Vol 39 No 6 November/December 2014

ACOUSTICS
BULLETIN

in this issue… **Improvement of voice alarm systems in underground railway stations**

plus… **Separating musical audio signals**

Third International Conference on Synthetic Aperture Sonar and Radar

Shining a laser spotlight on the egg box myth

Do wind turbines cause deafness?

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Front cover photograph:
Voice alarm systems are an essential part of underground emergency procedures.
(JuliusKielaitis / Shutterstock.com)

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.

Institute of Acoustics

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.

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Conference programme 2014/15

27 November 2014
Organised by the Amplitude Modulation working group
Methodologies for assessing AM in wind farm noise
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29 January 2015
Supported by the Speech and Hearing Group
The ear and hearing – a tutorial for acousticians
London

7-9 September 2015
Organised by the Underwater Acoustics Group
Seabed and sediment acoustics: measurements and modelling
Bath

29-31 October 2015
Organised with support from the French Acoustical Society (SFA)
Auditorium acoustics
Paris

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

Dear Members

The first four months of my Presidency have been a busy time. This letter is somewhat unique in that, because of Bulletin deadlines, I have had to write it a few days before our 40th Anniversary and Reproduced Sound Conferences but it will be published a couple of weeks afterwards.

First, I would like to thank all those dedicated individuals without whose energy and commitment these events would not be the big success they are. We are also honoured that a number of key speakers have accepted our invitations to attend. They include Leo Beranek, who recently celebrated his 100th birthday, and who will give the opening keynote lecture.

It will also be my pleasure to present to a number of worthy recipients medals and awards at the 40th anniversary event for their devotion and commitment to excellence in acoustics and on behalf of the Institute. The field of acoustics can be served in many ways and the individuals who are being recognised for their exceptional accomplishments and outstanding performance serve as an inspiration to us all.

Throughout our 40th year I have been honoured to be invited to a number of key events. Wherever possible I have attended to represent the Institute and I thank my colleagues in supporting the Institute at those events which I have been unable to attend. It is key to our strategic commitment that we remain visible outside normal Institute business.

Part of this visibility has been incorporated in the celebrations of the 40th anniversary across the country. A number of the branches have already held, or will hold, celebrations. One of our aims is to open these events to non-members, enabling us to reach out and promote the IOA generally, as well as encourage others to take part in future Institute events.

Our strategic plan continues to progress and ensures we meet our vision going forward.

We continue to promote the importance of acoustics and we recently published and distributed an information booklet on acoustics to MPs, members of the House of Lords and national assemblies and governments in the UK. Additionally, we have created a new award in the Institute's 40th year in memory of Professor Peter Lord, a founder member and former President of the Institute, to raise public awareness. The award is made annually for a building, project or product that showcases outstanding and innovative acoustic design.

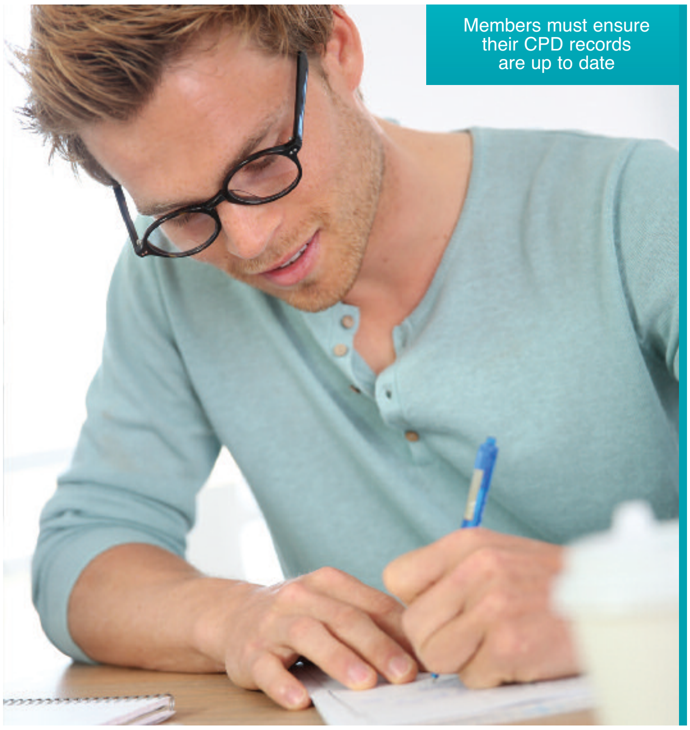
We are continuing to improve and develop our IT systems, ensuring we are able to offer both members and the public an effective and efficient system with our new website, providing more public focus with a careers' section and delivering an improved experience for online learning.

This will be the last Bulletin of 2014, which has been a stimulating year for me personally and a year of continuous development for the Institute. It has been a privilege to head a body of loyal and dependable individuals, both in the office and the membership. Thank you for everything you have done: you have truly made a difference. So although it's still a little early, I would like to take this opportunity to wish you and your loved ones a great time over the festive season. Let it be a time of harmony with each other, with good food and drink, and I also hope that you enjoy a great start to 2015 and all your wishes will come through…

William Egan, President

Revised CPD forms issued by Institute's Action Group

By Rachel Canham



Members must ensure their CPD records are up to date

The IOA's Continuous Professional Development (CPD) Action Group has revised the forms that members have to complete as a result of a wide variation both in the quality of those submitted so far and in the interpretation of the requirements.

As already reported, the Institute has implemented a CPD scheme and has now established an audit of members to demonstrate that it is maintaining CPD. It aims to review around 10% of member plans annually. Some will be reviewed automatically by the Membership Committee as part of the application process for MIOA and FIOA; the rest will be randomly selected.

The revised blank forms, an example completed form and a CPD guidance document have been uploaded to the IOA website both in the members' area and in the public area under Membership.

One difficulty has been keeping track of the CPD activity undertaken with regard to a particular goal. Therefore a "goal reference" has been introduced on the CPD plan and activity records so that it can be clearly seen what relevant activity has been undertaken.

Sheet 1 of the form is used to identify current competencies and future needs. These in turn can be used to determine your development goals, for which you should also provide a goal reference and the priority (high, moderate or low). Ideally, Sheet 1 should be contained on one page.

Sheet 2 sets out your professional development plan. Using the development goals and goal reference from Sheet 1, you should set out how you intend to address these and by when. You should also note the progress made on each goal and identify what follow up is needed – try not to leave any blank cells. Sheet 2 should also be contained on one page.

Sheet 3 is used to record your CPD activity. This should include information about the activity: what it was, when it occurred and its duration, what you learned, the relevant goal reference (or if it was general CPD) and how you intend to use the knowledge. Please avoid the use of acronyms. If you have to use them, be aware that the person reviewing your records may not work in the same field of acoustics as you, so explain each acronym the first time you use it. Failure to do so may mean you do not receive proper credit for your efforts.

It is important that you record all CPD activity undertaken – some may not be relevant to a specific goal but, nevertheless, is still good/useful albeit general or generic CPD. It is also important to set out the progress made on each goal. CPD activities include (for example):

- attendance at IOA/other relevant meetings, conferences and seminars
- reading *Acoustics Bulletin* and other technical publications
- reviewing relevant standards and guidance documents
- attendance at training courses
- learning about new instrumentation, modelling/prediction programmes
- internal company training.

Sheet 3 can be up to four pages long and should include your CPD activity for the previous three years. Once you have done some CPD activity and recorded it on Sheet 3, don't forget to update your progress on the specific goals identified in Sheet 2.

Your whole CPD plan and record should be no longer than six pages in total.

The IOA scheme is goal-based rather than the accumulation of hours or points and therefore the amount of CPD hours will depend on the individual. However, as a guide, you should aim for at the very least 20 hours a year and considerably more for those looking to upgrade membership.

It is recognised that IOA members are often required to complete CPD plans for other organisations or their employers. These can be submitted in lieu of the IOA forms, providing they demonstrate sufficient evidence.

Student Leah scoops DW Robinson prize

Leah Evans, an audiology student at the Institute of Sound and Vibration Research (ISVR), University of Southampton, is the latest winner of the Professor DW Robinson prize.

The award, named in memory of the late Douglas Robinson, is made annually by the IOA and the ISVR to the writer of the best ISVR MSc dissertation on a topic in the human aspects of sound or audiology.

Leah, who received the award from Professor Paul White, director of the ISVR, chose the application of the chronic care model to hearing services as her dissertation subject.

Leah Evans receives here award from Professor Paul White

Third International Conference on Synthetic Aperture Sonar and Radar

By Gary Heald

Following the success of the previous conferences on synthetic aperture sonar and radar, organised by the Underwater Acoustics Group of the IOA, Dr Gary Heald offered to chair the organising committee and third international conference held at Villa Marigola in Lerici, Italy. The previous two conferences had been held here because of its proximity to NATO's Centre for Maritime Research and Experimentation (CMRE). The conference was timed for September 2014 as there was a joint research programme meeting on this topic being held in the NATO centre just before. This ensured the experts from NATO countries would be in the area and so might wish to submit papers and present at conference.

Gary formed an international organising committee which included his colleague Professor David Blacknell, who is well known for his expertise in synthetic aperture radar. The other members were drawn from the sonar and radar community in Germany, the US and the CMRE. All of the conference papers were referred by members of a scientific committee. The call for papers solicited papers on a range of current topics of interest in both the radar and sonar research and development field.

For those unfamiliar with synthetic aperture here is a brief explanation. The angular resolution of a sonar or radar is given by the length of the array relative to the wave length being used. In traditional sonar or radar these array lengths are determined by a number of physical elements in an array and their spacing. These, however, are generally quite short and if they are made longer they can become very expensive or difficult to handle. Synthetic aperture exploits a shorter area but samples are taken as the array is moved through the water, in the case of sonar, or the air, in the case of radar. This, however, relies on the medium being relatively stationary (including the propagation) and, as the signals are going to be processed coherently, it is necessary to know the position of the array in each location with micro navigation accuracy. This creates many challenges – and these were the topics of many of the papers at the conference.

The conference attracted 30 papers from a wide range of countries. Many of the techniques in processing synthetic aperture sonar and synthetic aperture radar form a reason for common interest, although there are obvious differences due to the difference in the speed of sound in water and the significantly higher speed of light for the propagation of radio waves. There are also differences in the speeds available to the host platforms, the variations in the propagation and the dynamics of the target environment (usually the sea floor in the case of synthetic aperture sonar and land or the sea surface in the case of synthetic aperture radar). Delegates were in attendance from as far west as the US and Canada and as far east as Korea.

The conference was opened by Dr Heald who, after welcoming the delegates, introduced the keynote speaker, Dr Roy Edgar Hansen, from FFI in Norway and a world leading expert in the field of SAS and SAR.

His lecture, entitled *Synthetic aperture sonar: technology overview and future trends*, was well received and prompted a number of questions and discussion points from the specialist in both sonar and radar. The future trends section of the presentation agreed well with the themes for the sessions that had been set for the remainder of the conference. These were:

- Automatic target recognition (two sessions)
- Coherence and quality
- Improving synthetic aperture sonar
- Multiple input and multiple output
- Environmental consideration.

The programme included everything from the physics of signals for both acoustics and EM waves in the case of sonar and radar respectively, the latest thinking on sensors and beam forming, scattering from the environment and targets through to image processing and operator performance.

Each paper attracted a number of questions and comments from the audience and a good interaction between those from both communities ensued. One abiding theme throughout the conference was coherence and it was discussed during most sessions.

In a second paper presented by Dr Hansen he showed the variation in an image taken at different times, where one of the images was taken looking through an internet wave. Similar features existed in both image but there was a marked difference in their position due to the refraction effects. Once this effect is better understood it may open up opportunities for extraction of environmental features from the underwater environment (acoustical oceanography) over and above just seabed mapping and target detection.

One of the emerging fields in synthetic aperture sonar is multiple input and multiple output sonar where the bistatic angles for targets can be exploited. This technique is well known in the field of synthetic aperture radar and it is a good example of technology transfer between the two domains. One of the papers in this session was given by Dr Yan Pailhas of Heriot Watt University and the session was chaired by his co-author, Professor Yvan Petillot. It was interesting to see the potential application in detection of divers or unmanned underwater vehicles, more P8

The delegates at Villa Marigola

Gary Heald opens the conference

Dr Roy Edgar Hansen

P7 commonly known as intruder detection and asset protection.

By lunchtime on the second day some delegates were asking when the IOA was going to hold the next in this series of conferences, given the rapid advances that have been made since the previous conference in 2010. One of the driving factors here is the frequency of other conferences, particularly the EuroSAR conferences. These are held every two years and there had been a conference earlier in 2014. This may have been a contributing factor for the slightly reduced number of papers from people working in that domain attending the conference. A number of the delegates commented how much they were enjoying the smaller environment of a specialist conference, rather than some of the larger events with parallel sessions and little opportunity for detailed discussion after each paper.

After the closing of the second day everyone congregated at the Hotel Europa for a drinks reception followed by the conference dinner. The vista from the hotel provides views over Lerici, the Gulf of La Spezia and Portevenere beyond. Amongst the general conversation I could hear reference to sonar and radar, so the dinner provided another opportunity for delegates to network and discuss the papers from the conference and wider aspects of their work.

The final morning of the conference contained a single session containing the remainder of the papers on automatic target recognition.

The conference was formally closed at just before midday, but many delegates stayed to continue their discussions over coffee. During the closing remarks, Dr Heald thanked the organising committee, the scientific committee, the session chairs and all the presenters and contributors. The reviewers also included some of the IOA Underwater Acoustics Group's committee, who were not in attendance at the event, so I would like to record my thanks here. My thanks are also due to ONR Global, CMRE and Dstl for their sponsorship of the conference. I believe that the conference was very much enjoyed by all who attended and the technical quality of the papers is a testament to how rapidly this field is advancing and expanding.

***Dr Gary Heald** is a principal scientist in Naval Systems, Dstl and has been a member of the IOA Underwater Acoustics Group since 1994 and is a Fellow of the Institute.*

The two routes to Engineering Council registration

Corporate members are reminded that the Institute offers them the possibility of Engineering Council registration as CEng or IEng. Guidance and support is available by emailing **acousticsengineering@ioa.org.uk**

The two routes are:

- The exemplifying academic qualification for a professional engineer seeking CEng registration under UK-SPEC is an accredited MEng degree or an accredited BEng degree plus relevant learning to Masters level.
- For IEng registration an accredited BEng degree or a HND/Foundation Degree plus appropriate further learning to degree level (*if you entered higher education before 1999, a BEng/HND are usually acceptable for CEng/IEng respectively – please check with the office*).

Candidates who do not have these exemplifying qualifications may demonstrate that they have acquired the same level of knowledge and understanding by other ways, including writing a technical report (a separate IOA guidance document is available), taking Engineering Council examinations, following an assessed work-based learning programme or taking a further academic course specified by the relevant institution (*if this applies to you, please contact the office for specific personal advice*).

Here is a profile of a recent successful candidate:

Gurmail Paddan,
Institute of Naval Medicine, CEng

Gurmail Paddan studied at the Institute of Sound and Vibration at the University of Southampton after graduating from the University of Bath with a BSc (Hons) in mechanical engineering. His studies at Southampton culminated with a PhD entitled *Transmission of vibration through the human body to the head.*

He currently works at the Institute of Naval Medicine as Head of Acoustics and Vibration, running a small section dealing with all aspects of human exposure to noise and vibration in the Royal Navy and the wider Ministry of Defence. He is a Fellow of the IOA and of the IMarEST.

"I had been meaning to seek CEng registration for a little while, but never got round to filling in the form," he said. "The reason I have done so is that registration demonstrates attainment, recognition and competence in my field of assessing and controlling human exposure to noise and vibration.

"The process seemed rather daunting to start with, but the IOA was on hand to offer constructive and beneficial guidance when required. I would most certainly recommend that other suitably qualified people apply for professional registration."

