a reasonably robust estimate of the AM-penalised level. However, in that event, this might also provide an indication that the occurrences of AM are generally low, in which case an LPA might consider the impact does not warrant further action.

An alternative approach could be to aggregate the AM penalty ratings, and apply this to the averaged level of the valid measurements. This was not the approach directly implied within the DECC report; nonetheless, depending on the details of the data processing, it may be found that this approach produces an equivalent output.

It must be made clear, however, that the processing should not be based on taking an aggregation of the AM ratings and then assigning a penalty to the output – this approach would likely result in anomalies where AM marginally but regularly exceeds 3 dB depth (indicating additional AM character impact), but then combined with lower ratings results in a 0 dB penalty overall.

Why not write a detailed template planning condition?

It is important to make the distinction between a planning condition and a control scheme, and this was raised in the IOA workshop. Planning conditions are a mechanism for LPAs that must only be used to make an otherwise unacceptable proposal acceptable [15]. The control scheme is a tool to assess and penalise the impact of AM, to be considered when determining if an AM condition would be appropriate at a proposed development site.

The distinction between an "exceedance" and a "breach" in relation to the control was also queried in the workshop, and the DECC report sometimes uses these terms interchangeably. An exceedance of a limit (in this context, this means the rated WTN level exceeding the planning condition limit) is technically a breach of condition. However, the need for enforcement action is discretionary and determined by LPAs. This would normally be based on a judgement as to whether any limit exceedances are unacceptable (e.g. in terms of consistency, magnitude, time of day etc) and require enforcement action to reduce the impact. The interpretation of exceedances (technical breaches) in triggering enforcement action is a matter for the LPA to determine.

Planning policy compels decision-takers to consider a wide range of issues relevant to making plans and considering development proposals, including noise. These considerations must weigh the potential adverse impacts against the benefits. When it comes to compliance monitoring in relation to an AM complaint, it may be found at some sites that there is a persistent problem (possibly associated with certain commonly encountered wind speeds and directions), while at others it may be that penalty-attracting (and annoying) AM occurs very infrequently. In any event an LPA must consider whether or not formal planning enforcement is proportionate and in the public interest, in the light of the potential impacts on the health, welfare and the rights of both parties. The LPA may, therefore, make the judgement that, on balance, even if complaints are received and exceedances of limits are subsequently demonstrated, enforcement action is not expedient. On the other hand, it may be clear that exceedances of the limits due to AM are causing an impact that outweighs other considerations. The penalty scheme provides a means to weigh the potential impact of AM in the balance of consideration.

As detailed in the DECC report, the evidence base for the influence of duration and frequency of occurrence of AM WTN on subjective response is limited, and responses to WTN in general vary widely [7]. This is likely to be due to the wide range of non-acoustic factors that modify responses to exposure, but could also reflect the highly variable nature of WTN, the difficulty in quantifying both "dose" and effects, and the relatively small pool of exposed populations to draw on in experiments. The need for more objective measurements in epidemiological studies of wind turbine noise has been identified as a research need by the group developing the forthcoming WHO-Europe environmental noise guidelines [16]. In lieu of stronger research evidence, these admittedly difficult judgements will inevitably fall to LPA officers. Although environmental specialists will be qualified and experienced in making such judgements, it is hoped that best practice guidance can also be developed that would offer further support and consistency.

Use of level adjustments vs L_{90} differences

The RenewableUK exposure-response study conducted by the University of Salford [17] produced some of the experimental data on which this penalty scheme is based. The study included an experiment in which participants were asked to listen to an AM WTN-like sound and adjust the level of a very similar noise with steady amplitude to be equivalent in their judgement of annoyance. The equivalent P44

◀ P43

energy of the samples was matched to control for the influence of the overall level; in other words, to isolate the effects of changes in modulation from variance in L_{eq}[2], since equivalent environmental noises are typically judged to be more annoying with increasing level [18], WTN being no exception [19]. Other experiments also considered have taken a similar paired-comparison approach, controlling for L_{eq} [20]. The adjustments in level made by the participants can be viewed as a measure of the "equivalent annoyance" between the modulated and unmodulated sounds. One of the analyses in the RUK study included deriving adjustments relative to the L_{90}[3] levels of the paired samples. It has been suggested that, because the ETSU-R-97 assessment method employs L_{90} to compare WTN with limits, a decibel penalty scheme for use in that framework must also consider differences in L_{90} in order to be applicable [21].

The RUK study did consider this issue, and produced two figures, 22.1-22.2, included as an appendix to the report [17], noting that L_{90} might be a parameter worthy of further investigation to express annoyance ratings. These charts are replotted here in Figure 3, which shows L_{90} and L_{eq} level differences between AM/non-AM sounds judged equally annoying over a scale of modulation depth according to the AMWG method. One of the interesting features is that, at first glance, the L_{90} differences appear to show a "better' relationship with modulation depth than the L_{eq} level difference (i.e. the gradient of a linear regression line is closer to 1). This may give quite a misleading impression, until it is remembered that, for an artificial AM sound with constant mean, short term L_{90} is a measure of trough depth, which decreases for larger modulation depths when L_{eq} is held constant. This feature is visualised in Figure 4(a-d), which shows that the L_{90} for an artificial AM sound (ie the trough depth) drops while L_{eq} is held constant and modulation depth is increased – put simply, the peaks and the troughs both extend around the constant mean. It follows that the L_{eq}-L_{90} level difference for the AM sound, indicated by the vertical arrows in Figure 4, also increases proportionally with modulation depth – this should therefore be recognised as a form of measure for AM depth in these artificial AM sounds. In the experiment, the L_{eq} of AM vs non-AM sounds is constant for each comparison. The difference in levels (after adjustment by the participants) was derived by comparison of the AM signal and the steady sound (the latter for which L_{90} and L_{eq} are, by definition, very nearly equal). This means that the L_{90} results effectively plot the adjustments made by the participants combined with the AM sound's own L_{eq}-L_{90} level difference (i.e. another measure of AM depth) against a peak-trough modulation depth – in other words both the abscissa and ordinate of chart 22.2(b) in [17] (and the L_{90} trace in Figure 3) are valued against a type of modulation depth, and so a more closely 1:1 relationship should be no surprise; the gradient of this regression is biased by the physical parameters employed to derive it (NB. a similar conclusion is found in [6]). If this bias is removed, by subtracting the starting L_{90}-L_{90} differences between AM/non-AM sounds (prior to the participant adjustment), the plot reverts to the "L_{eq}" trace (Figure 3), as really all this latter plot shows is the actual decibel adjustment made by the participant, which affects any level parameter equally.

The clearest illustration of the problem can be given via a hypothetical example: a participant is presented with artificial AM/non-AM stimuli, both have the same overall $L_{eq,T}$ of 40 dB(A) and constant mean values. The steady sound has an overall $L_{90,T}$ of 39.5 dB(A) while the AM sound has a peak-trough modulation depth of 4 dB and an overall $L_{90,T}$ of 37.7 dB(A). This participant happens to have lower-than-average sensitivity to AM, and considers the stimuli to be subjectively equally annoying – they make no adjustment to the level. The recorded level difference between the sounds is then 0 dB in $L_{eq,T}$, and 2 dB in $L_{90,T}$. Despite there being no significant perceptual difference (to this individual), a difference in L_{90} is recorded, and would therefore indicate application of a penalty based on L_{90} differences, if such a system were adopted from this single hypothetical test. This example illustrates why the Salford study concluded that equivalent adjustments from the L_{90} results "cannot be identified"; such an experiment would need to control for L_{90} while changing modulation [17].

Setting aside for a moment these incongruities, we return to the original argument that the L_{90} level differences (which, as shown, merge a form of AM depth measure together with the adjustments actually made by participants) should form the basis of a penalty scheme for use with the current ETSU-R-97 method. As shown in

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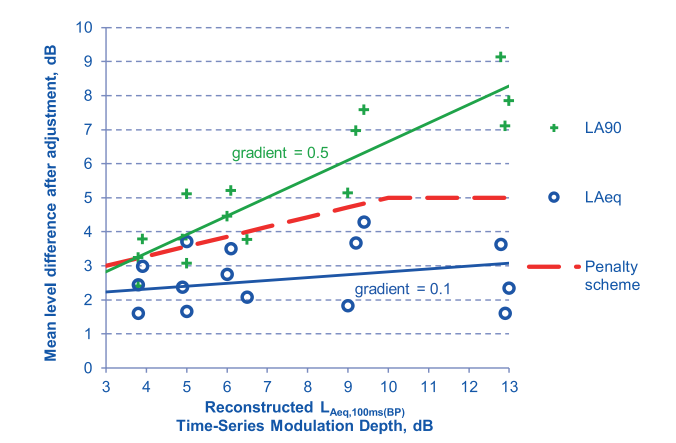

Figure 3: Comparison of L_{eq} and L_{90} level differences after subjective adjustment, data from RUK/Salford and AMWG studies [6, 17]