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Sustainability Design Task Force: good progress on a number of fronts

By Richard Cowell and Peter Rogers

Here is an update on the Sustainable Design Task Force's progress over the last few months.

Getting our own house in order

IOA HQ has been working hard to implement the approved office sustainability policy throughout this year, to address its direct impacts. We understand that we are making good headway, particularly with saving on paper, which is making a positive economic benefit. We will be looking to report the improvements at the end of the initiative period. We are in the process of shaping a wider sustainability policy that will be put before Council.

Guidance

Our Guidance Note 1 on Materials has now been through a peer review (internally and externally) and is returning to Council for final approval. We hope this will be available for members soon. For one particular aspect of social sustainability, a second Guidance Note has been drafted, highlighting ways in which acoustic practice makes a contribution to personal security. This will undergo a similar review process. We hope more guidance will follow and we are interested to hear from members of areas on which they would like further guidance.

Case studies

Following the publication of six examples of sustainable acoustic practice in the May-June Bulletin (pp18-19), a second set is now being collected, to continue highlighting these achievements. Members are encouraged to put forward examples that they feel show ways in which acoustics is supporting and influencing positively the delivery of sustainable practice.

Cross-disciplinary collaboration

Our initiative to encourage holistic, multi-disciplinary working has been supported by the Young Members' Group, who linked up with the CIBSE-affiliated Society of Light and Lighting for *Casting Light on Sound* – this produced interesting material for acoustic and lighting design collaboration, including consideration of the impact of light and sound on behaviour, health and wellbeing. (See September- October Bulletin pps 7-8).

Efforts are now being made through the volunteers to connect with each specialist group and craft a meeting involving invitations to other disciplines to collaborate and help us look outside our own boundaries, and appreciate the areas of influence that we may have. This begins with the Building Acoustics Group (BAG) who have agreed to work towards such a meeting next year. We will be approaching the other groups shortly, through our volunteer force (which is still open for keen and willing individuals that would like to assist with the delivery of one meeting).

If you would like get involved contact Richard Cowell (**Richard.Cowell@arup.com**) or Peter Rogers (**progers@sustainableacoustics.com**).

Education and CPD

We have been exploring how we can strengthen awareness of sustainable practice across the membership, and for those entering our ranks. We are developing on-line content, which will be classed as informal CPD, for all members to access. We have also had careful dialogue with the Education Committee and have begun preparing syllabus material, questions and model answers for Assignments to be integrated into developing education programmes.

For a more formal source of CPD, we have developed an outline for a half day workshop, covering principles of sustainable acoustic practice, social benefits and materials selection during 2015.

So although there is much to do, and so little time, we are comfortable that the SDTF is making good progress. We are also seeing support from many for strengthening the profile of the IOA in this mainstream expectation. Our successes will be those actions which are derived from steps taken by you, the membership, taking forward the insights that we hope will percolate through our practice and help everyone.

Seventy-six more membership applications approved by Council

Seventy-six applications for membership were approved by Council in September following the recommendations of the Membership Committee. Of the total, 51 were for new or re-instated membership, the rest were for upgrades

FIOA
Stephen Dance
John Davy

MIOA
Mercedes Astrain
Sam Bignell
Dermot Blunnie
Thomas Brown
Benjamin Butler
Wai Fat Cheng
Michelle Clifton
Martin Court
Salah Fahmy
Thomas Goose
Belinda Grattan
Peter Hargreaves
Wilson Ho
Momo Hoshijima
Philip Jordan
Ching Mau Lam
Ida Larrazabel
Maurice Maassen
Alex Nicolson
Simon Redfearn
Roger Roper
Johnny So
Gwenc'hlan Tournier
Russell Tipping
Richard Windle
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Phil Blakemore
Colin Bothwell
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Adam Collett
Timothy Coombs
James Cooper
Steve Davenport
Kevin Emery
James Glen
Helder Gonclaves
Louise Hill
Myles Hill
Oliver Kadel
Andrew Kells
Andrew Knight
Graeme Littleford
Mike McCabe
Karen Millar
Lily Nikolova
Max Reynolds
Jack Richardson
Thomas Robotham
Timothy Sherlock-Brown
Patrick Shuttleworth
Richard Stark
David Stevens
James Stokes
Chenette Thomas
Conor Tickner
Matthew Wright

Technician
Duncan Arkley
Andrew Beamish
Angela Goodhand
Daniel Ibrahim
Darren Marshall
Christine Park
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Affiliate
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Student projects: bikes, pumps and resonators

London Branch report

By Steve Dance

Dr Steve Dance (The Acoustics Group, London South Bank University) introduced two of his MSc students, Christina Higgins and Eugenie St Cluque. Both presented a thesis summary covering the following topics: Helmholtz resonators and whole body vibration, the former a winner of the Acoustical Society of America Newman Medal for Architectural Acoustics.

Each was given 15 minutes to outline her dissertation, with questions held until the end. Christina started with her project entitled *An investigation into the Helmholtz Resonators of the Queen Elizabeth Hall, London*, a collaboration with Ramboll Acoustics. She explained the theory of resonators before describing the current installation at the South Bank Centre. The resonators, dating from 1967 when the hall opened, are fixed to the walls of the QEH using asbestos ropes, so replica samples were constructed at LSBU and by the South Bank Centre. The original polyurethane foam covering the apertures of the original resonators had disintegrated, and so additional foam was added to the inside of the replicas. The absorption characteristic of 24 resonator cells was tested in the reverberation chamber with four sizes of aperture. The modular absorbers were further investigated using 25 mm thick foam and an acoustic curtain fixed at three distances from the facing plate. The acoustic performance, measured to ISO 354, matched that predicted by resonator theory. However, the performance was found to be significantly improved with the application of the foam and the acoustic curtain. Christina suggested further research was required!

Eugenie presented her research on the whole body vibration induced by cycling with the aim of preventing regular cyclists from body fatigue, both in the short and long term. A combination of bicycles, road surfaces and measurement locations led to the conclusion that the grade of road surfacing and saddles were of most importance to the measured vibration amplitudes. The effect of head resonance was considered, as it was suggested that headaches could be induced from the vibrations at 15 Hz to 30 Hz. The daily dose exposure was calculated for each cycling scenario with the conclusion that bike couriers should have a very short working day! Eugenie now works for Sandy Brown Associates.

The presentation ended in the usual way by continuing the discussions over a beer.

The branch would like to thank Christina and Eugenie for informative and entertaining presentations and WSP for providing the venue.

Midlands Branch reports

By Kevin Howell

Managing the production of the world's largest noise map

In June the Midlands Branch met at Jacobs in Coventry where Peter Hepworth presented *Managing the production of the world's largest noise map*. The noise map in question was that produced to fulfil England's obligations for the second round of the EU's Environmental Noise Directive. The results will also be used to enable the social and health costs of road and rail noise to be determined. Peter explained the project brief and the tendering process and then went on to describe how Hepworth Acoustics and their partners delivered the project to the demanding seven month timescale. For the project they had collaborated with their long-time partners Acustica (UK), DARH2 (Croatia) and Stapelfeldt (Germany). The input data had been provided (by Extrium) and from this the noise calculations were performed on more than 26,000 km of major roads, 5,000 km of major railways and 65 agglomerations (urban areas with a population of at least 100,000) to produce an integrated noise map. The successful completion of the project also demonstrated that it is possible to manage and deliver such a project in a short timescale even when contributors are located in several countries. Many thanks go to Peter for his excellent talk and to Jacobs for hosting the meeting.

Behind the scenes at BBC Birmingham

The July meeting was a behind-the-scenes tour of the BBC premises in The Mailbox, Birmingham. The tour (which was limited to 20 participants) included visits into the *Midlands Today* TV studio, the Radio West Midlands studio and the studio used for recording radio drama, most notably *The Archers*. Much time was spent in the latter discussing the various sound effects used in recordings and the design and use of the semi-anechoic space that is used for recording "outdoor" sequences. We also visited the TV control room, in which the various responsibilities and roles were explained, and also the production support area where staff monitor 24/7, and provide support to all local BBC television and radio stations. Our two enthusiastic tour guides, Jane and Shaun, informed us of many aspects of production from script to screen (or radio!). Because of the technical nature of our group, we were very fortunate on this tour to also be accompanied by Keith Quiney, a BBC broadcast engineer, who added much technical insight and succeeded in answering our many technical questions. This was an excellent and enjoyable tour and thanks go to Jane, Shaun and Keith, and also to Fiona Rogerson for arranging the evening.

Signal processing for acousticians

In August we returned to URS at Nottingham where Steve Cawser presented *Signal processing for acousticians*. Steve's talk reminded everyone that when we use a modern sound level meter we are making use of a significant amount of digital signal processing. To some extent, we are generally only interested in what has gone into the system and the numbers we can get out and use, and we may have become less aware of any limitations inherent in the process. Steve started by describing the components of a system and explaining the parameters that affect the output. These include the sampling frequency, the bit rate, the spectral range, the anti-aliasing process, and the limitations that each create in digital audio and signal processing systems. He cited a number of examples to demonstrate what could happen to your results if these parameters are not appropriate for the measurement/recording being carried out. Steve's talk resulted in some interesting questions from the audience. Thank you very much Steve and also URS for hosting the meeting.

Lights, camera, action: branch members at BBC Birmingham

Priorities in civil and military aviation acoustics

Southern Branch visit

By Reena Mahtani

In September Southern Branch members attended QinetiQ's Noise testing facility in Farnborough for an evening of discussions around aviation noise. The event had been fully booked a few weeks in advance, and proved to be well worth the hype. Apart from the two speakers, another reason for this excitement was the setting, which was inside the 11,000m3 noise testing facility (one of the largest anechoic chambers in the world). Its connection to a wind tunnel also made this a unique location for a meeting that left everyone suitably impressed.

The event focused on two areas of aviation noise: military and civil. In the absence due to ill health of David Patience from BAE Systems who had been due to speak on military aircraft, we had a presentation on research techniques for modelling helicopter noise from Dr Rodger Munt, who has recently retired from the role of Trusted Advisor to QinetiQ. Although it was based on research that was not recent, most of the outcomes have been incorporated into defence programmes around the world and it offered a fascinating insight into his methodology.

The civil side of fixed wing aircraft was introduced by Nicole Porter, from Anderson Acoustics. It consisted of an insight into policies that govern airports' noise management programmes and recent research on health caused by aviation noise. Afterwards she focused on Heathrow, the case she knows best in her current role as the seconded expert involved in the current noise management planning. She explained the reasoning behind such ideas as respite and current airspace trials to test refined flight path patterns over the southern counties.

After the event, participants enjoyed a tour around the facilities. Following the great feedback, efforts will be made to run a similar event at the location for those unable to attend on this occasion.


The noise test facility at Farnborough

Shining a laser spotlight on the egg box myth

By Ben Piper

Egg boxes have often been suggested as a cheap acoustic treatment for the home studio. In March 1988 the Riverbank Acoustical Laboratories measured the absorption properties of egg boxes, finding that their noise reduction index was 0.4 [1]. The results showed that at low frequencies egg boxes did very little but from 700 Hz up there were some moderate levels of absorption. This experiment deals with the question of whether they can be used as absorbers but what about their diffusion characteristics? This article will use the example of measuring the spatial distribution of reflections from a panel covered with egg boxes to show how the non-invasive technique of refracto-vibrometry can be used to measure a sound field.

Refracto-vibrometry

A scanning vibrometer is typically employed to measure the vibration of surfaces, particularly in the automotive and loudspeaker industries. Vibrometers work on the principle of laser Doppler vibrometry where a laser beam is focussed on a vibrating target and the Doppler shift of the light caused by the moving surface is measured by the instrument. Mirrors within the instrument are mounted on rotating stages allowing the laser beam to be scanned at a number of angles giving full 2D scans of vibrating surfaces. They are highly sensitive instruments that offer the possibility of measuring a large number of points on a surface in a fast and non-invasive way.

One of the uncertainties associated with this method is the effect of sound on the laser beam as it passes from the instrument to the surface in question. As a sound wave travels through a fluid medium it causes local changes in density that result in small changes in the fluid's refractive index and therefore in the speed of sound and, consequently, the time of flight. To the vibrometer, these are indistinguishable from surface vibrations and it interprets the local perturbations as small velocity components.

Refracto-vibrometry makes uses of this phenomenon to make relative measurements of the spatial distribution of sound within a 2D measurement plane by employing a static reflecting surface behind the measurement plane. Figure 1 shows a typical layout.

There are several options for the static reflecting surface including mirrors, retro-reflective cloth, tape and paint. Each has its own benefits and weaknesses but for a flexible set-up a large retro-reflective cloth curtain is preferred. Its surface is made from many tiny glass hemispheres which reflect a high percentage of incident light back in the direction it came from with a small amount of light scattered.

Refracto-vibrometry could be applied in any indoor environment so long as the background noise is low, the sound field being measured is loud and there are not strong thermal currents. Due to its highly controlled acoustics, an anechoic or hemi-anechoic chamber is ideal for these measurements. The size of the room limits the amount of time available for each measurement point and as a result the lowest frequency that can be measured. If, for example, a measurement was being made where the loudspeaker was placed in the centre of a 3 metre wide room with the reflector and the vibrometer positioned at opposite walls the time the sound would take to hit the reflector would be close to 4.5 milliseconds giving a theoretical low frequency limit of 220 Hz.

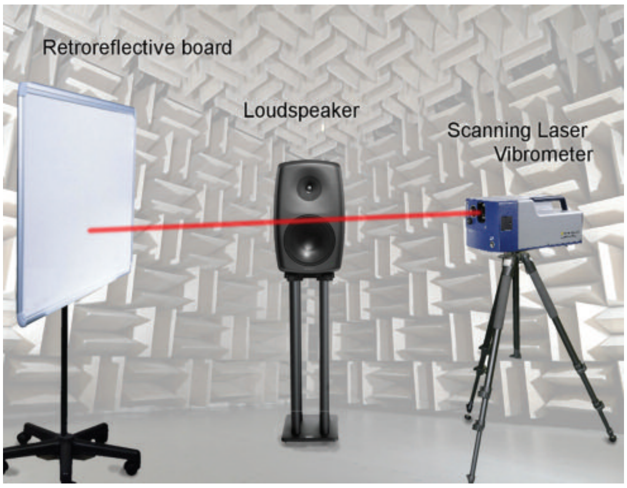

Figure 1 - Typical refracto-vibrometry set-up

The scattering from an egg box panel

For a demonstration of the kind of measurements that are achievable using the refracto-vibrometry technique previously described and to help shine further light on what acoustical properties that egg boxes actually have, a 60 cm x 60 cm wooden panel was covered with evenly spaced egg boxes. The egg boxes were six egg size and with the same shape compartments. The panel was mounted on a screen holder in the centre of a hemi anechoic chamber. A loudspeaker was placed 1.5 metres away and the tweeter was aligned with the centre of the panel using a laser plumb line. A photo of this set-up is shown in Figure 2. The horizontal guide is offset as the plumb line was placed on top of the loudspeaker.

The signal connected to the loudspeaker was a 20 nanosecond impulse from a function generator with a 1.5 V RMS amplitude and 1 kHz high pass Butterworth filter applied. With the speakers output set to maximum this produced a signal at the egg box panel in excess of 90dB. The pulse had an 11 Hz repeat frequency. The signal was also connected to the vibrometers trigger in. The vibrometer, a Polytec PSV-400-M, was then set to measure a grid of 150 x 150 points corresponding to a plane in front of the egg box panel of 1 m x 1 m. For each point 2048 samples were recorded at a sample frequency of 51.2 kHz. To increase the quality of the measurements 25 averages were recorded at each point. This resulted in a scan time of 10 hours. Figure 3 shows the measurement data at a single point.

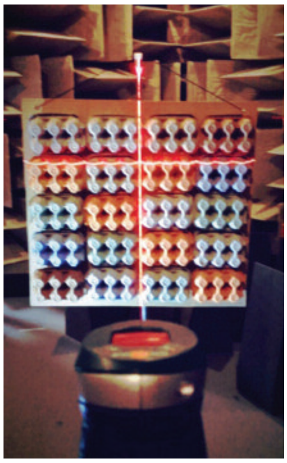

Figure 2 - Photograph of egg box panel alignment in a hemi anechoic chamber

There are two distinct peaks in the data, the first is the impulse as it radiates through the air and the second is the mechanical vibration of the retro reflective curtain. The second peak takes several milliseconds to settle and this dictates the minimum number of samples for each measurement. It is only the first eight milliseconds which are of interest. The results form a data matrix of x and y coordinates and time samples which can be used to create a video of the sound field.

Figure 4 shows eight frames, each 15 frames apart, taken from the video generated from the data. The central axis of the panel and loudspeaker is marked in frame 1. The higher frequency components contained within the impulse are scattered evenly and periodically by the egg boxes with some of the energy absorbed. The low frequency energy contained in the impulse is not effectively scattered and is reflected as a single strong reflection that trails the higher frequency scattering. This can clearly be seen in frame five highlighted by an arrow. There is also a strong reflection of the whole impulse from the small amount of uncovered wood surface at the top and bottom of the panel. This can initially be seen at the top of frame four highlighted by an arrow.

From this measurement it is clear that egg boxes have diffusion properties at higher frequencies. However, at low frequency they are effectively transparent. It would be interesting to explore what the subjective effects are of scattered high frequency energy trailed slightly in time by the unscattered low frequency energy of a reflection. For the purpose of the home recording studio it is unlikely to provide any benefit. Therefore the conclusion must be that egg boxes are not useful for their diffusion properties. A video of the full dataset will be available on YouTube soon.

Ben Piper *is a Higher Research Scientist at the National Physical Laboratory working in the fields of optical acoustics and MEMS microphones. He completed a Doctorate in acoustics and sodar in 2011 at the University of Salford, where he was also involved in testing the subjective annoyance of wind turbine noise. He is a member of the IOA Measurement and Instrumentation Committee.*

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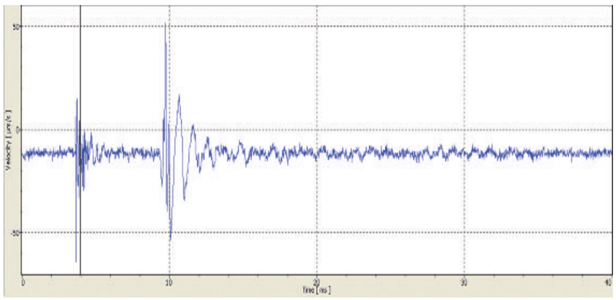

Figure 3 - Measured velocity data for a single point

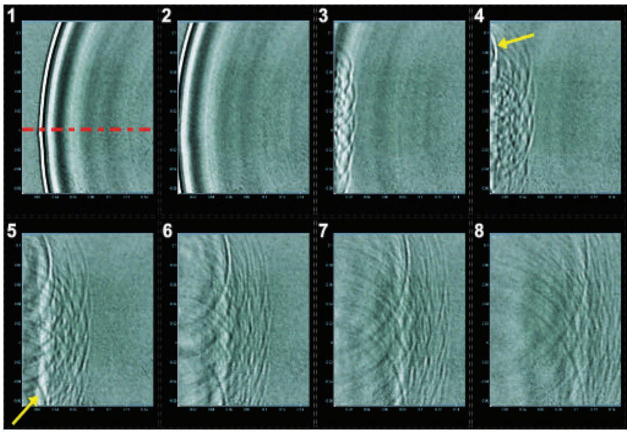

Figure 4 - Eight frames showing the scattering of an impulse by a panel of egg boxes

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Two firms heavily fined by courts for failing to protect staff from noise

A firm has been fined £15,000 and ordered to pay £4,457 in costs after failing to protect its workforce from excessive noise levels made by production machinery.

Keighley-based Fibreline was prosecuted by the Health and Safety Executive (HSE) at Bradford Crown Court for breaching health legislation.

The court was told that an HSE investigation found the company had not made a suitable assessment of the noise levels in the factory between 2006 and 2013.

Noise levels had become excessive from 2008 when a third machine was added to its feather pillow production process, reaching between two and three times higher than the maximum allowed; and from 2011 in the foam fabrication process when two glue-spraying booths were located side by side.

Fibreline, as an employer, should have known its workforce was being subjected to loud noise, and made personal hearing protection compulsory in the two areas when the production changes were made. However, wearing hearing protection was not introduced until 2013.

In addition a health surveillance programme for noise exposure should have been operating for affected workers, but this was not brought in until 2013, when 40 employees had to be given a hearing test.

And as the result of another prosecution by the HSE, a manufacturer was fined £7,000 and ordered to pay £1,279 in costs at Basingstoke Magistrates Court for allowing employees' health to be put at risk from noise and vibration.

Brooks Crownhill Patternmakers, a precision engineering company based in Andover, Hampshire, admitted single breaches of the Health and Safety at Work etc Act 1974; the Management of Health and Safety at Work Regulations 1999; the Control of Vibration at Work Regulations 2005; and two breaches of the Control of Substances Hazardous to Health Regulations.

The offences came to light after an inspection by the HSE revealed that risks to health from exposure to vibration, noise and dust had not been adequately managed or controlled.

New acoustic test facility for building materials

Acoustic testing of low carbon construction materials is one of the services available at a new £1 million facility at the University of Bath's Building Research Park, Swindon.

The HIVE, the first facility of its kind in the UK, was officially opened by the University's Chancellor, the Earl of Wessex.

The HIVE offers a "plug and play" facility and expertise to test and evaluate materials and systems in a ready-built open air environment, speeding time to market for innovative materials.

The building has eight individual cells which are carefully constructed to be completely insulated from each other, each with a single face left exposed to the external environment. The faces are used to install walls made from a whole range of materials and construction systems, and the performance of these walls is evaluated in real life conditions – creating a more accurate picture of environmental performance than the u-value assessments currently used in building regulations.

Dr Mike Lawrence, Director of the Building Research Park, said: "Finding new, sustainable methods of construction – properly tested in a real building such as the HIVE – is essential if the UK is to lead the way in low carbon homes and meet challenging emissions targets."

Some of the research already under way includes testing the thermal and acoustic performance of double skin facades, along with the performance of different window types and acoustic ventilators with Mach Acoustics to help increase use of low impact natural ventilation.

For more details go to **www.bath.ac.uk/brp**

Dr Mike Lawrence at the HIVE test facility

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Making all the right noises at Glastonbury

Noise specialist Richard Willson was in action again at this year's Glastonbury festival – with a mission to protect staff from excessive noise.

Richard, noise at work consultant for TESS, The Event Safety Shop, is one of the UK's most experienced festival noise specialists, having also worked at the Latitude, the Leeds and Reading festivals, Festival Republic and BBC events.

His task at this year's Glastonbury: to ensure the wellbeing of festival employees and concession staff under the Noise at Work Regulations and ensure noise limits were adhered to during the five days of the event.

One of his biggest challenges was the sheer size of Glastonbury. Covering some 900 acres, it is the largest green field festival in the world and one that attracts 200,000 festival goers and has approximately 60,000 staff on site. To assist him, he used 10 doseBadge noise dosimeters and an Optimus Red sound level meter.

He said: "Recent changes to the Noise at Work Regulations mean they now apply to festivals, so my work begins with a visual survey of the site to pinpoint where we see a need for ear protection in noise hot spots and estimate how many staff will need ear plugs or other protection.

"We aim to have over 70% compliance as a general rule of thumb at any one time and this would cover everyone from festival staff to traders and concession employees.

"Using the data, we create a noise map of the site and then work up red, amber and green zones which range from constant noise levels that require mandatory ear protection to be worn, through to warnings of intermittent excess noise or low risk areas.

"You have some areas that are obvious red zones, such as The Pit at the front of the stage where security and medical staff are based. Normally, a festival will start around 11am and go through to maybe 1am the following morning. There is some down time when the roadies are changing sets, but other than that there will be very high noise levels in this area and anyone based there will be suffering from long term exposure.

"Fortunately the security staff are very experienced and understand the risks. Roadies and the musicians are also at risk, so much so that their jobs are listed as one of the top five noisiest in the UK – that's alongside jobs such as airport ground staff and construction workers.

"The awareness of noise is increasing but we still have issues persuading other personnel on the site of the risks of noise levels for their staff, for example, with some of the bar concessions further away from the main stage but who have their own sound and PA systems in confined spaces.

"We understand that they want to have the music on loud to create an ambience and attract people in, but they also have to understand the damage it can cause to people's hearing. Hearing damage and loss is a very serious condition and sufferers of tinnitus have been known to commit suicide because of the misery it causes. With this kind of situation we have to negotiate and persuade, but we also understand it is problematic if bar staff wearing ear plugs can't hear the customers properly.

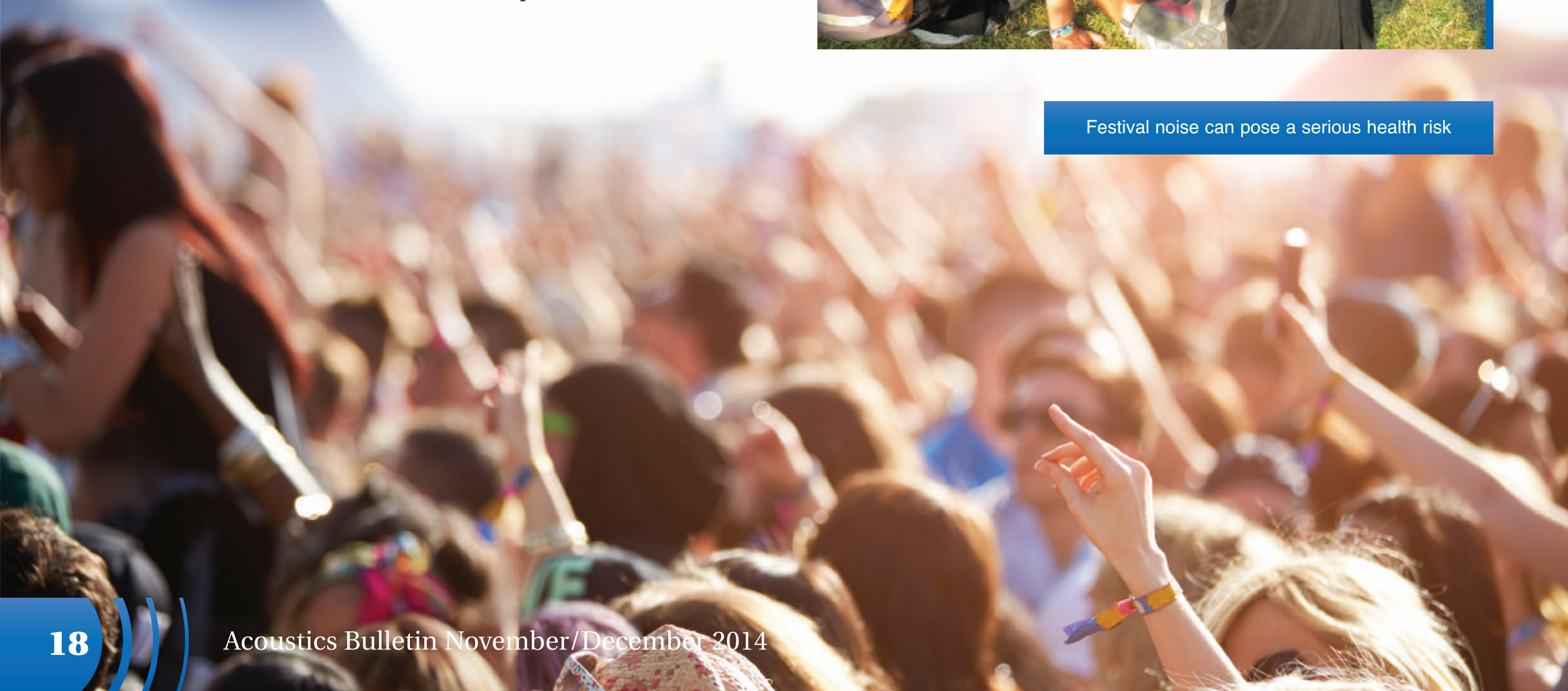
"The data we collect from the doseBadges and using the Optimus Red SLM gives us the evidence we need to make the case and we are able to show the high level readings and come up with a solution.

"At this type of festival, you can regularly expect noise levels to exceed 110 dBA and you need to understand the risks that brings. Having said that, you also need to be aware of the variances expected during a festival day or weekend. You wouldn't expect Dolly Parton to be as loud as, say, Metallica. There has to be a lot of common sense applied.

"But every festival is different and the sheer size of Glastonbury poses a problem. It might take me two hours just to walk around the site to put the doseBadges in place. We then need at least six hours of recordings and then it will take me another two hours to go around and collect them all in again before we can download and analyse the results.

"Overall, festival management are becoming more aware of the Noise at Work Regulations and how they apply to their event. They need to be able to understand the data we collate and see it as clear evidence. The same applies for local authorities who are pushing compliance more and more at these type of events as they take place within their region."

The TESS team analyse their data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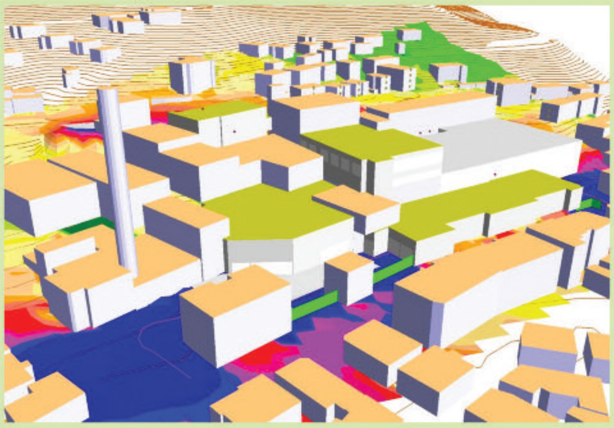

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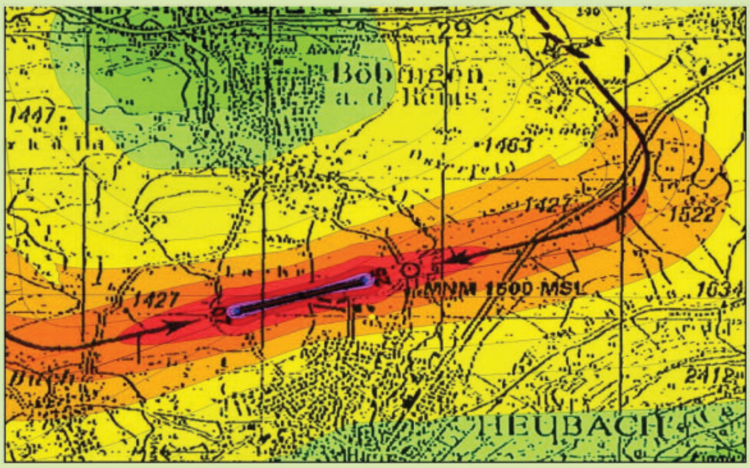