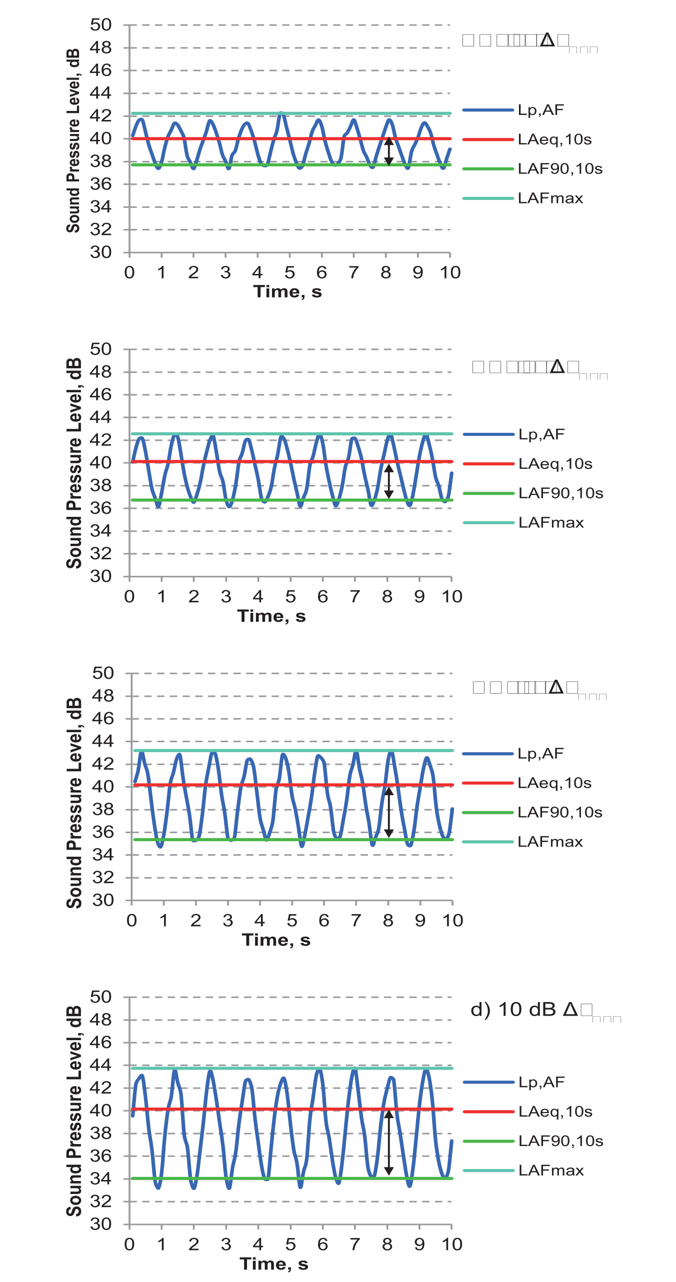

Figure 4: Example of changes in level parameters for artificial AM signals with f_{mod} = 0.9 Hz and increasing modulation depths; a) ΔL_{mod} = 4 dB; b) ΔL_{mod} = 6 dB; c) ΔL_{mod} = 8 dB; d) ΔL_{mod} = 10 dB

2. Equivalent continuous (time-average) sound level defined in BS EN 61672-1

3. 90% exceedance (10th percentile) value for the Fast time-weighted sound level defined in BS EN 61672-1, typically derived from values sampled at 10-100ms intervals ('true' values are derived from full sample rate)

Figure 3, this would suggest a sliding value of roughly 3-8 dB over an AM depth in the range 3-10 dB, rather than the penalty scale proposed. If real AM WTN behaved in the same way as the artificial signals (i.e. the L_{eq}-L_{90} difference within the WTN, when measured over the full 10-minute assessment period, increased significantly during real periods of high AM, as for the artificial constant-mean sinusoid-type signal envelopes considered above), then this might justify a scheme based on some form of L_{90} differences – although not from the RUK experimental dataset, due to the reasons exemplified above. However, when measured over a 10-minute period, the L_{90} of real AM WTN does not typically appear to behave in this way, i.e. it is not simply a measure of trough depth in the signal. It is strongly affected by the fluctuating mean of the level, as well as extraneous background noise, factors which were deliberately controlled in the experiments to manage their influence on the results. So the real question is whether or not the L_{eq}-L_{90} relationship for a WTN signal, assumed in ETSU-R-97 to be 1.5-2.5 dB, continues to hold over typical 10-minute periods under real, variable AM conditions. This is a question that could potentially be addressed in further studies, but neither the DECC review nor the AMWG research yielded strong evidence to suggest that it does not. The DECC report states that the character penalty should be added to 'the overall time-averaged level', which in this context does in fact mean the 10-minute L_{eq} of the WTN. The ETSU-R-97 methodology uses $L_{90,10min}$ as a proxy for $L_{eq,10min}$, and so, unless it is shown this proxy relationship is not appropriate for assessment of real WTN, addition of the penalty to the $L_{90,10min}$ is the recommended means of implementation.

Night-time penalty

The DECC review highlights the increased impact of AM occurring during the night, citing the field study literature and subjective reports from participants [7]. Analysis has also shown that AM can in some circumstances increase at night [22]. These two factors combined show that there is a need to focus the control of AM on the night-time, when sensitivity and risk both appear to be highest. The way this is achieved in the scheme is by effectively "equalising" the day and night noise limits when character-penalised AM is present. At the IOA workshop (which was attended by both wind farm developers and opposing campaigners, in addition to consultants and local authorities), some critical feedback was made, claiming that this was "fixing ETSU by the back door", and "unfair on existing wind farms". The reasoning behind the proposal, as well as its necessity, is clear: the additional impact of AM at night should be controlled. If a wind farm development has been consented with less stringent night-time limits, this means the impact of AM could (when present) be greater at night – to ignore this would be to disregard the research findings. The scope of the study was to propose a control for AM, and that is what has been delivered; the study did not include reviewing ETSU limits in general within its scope. The control has also been deliberately limited to new planning case situations; its application for retrospective assessment of existing consented sites was likewise outside the scope of the study.

More recent research

It has already been several months since the DECC report was published, and even longer since it was drafted. New research on AM WTN is regularly being published, and future studies could illuminate hitherto unexplained matters or even reveal contradictory evidence to that reviewed. Three studies in particular were added to the consideration as annexes to the final report, as they were published too late to be included in the main review. One was the presentation of findings from the Health Canada-sponsored field study[4]; a large-scale epidemiological research project involving 1,238 participants in a survey that measured both subjective (self-reported) and objective measures of health effects in populations exposed to WTN- amongst other findings, this study again supports the strong association of the time-averaged level of WTN with annoyance responses. The other two comprised laboratory exposure-response studies of subjective reactions to AM WTN, which attempted to increase the understanding of otherwise lesser-studied features.

There are some particular findings from this research that merit further mention here: Schäffer et al [23] reported the lab results from an experiment that included 60 participants; a substantially larger sample than recruited for the other lab experiments considered in the main report, and including a relatively wide demographic in P46

4. Several papers and reports present the wide-ranging findings from this study – a publication list can be found in reference [7].

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terms of both age (18-60 years) and living environments (52% "rural", and 72% "quiet"). The AM features in the WTN sounds presented had a peak-trough depth of approximately 6 to 8 dB, i.e. attracting a penalty in the region of 4-4.5 dB under the scheme presented above. The difference in terms of equivalent annoyance between the L_{eq} levels for the AM versus non-AM sounds was found to be on average approximately 2 dB; 95% confidence intervals were spread up to around 2 dB from the mean. These results are in broad agreement with those from the studies involving much smaller numbers of people, which also gives confidence that the penalty scheme as proposed is appropriate for an increasingly large sample.

In common with the DECC report, the study also highlights the important distinction between the "short term annoyance' used to study responses in the labs, and the 'long term annoyance" studies in field research. As mentioned above, real noise exposure can induce complex reactions, and objective noise evaluations explain a surprisingly small part of the variance in annoyance responses [24], which for WTN can be influenced by a host of non-acoustic factors [8]. A challenge now facing acousticians, psychologists and policy-makers is how to address this dichotomy in a reasoned, fair and sustainable way.

Conclusion

The results of the DECC review have been used to recommend a control for AM. Various factors have been considered, and a recommendation made that balances the need for protection with the weight of the available evidence. There remain some areas on which the evidence was lacking, and these issues should be addressed by way of best practice guidance, supported by further research evidence; some suggestions have been presented for consideration and discussion. The authors hope that the IOA and its members will continue to play a significant role in establishing best practice for UK acoustics professionals, and that this will lead to better decision-making and development planning in the wind energy sector.