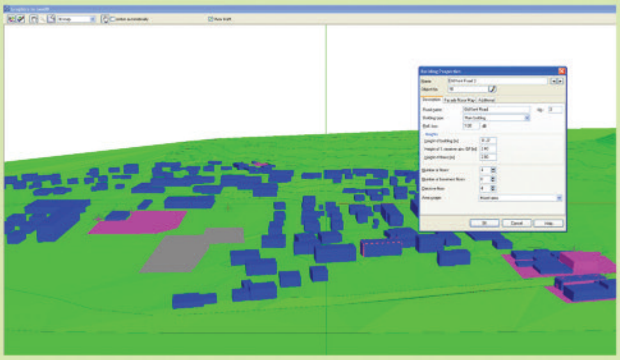

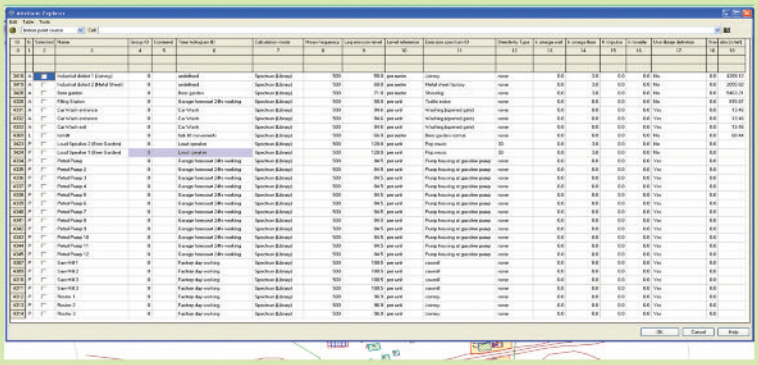

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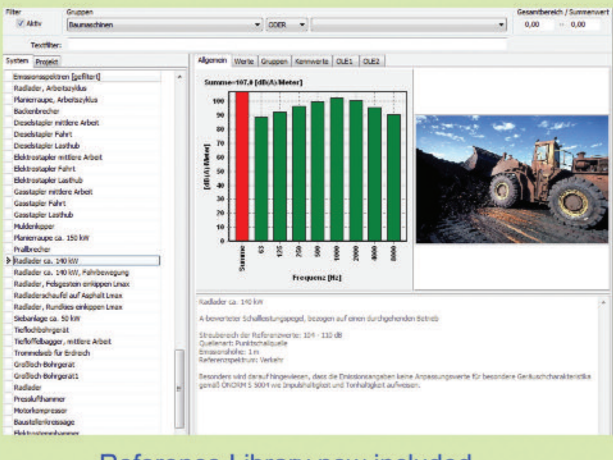

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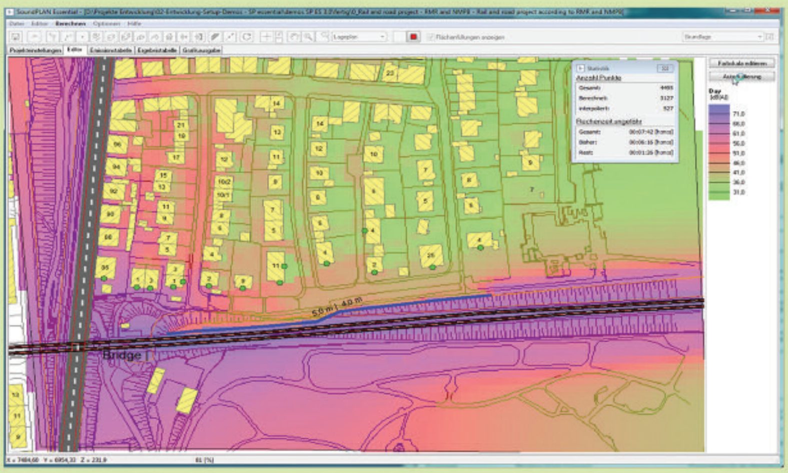

New integrated Master's programme in audiology at Southampton

The University of Southampton has launched a new integrated Master's programme in audiology – the first of its kind in the UK.

The new course will offer students the opportunity to complete their undergraduate and Master's level audiology training in a single programme, to qualify with an MSci Healthcare Science (Audiology).

The MSci is an undergraduate-entry programme involving four years of full-time study. The first three years are identical to the existing BSc Healthcare Science (Audiology) programme at Southampton and includes 40 weeks of clinical placement. The additional fourth year will extend students' knowledge, scientific, cognitive and leadership skills in research, clinical decision-making and specific clinical areas of audiology. A part-time option for the final Master's level year will also be available for students who wish to start working in audiology at the end of the third year. Students already studying the BSc can to transfer onto the MSci, visa permitting for international students.

For more details go to **http://goo.gl/kDuq00**

New imaging technique could mean lighter and thinner aircraft

The next generation of aircraft could be thinner and lighter, thanks to the development of a new imaging technique that could detect damage previously invisible to acoustic imaging systems.

The nonlinear acoustic technique has been developed by researchers from the University of Bristol's Ultrasonics and Non-destructive Testing (NDT) research group.

It has long been understood that acoustic nonlinearity is sensitive to many physical properties including material microstructure and mechanical damage. The lack of effective imaging has, however, held back the use of this important method.

Currently engineers are able to produce images of the interior of components using ultrasound, but can only detect large problems such as cracks. This is like detecting only broken bones in a medical environment.

Imaging of acoustic nonlinearity is achieved by exploiting differences in the propagation of fields produced by the parallel and sequential transmission of elements in ultrasonic arrays.

Dr Jack Potter, Research Assistant in the Department of Mechanical Engineering, who led the study, said: "Imaging acoustic nonlinearity not only provides sensitivity to smaller defects than is currently possible but may have the potential to detect damage before macroscopic material changes occur.

"This would enable intervention before cracks have even begun to form, as well as predicting the remaining life of an engineering structure. Crucially the technique has been achieved using standard inspection equipment, which will allow for the rapid implementation of the technique in numerous applications."

Such advances in non-destructive evaluation not only increase the safety of engineering structures but can help future design, for example, allowing the next generation of aircraft to be built thinner and lighter.

The findings are published in *Physical Review Letters* together with an accompanying article in *Physics.*

Dublin sound project scoops EAA Soundscape Award

A project in Ireland has won the European Soundscape Award 2014 for its work on acoustic planning and urban sound design.

The prize, presented by the European Environment Agency (EEA) in Bern, recognises initiatives that can help reduce noise and create healthy soundscapes.

Led by Sven Anderson, an urban acoustic planner at Dublin City Council, the project, entitled Manual for Acoustic Planning and Urban Sound Design, sought to encourage a deeper level of interest in the urban sound environment, both within the city council and among the wider public.

The project included two large public sound installations at prominent urban locations in Dublin:

- Continuous Drift is an installation based around four retractable umbrellas that cover Meeting House Square in Dublin's most popular tourist destination and cultural quarter. The umbrellas act as the backdrop for different sonic atmospheres which can be activated using mobile phones.
- The second installation, Glass House, listens to films being screened in an adjacent cinema, using their melodies to create a subtle sonic trace that hovers in the public space outside. In addition to the installations, the project included the three-day symposium *Beyond Noise and Silence: Listening for the City* and presentations at several international conferences.

The Department of Ecology at Aristotle University of Thessaloniki won the runner-up prize with the proposal for a practical methodology to identify Quiet Areas (QAs). Quiet Areas are defined as sites undisturbed by noise from traffic, industry or recreational activities under the Environmental Noise Directive.

Identifying QAs using traditional measurement and modelling techniques can be costly and resource intensive, so the university developed a method involving mapping and land use data as a more efficient way to identify priority areas to protect from noise pollution.

At the Bern meeting, which was attended by noise experts from 39 countries, the EEA launched the 2014 update of its Noise Observation and Information Service for Europe (NOISE), an interactive database illustrating exposure to harmful levels of noise across Europe's major transport networks and in more than 400 cities.

It shows that road traffic is the dominant source of unhealthy exposure, with at least 61 million Europeans affected. Data from 69 airports reveal that almost three million people are adversely affected by aircraft noise near airports. Railway noise affects almost eight million people, while noise from Europe's largest industrial sites affects almost half a million people.

Do wind turbines cause deafness?

No proof yet, say scientists

Can wind turbine noise cause severe hearing damage or even deafness to people living nearby?

The answer, according to scientists at the University of Munich who have recently concluded a study on the effects of low frequency noise on the inner ear, is that the case remains to be proved.

However, a firm link between the two was made in the British press following the publication a research paper by the German team in the Royal Society journal *Open Science*.

In their study, 21 men and women aged between 18 and 28 years were exposed to a frequency of 30Hz at 80 dB (A) for 90 seconds.

In comparing the naturally emitted sounds made by the ear before and after the experiment, the research team found that they changed drastically when normally they would be expected to be the same. This they took to be a change of the mechanism of the inner ear.

"Low-frequency sounds, contrary to their unobtrusive perception, strongly stimulate the human cochlea and affect amplification processes in the most sensitive and important range of the human hearing," they stated.

Because low-frequency noise is emitted by some wind turbines, three British newspapers – *The Daily Express*, *The Daily Mail* and *The Daily Telegraph* – concluded that the findings showed that exposure to turbine noise could result in hearing damage and even deafness.

But Dr Markus Drexl, one of the seven joint authors of the report, entitled *Low-frequency sound affects active micromechanics in the human inner ear*, told *Acoustics Bulletin*: "The conclusions drawn by some sections of the press are not supported by our data.

"We have shown that brief exposure to low frequency sound modulates inner ear activity in a very unusual way, even after the offset of low-frequency sound and continues for a few minutes.

"If this is the first indication of a beginning sound-induced hearing loss it remains to be seen and would require further experiments, probably with longer exposure durations.

"We have certainly not shown that wind turbine noise causes hearing impairment or deafness.

"The motivation for the study was indeed to see how low-frequency sound in general (and possible sources are indeed wind turbines, air conditioning units etc.) affects the human inner ear.

"For us, the most important result was that there is a significant discrepancy between the perceived loudness of low-frequency sound and the prominent, slowly oscillating changes of inner ear activity."

No proven link yet between turbine noise and deafness

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Acoustics – what has changed during the past four decades

In the second part of our series to commemorate the Institute's 40th anniversary this year, the Building Acoustics, Environmental Noise and Speech and Hearing Groups look back at key developments in their sectors since 1974.

Developments in building acoustics 1974 – 2014

By Michael Barron, Robin Mackenzie, Richard Mackenzie and Raf Orlowski

This article traces developments in building acoustics through progress reported in *Acoustics Bulletin* over the past 40 years in technical papers, reports of the Building Acoustics Group, standardisation and product innovation. Since building acoustics covers such a wide area of engineering the authors have been required to restrict the article to the two largest areas of activity viz auditorium acoustics and sound transmission in dwellings. Inevitably, important areas such as building services noise, the acoustics of the external façade, structural vibration and the acoustic design of schools, offices and hospitals have not been covered in this paper.

Part 1 – Auditorium acoustics

The last 40 years have been exciting times in auditorium acoustics, in which major progress has been made. The auditorium acoustics world is international, relying on communication in journal papers and specialist meetings. The IOA has contributed in a major way with a very successful series of Auditorium Acoustics conferences, mostly linked to individual auditoria.

In terms of new results, the first decade from the mid-1970s to mid-'80s, was the most influential. But a brief look backwards is helpful. In the immediate post-war period, many auditoria were built with reverberation times (RTs) that were too short, because of inadequate hall volume. It was Beranek who realised that the Sabine equation was valid but that the absorption figures for seating and people were too small. He proposed treating the audience on an area basis rather than per seat. The short reverberation times were a consequence of improving seating standards (i.e. floor area per seat). The 1951 Royal Festival Hall was a classic example of the RT problem. At that time, reverberation time was the only measurable quantity with significance for listeners, but there was a general understanding that there was more to discover. This implied that concert hall listening must be a multi-dimensional experience, a conclusion confirmed by Hawkes and Douglas in 1971.

Subjective experiments in anechoic chambers were begun in 1950 in Germany (initially in Göttingen). In the 1960s several measurable quantities were proposed that experiments had shown were relevant to concert hall listening, but which were the really important ones? The size of the challenge was amply illustrated by the ill-fated Philharmonic Hall in New York (1962-1976); one of its main problems was linked to a phenomenon unknown at the time. Marshall proposed in 1967 that early lateral reflections were important, which created an impression of space around the performers. Subsequent experiments confirmed that spatial impression was indeed an important component of good acoustics. Early lateral reflections were absent in Philharmonic Hall among other complications.

It was the development of the dummy head (with moulded human ears) that enabled subjective experiments into listeners' preference and the important qualities for concert hall listening. Two major studies were undertaken in Germany, in Göttingen and Berlin. Based on their results, one can construct a consensus view that four qualities are paramount: clarity, a sense of reverberation, spatial impression and loudness. Corresponding objective quantities are the early-to-late sound index, the early decay time, the early lateral energy fraction and sound level with a calibrated sound source (known as Strength). Each of these quantities varies with seat position, contrary to RT which is usually independent of position. These quantities could be measured and predicted by scale models or the slowly evolving computer simulation models. They were also included in ISO 3382:1997. Since 1997, several additional measures have been proposed, but only the late lateral level, linked to subjective 'envelopment' has been added.

Auditorium modelling

Acoustic scale modelling dates back to 1936, but had been little used before the 1960s as a design aid. Large scales were employed such as 1:8 and 1:10. These models could be used for objective testing, generating numbers of quantities mentioned above for instance. Alternatively they could and can be used for subjective testing by playing speeded-up music through the model and slowing it down again for listening tests. Digital processing has greatly improved the ease of both objective and subjective testing. A major complication of scale model testing is air absorption, which increases with increasing frequency. It can be compensated by using dried air or nitrogen; alternatively for objective measurements air absorption data can be used to correct impulse responses. Smaller modelling scales such as 1:50 have also been used for objective modelling, without the expense of large models and big spaces to accommodate them.

Computer modelling used as its starting point an array of 'sound rays', each ray was followed until it became too quiet, by for instance hitting the audience area. However, sound rays are only truly representative at high frequencies. Improved methods were gradually developed, using beams rather than rays for example. While the first programs assumed that all surfaces were flat, producing specular reflections, many surfaces in actual auditoria are not flat and therefore introduce some scattering of sound. Progress in this case depended on quantifying scattering with the proposal for a scattering coefficient (also mentioned below). Reliable programs now include the behaviour created by scattering surfaces. A further phenomenon that should be included is diffraction effects on reflection from finite dimension surfaces; this has also been partially implemented in some computer models.

Computer modelling is attractive as an aid to design due to its low cost and quick implementation. The user needs to be confident that the program correctly represents real acoustic behaviour. Computer or scale modelling are also valuable research aids, which allow basic questions to be resolved, such as where is the optimum location for scattering treatment in an auditorium.

Scattering on wall and ceiling surfaces

Concert halls of the 19th century, several of which have good acoustic reputations, were true to the architectural style of the time with elaborate decoration on the walls and ceiling. Typical examples of this decoration include window-like surrounds, niches containing statues and coffered ceilings. Unknown to the designers of these halls was the fact that they had created acoustically scattering surfaces beneficial to sound quality. The arrival of the Modern Movement in architecture after the First World War meant a return to plane surfaces and in some cases acoustic problems. Scattering surfaces are valuable in acoustic spaces but what is the degree of scattering produced by a particular surface? Schroeder in 1979 proposed a series of mathematical designs with predictable scattering, the best known of these is probably the quadratic residue diffuser (QRD). This was first used in a concert hall in 1983 in the Michael Fowler Centre in Wellington, New Zealand. Dealing with the more general scattering surface however, both a scattering and a diffusion coefficient have now been defined, which can be measured in laboratory conditions. The scattering coefficient is used in computer simulation models.

Development of concert hall design

Prior to 1950 there had been two popular plan shapes for concert halls: the rectangular plan and the theatre form. The rectangular form was well-judged for its acoustics but considered architecturally retrograde following the arrival of the Modern Movement. The theatre form, with many balconies, was less successful; likewise the fan-shaped plan had a poor reputation. The 1960s and '70s can be called the period of experimentation. If it was not just a question of reverberation time, was it also perhaps a large amount of scattering surface to produce a diffuse sound field? Or subdividing the audience into terraces (Berlin Philharmonie of 1963)? Or enhanced early lateral reflections as in Christchurch (1972) and Wellington, New Zealand?