Authorship and acknowledgements

__Mike Lotinga__ was a researcher on the DECC review and noise consultant on several wind farms. __Richard Perkins__ led the research team on the DECC review and formerly chaired the IOA Working Group on Wind Turbine Noise, including the development of the Good Practice Guide. Now a consultant, __Toby Lewis__ previously worked as a local authority environmental protection officer with involvement in wind farm public inquiries. The preparation of this article benefitted from helpful feedback received from Matthew Cand (Hoare Lea).

References

A full list of references can be obtained from the IOA.

The assessment of noise from construction of offshore renewable energy infrastructure

By Jonathan Sims of Hoare Lea Acoustics

Introduction

Due to the increasing desire for renewable energy, and the reduced acceptability of onshore wind developments in the UK, the last few years has seen an increase in the development of large offshore wind farms. Whilst these are generally too far offshore for operational noise to be a concern, with turbines typically installed between 5 and 30 km from the coastline, installation of offshore turbines frequently requires piles to be driven into the seabed during construction of the turbine foundations. Offshore piling can only be carried out under calm sea conditions and relatively low wind speeds so, in order to minimise construction periods, piling is typically undertaken whenever weather conditions allow, which often results in piles being driven late at night or in the early hours of the morning.

This paper discusses the peculiarities of assessing this type of construction noise. In particular, this paper includes a brief discussion of the consenting process that applies to offshore wind energy developments, methods for predicting onshore noise levels from piling works at large distances from the coastline, a discussion of the appropriateness or otherwise of standard construction noise criteria to this type of noise, and an example of long term monitoring that has previously been carried out to monitor noise levels during construction of an offshore wind farm, including examples of noise levels measured at onshore locations during offshore piling.

For the purposes of this paper, offshore renewable energy infrastructure includes:

- Offshore wind turbines
- Offshore substations
- Offshore meteorological masts
- Offshore cabling.

The construction of onshore infrastructure elements (e.g. onshore cabling, substations etc.) associated with offshore renewable energy projects is not considered in this paper.

Planning process

The planning process for offshore renewable energy infrastructure in the UK varies, depending on which country has planning responsibility. The different planning processes are briefly described below.

England and Wales

For offshore renewable energy projects of more than 1 MW and less than or equal to 100 MW located in the seas around England and Wales, planning approval is considered and determined by the Marine Management Organisation under Section 36 of the Electricity Act. Whilst onshore local planning authorities are not responsible for determining permission for offshore developments, the relevant local authorities (i.e. those local authorities that could experience impacts from the proposed offshore development within their local authority area) are statutory consultees, and so will also input during the consultation process. A full Environmental Impact Assessment (EIA) is likely to be required.

For offshore renewable energy projects of over 100 MW located in the waters around England and Wales, the Nationally Significant Infrastructure Project (NSIP) process applies. In broad terms, this involves a formal consultation process with all relevant stakeholders (which will include any relevant local authorities) and production of a full EIA, followed by an examination process that involves planning inspectors reviewing the EIA and putting questions to the developer and the project team. Often this is in the form of written questions, however formal Hearings can also take place as part of the NSIP examination process.

Scotland

In Scotland, all offshore wind energy applications are dealt with by Marine Scotland, although the relevant local authorities will still be statutory consultees. The NSIP process does not apply in Scotland, however a planning application for offshore wind energy development is likely to still require a full EIA and may also be subject to a public inquiry, depending on particulars of the development.

Northern Ireland

In Northern Ireland, applications for offshore wind energy developments are considered by the Department of the Environment,

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although as with other areas of the UK, the relevant local authorities will be considered statutory consultees. Applications for offshore renewable energy development within waters around Northern Ireland are likely to require a full EIA, and may be subject to a public inquiry, as with other areas of the UK.

All developments

All offshore renewable energy developments will also require a marine license (issued by the Marine Management Organisation in England, Natural Resources Wales, Marine Scotland or the Department of the Environment in Northern Ireland) and, since the seabed around the UK and the rights to generate offshore energy are managed by Crown Estates, a lease will need to be agreed between the developer of the offshore renewable energy development and Crown Estates. Crown Estates will only grant a lease once all other permissions (e.g. planning consent, marine licence etc.) have been granted.

As can be seen from the above, the planning consent process for offshore renewable energy development involves satisfying several different bodies, whichever part of the UK the development is located in. In addition, a full EIA is likely to be required for all offshore wind energy projects. This therefore raises the question of whether or not noise needs to be considered as part of a planning application, and if so, what aspects of noise need to be considered?

Potential noise impacts

The potential noise impacts from offshore wind farms can be considered in two separate and distinct categories, operational noise impacts and construction noise impacts. These two different aspects of offshore noise are discussed below.

Operational noise

Offshore turbines tend to be larger than onshore turbines (both in terms of physical dimensions and generating capacity), with typical sound power levels for current offshore turbines of the order of 115 dB(A) when they are operating at maximum power output. These noise levels are not high enough for operational noise from turbines to be an issue at onshore locations unless the turbines are located close to the shore. Since most offshore wind farm developments currently being developed in the UK are situated a significant distance offshore, for the majority of offshore wind farm developments operational noise from the turbines affecting onshore noise sensitive receptors would not be expected to be a problem. Noise from onshore elements of an offshore wind farm (e.g. substations, converter stations, etc.) is therefore likely to form the main potential source of operational noise impacts for such developments.

Construction noise

The construction of an offshore wind farm is likely to involve several potentially noisy activities, but the activity that is likely to generate the highest levels of noise for most offshore wind turbine developments is the construction of foundations. For the most part, this is likely to involve the installation of one or more piles for each of the turbines and the offshore ancillary equipment (e.g. substations, meteorological masts etc.). These piles can be very large (up to around 6 m in diameter) and are typically installed using impact piling. The sound power level generated during impact piling can be upwards of 140 dB(A) and noise generated by impact piling is, by nature, impulsive.

The construction of current offshore wind farms may involve the construction of several hundred turbine foundations, and therefore the construction phase of an offshore wind farm can last for three to five years. In addition, offshore piles can only be installed under calm sea conditions and low winds so, to avoid further extending the construction period, piles are typically installed whenever weather conditions allow. This means that, for most current offshore wind farms, some piles are likely to be installed during the night. There is therefore the potential for offshore piling during the construction phase of an offshore wind farm to be audible at onshore noise sensitive receptors. The focus of this paper is therefore the assessment of potential noise impacts from offshore piling.

Piling noise – the potential problem

The obvious question that arises from the above discussion is whether or not noise from offshore piling is, in reality, a problem at onshore noise sensitive receptors. The following figures show 100 ms L_{eq} time histories that were measured at onshore locations during piling operations that were taking place locations of the order of 15 km to 20 km offshore. The chart on the left shows the overall dB(A) levels and the chart on the right shows the unweighted noise level measured in the 100 Hz third octave band for the same measurement period.

As can be seen from Figure 1, 100 ms L_{Aeq} noise levels of between 45 and 50 dB(A) were measured onshore during this period, with noise levels during piling events of the order of 5 to 10 dB(A) above the underlying baseline noise levels. Piling events are also clearly visible in the 100 Hz third octave band time history, with measured noise levels during piling events being up to 15 dB above the underlying baseline noise level in this frequency band. Noise from piling during this period was, not surprisingly, clearly audible and complaints from residents were received during this particular piling operation. Similar noise levels have been measured during other periods of piling, and measurements combined with audio recordings have shown that, due to the impulsive and low frequency nature of piling noise, piling can be audible even if the level of piling noise is below the prevailing baseline noise level. This is consistent with the reported findings of other investigations into noise from offshore piling in the UK [1].

The installation of a single pile takes around four hours, and as previously discussed piling will occur whenever weather conditions allow. Since many piles will need to be installed during the construction period and favourable weather conditions for piling could occur for several days at a time, piling can occur for several consecutive nights, and it is therefore possible that significant disturbance can occur during offshore piling works, even if this work is taking place at large distances offshore. It should, however, be emphasised that piling activities can also be completely inaudible at onshore locations, and it is possible for piles to be installed during night-time hours without disturbing residents of onshore properties. These large differences in onshore noise levels that can be experienced during offshore piling works are due to the influence of weather conditions on noise propagation, which is discussed in more detail in the following section.

Effects of weather conditions

As can be seen from the results presented in the previous section, it is possible to experience relatively high levels of noise at significant distances (circa 15 km to 20 km) away from offshore piling activities, typically during onshore winds. Onshore construction would be a very different situation, as it would usually be expected that onshore construction noise would become inaudible within a separation distance of a few kilometres, even when the wind is blowing from the source to the receiver. The question therefore arises, why, under certain conditions, are much higher noise levels experienced at large distances from offshore piling than would be expected based on experience of onshore piling?

The clear difference between propagation of sound over water and that over land is that, in the former case, the surface over which sound is propagating is acoustically hard and relatively flat, and in the latter case the surface over which sound propagates is likely to be a combination of acoustically soft and hard ground and there are likely to be variations in ground height, buildings etc. along the propagation path. Under downwind propagation (i.e. when there is a component of the wind blowing from the source towards the receiver), sound will be refracted downwards in both the case of propagation over water and propagation over land. For the case of propagation over water, however, the acoustically hard water surface will result in very little absorption of acoustic energy where the sound field meets the P50 ▸

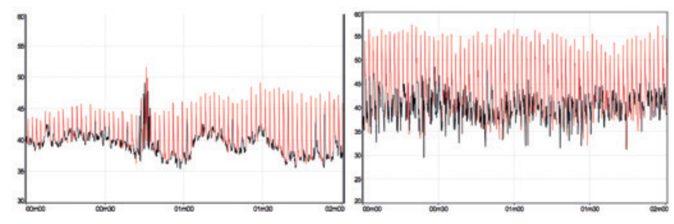

Figure 1: Time history of measured 100 ms onshore noise levels during offshore piling. The above noise levels were measured just after midnight. Note the different vertical scales

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water surface. Since piling only takes place under calm sea conditions, the sea surface will also be relatively flat and therefore there will be a relatively low degree of scattering of energy reflected from the sea surface. In the case of downwind propagation over land, there will be a much greater degree of absorption of energy where the sound field meets the ground, and intervening topography between the source and receiver will introduce more scattering of energy reflected from the ground surface compared to the case of propagation over water. These differences will result in the influence of multiple surface reflections under downwind propagation being much greater for propagation over water than for propagation over land.

In addition, the changes in sound speed profile with height above ground, and hence the degree of downward refraction of sound that will be experienced under downwind conditions, are likely to be different under propagation over water as compared to propagation over land. Examples of these effects are included below. Figure 2 shows the variation in sound speed with height above the ground for “weak” refraction, “normal” refraction, “strong” refraction and a “low level jet” condition [2]. All of these sound speed profiles represent a wind direction blowing from the left to the right of the chart, however the variation of sound speed with height above the ground varies between the different profiles, and these differences are mainly due to differences in wind shear. The weak, normal and strong sound speed profiles are based on the common assumption of a logarithmic change in sound speed with height above the ground, but with varying calculation parameters. The low level jet profile is representative of sound speed profiles that exhibit very rapid changes in sound speed with height above the ground. These low level jet sound speed profiles are, in the UK, more likely to occur over the sea and for onshore winds, and are less likely to occur over land.

To illustrate the effects of these different sound speed profiles on the propagation of sound, Figure 3 shows modelled propagation results for each of the above sound speed profiles. All of the modelled results relate to downwind propagation over an acoustically hard surface, at a frequency of 50 Hz, with the source located at a height of 100 m on the left of the plot and all cover a propagation distance of 8 km along the x-axis.

As is clear from the results shown in Figure 3, as the intensity of downward refraction increases, sound becomes trapped in a layer close to the ground surface and the more rapid the changes in sound speed with height above the ground, the more defined this layer becomes. For very rapid changes in sound speed with height (e.g. the low level jet case), the combination of very strong downward refraction and a reflective ground surface can be thought of as a wave guide. Under downwind propagation over water and with rapid changes in sound speed with height, propagation of noise from offshore piling can therefore be expected to be enhanced at onshore locations.

Predicting noise propagation from offshore piling

Given that noise from offshore piling can be audible and can reach relatively high noise levels at onshore locations under some weather conditions, but is highly variable, it is clearly desirable to be able to predict onshore noise levels under varying weather conditions. The advantages and disadvantages of various potential methods for predicting propagation of noise from offshore piling are therefore discussed below.

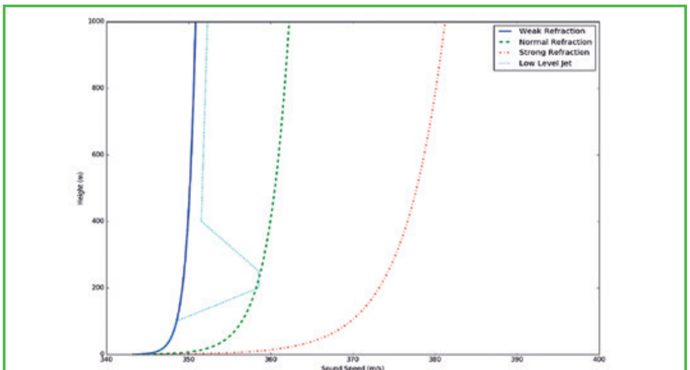

Figure 2: Examples of sound speed profiles

ISO 9613

The prediction method that is outlined in ISO 9613-2, 1996 [3] is perhaps the most widely used environmental noise prediction methodology in the UK and would therefore seem to be an obvious candidate for predicting noise propagation from offshore piling. This method has several advantages: ISO 9613 is an international standard and therefore is widely used and recognised; the methodology is simple to use and requires relatively few input parameters; and predictions are quick to produce and commercially available software implementations are available that can be used to produce predictions at either point locations or in the form of noise contours.

The scope of ISO 9613 states, however, that the prediction method is not applicable to inversion conditions over water. While no comment is made as to the applicability of the prediction method for downwind propagation over water, there is no difference from a noise propagation point of view between a temperature inversion and downwind conditions (both can result in similar changes in sound speed with height), so this would also imply that the ISO 9613 methodology may not be applicable for downwind propagation over water.

In addition, the ISO 9613 methodology is an empirical, engineering method and therefore does not consider the effects of ground absorption or meteorological effects in great detail. This is generally not problematic for the prediction of noise propagation over short to medium distances (e.g. up to 1 km with the default ISO 9613-2 methodology, with accurate predictions possible for extended distances given some adjustments to the prediction method [4, 5, 6]), however for the large distances of up to 30 km or so that can be involved for the propagation of offshore piling noise, the approximations involved in relation to meteorological and ground absorption effects in the ISO 9613 method are likely to lead to significant inaccuracies in predictions. As such, ISO 9613-2 is not likely to give suitably accurate estimates of noise levels at onshore locations during offshore piling activities.

ISO 13474

ISO 13474, 2009 [7], sets out a framework for the calculation of a distribution of sound exposure levels from impulsive sound sources, and therefore at first glance appears to be ideally suited to predicting noise from offshore piling. This standard is again a recognised international standard and is relatively simple to use (if enough information is known in relation to propagation conditions). The major benefit of ISO 13474 over ISO 9613-2 is that methods for calculating ground impedances and sound speed profiles are included in the standard.

ISO 13474 does not, however, describe how to relate the calculated ground impedances and sound speed profiles into the respective excess attenuations for use in propagation attenuation calculations. In

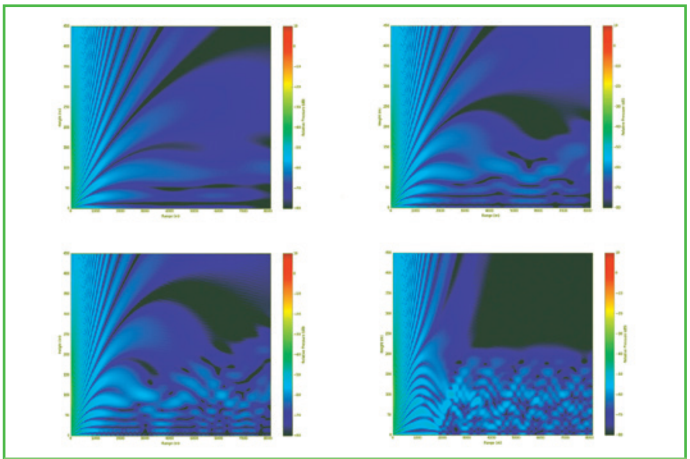

Figure 3: Examples of modelled noise propagation for “weak” refraction (top left), “normal” refraction (top right), “strong” refraction (bottom left) and for a low level jet (bottom right). All predictions are in units of relative pressure at a frequency of 50 Hz and all plots include a source on the left of the plot at a height of 100 m and propagation over an acoustically reflective ground surface. Results are shown up to a height of 450 m (y-axis) and for a propagation distance of up to 8 km (x-axis)

addition, in order to produce distributions of sound exposure levels at a given receiver location, ISO 13474 requires some knowledge of how frequently different meteorological conditions (and hence different sound speed profiles) occur, which in turn may require long term meteorological surveys to be undertaken before noise predictions can be carried out.

Given the above, whilst there is useful guidance contained within ISO 13474, particularly in relation to calculating ground impedances and sound speed profiles, it would generally not be possible to use ISO 13474 to predict onshore noise levels without some additional knowledge (in particular, the excess attenuations that would be expected under different meteorological and ground conditions).

IOA GPG SGN 6

Whilst not intended for use in predicting noise from construction work, Supplementary Guidance Note 6 of the Institute of Acoustics Good Practice Guide to the Application of ETSU-R-97 (SGN 6) [8] provides a method for predicting noise propagation over water. The calculation method set out in SGN 6 is very simple and requires very few calculation parameters (essentially just source sound power level and horizontal distance between source and receiver), therefore predictions using this method are very quick and simple to produce. Reference to the papers on which this calculation method is based [9] also show that this method is relevant to noise propagation under low level jet conditions.