As an example of varied designs, one can look at the three very different halls which were completed in Britain in 1982: the Barbican Concert Hall, London, St. David's Hall, Cardiff and the Royal Concert Hall, Nottingham. The Barbican Hall had an imposed height limit which resulted in an overly wide hall with inadequate volume. St. David's Hall has a design inspired by the Berlin Philharmonie with what are often called vineyard terraces; it has gained a good reputation for its acoustics. The Nottingham hall has a cross-section designed to promote early reflections from the side. The diversity of designs from 1982 illustrates the situation prior to a major transition that occurred in the later 1980s. This transition principally concerned the relationship with the client, rather than any new acoustic discovery.

Acoustic consultants had often allowed themselves to be overruled by architects. Yet poor acoustics in a completed hall is often resistant to much improvement. A concert hall is for listening to music so the acoustics should be paramount and need to take precedence over the architecture, which may anyway be strongly influenced by design fashion. Thus it was necessary to increase the status of the acoustician within the design team. Acoustic consultants also needed to take more responsibility for their advice and engage in less experimentation. Since around 1990, two concert hall forms have dominated: the parallel-sided hall and the vineyard terrace hall. One person who could claim some credit for raising the standing of acousticians involved in auditoria is Russell Johnson from New York (1923 - 2007). He sometimes made himself unpopular by refusing to compromise, but the larger acoustical community has benefitted from this transition.

Among the significant parallel-sided halls since the mid-1980s are the Konzerthaus in Berlin (1986), halls in The Hague (1987), Dallas, Texas (1989) and, nearer to home, Birmingham Symphony Hall of 1991. Further examples are Tanglewood, Massachusetts (1994), Seattle (1998), Lucerne (1998), Tokyo (2000) and finally The Sage, Gateshead (2004). Though fewer in number, the following recent terraced halls have been completed: Belfast (1997), Sapporo, Japan (1997), the Disney Hall, Los Angeles (2003), Copenhagen (2009) and Helsinki (2011). An interesting hybrid has been built in Manchester; the Bridgewater Hall of 1996 is parallel-sided towards the stage end with a terraced arrangement of P24

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The acoustic characters of parallel-sided halls and terraced halls are different, each with their advantages and disadvantages. The parallel-sided hall offers a rich sense of reverberation, sometimes at the expense of clarity; the narrow width of these halls creates a good spatial impression. The maximum number of seats for a parallel-sided hall is around 2,200, smaller than with the terraced hall.

One advantage of the terraced hall is the creation of a stronger sense of involvement in the performance, as opposed to the more formal situation in the parallel-sided hall with musicians facing the audience. There is considerably more flexibility of design in the terraced hall, though in architectural and acoustical design terms it is much more demanding. Very good acoustic conditions can be created with this form, though there is the limitation for the terraced hall of poor balance for listeners to the sides of the orchestra.

Variable acoustics

A balanced sound is obviously necessary. For listeners, a crucial balance is between perceived clarity and reverberation. With recordings one can get near the optimum balance by microphone placement etc. But this is more difficult to produce throughout an auditorium. Some consultants have sought to enhance the sense of reverberation; one technique has been the use of reverberation chambers, as found in Birmingham Symphony Hall. For this, the main auditorium is surrounded by empty chambers that are coupled by openings to the auditorium, openings which can be closed or opened. The result is to produce an extended decay of sound, audible when the music stops. It is probably fair to say that these chambers have had mixed success.

Reverberation chambers are an example of variable acoustics. In most recent medium-size concert halls, variable acoustics is a built-in component, offering quite large changes in reverberation time. The demand for this often derives from the need to have a long reverberation time for acoustic instruments (as used in standard classical music), while also being able to accommodate amplified instruments, which require short reverberation times. Amplification is frequently used for folk and world music, for instance. The most common technique to produce a reverberation time change is to introduce retractable sound absorbing drapes or banners; the areas required are however large, as can be easily predicted by the Sabine reverberation equation.

The use of electronics to increase reverberation time dates from the late 1960s. The first system was developed by Peter Parkin for the Royal Festival Hall, London, to overcome the deficiency in the reverberation time. This system, known as Assisted Resonance, used multiple channels each tuned to a different frequency. Another system, Multiple Channel Reverberation, used many broadband channels. Since those days several alternative systems have been developed, which are more stable and require less maintenance. However, musicians are often wary of complicated electronic enhancement, as illustrated by the Festival Hall. It still has a short reverberation time, which could easily be enhanced electronically, but since 1998 no enhancement has been used.

Stage acoustics

A further aspect requiring attention in auditoria is the acoustical conditions for the performers, who need appropriate supportive conditions to perform at their best. This question was only first addressed in the mid-‘80s, principally by Gade. He had the luxury of two nearby anechoic chambers; by placing a musician in each and linking them electronically, he could investigate the conditions for good ensemble. In simple terms, his conclusion was that reflected energy with more than a certain level and within 100ms of the direct sound was required; his proposed measure is called Support.

In a recent research project at the University of Bath, Dammerud looked specifically at the state of affairs for musicians in a symphony orchestra. It was soon realised that the acoustic situation on stage for a full orchestra was different from that of a small chamber group, with few reflections from the floor reaching musicians and direct sound between musicians often being obscured by other players. The Support measure did not correlate with satisfaction by performers. Two major conclusions of this work were that the priority for musicians was to hear their fellow musicians and that this was not helped by a low reflector over the stage. A narrow stage with a significant height above it was the preferred condition.

Opera houses

Forty or so years ago, many people might have predicted that opera was a doomed, outdated art form patronised only by the rich. In fact, while the number of new houses is small, opera has survived with new audiences able to access what is always expensive to produce through recordings and live relays from actual performances. The principal new opera houses are the Dresden Staatsoper (rebuilt in 1985), the Opéra Bastille, Paris of 1989, Glyndebourne Opera House 1993, Guangzhou Opera House 2010 and three new houses in Scandinavia: Gothenburg 1994, Copenhagen 2004 and Oslo 2008.

In the case of reverberation time, there are differences in taste. Many of the old houses have short reverberation times, such as Covent Garden with 1.1 seconds; a short reverberation time favours the sung text at the expense of the orchestral sound. The Dresden Staatsoper, destroyed in the war, was however rebuilt with a 1.8s reverberation time, which will give a richer acoustic character. Longer reverberation times were used by the Scandinavians for their new opera houses.

The other acoustic concern important for opera is the balance between the singers and the orchestra, the orchestra often drowning the singers. To overcome this, careful design of surfaces, particularly around the proscenium arch, is necessary to enhance the singers’ sound as much as possible.

Conclusions

The rather hit-and-miss days of concert hall design prior to the early 1980s are now a thing of the past for competent consultants. The important characteristics for good acoustics are much better understood, the ability to test designs before construction now exist and the status of the acousticians relative to the P26▶

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P24 architect is much enhanced. For these reasons, there is now much greater confidence in acoustic design, with reasonable expectation of good acoustics in new halls. In recent years the price of success has been more conservative design with greater reliance on precedents. Nevertheless, the search goes on, more remains to be discovered in the pursuit of 'excellent' acoustics.

An interesting concert hall is currently under construction in Paris, its new Philharmonie is due to open in 2015. The design of this hall explores the possibility of an auditorium enclosure surrounded by a larger volume linked by significant openings. The Institute of Acoustics will be holding an Auditorium Acoustics meeting in Paris in October 2015, linked to this new auditorium.

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Part 2 – Sound Transmission

Years leading up to 1974

The immediate post-war years were a highly productive period which saw the consolidation of the theories upon which modern sound insulation principles are now based. Fundamental studies were carried out by Aston and Parkin in the UK, Beranek in the USA, Cremer and Heckl in Germany, Ingemansson and Kihlman in Sweden, and by Kosten and van den Eijk in Holland. A considerable number of field studies were carried out in the UK by the National Physical Laboratory and the Building Research Station (later to become the BRE) in which wall insulation was correlated with occupants' satisfaction level resulting in BRS Digests No. 88 and 89, published in 1956. These laid the foundations of the sound insulation provisions of the first Building Standards Regulations which were published in 1963 in Scotland and in 1965 in England & Wales and consolidated in 1971 with explanatory memoranda and restrictions on flanking construction added.

By the early 1970s the BRE was the pre-eminent organisation involved in sound insulation research, not only in the UK but arguably throughout the world. The CSTB in France and NRC in Canada carried out significant research in concrete and timber constructions respectively. NBS in the USA and TNO in Holland were particularly active in trying to determine the most suitable form of single figure ratings for dwellings and most other northern European countries had government sponsored research into sound insulation in dwellings.

In the UK, three commercial organisations, AIRO, SRL and British Gypsum, had built sound transmission laboratories to serve the increasing need by product manufacturers to have new materials and designs assessed. Three universities, Heriot-Watt, Liverpool and Salford, had sound transmission suites built to undertake research into sound insulation of walls and floors. The BBC was also very active in this period carrying out research into the sound insulation of lightweight timber partitions mainly for studio design.

First decade 1974 - 1983

The introduction of the Building Regulations was a considerable stimulus to university research in the UK. Research at Liverpool University focussed on the transmission of sound in buildings using impulse methods and fundamental studies into structure-borne sound insulation. Studies at Heriot-Watt University focussed on the sound insulation of lightweight walls and in applying the use of Statistical Energy Analysis to investigate coupling loss at construction joints. These areas of study set the foundation for many research programmes during the following two decades.

The most productive centre for sound insulation research was the BRE, which produced more than 20 current papers during the decade covering all aspects of wall and floor transmission. Two of these papers were particularly significant and served to influence major changes in future Building Regulations. In the first study, published in 1977, involving attitude to noise, it was found that around 7½% of the population (3.5 million people) were bothered by noise from neighbours. In the second study, published in 1978, involving the sound insulation performance between dwellings built in the early 1970s, it was established that, on a survey of 1,700 party walls and floors, 55% of the walls tested failed to reach the airborne grade requirement and 11% had particularly poor sound insulation. It was further found that 63% of the floors failed to meet the impact standard, with 33% giving a particularly poor performance. This was a serious indictment of the application and provisions of the Building Regulations, which were nevertheless consolidated again in 1981 with little change to the specified constructions or measurement and assessment procedure.

Around this time a significant change to measurement procedure was proposed by British Standards in BS 2750:1980 '*Method of measurement of sound insulation in buildings and of building elements*' and BS 5821:1980 (revised 1984) '*Method of rating sound insulation in buildings and of building elements*'. The existing grading procedure using AAD (aggregate adverse deviation) was replaced with new ratings, $D_{nt,w}$ (weighted standardised level difference) for airborne sound and $L'_{nt,w}$ (weighted standardised sound pressure level) for impact sound insulation. It took, however, another five years for this standard to be adopted within the Building Regulations.

Towards the end of the decade much research focused upon the failure to meet performance standards as identified by post completion testing. Poor workmanship, such as partially filled joints in walls, was a common occurrence, which together with some inadequate 'deemed to satisfy' wall and floor specifications were identified as the main causes of failure. However, it would take a further 10 years before these problems would be adequately dealt with by changes to the Building Regulations.

Second decade 1984 - 93

Research at the start of the decade had identified a clear link between post construction testing or the absence thereof and failure due to poor workmanship. The resistance to the inclusion of mandatory post completion testing within the Building Regulations was largely due to the cost and time involved in carrying out sound tests using analogue based equipment and serial processing of data. Research was undertaken under the aegis of the International Standards Organisation to develop a short (and less expensive) test method. A survey (short test) method was finally published in 1993; however the work programme coincided with major advances in acoustic instrumentation, particularly portable digital sound level meters and related real-time analysis.

Both England and Wales and Scotland acted similarly to resolve the issues, identified by the BRE, by introducing new Regulations Part E in 1985 and Part H in 1987 (both amended in 1992). The changes to the 'deemed to satisfy' specifications were significant in two respects: firstly that they were now contained within an Approved Document, which was not a statutory instrument, ▶

Modern homes have better sound insulation

thus allowing the possibility of more frequent updating without the need for parliamentary approval and secondly they removed poorly performing walls and floors (such as autoclaved concrete blockwork), introduced new timber wall and floor designs and gave more attention to construction joints. Provision for conversion of flatted dwelling was also introduced. The $D_{nt,w}$ and $L'_{nt,w}$ method of rating was also adopted, but in doing so the impact sound performance standard was lowered slightly, in part for reasons of political expediency, to reduce the high level of failure found in specified floor constructions from the 1978 figure of 63% to a more 'acceptable' figure of 50%.

The introduction of the EU Construction Products Directive in 1993 meant that all construction products with acoustic properties would be tested, and have their performance declared according to harmonised standards (CE mark). It also was the stimulus towards greater harmonisation in measurement standards across the EU.

Increasing research on timber and metal framed party walls and floors were carried out during this period by timber frame manufacturers, British Gypsum and overseas by NRC in Canada. Also much attention was being given by researchers and consultants alike to better understanding flanking transmission and the issues involved in the refurbishment of existing buildings.

Towards the end of the decade much work was being undertaken under the aegis of BSI and ISO to develop a whole new series of standards involving the Rating of Sound Insulation in Buildings and Building Elements.

Third decade 1994 -2003

Research continued during this decade on flanking transmission and impact sound transmission together with new programmes of work into the rehabilitation of dwellings. The increasing use of timber frame construction throughout the UK gave rise to considerable industry sponsored research into timber wall and floor designs and the use of flexible cellular polymers as replacement for mineral fibre.

Research also continued on the suitability of the Building Regulations performance standards, particularly in the light of higher standards evolving elsewhere in Europe and also the need for post-completion testing in England and Wales to assess the quality of materials and workmanship. Although statutory provision for post-completion testing was removed from the Scottish Building Regulations in 1990, testing continued to be carried out in parts of Scotland backed by a 1984 judgement in the Scottish courts. Considerable research evidence was showing that pre-completion testing significantly reduced the likelihood of failure to meet the performance standards.

The English House Condition Survey in 1996 and one by MORI in 2000 showed that the problem of noise from neighbours in England and Wales had not significantly improved from the situation identified in 1978 by the BRE. It was now becoming clear that changing social patterns, louder TVs and music systems were creating a situation whereby neighbours were becoming less tolerant to noise and were demanding higher standards of sound insulation. Politicians were now becoming increasingly aware and seeking answers from the industry and regulatory bodies. P28


Building Regulations have improved standards

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◀P27 In January 2001 a decision was finally taken to include pre-completion testing as a means of demonstrating compliance in the amendments to Part E. The construction industry was, however, concerned at the additional cost of testing, which was estimated at £17 million a year. In July 2002, after lobbying from the industry, a Green Paper was introduced allowing the use of Robust Standard Details (RSD) as an alternative to pre-completion testing, provided the industry could develop such designs before the planned date of publication of the revised Approved Document E in August 2003. This challenge led to one of the largest sound transmission projects ever undertaken, involving 1,300 dwellings being tested throughout the UK with 13 RSDs being designed in six months by the Building Performance Centre at Edinburgh Napier University. The designs were incorporated in a White Paper – *Amendment of the Building Regulations to allow Robust Standard Details to be used as an alternative to pre-completion testing* – published by the Office of the Deputy Prime Minister in August 2003.

Approved Document E 2003 (amended in 2004) included the most comprehensive set of amendments to the provisions for sound insulation since the introduction of the regulations in the 1960s. In addition to pre-completion testing, the performance standards were modified to allow the use of the spectrum adaption term, C_{tr}, to address issues regarding low frequency airborne sound insulation, as introduced under the BS EN ISO 717-1 (1997) *Rating of Sound Insulation and Building Elements.* Other major changes extended the regulations to include rooms for residential purposes, such as in hotels, halls of residences and the like; Standards were introduced for internal walls and floors; the control of reverberation, though use of appropriate absorption, in the common internal parts of buildings and acoustic conditions for schools was introduced via guidance under *Building Bulletin 93 - Acoustic Design of Schools.*

In order to both ensure that there was an adequate pool of qualified acoustic consultants to undertake pre-completion testing, UKAS-accredited firms were supplemented by a new registration scheme set up by the Association of Noise Consultants (ANC). They were also given responsibility for auditing the performance standard achieved by RSDs.