Since the prediction method in SGN 6 is relevant to low level jet conditions, it is, however, likely to over-estimate noise levels at coastal locations under other meteorological conditions. In addition, the SGN 6 method assumes propagation over an acoustically hard surface for the entire propagation path. As such, the method is likely to significantly over-estimate noise levels for receptor locations that are even relatively short distances inland, where ground absorption will have a significant effect on the noise levels at the receptor.

Parabolic equation models

Both ISO 13474 and the papers referenced in SGN 6 [9] make reference to the use of parabolic equation calculations to predict noise propagation attenuation over distance with varying ground absorption and atmospheric conditions. Parabolic equation methods involve the step-wise calculation of noise propagation, based on numerical approximations at each calculation step, and therefore have the advantage other the other methods described above that that ground absorption, sound speed profile and terrain height can be explicitly specified for each calculation step and therefore can vary arbitrarily between the source and receiver [10, 11, 12, 13, 14].

The disadvantages of parabolic equations methods are that calculations are produced at single frequencies and therefore in order to produce a broadband noise level prediction, many individual frequencies would need to be calculated (typically around 120 individual frequencies would need to be calculated for frequencies between 50 Hz and 3 kHz before the parabolic equation prediction would converge to an overall A-weighted solution). This results in parabolic equation predictions being more time intensive and more complex than the typical engineering methods described above. However this can be mitigated to some extent by using efficient implementations of the parabolic equation method, such as the Green's Function Parabolic Equation (GFPE) method [11]. In addition, there are no commercially available software implementations of parabolic equation methods that the author is aware of.

Prediction recommendations

Despite the above disadvantages, the ability of parabolic equation methods to accurately account for changes in ground absorption and sound speed profiles (and hence ground type and meteorological conditions) at each step along the propagation path is likely to result in parabolic equation predictions providing more accurate estimates over the large propagation distance involved in offshore piling. As such, it is parabolic equation methods that would be recommended by the author for the prediction of offshore piling noise affecting onshore receptors.

Assessment methodology

The above discussion has identified an appropriate method for P52

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predicting noise from offshore piling, therefore the question of how to assess these predicted noise levels now arises. Appropriate assessment methodologies are therefore discussed in the following sections.

BS 5228

Since the noise source being discussed in this paper is associated with construction activities, perhaps the obvious choice of assessment methodology is that outlined in BS 5228, Code of Practice for Noise and Vibration Control on Construction and Open Sites, Part 1, Noise [15]. There are three sets of example noise criteria in BS 5228, the "ABC Method", the "2 – 5 dB Change" method and a set of example thresholds for the provision of temporary noise insulation. Comparison of all of these three methods would suggest that a level of between 45 dB L_{Aeq} and 55 dB L_{Aeq} would equate to a negligible noise impact during night-time periods. Whilst it has been demonstrated in Figure 1 above that measured 100 ms noise levels at onshore locations during piling can exceed 45 dB, since the piling noise is impulsive and not constant and an individual pile would typically take around 4 hours to install, the L_{Aeq} over an 8 hour night time period would typically be between 40 and 45 dB $L_{Aeq,\,8\,hr}$, even under weather conditions that would enhance onshore noise propagation.

The BS 5228 criteria would therefore suggest that offshore piling noise would not cause noise disturbance at onshore locations, even under the typical worst-case conditions. As discussed in section 4 of this paper, onshore piling noise can be clearly audible and, due to the low frequency and impulsive nature of the noise experienced at onshore locations, can cause complaints at onshore locations. Since piling can occur for extended periods at night (e.g. for one or more weeks) and the complete construction period could cover several years, it is possible (although not inevitable) that significant annoyance could be experienced at onshore locations during offshore piling. The criteria in BS 5228 would therefore not appear to be entirely suitable for assessing this type of noise.

BS 4142

Given that offshore construction will take place over an extended period of several years, and is related to a commercial development, it may be arguable that this is industrial / commercial noise and therefore the methodology outlined in BS 4142, Methods for Rating and Assessing Industrial and Commercial Sound [16], may apply. Applying this method would allow for the impulsive nature of offshore piling noise to be accounted for in the assessment.

As an example, for the period shown in Figure 1, the L_{Aeq} from piling noise was approximately 5 dB above the underlying L_{A90} excluding the effects of piling noise, and adding the 9 dB penalty that would be suggested by BS 4142 for noise sources that are highly impulsive, this would result in a rating level of 14 dB above the underlying background L_{A90}. The guidance in BS 4142 would suggest that this is indicative of a significant adverse impact for this period of piling, which took place during the night-time and under favourable conditions for noise propagation.

Offshore piling is, however, essential if offshore renewable energy is to play a part in UK power generation. If piling were to be limited to only daytime hours, or was only permitted during unfavourable conditions for noise propagation (e.g. offshore winds), this would be likely to significantly extend construction periods for some if not all developments, which would in turn result in any other impacts during construction lasting for an extended duration. Since the BS 4142 methodology is not strictly applicable to the assessment of construction activities, the potential impacts of extending the works as a result of applying noise mitigation measures are not explicitly accounted for in the assessment method. As such, the BS 4142 methodology may also not be entirely appropriate for the assessment of noise from offshore piling.

Pragmatic approach

Given that neither BS 5228 nor BS 4142 seem entirely appropriate for the assessment of noise from offshore piling, an alternative pragmatic approach is proposed. This involves early engagement of environmental protection officers from the Local Authorities within which residents could experience noise from offshore piling. Indicative noise levels at onshore locations can be predicted for different weather conditions using the methods described earlier in this paper, and if felt necessary by the environmental protection officers, noise limits can be applied based on the range of predicted noise levels that are expected under differing weather conditions and that can be practically achieved (as opposed to noise limits that are suggested in British Standards that may not be entirely appropriate to offshore piling noise).

It will, however, generally not be possible to predict how frequently different noise levels are likely to occur, as this will be highly dependent on the frequency of different weather conditions at a particular site, which would typically not be known in sufficient detail. In addition, there are likely to be uncertainties in any modelling that is undertaken, for instance with regard to precise sound power levels generated during piling, the precise absorption properties of any ground between the source and receiver etc. As such, monitoring should be undertaken during piling works to demonstrate noise levels are in line with expectations and in compliance with any noise limits.

The above approach has been applied on past projects which have been successfully completed. It should however be noted that since offshore piling noise is very likely to be audible during some times during offshore construction, it is likely that some complaints will be received from affected residents. It is therefore vital that the monitoring discussed above is undertaken so that it can be demonstrated that onshore noise levels during piling are as expected.

Monitoring of offshore piling noise

As discussed above, the monitoring of onshore noise levels during offshore piling is an important part of demonstrating that piling noise is not causing an unacceptable impact. There are, however, several potential forms that this monitoring could take, which are discussed below.

Reactive monitoring

One possibility for monitoring noise levels from offshore piling is to wait until noise complaints are received and then attend the complainant's property to measure noise levels. This has the advantage that noise levels are measured at the actual property from which complaints originated. However, since piling only lasts for around four hours per pile, it is likely that by the time complaints have been received, the piling work has been completed. In addition, even if monitoring can be undertaken while piling is still ongoing, onshore noise levels are highly dependent on weather conditions, which may change between the point at which a complaint is received and the point at which noise levels are measured.

As such, reactive monitoring is generally not suited to the measurement of onshore noise levels generated by offshore piling.

Sample measurements

An alternative to the above is to take sample measurements at selected onshore locations during offshore piling works, for instance at the start of the offshore construction period or periodically throughout construction. The advantage of this measurement method is that measurements can be scheduled in advance, in line with the expected construction programme and can cover any activities that might be expected to be particularly noisy.

The disadvantage of this method is that, by definition, the measurements will not cover the whole construction period and will therefore inevitably not cover the full range of meteorological conditions that may be experienced during construction. As such, in the event that complaints are received, it may be difficult to demonstrate that, under the weather conditions that occurred during the complaint, onshore noise levels were in line with expectations.

Continuous monitoring

Given that the above methods have significant drawbacks in terms of demonstrating that noise levels are as anticipated at all times, and in particular under all weather conditions, past offshore renewable energy projects have successfully made use of continuous monitoring over the full construction period. Whilst the upfront costs of continuous monitoring are higher than for the other monitoring alternatives discussed above, with currently available equipment options costs are not excessive, particularly in relation to the typical construction costs for an offshore wind farm. The advantages of continuous monitoring include the fact that monitoring equipment can be installed with power supplies and fixed line or mobile modems so that data is

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recorded and sent back to a data server, meaning all measurement data is instantly available. Since data is recorded constantly, measurements will be available for any complaint periods and so analyses of data during the precise periods of any complaints can be provided. Continuous monitoring equipment can remain in place for the full construction period (e.g. three to five years), with only infrequent service visits. Therefore for long survey periods, continuous monitoring is ultimately likely to be more cost effective than other survey methods that require frequent site visits.

Figure 4 shows an example of a continuous noise monitoring system, built around a Class 1 all-weather sound level meter mounted on a custom made bracket and connected to a weather-proof box containing local data storage and a broadband landline modem for communication purposes. This particular monitoring system was installed at a site for a period of three years and continuously monitored 100 ms, 1/3 octave band data and audio recordings, for the complete construction period, which could then be analysed during any periods of complaints. The analysis of complaints periods was reported to the Local Authority within approximately 1 week of complaints being received.

Conclusions and recommendations

This paper has discussed the specific issues with regard to the assessment, prediction and measurement of noise from construction of offshore renewable energy infrastructure, specifically piling during the construction of offshore wind farms. It has been demonstrated that, under certain conditions, noise from offshore piling can be clearly audible at onshore receptors, even if piling takes place at large distances of 10 km or more from the coast. As such, piling noise from offshore construction activities should be assessed as part of any environmental noise assessment for new offshore renewable energy developments.

The recommendation of this paper is that predictions of onshore noise levels from offshore piling should be calculated using parabolic equation methods. In addition, a method of assessing onshore noise levels should be agreed with environmental protection officers as part of the planning process for new developments, bearing in mind that it may not be appropriate to use methods outlined in standard guidance documents for assessing construction noise. Since levels of noise experienced onshore during offshore piling will vary significantly under varying weather conditions, any assessment methodology should be accompanied by a programme of onshore noise monitoring during piling. Due to the potential for large variations in onshore noise levels, this paper advocates the use of continuous monitoring during piling, especially given the availability of modern equipment that can be left in place for extended periods of time and from which data can be retrieved remotely.

***Jonathan Sims** is an Executive Engineer with Hoare Lea Acoustics, where he has worked for the past 10 years on both architectural and environmental acoustics projects. Over recent years, he has been involved with several projects that have explored the use of numerical modelling methods in relation to the prediction of environmental noise propagation effects.*

References

A full list of references can be obtained from the IOA.

Figure 4: Example of a customized long term noise monitoring system for monitoring of offshore construction noise

Predicting noise behaviour in building acoustics – a case study example

By Paul Absolon and Dr Max de Salis

Background

Launched in 2000, Moneypenny leads the UK telephone answering service and outsourced switchboard market, looking after more calls for more businesses than any other company of its kind.

With a purpose-built development on the cards in its home town of Wrexham, Wales, Moneypenny had a 10-acre plot with which to design a new office space which could house up to 1,000 employees.

However, unlike many traditional office projects of this nature; Moneypenny approached the building design in a unique way. The £15 million headquarters' top line brief was to create a development which would literally "put a smile on people's faces".

While the wider landscape was to include innovative features such as a tree house and a village pub for staff, the main three storey office had to satisfy the "work hard, play hard" mantra of the business – and at the same time deliver an environment which fostered team work, collaboration and interaction. To help achieve this, founder Ed Reeves was clear on one thing: the office had to be open plan yet feel welcoming, homely and inspiring.

Given the nature of the telephone and switchboard operations, this presented an unprecedented design challenge from an acoustic perspective. How could such a fluid space be achieved in a high density, high call volume environment, where call quality was crucial to business performance and customer service?

To address this challenge, the client appointed PDA Ltd as acoustic consultants on the project at concept stage – before the footprint or external design had been produced.

Defining specification

Unlike traditional commercial building projects, the acoustic performance of the space at Moneypenny was not to be determined solely by traditional objective standards or guidelines. Moreover, the employer requirements regarding the acoustic environment were initially subjective in that it was imperative to limit perception of different conversations between adjacent individuals to an absolute minimum.

The starting point to define the target sound levels for the new offices therefore looked to the company's existing premises for an initial benchmark.

The existing rented offices used by the client were of a standard open plan office type with standard suspended ceilings of reasonably low ceiling height fitted with acoustically absorbent tiles. In addition the space had traditional individual window lights of limited coverage. This space had been made to work acceptably for the client using acoustic screens, various absorbent wall hangings and background masking noise. However, the vision for the work spaces in the new development was to present a significantly more challenging acoustic environment due to the following factors:

- Feature significant proportion of floor to ceiling glazing and high ceilings with non-continuous baffle / raft type ceiling to allow heat transfer and ventilation to the slab above.
- Minimise the use of screens to retain / improve visual connection between individuals as well as between the individuals and their surrounding environment.

Based on the design vision, it was agreed that the practical goal should be to ensure that the new space retained and / or improved on the acoustic environment and levels of privacy that were exhibited in the existing premises. Seeking to define objective target performance criteria for the new space, PDA adopted the following methodology.

Modelling

PDA modelled both the existing space and the proposed new space in CATT acoustic 3D ray tracing software for comparison.

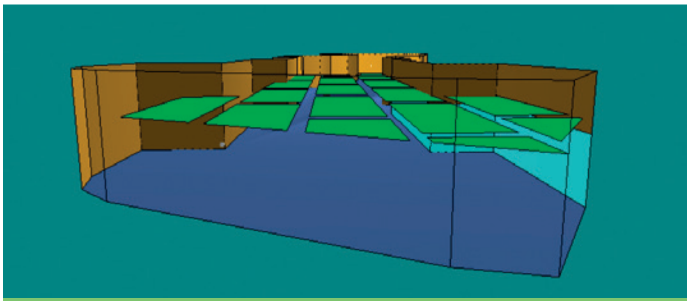

Figure: Screenshot showing Simplified CATT Model of Raft Ceilings in the Proposed Space (Unfurnished)

The ability to model diffraction around screens in CATT was very useful in this instance, as it allowed PDA to show the effect of the raft ceilings and the effect of increasing and decreasing height and density of screening. Subsequently the models were able to predict the room acoustic properties of the space and also the noise transfer between work stations.

Using the said models the layouts and treatments could then be tweaked to show that the speech noise transfer between individuals in the proposed space would be reduced compared to the previous space in spite of the challenges presented by the proposals.

Auralising

The vocal sound transfer between the PAs in the existing and the new environment were further "auralised" using a limited audio simulation to approximate the combined vocal effect of a number of people taking enquiries around a single "control" person. This meant that the predicted change in "Soundscape" from the existing to the proposed environment could be subjectively assessed, as could the effect of adding different levels of masking noise.

Testing

With respect to commissioning of the space it was determined that a simple measure of the mid-frequency reverberation time T_{mf} (average of 500 Hz, 1 kHz and 2kHz) results would be the most simple and practical way of measuring the acoustic environment. The predicted T_{mf} for the modelled PA floor was 0.75 seconds and as such a criterion of $T_{mf} \leq 0.8$ was chosen as the test criterion value.

As part of the conceptualisation process, PDA modelled circa 40 scenarios and conducted circa 20 simulations.

Acoustic treatment

Following the acoustic modelling at concept stage, PDA followed the project through to building design and played an active role as part of the design team. At this point, the importance of 'real world' acoustics became prominent and required the acoustic consultants to interface with architects AEW and the contractors to provide guidance on how the interior environment could be acoustically treated to achieve the agreed specification. Moreover, any acoustic product applied in the new space had to provide a highly aesthetic finish.

As such, the design team agreed on the use of absorptive ceiling and wall treatments as per the specification from PDA. The main challenges facing the design and manufacture of the acoustic treatment were as follows:

- Treatments needed to follow the curvature of the building
- Different fabric facings were required throughout the building to avoid monotony
- Wall treatments had to withstand impact

- Ceiling treatments had to be demountable to allow service access behind the rafts.

The precise performance and practical requirements of the specification greatly limited the choice of acoustic treatments which could be used. After putting the details out to tender, CMS Danskin Acoustics was appointed as the product partner on the project, with a brief to design and manufacture its SuperPhon range of absorptive panels.

From design to manufacture

Working closely with the AEW and PDA, CMS Danskin Acoustics undertook a bespoke design process which balanced aesthetics with installation practicalities.

SuperPhon panels at 40mm thick were manufactured in a range of sizes. Installed direct to the skirting, the SuperPhon High Impact was installed up to a height of 1.8m to protect the acoustic performance in the event of an impact from passing traffic. The maximum height at which the panels were installed was 9m, with the average height being to 3.5m.

CMS Danskin Acoustics cut the radii to the panels and supplied them ready to install on-site. In doing so, this removed the need for cutting on-site and improved the accuracy of manufacture. Both CMS Danskin Acoustics and PDA provided site supervision to protect the integrity of the acoustic treatment design.

Two thousand five hundred wall panels were installed over the two operational storeys of the new building, with a total contract value of £200,000. From an aesthetic perspective, CMS Danskin Acoustics delivered a highly varied range of finishes and colours, from funky and bright patterns through to highly creative gooseberry fruit prints.

For the raft panels, approximately 1,500 rafts were hung from adjustable wires. The most common size was 3000mm x 1200mm but some were manufactured with radii corners to accurately follow the building profile.