Fourth decade 2004 -14

During the past 10 years, improvements in digital processing and visualisation has seen added impetus given to the use of established techniques for the measurement of sound transmission such as sound intensity, scanning laser vibrometry and maximum length sequence (MLS) methods. New software tools based on the guidance given in EN ISO 12354 (2000) - *Building acoustics. Estimation of acoustic performance in buildings from the performance of elements*, have progressively been introduced to enable rapid computation of sound transmission in buildings at design stage, although the overall use of all of these methods within building acoustics remains small.

BB 93 has aided classroom teaching

In 2005 Scotland introduced the Building (Scotland) Regulations 2004, becoming the first EU country to arrange its Guidance Documents in sections aligned to the Essential Requirements of the Construction Products Directive. However, the performance standard remained unchanged and did not include the C_{tr} spectrum adaption term. Nor were the regulations extended to include internal walls, reverberation in common areas or apply to school buildings. In support of the new regulations a good practice guide, *Housing and Sound Insulation*, was published in 2006.

In December 2006 the Department of Communities and Local Government (DCLG) published a *Code for Sustainable Homes.* Developers were awarded between 1 to 4 points for achieving higher standards of sound insulation than required by Part E of the Building Regulations. This was updated in April 2014. Scotland adopted a similar process, but through the introduction of a new section (7) to the Technical Handbooks - *Sustainability*, in 2011.

Research continued with much attention being paid to the effectiveness of the C_{tr} as evidence gathered of conflicting outcomes whereby constructions which complied with the performance standard were being viewed 'unacceptable' subjectively. As more data became available, the suitability of C_{tr} spectrum adaption term continued to be questioned and in 2013 the DCLG commissioned research to undertake a 10 year review of the changes introduced in Part E including the C_{tr} and the outcome is due to be published in late 2014.

In order to assess the impact of pre-completion testing and robust standard details, the NHBC investigated and reviewed the pattern of noise problems reported by occupiers of new homes registered with NHBC since the introduction of PCT and RSDs in 2004. The findings from that work, published in the report *Sound Progress* (2014) indicated a 57% drop in contacts to the NHBC in relation to problems from transmitted noise in new attached homes. It is clear that PCT has significantly reduced the rate of failure due to poor workmanship or detailing and that RSDs have provided a level of sound insulation which is now amongst the highest in Europe. The impact of RSDs and their benefit to society was further recognised by the award of the Queen's Anniversary Prize in 2009 to the Building Performance Centre at Edinburgh Napier University for their pioneering work in this area.

The introduction of RSDs has acted as a major catalyst for new sound insulation product design by industry, including resilient bars, mats and wall membranes, floating screed materials, acoustic battens and many other products currently at research and development stage.

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Footnote – Building Acoustics Group (BAG)

The Building Acoustics Group was not among the founding groups launched in 1974 at the formation of the Institute of Acoustics, but a survey carried out in late 1976 indicated that more than100 members were involved in the sector as consultants or researchers and so a decision was taken to form BAG during 1977. It is now one of the largest groups with currently more than 1,320 members.

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Environmental noise 40 years on

Overview

The IOA's Environmental Noise Group comprises about 1,500 professionals engaged with managing environmental noise in one way or another, often noise from transportation, industry, neighbours, and construction. Members' roles vary from research into understanding the impacts of noise, assessing new noise reducing technologies, advising at the land use planning stage, developing standards and good practice guidance, to enforcing environmental noise legislation. This article summarises how the different types of environmental noise have been managed over the past 40 years, and looks at some key drivers in the evolution of their measurement, assessment and control. Members of the IOA have been instrumental in all these developments.

Neighbours and nuisance

The UK National Noise Survey in 2000 showed that over four out of five respondents heard noise from neighbours and/or other people nearby and over a third being were bothered, annoyed or disturbed to some extent. In fact, the proportion of respondents who reported being adversely affected by noise from neighbours had increased over the previous 10 years.

Excessive noise from neighbours can cause stress, impact our quality of life and enjoyment of our homes. If direct approaches to neighbours to remedy the problem fail, local authorities can be contacted. The Noise Abatement Act 1960 provided the tool for addressing complaints of noise, including noisy neighbours, until the introduction of the Environmental Protection Act (EPA) in 1990. This act sets out the duty for local authorities to not only investigate all complaints of noise but to also serve an abatement notice in the event that the noise is considered to be a statutory nuisance. It is therefore now possible to issue warnings and on-the-spot fines to noisy neighbours who do not cease making noise.

The Noise Act 1996 provides an objective way of assessing and dealing with noise complaints for night time noise from dwellings in instances where the EPA may not have been effective, for example one off loud parties. The Clean Neighbourhoods and Environment Act 2005 extended these powers to include licensed premises.

The IOA established a working group to produce guidance and criteria on the control of noise from pubs and clubs. In 2003 the group published a Good Practice Guide. Industry representatives produced a guide to noise control for licensees in 2003 which mirrored the IOA Good Practice Guide very closely.

Moving to the control of construction noise, the year 1974 welcomed the arrival of the Control of Pollution Act 1974, with Part III most commonly known for its powers relating to the management and control of noise at construction sites. With construction sites presenting inherently noisy activities and a Government keen on growth and development, this Act provides the mechanism of the voluntary application for prior consent for noise making activities in addition to powers for local authorities to control construction site noise, when necessary. Other powers include the control of loudspeakers in the street and the preparation, approval and issuing of codes of practice to minimise noise by the Secretary of State, in addition to providing a definition of "Best Practicable Means" which is widely in use today.

With a constantly evolving legislative landscape, it is possible that there could be changes to the suite of legislation available for addressing neighbour noise and noise nuisance. However, against a backdrop of minimising legislative burden, there is likely to be a greater focus on the effective use of existing powers, coupled with increased reliance on the planning system to design out potential noise problems before a nuisance occurs, rather than extending the use of reactive enforcement tools.

Industrial noise

The most commonly used method for assessing the impact of Industrial noise in the UK is BS4142. This standard was first published in 1967, and has continued with minor amendments to the present day, with the latest published version issued in 1997. Research into the application of this standard was conducted after the 1990 revision which concluded that the failure of the standard was often due to it being used outside its intended scope of application and the method did not adequately take into account the acoustic features of the noise. BS4142 is currently undergoing its most substantial rewrite since the original version was published. The new version is expected to be published towards the end of this year.

Noise from all industrial processes was historically controlled by local authorities using planning conditions and statutory nuisance. This included the regulation of noise from industrial processes falling under Part 1of the Prescribed Substances Regulations (SI472), even though all other pollutants were controlled by the national Environment Agency.

In 1996 the European Union Integrated Pollution and Prevention Control Directive (EU IPPC Directive) was introduced, and implemented by the Pollution Prevention and Control (PPC) Regulations. Under this legislation the Environment Agency England and Wales, Scottish Environmental Protection Agency and Northern Ireland Environment Agency began to control noise from industrial processes permitted by them.

IPPC is a regulatory system that employs an integrated approach to control the environmental impact of industrial emissions and involves determining the appropriate controls for industry to protect the environment through a single permitting process. To gain an IPPC permit operators of industrial sites must show that they have systematically developed proposals to apply the Best Available Techniques (BAT) to pollution prevention and control, and that they address other requirements relevant to local factors.

The industrial Emissions Directive is currently coming into effect throughout Europe which is on a similar theme to the IPPC directive, but will apply to additional industrial sectors.

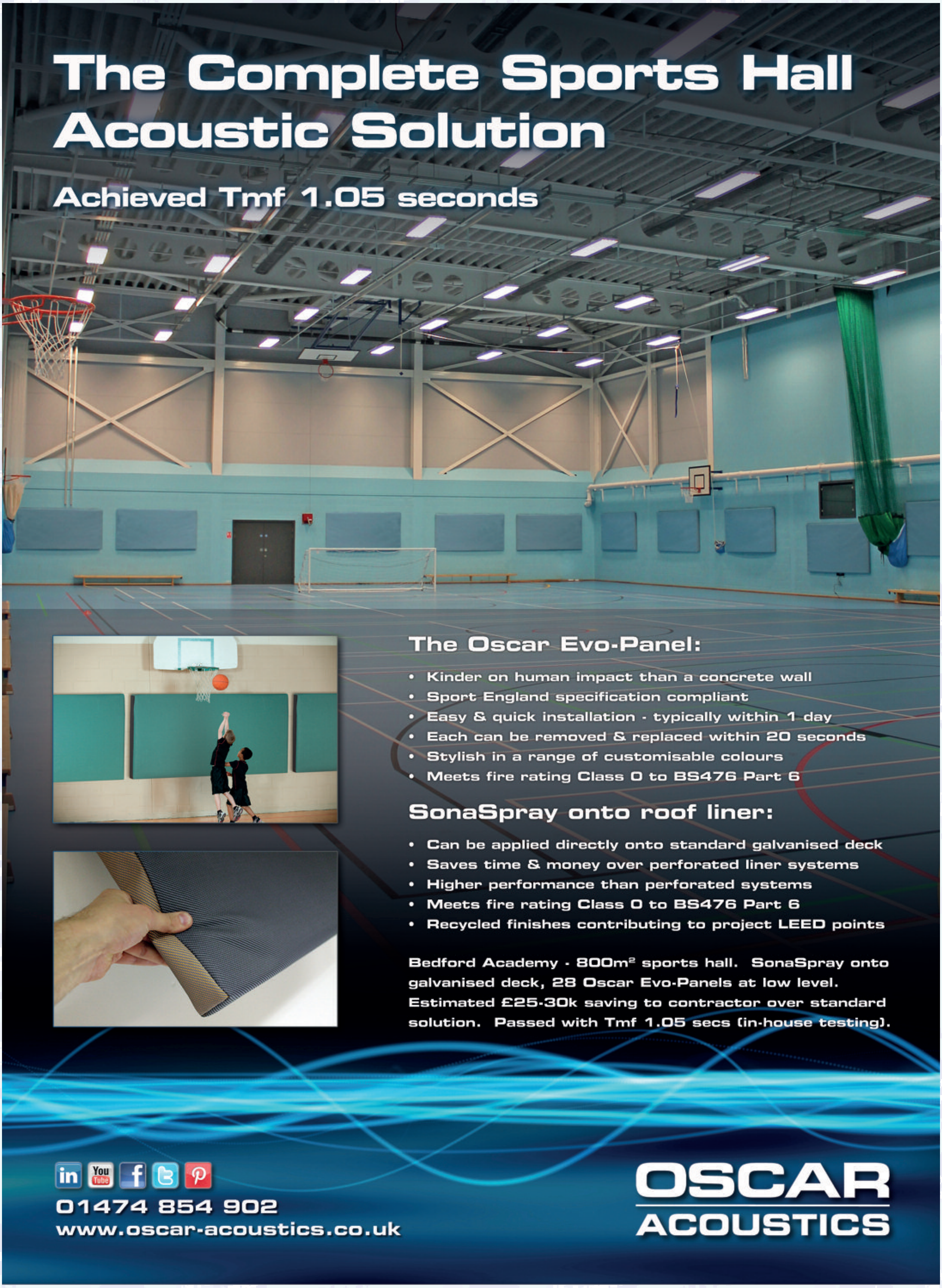
The future of industrial noise assessment is likely to involve greater use of more sophisticated ratings and acoustic feature corrections reflecting available technology and ever expanding knowledge in the field of environmental acoustics.

Industrial noise is subject to an EU directive

Planning and noise

Many IOA members participate in the planning system to anticipate, quantify, assess, manage and control the effects of noise and vibration. This has been the case since at least 1973 when ministers first published guidance on planning and noise in the form of Circular 10/73 in England, Circular 16/73 in Wales, and Circular 24/73 in Scotland.

Perhaps most notable, with the benefit of hindsight, is that all these circulars contained very few precise rules and provided few numerical standards for noise, advocating the use of common principles to try and deliver the best acoustic outcome. This lack of noise standards in the 70s and 80s contributed to inconsistent application by local planning authorities and growing complaints from developers that they did not face a "level playing field" P32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◂P30 when submitting planning applications.

Replacement Government guidance, PPG 24: Planning and Noise was published in England in 1994, TAN 11: Planning and Noise was published in Wales in 1997, and PAN 56: Planning and Noise was published in Scotland in 1999. These documents provided guidance to local planning authorities on the use of their planning powers to minimise the adverse impact of noise. The various documents had some important differences, but all introduced the new concept of four Noise Exposure Categories (NECs), ranging from A-D, to help local planning authorities in their consideration of applications for residential development primarily near transport-related noise sources. Category A represented the circumstances in which noise is unlikely to be a determining factor, while Category D related to the situation in which development should normally be refused. Categories B and C dealt with situations where noise mitigation measures may make development acceptable. These documents were very influential and have been heavily relied upon by practitioners for many years. Some critics highlighted that these sources of guidance were an unhelpful mixture of policy and technical advice that led to a mechanistic approach to noise assessment and sometimes inappropriate decision making.

Scotland was first to update planning and noise policy in 2011 with the separation of noise policy in PAN 1/2011 from technical advice in TAN 1/2011. The Planning Advice Note provides advice on the role of the planning system in helping to prevent and limit the adverse effects of noise. Information and advice on noise impact assessment methods is provided in the associated Technical Advice Note Assessment of Noise. Helpfully, Appendix 3 of the Technical Advice Note provides Excel Workbooks to assist in the technical evaluation of noise as part of the planning process. The technical advice is comprehensive and has attracted some comment that it appears better suited to appraisal of large scale strategic infrastructure schemes rather than the appraisal of the more common planning applications for smaller scale type of development.

In England PPG 24 was cancelled when the Government published revised planning policy in the form of the National Planning Policy Framework (NPPF) in 2012. The NPPF focuses on using local plans to promote good design and the avoidance of unacceptable noise impacts on health and quality of life in the context of government policy on sustainable development; although it warns against dealing with noise in isolation. Apart from mineral development there is no technical guidance provided in England. Revised and updated advice, without any technical content, on how planning can help to manage potential noise impacts was first published on line on 6 March 2014. In England the policy emphasis on preventing or avoiding the significant effects of noise on health and quality of life and of mitigating adverse effects in the context of government policy on sustainable development, has been broadly welcomed. But the absence of technical guidance has drawn sharp criticism, and concerns regarding a possible return to inconsistent application by local planning authorities have been voiced. Consequently, several professional groups including the IOA have come together to assist in the drafting of professional guidance to fill this gap.

Wales continues to work with TAN 11, although the Assembly seems likely to refresh the guidance to take into account updated standards etc. rather than undertake wholesale change.

It is worth highlighting the work that IOA members contributed to the development of the IEMA Guidelines of Noise Impact Assessment due to be published later in 2014. This guidance sets out good practice standards for the scope, content and methodology of noise impact assessments. It encourages greater transparency and consistency between assessments.

The issues of tranquillity and identification and provision of quiet areas have received more focus recently. It has been mooted that the immediate challenge is to harness our knowledge and understanding of places with good quality acoustic environments (soundscapes) and to motivate local people and relevant authorities to respect and protect such special places.

The planning system provides IOA members with an opportunity to forestall the potential negative effects of noise and vibration, to improve existing undesirable circumstances and to promote positive soundscapes. Local planning authorities and acousticians can use the planning system to contribute to a sustainable future through focussing on delivering good quality acoustic design in the built environment, and, for the first time, by protecting areas of tranquillity. In order to achieve these aims, we should aspire to move beyond the prescriptive imposition of fixed noise standards and the mechanistic assessment of the suitability of a site for noise sensitive or noise generating development – in the future we should strive to ensure better acoustic outcomes that are appropriate to local circumstances for every new development.

Transportation noise

The Wilson Report identified road traffic as the greatest source of noise, but it was not until 2002, when the European Commission's Environmental Noise Directive (END) legislated for extensive mapping of noise across Europe, that the extent of the problem began to be systematically quantified. The results of mapping all cities over 250,000 people, major roads, railways and airports in 2006 showed that over 100 million people were exposed to noise above L_{den} 55dB, with roads accounting for about 85%, railways 10% and airports 1%. Given that noise above such levels can affect health (see below) it is important to review the progress that has been made in the last 40 years to address this form of pollution.