The new Moneypenny HQ

Building commissioning

Following the installation of the panels, and ahead of the building becoming operational, PDA undertook pre-commissioning testing in the unfurnished open plan spaces to ISO 3382-2:2012 requirements.

The measured T_{mf} for the two tested floors at the end of the project were 0.68 and 0.72 seconds respectively, therefore showing compliance with the required criterion and reasonable agreement with the modelling.

***Paul Absolon** MIOA FISMM is Technical Director, CMS Danskin Acoustics and **Dr Max de Salis** PhD BEng (Hons) MIOA, is a Director of PDA Ltd*

Take off for xPlane analysis system at Heathrow

Heathrow Airport has launched xPlane, an online system developed by Brüel & Kjær that enables the surrounding community to self-analyse detailed information about long-term aircraft activity above them.

The system was built in collaboration with the community to ensure the public's needs were captured during the development process. Expanded capabilities will be added over time as the community becomes familiar with the service.

Some airports show general flight tracking information on their website, but the broad nature of the data makes it difficult to relate the information to a specific location on the ground.

Other systems allow operations to be replayed around a location, making it, says Brüel & Kjær, challenging to get a big-picture overview of what's happening and how longer-term trends are affecting a particular site.

xPlane fills this information gap by making longer-term, location-specific information readily available. It uses a viewer's individual position to present information that improves their noise understanding and airport engagement. People can see how close, how often and what types of aircraft are influencing the noise they experience.

xPlane uses the same data captured by Airport Noise and Operations Management System (ANOMS), Heathrow's noise and flight track monitoring solution from Brüel & Kjær.

On track: the xPlane system in action

AcSoft launches new e-commerce rental website

A growing rental division has led AcSoft Group – comprising AcSoft Sound & Vibration, Svantek UK and G.R.A.S.UK – to launch www.acsoftrental.co.uk, an e-commerce website designed to make it easier for customers to hire sound and vibration monitoring instrumentation, software and sensors.

The Bedford-based organisation says entering the online e-commerce market provides an additional opportunity for it to align with its growth objectives, whilst developing closer relationships with customers by better understanding and responding to their needs.

Paul Rubens, AcSoft Group's General Manager, said: "We originally established the rental division for customers who require products on a short-term basis or who need to plug a gap for a specific project.

"Online services are also becoming more and more important to our customers, so we have responded by making our products available to rent via the web. Not only does the new website make it easier to do business with us, but it also helps customers become more efficient."

The e-commerce website features products from all three AcSoft Group companies and enables customers to complete the entire rental transaction online. The service will function across any mobile and digital device.

AECOM takes centre stage at new Shakespeare theatre

AECOM has been appointed by Knowsley Metropolitan Borough Council to deliver acoustics consultancy services for the Shakespeare North Playhouse, a new Shakespearean theatre and education centre in Prescot, Merseyside. AECOM will also deliver building services engineering, fire engineering and cost management for the scheme.

The Shakespeare North Playhouse is a 345-seat new theatre, which will be the only replica of a Jacobean court theatre in the world. It will provide a place where actors, writers and students will be able to study and perform Shakespeare. It will also be the only actor training programme in the UK in relation to Shakespearean performance practice.

Construction of the new theatre is due to commence in late 2017. The surrounding building will form a "wrap around" to the Jacobean centre, providing front of house facilities as well as space for education and community projects.

The landmark development is expected to attract thousands of visitors to the area, with Prescot joining Stratford-upon-Avon and the Globe in London as one of three key destinations for fans of Shakespeare.

Corinne Ballarini, Regional Director and acoustics lead for the project, AECOM, said: "The acoustics team is very excited to be involved with this prestigious development. The opportunity to work on such a unique and culturally-significant theatre is fantastic."

AECOM will work closely with Knowsley Metropolitan Borough Council and Helm Architecture to deliver the scheme. The commission follows AECOM's recent appointment as acoustic consultant for the English National Ballet's new school, which includes theatre studio space, studios for rehearsal and a music room for the English National Ballet Philharmonic.

Vison for the future: the new Shakespeare North Playhouse

AV Calibration on the move

AV Calibration operations have moved to ANV Measurement Systems' Milton Keynes base following the retirement of staff member Barrie Baker and the lease at its site at Chicksands, Bedfordshire coming to an end. The new address is: Beaufort Court, 17 Roebuck Way, Milton Keynes MK5 8HL.

The scope of UKAS accreditation remains unchanged with ANV continuing to offer calibration for all major makes of sound and vibration instrumentation including sound level meters, tapping machines, vibration meters, microphones and accelerometers.

Existing calibration contracts will remain unchanged as there has been no change to the legal entity (both ANV Measurement Systems and AV Calibration are trading names of Acoustics Noise and Vibration Limited).

ANV Measurement Systems purchased the goodwill and assets of AV Calibration in 2009. At the time, the decision was taken to continue trading temporarily as AV Calibration.

Contact Kiran Mistry (Calibration Manager) at **kmistry@anv.uk.com** or **01908 642846** for any queries.

Happy silver anniversary for wind turbine noise specialists Hayes McKenzie

Hayes McKenzie Partnership, best known to many in the industry for its work in wind turbine noise, has recently celebrated its 25th anniversary.

It was launched by Malcolm Hayes and Andy McKenzie who, in Andy's words, "got together, essentially, on the back of the non-fossil fuel obligation, which made wind farm development cost-effective for the first time, and Malcolm having been alerted to the potential noise issues which would inevitably arise".

The pair, old friends from undergraduate days at the Institute of Sound and Vibration Research, hatched their plan at Pizza-Pan (now long-gone) in Southampton in spring 1991 and their first two clients appeared shortly after.

The latest developments in sound level meters, at that time, enabled unattended background noise monitoring, and thus correlation with wind speed. This enabled the pair to pioneer the procedure which eventually became ETSU-R-97 following agreement between representatives of the wind industry, local government and various others.

Growth was slow in the early stages and the wind industry went very quiet around the millennium but came back with renewed vigour around the time of their 10th anniversary and the company started to grow more quickly, for a while incorporating an Australian office, jointly with APW in Sydney.

Although this venture effectively ceased when one of its key staff came to work for them in the UK, their workload continued to grow, along with the industry, working for both developers and planning authorities. The wind turbine infrasound debate resulted in a commission from the Department of Trade and Industry, as it was then, to investigate the issue at three sites, with results published in 2006 and in 2010/11. Concerns over the way ETSU-R-97 was being applied resulted in another commission from the Department of Energy and Climate Change, which eventually led to the publishing of the IOA Good Practice Guide on wind turbine noise assessment.

In 2015, wind farm development in the UK, and particularly in England, was drastically cut by the government which has meant Hayes McKenzie turning to other areas, but also having time to become accredited by UKAS for wind turbine source noise testing (one of only two companies in the UK). This has not, however, stopped Hayes McKenzie critiquing the most appropriate ways of dealing with amplitude modulation from wind turbines and even looking at possible changes to ETSU-R-97 itself at the December wind turbine noise conference (see page 18).

Andy McKenzie (fifth left) and Malcolm Hayes (fifth right) with their team

Merford in swoop for noise technology specialist Sonobex

Dutch-based Merford has acquired award-winning noise control technology specialist Sonobex.

Adrienne Vertooren, Merford General Manager, said: "They have the brainpower, we have the scope to invest and produce.

"By joining forces, we can together make a difference in issues within noise control, even the complex issues that we previously could hardly tackle."

Dr. Daniel Elford, Chief Technology Officer of Sonobex, said: "There is a great synergy between Sonobex and Merford with a shared focus on innovation and product development.

"This presents a fantastic opportunity for generating routes to market for our propriety noise control technology. We have exciting times ahead."

Sonobex, the winner of the IOA-sponsored innovation category in the 2016 John Connell Awards, is based at the Building Research Establishment, Watford, where Merford has its UK office.

Since its launch in 2012 as a spin-out company from Loughborough University by Dr Elford and Dr Luke Chalmers it has worked on developing innovative technologies and solutions within the noise control sector. Its acoustic panel technology, SonoTEC, has been patented by Sonobex and is ready for the market.

Merford is a Dutch family business founded in 1956. The company, which has its headquarters in the Netherlands, has grown into an international business specialising in noise control, special doors, operator cabins and sheet metal. It has 180 employees working in five divisions.

Top team: (left to right) Joost Vertooren, Daniel Elford, Luke Chalmers, Adrienne Vertooren, Karol Bugaj and Richard Wilson

Room Acoustics

By Heinrich Kuttruff

Review by Chis Middleton of Acoustic Design

Weighing in at just 762 grammes, this the 6th edition of Kuttruff's standard text is a well presented handbook covering both the theory of room acoustics and the practical applications. It will no doubt continue to be a key foundation for students hoping to design auditoria, although there is something for everyone with an interest in the subject, with information relevant not only to prestige auditoria but also the more "run of the mill" sports halls and school buildings.

Following a concise introduction highlighting the importance of both the science of room acoustics and subjective perception, the major part of the book sets out the theory which underpins our understanding of how rooms behave. Starting from the wave equation, the book works steadily through the advanced mathematics which describe the propagation of sound waves in a room and how we measure them. Students should welcome the clear and logical progression from first principles and the generous provision of simple diagrams.

There is fairly comprehensive coverage of room geometry, diffusion, absorbers, subjective room acoustics and measuring techniques, along with an introduction to electroacoustics. Those not involved in designing major auditoria on a full time basis are unlikely to read it all, although it should still be a useful reference source for consultants involved with more mundane buildings, particularly those wishing to use their ray traced analysis software in a more informed way.

Towards the end of the book is a very readable chapter on room design, with a thorough coverage of room shape, direct sound, lateral reflections and the like. There is sound absorption data for only a small sample of materials and relatively limited data on scattering coefficients, although as the author explains, there are so many reference texts readily available containing the necessary information. There is emphasis on the importance of marrying the theory of room acoustics with experience and good practice.

Overall, this handbook should be useful to anyone involved in room acoustics, containing a clear explanation of the theory, practical application and the most up to date guidance.

Published by CRC Press 2016
ISBN: 9781482260434
https://www.crcpress.com/

Don't be grossly misled by astonishing wind turbine noise complaint figures

I write in response to an article in the December issue of the *Noise Bulletin*, entitled *News from the IOA 'ETSU – is it time to move on?' meeting: Agreement still elusive*. Having attended this IOA workshop meeting, I was pleased to see coverage outside the IOA and a good range of opinions and views reported. I was, however, taken aback by one particular quote – a senior district council officer was reported as having said, and I (re) quote, that: "He was faced with hundreds of [wind turbine noise] complaints a month"[1]. I was unable to recall whether I had paid attention when this had been said during the meeting, and found this to be an apparently shocking claim – even if only a slight exaggeration, this would mean annual wind turbine noise complaints into the thousands at a single local authority! According to this council's own estimations1, as of August 2016 there were less than 20 separate wind farm / single turbine installations operational within or near to the district boundaries, so this would be a quite staggering number of complaints, and undoubtedly grave cause for concern amongst residents and council health protection officers, not to mention wind farm operators and the wider acoustics community.

As a check on these somewhat astonishing figures, I subsequently registered a Freedom of Information request for the actual numbers of complaints received by the council during the whole of 2016. The helpful response I received revealed that, in the entire year, one formal complaint from residents about wind farm noise had been recorded by the council. My request and the corresponding responses can be viewed here:

https://www.whatdotheyknow.com/request/number_of_complaints_from_reside#incoming-925678

My purpose in writing this letter is not to criticise, as many things can and often are said in the heat of the moment, nor to depreciate the impact noisy wind farms can have on their neighbours. I simply seek to present freely-available facts, so that casual readers are not grossly misled as to the reality of the situation.

Mike Lotinga
Principal Engineer, Acoustics, Noise and Vibration, WSP | Parsons Brinckerhoff

1. Huntingdonshire Local Plan to 2036: Wind Energy Developments: http://consult.huntingdonshire.gov.uk/portal/pp/hlp2036/windenergy?tab=files

New engineering award for Dame Ann Dowling

Professor Dame Ann Dowling has been awarded the James Watt International Gold Medal by the Institution of Mechanical Engineers.

The award, made every two years, is in recognition of her work associated with efficient, low emission combustion; and understanding, modelling and reducing the noise from cars, helicopters and fixed-wing aircraft.

Dame Ann is Professor of Mechanical Engineering and Deputy Vice-Chancellor at the University of Cambridge, and is currently the President of the Royal Academy of Engineering. She is a Fellow of the IOA

Her first degree is in mathematics from Girton College, Cambridge, and she has a PhD in engineering. She worked on the aeroacoustics for Concorde, then moved to underwater acoustics and automotive noise. She led the Silent Aircraft Initiative, a collaboration with MIT, which developed a conceptual design for a novel, ultra-low noise, fuel-efficient aircraft.

She is keen to encourage young people, and particularly girls into engineering, and points to great progress as now many engineering degree course have more than 25% girls. "Looking forward, it is important to keep women in the engineering profession," she said.

Dame Ann Dowling speaking at Acoustics 2014


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Emily Norman appointed Sales Director at AcSoft Group

Emily Norman has been appointed Sales Director of AcSoft Group, comprising AcSoft, Svantek and G.R.A.S UK

Prior to taking up her new role, she was Sales Manager at G.R.A.S UK having joined the AcSoft Group in 2011. She comes from a sales and financial background and has previously worked in customer facing roles in both the retail and technical sector.

John Shelton, Managing Director at AcSoft Group, said: "Emily will help strengthen the senior management team to ensure the business maintains and builds on this momentum. She will oversee new business development and maximise opportunities in our key target markets."


Emily Norman

New stage for Ando Randrianoelina with Theatre Projects in Paris

Ando Randrianoelina has joined Theatre Projects' acoustic team in Paris.

In addition to eight years' experience in acoustic consultancy with Buro Happold in England and Peutz in the Netherlands and in France, she spent five years in applied scientific research, mainly in computational acoustics, and strived to orient her work towards architectural acoustic topics including sound diffusers.

Ando was in charge of the acoustic design of several public spaces such as the Grand Museum of Egypt in Cairo, the Glasgow Museum of Transport and the EU Residence Palace in Brussels as well as many performing arts venues such as the Maison des Arts et de la Culture, (Epinay sous- Sénart, France), La Vapeur (Dijon, France), and the Poppodium Hedon, (Zwolle, Netherlands).

At Theatre Projects she will be working with Sébastien Jouan, Principal Acoustic Consultant, Victoria Chavez and Rob Harris.


Ando Randrianoelina

Cirrus Research strengthens sales team with four new appointments

Noise monitoring specialist Cirrus Research has made four new appointments.

Lesley Roberts has joined its UK calibration sales team, a role that will also develop into rental and training sales, both highlighted as strong and growing markets for the company. Simon Evans is the new design engineer, a key appointment in the company's award winning R&D division. Sue Rowson has joined as Sales Administrator and Isabella Ashraf is a new appointment for internal sales to be based in the Cirrus' Germany office.

Cirrus Research Managing Director Daren Wallis said: "These are all key appointments and will particularly strengthen our sales team this year with many new opportunities already apparent. The last two years saw Cirrus launch two new key products in the Revo hand-arm vibration meter and the doseBadge5 noise dosimeter. This year is no less exciting with further significant business announcements to come."

Newcomers: (left to right) Lesley Roberts, Sue Rowson and Isabella Ashraf

Latest Sea software aims to make a splash

An updated version has been launched of dBSea 2.0, a software tool for the prediction of underwater sound propagation in complex environments.

New features include:

Under the hood

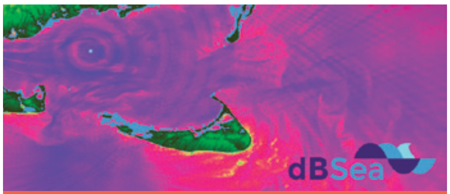
- Range-dependent sediment and sound speed profiles
- Full, three-dimensional solving ready
- Sources can be embedded into the seabed (ideal for pile driving and underground construction)
- Increased solving speed and accuracy
- Support for more formats lets users import from a very wide range of data sources
- More control of solver parameters

Graphics

- dBSea now exports animations of moving sources
- Upgraded 3D rendering
- Direct export and import of shapefiles
- Map for editing range dependent environmental properties

Models are represented in 3D and may be rotated and zoomed to allow easy navigation of the problem environment and examination of prediction results. Noise mitigation methods may also be included. Users can import their own recordings and/or spectral data to achieve site specific prediction. To examine results in more detail, all levels can be viewed either in dBSea or exported to GIS of your choice. Levels are calculated in octave or third octave bands.

A trial version of the software and sample scenarios are available on **www.dBSea.co.uk**



dBSea 2.0 can export animations of moving sources

Campbell Associates unveil the latest Norsonic sound intensity system

The new Norsonic sound intensity system is now available from Campbell Associates.

The Nor150, fitted with a sound intensity option and the sound intensity probe kit Nor1290, is a tool for all types of sound intensity measurements and is designed for use in all types of conditions. The in-built application software guides users through the ISO 9614 measurement procedure and gives answers on screen.

The remote control handle using a Smartphone as a measurement control and displaying device enables user to perform all measurements with a single hand operation.

All measurements are made with one spacer – there is no need to change spacers as the Norsonic system uses smart technology to enable the full frequency range to be measured simultaneously.

It offers full software for professional reporting – simply drag and drop your measurement files for post processing and quick presentation of test certificates.

For more details ring **01371 871030** or visit **www.campbell-associates.co.uk**


The Nor150 in action

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Committee meetings 2017

DAY	DATE	TIME	MEETING
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	29 June	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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