With road traffic as the predominant source, it was appropriate that the first statutory regulation to mitigate transport noise was the Noise Insulations Regulations (NIR) for roads in 1973. Similar regulations for railways followed in 1996. The regulations accepted the status quo, by requiring noise insulation to be given to dwellings affected by high noise levels from new or altered roads, but not existing roads. The noise limits $L_{10,18\,hr}$ 69dB at the façade were chosen at levels thought to be unacceptable based on the state of knowledge at that time and in view of what was practicably achievable, and not prohibitively expensive, in the UK. The levels adopted have not changed in 40 years and it is interesting that those levels are still used today as levels that are considered "unacceptable".

Following noise mapping in 2006 Noise Action Plans also flowed from the END, and aimed to address noise from the existing situation. Priority Areas were identified above the NIR qualifying criteria, but in practice, very little pro-active noise mitigation ▸


Airport expansion has triggered much debate on noise

has resulted. New and widened roads are subject to Environmental Impact Assessment and designed with noise barriers and a variety of effective quiet road surfaces that have emerged in the last 20 years and, as a last resort noise insulation is offered to dwellings above the NIR qualifying criteria. The Land Compensation Act 1976 also makes provisions for compensation to be paid where noise from road and railways reduces the value of properties.

Road traffic vehicles have become quieter, as a result of engine and tyre technological developments driven by EU regulation. With traffic growth now slowing, particularly in major cities where traffic demand management measures are becoming more common, there is the prospect of noise levels reducing in the future. The long-anticipated shift to electric cars could one day create real reductions, but at present no-one is quantifying this when assessing future levels of road traffic noise.

Technological developments have also reduced noise levels from trains, but even more significant has been the reduction in noise levels from aircraft. Under international regulations noise levels from new aircraft have been driven down such that aircraft coming into service now are more than 10dB quieter than a few decades ago. These technology improvements are expected to continue, although more slowly.

Airports are effectively self-regulated, for example creating their own Noise Action Plans under the END, and it was not until 2010 when the Airports White Paper made noise insulation statutory at noise levels above $L_{eq,16\,hr}$ 63dB. As airport operations expand there is much debate concerning noise management regimes with some airports spending a great deal of money on voluntary noise mitigation and insulation schemes. This year Gatwick Airport set a precedent by offered to pay £1,000 towards council tax payments as compensation to people affected by a second runway, if one is built. This approach would go some way, although only a little way, towards making up for the lack of provisions under the Land Compensations Act for those affected by airport expansion. Heathrow has been exploring ways to provide alternative solutions for schools to assist with outside learning and play. One approach that has already proved successful in a local school under Heathrow's flight path, is the provision of "Adobe buildings".

Airport expansion has also triggered much debate on the health effects of noise, despite the fact that airports affect far fewer people than roads. Research evidence continues to be gathered and it is now routine practice to assess health effects of noise including annoyance, sleep disturbance, strokes, heart disease and loss of children's learning in schools affected.

In the future there will be even more pressure on controlling transport noise because of its health effects. Although there is little prospect of tackling the status quo, new infrastructure proposals will be scrutinised to ensure that they adopt the very best noise management methods. Technology will also continue to play its role at reducing noise at source. Improved methods for communicating noise and its impacts will be central to all debates. The emerging studies of soundscapes will also add to the understanding of perception of noise. Monetisation of noise, and the balancing of the social costs and benefits is becoming even more important in the decision making process. Whether the noise benefits from good future noise management will outweigh increases in traffic due to our insatiable desire to travel will depend largely on the appetite policy makers have to develop and enforce it. Chances are that transportation noise will be quieter in 40 years' time, but maybe not much.

Credits

This article has been produced by the committee of the Environmental Noise Group comprising Steve Mitchell, Colin Grimwood, Dani Fiumicelli, David Waddington, Tony Clayton, Nicole Porter, Bernadette McKell, Claire Parsons and Rob Miller.

Speech and hearing

As noted in the Speech and Hearing Group's "mission statement", speech and hearing relate to a number of sub-disciplines, each of which have acoustic aspects, and these have each developed significantly over the last 40 years. We have selected a few notable aspects, of particular interest to individual members of the group committee, and describe progress and evolution of each of those below.

Developments in audiology – *by Graham Frost*

In the past 40 years, there have been a number of significant developments within the field of audiology in both diagnostics and rehabilitation. Many members of the Institute have been instrumental in these developments in addressing the various acoustic challenges that they presented. In 1978, David Kemp, from the Institute of Otology and Laryngology, University of London, became the first to measure small acoustic signals generated within the inner ear, a phenomena referred to at that time as cochlear echoes and which later became known as otoacoustic emissions. It had been known for some considerable time that the mechanics of the basilar membrane within the cochlea provided some frequency selectivity but in itself could not account for the specificity that we can achieve when discriminating frequency. Otoacoustic emissions were later shown to be part of a frequency specific amplification process arising from a number of mechanisms occurring within the cochlea. It is now known that there are two types of otoacoustic emissions, spontaneous, which occur without any external acoustic stimulus, and evoked, which require an external acoustic stimulus. The acoustic challenges presented by this research were the measurement of the extremely low level acoustic emission signals in the auditory canal, in the presence of competing physiological, environmental and measurement system noise, and the production of an appropriate test stimulus within the auditory canal to facilitate the measurement of evoked emissions. Both of these required advanced levels of signal processing. It was subsequently found that the measurement of otoacoustic emissions could be used as an effective test of hearing loss of cochlear origin and has become of significant clinical importance by providing a simple, non-invasive, objective measurement of hearing function, which lends itself to the screening of new born babies and children who are unable to participate in hearing tests which require a subjective response.

The mid 1970s onwards have seen the continued development of cochlear implants. Unlike conventional hearing aids, which deliver an appropriately amplified and processed acoustic signal to the ear canal of the hearing impaired individual in order to optimise the use of their residual hearing, cochlear implants are primarily used when there is little or no useable residual hearing of acoustic signals. The implant processor converts the original acoustic stimulus into an appropriately processed electrical signal which then directly stimulates the inner ear and auditory nerve. This provides the user with the sensation of hearing, although what is actually heard can be very different from the original acoustic signal. These devices have grown progressively more sophisticated and effective, and some members of the IOA, particularly those working in the field of speech, have played a vital role in implant development particularly in the speech processing strategies employed to optimise potential discrimination.

The most significant development in acoustic hearing aid technology since the introduction of the first electrical devices, and in the past forty years, has been the implementation of digital signal processing (DSP) in the mid 1990s. Although digital processing had been used in many other audio and communication engineering applications, it had not previously been possible to employ it in a hearing aid. As a result of the demand to make hearing aids smaller and smaller, it had become necessary for hearing aids to operate on a small single cell battery of 1.3 volts. The ability to provide the dynamic range required of a hearing aid from such a low voltage had eluded manufacturers up until this time. DSP now provides the hearing aid manufacturer with unprecedented flexibility. Not only can hearing aids now provide greatly improved frequency and intensity specific amplification characteristics, DSP hearing aids can also provide sophisticated real-time analysis of the sound environment in which they are used and apply appropriate adaptive processing to continually optimise user benefit. As in other areas of acoustics, hearing aids now employ adaptive narrow band directional microphones, noise reduction strategies, based on the spectral characterisation and identification of speech and noise in specific frequency bands, feedback management, using automatic gain control and active cancellation, and frequency shifting (or transposition) where acoustic signals may be moved from frequency areas where is little or no useable residual hearing, to other areas where potential benefit is greater.

Acoustics in the speech and language therapy clinic – *by Evelyn Abberton*

Speech is the most important acoustic signal in our environment, yet 40 years ago acoustics made only a token appearance in the Speech Therapy Diploma syllabus, for example in the form of room acoustics or standing waves in a tube, but rarely as a level of representation of speech to complement articulatory description or perception. Students were simply put off. A contributed section of the Quirk Report into Speech Therapy Services (HMSO 1973), however, described possible ways in which speech acoustics might contribute to work in the speech clinic. Interactive speech acoustic displays, quantitative analyses and evidence based reports would take therapy into more scientific, as well as more humanly relevant practice.

Forty years later, the vision outlined in 1973 is still only partly achieved. This is because, although relatively cheap computer based analyses are widely available, the nature of speech as a means of communication rather than simply as an acoustic signal has often not been taken into account. For example, many centres and applications still base analyses on an artificially sustained vowel rather than natural connected speech.

Nevertheless, progress has been made: speech and language therapy is now a degree entry profession, and many therapists now have master's degrees and doctorates. Syllabuses include potentially more relevant modules on speech acoustics and clinicians' knowledge and confidence have increased. A range of speech analytic tools including spectrography and other temporal and frequency analyses as well as electroglottography (EGG) have become accessible, and even Automatic Speech Recognition and synthetic speech systems are therapeutic tools – albeit still in need of phonetic improvement. In the Voice Clinic, therapists and laryngologists routinely use suites of acoustic and EGG analyses associated with stroboscopic laryngeal endoscopy. It is still essential, even now, that acoustic analyses for clinical application do not simplistically measure for measurement's sake using familiar and computationally convenient algorithms. Algorithms must be psycho-acoustically relevant and relate to parameters of speech production, hearing and perception if they are to have credibility with clinicians and speech scientists. Speech is not just an acoustic signal like any other.

Developments in voice care – *by Roz Comins*

Whilst voice scientists have increased knowledge, experts in the "art of voice" have improved methods and voice care, that previously existed only in speech therapy, and this has spread to many people who depend on their voice at work. This began with the multi-disciplinary Oxford Voice Clinic set up in the 1980s by Tom Harris, a laryngologist, and Sara Harris, a speech and language therapist (SLT). As the different voice disciplines began sharing expertise, the British Voice Association (BVA) and the Voice Care Network UK (VCN) evolved. In the VCN, SLTs and Voice Coaches combined voice care with practical development of the speaking voice. Studies were made, plans prepared and organisations involved in teaching, learning and schools became involved, especially Initial Teacher Training (ITT), teachers' unions and health and safety authorities. Every year now, the VCN delivers practical voice workshops and support to thousands of trainees, teachers and lecturers. This reduces the high percentage of workers in education who suffer from voice disorders, promotes efficient voice production, raises the standard of skills in spoken delivery and encourages learning.

Speech intelligibility in buildings – *by Emma Greenland*

The application of speech intelligibility (SI) technology has developed rapidly over the past 40 years following developments in the telephony, military communications, sound system industries and after being embodied in major BS and EN standards following the Hillsborough, Bradford and King's Cross disasters. IOA members have contributed significantly to this field and the development of these standards, notably Peter Barnett, Herman Steeneken and Peter Mapp. Objective testing has now overtaken use of subject based word score testing for most applications. SI field testing is now commonly carried out for PA and Voice Alarm (VA) systems in public buildings, and SI design is now a major requirement for UK schools, particularly open plan classrooms, and also courtrooms. Objective speech intelligibility metrics have developed considerably, from Articulation Index (AI) to Speech Intelligibility Index (SII), to various versions of Speech Transmission Index (via the now obsolete RASTI, to STI and most recently STIPa , which are the de facto parameters in use for measuring PA/VA and other voice communication systems today). Recent advances include the new standardised qualification bands for STI (which may be applied to specific applications and room types), and efforts to address the limitations with STI-related measures, such as binaural effects and sound system related signal processing effects (frequency response, equalisation and compression). Special populations such as non-native listeners and hearing impairment/age-related hearing loss have also been accounted for by the new standardised procedure. The relationship between intelligibility and listening difficulty has also been standardised.

Progress in speech an acoustic forensics – *by Philip Harrison*

The forensic analysis of speech in the UK began in the 1960s, the decade before the formation of the Institute of Acoustics. The earliest cases were undertaken by academic phoneticians working in university departments and concerned the identification of speakers in criminal recordings such as hoax 999 calls and covert recordings made by the police. Experts would reach an opinion based on a comparison of the speaker in the criminal recording with a reference recording of the suspect, which mainly focused on a detailed auditory analysis of speech features including pitch, intonation, patterns of pronunciation and voice quality (timbre).

The field has progressed significantly since those early days in many respects. Whilst the number of forensic speech and acoustics analysts is still relatively small, the number of cases undertaken is sufficient for most practitioners to work full time as sole practitioners, within dedicated laboratories or within security agencies or police forces. The growth has been driven by the increase in the amount of audio material generated by the police and the general public, a greater awareness of forensic capabilities and the acceptance of such evidence by the courts. The analysis methods have also developed over P36

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◂P35 time as the analysis tools have become more widespread, moving from standalone hardware and mainframe computers to freely available software that will run on PCs. Speaker or voice comparisons now include a significant proportion of computer based analyses such as spectrographic examinations of speech segments and automatic estimation of fundamental frequency and formant frequencies alongside the auditory assessments. In recent years, significant improvements have been made in the performance of automatic speaker identification systems, which represent speakers as statistical models derived from speech features. These systems are being introduced internationally to complement traditional forensic analysis techniques.

The range of forensic analyses undertaken has also grown, incorporating for example transcription of difficult recordings, profiling of unknown speakers to determine factors such as ethnicity, regional and social background, and the assessment of claims of identity by witnesses. The field also includes more technical tasks such as the enhancement of audio recordings to improve sound quality and intelligibility, determining the authenticity of recordings and identification of sounds within recordings. Again, technological developments have driven progress in these areas. In the case of enhancement, the early equipment comprised outboard analogue filters, which were superseded by dedicated digital signal processing hardware. Nowadays, the range of digital filters available within computer software far surpasses their analogue equivalents and allows processing to be done significantly faster than real time. The methods used for authenticity examinations have undergone large shifts as recording formats have moved from analogue to digital. Well established techniques involving the visualisation of the magnetic fields patterns on tapes and the analysis of switching transients (audible clicks generated by the action of the record function) cannot be applied to digital recordings. Consequently, new methods including the analysis of the electrical network frequency (ENF), i.e. mains hum, are now being developed and implemented in casework.

The field has greatly benefitted from the creation of a professional organisation, the International Association for Forensic Phonetics (IAFP), in 1991, which became the International Association for Forensic Phonetics and Acoustics (IAFPA) in 2003 to reflect the increasingly technical and diverse nature of the field. The journal of the IAFPA, which was established in 1994 and is currently titled *The International Journal of Speech Language and the Law*, continues to be a platform for many ground breaking publications. Over the past decade, many other professional bodies and organisations in the areas of speech and acoustics have introduced forensic subcommittees, special sessions at conferences and dedicated conferences. Significant growth has also occurred within academia, as demonstrated by the number of forensically-focused PhDs, forensic research projects, taught modules and post-graduate courses. As more speech is recorded and computing power increases, the field will no doubt continue to grow and develop in collaboration with academic researchers.

Developments in (computer) speech technology – *by Gordon Hunter*

The last 40 years essentially **has** been the history of (computer) speech technology. Whilst, on the other hand, it is true to say that speech technology research had taken place prior to 1974 – the Hungarian Thihamér Nemes unsuccessfully attempted to patent an automatic speech transcription system using the soundtrack of a ciné film as early as 1930, initial experiments in automatic spoken digit recognition were carried out by Fry and Denes at UCL in the mid 1950s, and the conversing computer *HAL* in Arthur C. Clarke's *2001 – A Space Odyssey* of 1969 was said to have been inspired by hearing an IBM704 giving a synthesised rendition of *Daisy, Daisy* when he visited AT&T Bell Labs in 1962 – all achievements up to that point now seem extremely primitive compared with what has come subsequently. Nevertheless, in was anticipated during the 1960s (and even in the 1950s) that "Speech and language processing technology would get fully developed within 10 to 20 years". 50 years on, we are still waiting for that goal to be achieved, but great progress towards it has been made.

The first automatic speech recognition (ASR) system to give reasonable performance whilst supporting a moderately large vocabulary was *Harpy*, developed in the mid-late 1970s by Klatt, Lowerre and Reddy at Carnegie-Mellon University in the USA. Building on improvements in the acoustic modelling of speech sounds aided by advances in signal processing (such as the Fast Fourier Transform) from the 1960s onwards, researchers, including Baker, Rabiner, Jelinek, Bahl and Mercer, developed and applied statistical modelling and pattern recognition techniques – such as N-grams and Hidden Markov Models – to both acoustic and linguistic aspects of speech recognition. Such improved methodologies, coupled with greater computational processing power and more memory, led to significant improvements during the 1980s and early 1990s, and the first commercially successful automatic speech recognition dictation tools, such as IBM's *Via Voice* and *Dragon Dictate* (now Nuance's *Dragon Naturally Speaking*) were marketed to the public in the mid 1990s. Such products have continued to improve, and some manufacturers of ASR systems claim theirs can give word recognition accuracy rates in excess of 95% in good conditions. However, many users of such products would argue that in real application situations, typical success rates are rather lower, and ASR tools are primarily still only extensively used by people who have to work hands-free due to disability or needing to use their hands for other essential purposes, e.g. whilst operating machinery, whilst driving, or even performing surgery ! Nevertheless, ASR systems are finding more and more practical applications in, for example, "dialogue systems", where a caller's spoken responses are analysed, e.g. when 'phoning a utility company to enquire about or pay a bill, and responses are given and actions taken accordingly.

Speech synthesis, or "Text to Speech" (TTS) systems have also made major advances over the last 40 years. Early examples, such as the "speaking clock" service, just used recordings of people speaking entire phrases. More recently, "diphone" and "triphone" synthesisers have been developed, which combine very small pieces or recorded human speech together using sophisticated prosody models of timing and intonation, giving results which sound highly satisfactory – from both the points of view of intelligibility and sounding natural. Such TTS tools can also be deployed within the sort of dialogue systems described above.

Perhaps less progress has been made in speech biometrics – particularly speaker recognition, the true meaning of "voice recognition" (often misused when "speech recognition" is actually implied). Many commercial and government institutions have investigated the potential of using the distinctive acoustic characteristics of an individual person's voice as a means of identifying them – and hence removing the need for passwords, ID cards, etc. However, the variability within each individual's voice – due to stress, illness and even just emotional state – is quite large and comparable to the differences between individuals, and reliable practical automated application of voice biometrics still appears some way off.

Conclusions

The short pieces above illustrate the great progress made in improving systems and services of practical benefit through applying acoustic science and technology in fields related to speech and hearing over the 40 years since the Institute's foundation. However, despite such progress, it is clear that much still remains to be achieved, and there should be scope for applying acoustics to speech and hearing-related problems for at least another 40 years to come. ◘

Improvement of voice alarm systems in underground railway stations

By Luis Gomez Agustina MIOA of the Acoustics Group, London South Bank University

Introduction

Voice Alarm systems (VA) are an essential part of subsurface underground station emergency and evacuation systems. Their main purpose is to assist in the management of emergency situations and evacuation procedures by providing key verbal instructions to the occupants. However, these life-critical systems will be ineffective and even counter-productive if the speech messages broadcast are unintelligible.

The 1987 Kings Cross underground station disaster and more recently the July 2005 bombings on London Underground (LU), raised the awareness of the importance of an effective VA system for a safe and efficient evacuation procedure[1,2]. However, following recent research[3] it appears that more can be done to improve VA system performance and therefore contribute to safer underground stations.

Currently in many London Underground stations and particularly on subsurface platforms, the announcements broadcast by the VA system are still not adequately intelligible and often do not reach the minimum specified performance target. This lack of performance could become a contributor during a major disaster.

An increasing demand for improved acoustic performance of VA systems in underground stations should not only seek to provide audible and intelligible vital instructions during an emergency. It should also aim at assisting passenger flows and providing necessary travel/passenger information with a high degree of clarity and acoustic comfort thus conveying an increased sense of wellbeing and expected quality in the service provided.

The process of designing and implementing VA systems for underground stations is complex and depends on multiple interrelated factors: station design, operational and logistical constraints.

The system performance directly relates to its electro-acoustic characteristics as well as the space where it is installed. Underground stations often present complex P38 ▶

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Our client is a UK leading provider of architectural and building services based in London. They are urgently seeking an Architectural Acoustic Consultant with a minimum of 2 years commercial experience. You need to be degree qualified in Acoustics or closely related discipline, hold IOA membership and also have a driving license. Duties of this role will be survey work, project management, mentoring junior staff, report writing and inputting into business development. You will work on projects that service clients both in the public and private sectors within the divisions of transportation, buildings (theatres, concert halls, performing arts centres, broadcasting studios etc). If successful you will receive a competitive salary, comprehensive benefits package and excellent career progression.

Senior Environmental Acoustic Consultant – London £30-35K+
A leading multinational multidisciplinary consultancy is now looking to recruit a Senior Environmental Acoustic Consultant to join their Noise and Acoustics team in their London office. The successful candidate will be offered a senior position within a reputable team, a highly competitive salary, a flexible benefits package, and room for personal input into team and business development. Applicants must hold a related BSc or MSc, and IoA Diploma, and IoA Membership, a full driving licence, and excellent communication skills. The successful candidate will also have five+ years consultancy experience with a bias towards environmental acoustics, extensive experience with Acoustic Modelling software, and a proven ability to manage a multitude of projects and a team of specialist consultants.

Interested in our current Acoustic job opportunities? Please do not hesitate to contact Amir Gharaati on 01792 365 101 or alternatively email amir.gharaati@penguinrecruitment.co.uk

Technical Sales Engineer – West Yorkshire £30-40K+ bonus
Our Client is leading manufacturer of noise control products to the commercial sector, and is looking for a Technical Sales Engineer to work from their offices in West Yorkshire. You will be responsible for the sales of products such as acoustic enclosures, air handling units and ventilation systems. Liaising between clients and other industry contacts you will provide technical guidance from preplanning to completion on projects, and ensure that maximum up selling of the company's products is achieved. You need to have a proven track record in sales within the industrial market for noise control, have an up to date awareness of the market and be an excellent communicator. Qualifications required are an MSc or BSc in an Acoustics related discipline, a minimum of 5 years commercial experience with the Acoustics noise control sector and a full clean driving license. On offer is competitive salary, generous bonus structure and flexible benefits package.

Noise Consultant – West Wales £20-30K
Our client is a UK leading independent Acoustics consultancy, looking to recruit a Noise Consultant to be based in their offices situated in West Wales. Specialising in Wind Farm projects, our clients work closely with the public sector and developers, to provide technical guidance and a professional service from preplanning to completion. Requirements are an MSc in Acoustics or closely related subject, a minimum of 2 years commercial experience in Acoustic consultancy, up to knowledge and understanding of UK guidelines and regulations, extensive experience of noise modelling software and familiarity of noise monitoring equipment. Duties will include project management , liaising with clients, local authorities and the public, running installations of monitoring equipment and organising logistics, collating and analysing data, noise modelling, writing technical reports, and providing guidance and support to clients. You need to have excellent communication skills and be able to work on your own initiative with a team orientated attitude.

Senior Building Acoustician – Sheffield/Manchester/Leeds £30k+
A renowned multidisciplinary consultancy, providing specialist services to the built environment, is currently looking to hire a Senior Building Acoustician to their London branch. Applicants are expected to have an architectural or buildings focus with at least five year's experience, a BSc/MSc, an IoA Diploma, and Full IoA Membership. You will also have a proven ability to manage a variety of large scale projects, and a team of specialists. This role presents an impressive client base and project portfolio, along with an impressive starting salary, room for promotion, a variety of benefits, and the support of a friendly and dynamic team.

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◂P37 geometrical and architectural features which severely challenge the achievement of the desired performance.

Awareness of the design environment and understanding of acoustic concepts, testing and modeling techniques can greatly assist the design to minimise the effect of inevitable external limiting factors and practical constraints.

Despite the importance of VA systems in mass transit systems, there is very little research reported in the literature providing relevant knowledge, particularly in the context of real world underground spaces. Experimental data and practical design knowledge is not released by companies responsible for the design, installation and maintenance of VA systems. Moreover it was found that contractual or custom performance specifications are often not suitably set out which can lead to ineffective designs.

The research[3,4] outlined in this article provides an insight into the practical aspects of electro-acoustic design of VA systems under real conditions found in underground stations. It is also encouraged through critical analysis to reflect on the current underrated importance of VA systems in underground stations. It suggests that attitudes should be changed and proposes technical specification changes with the ultimate aim of ensuring improved system performance to contribute to safe emergency procedures.

The research results, knowledge and insights presented in this article were obtained from practical experience in numerous test sessions and designs undertaken in real stations.

VA systems on underground platforms

Voice Alarm systems

Within London Underground, Public Address systems (PA) installed in subsurface stations are classed as Voice Alarm systems since they are an integral part of the station's fire alarm and emergency evacuation system. VA systems in that environment form the communication element of the statutory requirements under Fire Precautions Sub-Surface Railway Stations Regulations 1989. VA systems were first introduced in LU subsurface platforms in 1991 after recommendations made after Kings Cross underground station fire[5].

Overground stations do not require fire alarm evacuation systems thus sound systems installed on these stations are classed as PA systems.

The last part of a VA system (figure 1), named as the electro-acoustic transmission section, comprises three elements: the loudspeaker array (sources), the room space (acoustic transmission channel) and the listener (receiver) (figure 2).

It is in this last section of the chain where the performance of the whole system is delivered (perceived at the listener's ears or measured at a microphone).

The main function of a VA system in a space is to deliver and convey speech messages which can be satisfactorily understood by the occupants (i.e. staff and passengers) particularly in the case of an emergency. Speech intelligibility is the most important performance requirement in attaining the purposes of VA systems in underground stations and is the central performance parameter of this study. The Speech Transmission Index (STI) and its condensed version STIPA (Speech Transmission Index Public Address)[6] have been globally accepted as the de-facto industry standard metrics for the objective assessment of speech transmission quality and predictions of speech intelligibility of/from PA/VA systems.

The potential degrading factors from the input, signal processing and amplification sections are mostly of an electronic nature including electrical noise, non-linear distortions and limited bandwidth. The control and mitigation of the electronic degrading factors of the first three sections is relatively simple to attain. However, speech signal degradation in the electro-acoustic transmission section is more difficult to control and reduce. Consequently this section of the VA system is often the most critical and challenging for achieving satisfactory performance particularly in complex and acoustically difficult spaces such as underground stations. ▸

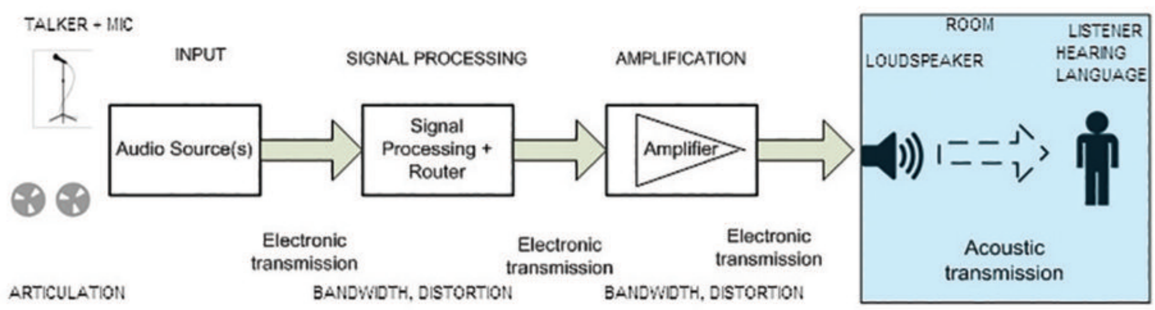

Figure 1. Basic block diagram of a Voice Alarm system and influencing factors

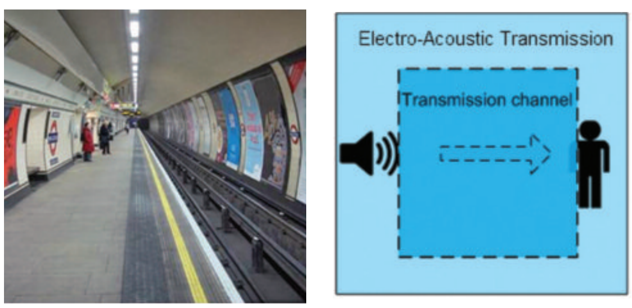

Figure 2. Electro-acoustic transmission section diagram (left) and example of an actual electro-acoustic transmission channel on an underground platform (right).

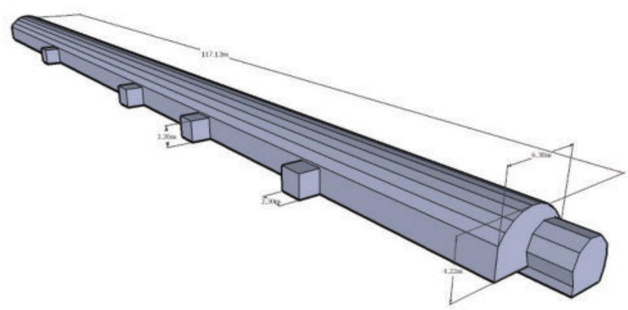

Figure 3. Main dimensions of typical London Underground subsurface station platform

This article focuses on the electro-acoustic section of the VA systems of London Underground subsurface stations. For the purpose of analysis, it is assumed that listeners share the same first language as the announcer, the hearing ability of receivers is normal and all the sections before the electro-acoustic section operate in optimal conditions. However, it should be noted that 23% of Londoners aged 16-34, and 40% of all adult Londoners have a first language other than English[7,8] Furthermore, in 2010 over 25,000 people were registered as deaf or hard of hearing in Greater London[9] and it is predicted that in the next 20 years the number of Londoners who are over 65 will increase by 33%[10].

Underground station platform characteristics

Subsurface platforms are the most challenging subsurface circulation space for quality sound reproduction in underground stations.

The majority of subsurface platforms are enclosed spaces of straight shape containing a single passenger platform and railway track. They are characterised by a large volume (3000m^3-4000m^3) of a disproportional shape in which the length (120-140m) is many times the height (~5m) and width (~6m), (figure 3). Deep platform stations are subsurface platforms which run typically at 20m below surface.

This extreme shape prevents the sound field from being diffuse when it is created from a single source[11]. Duct acoustic theory is not applicable due to the platform's large dimensions relative to the acoustic wavelengths of interest. The acoustic field in a platform excited by a single sound source is very different to the more complex field created by a multisource arrangement as it is the case of VA loudspeaker distributed systems. This fact is central in the potential design and performance prediction approaches to be employed

Platform spaces contain opening areas connecting the main volume to other spaces such as other platforms, concourses, train tunnels and ventilation outlets. Depending on the type and cross sectional size, these interconnecting apertures can act as an area of effective acoustic absorption, create local coupling effects and/or convey background noise from remote areas.

Surface materials in these platforms are acoustically characterised by being large, flat, smooth, hard and highly reflective. These boundaries tend to contain no furniture or other large fixtures. These surface qualities promote the formation of standing waves, echoes, highly reverberant sound fields, increase of background noise and the unobstructed travel of sound down the platform length, (figure 4). The long and characteristic reverberation of platforms equipped with VA systems is caused by the platform's large volume, the prominence of highly reflective surfaces and numerous other sources (loudspeakers) at a distance from a given receiver. The cross section of the volume approximates to a semi-circle. Walls and ceilings are typically concave surfaces which have the potential to cause undesired focusing effects, (figure 4).

The speech intelligibility performance of an underground platform VA system is a relatively complex phenomenon and depends on multiple interrelated factors and parameters.

The fundamental parameters affecting speech intelligibility in the electro acoustic section are the room reverberation characteristics and speech signal to noise ratio (SSNR) experienced at the listener position. They are directly determined in different measure by the interrelated factors and parameters listed below:

- Volume and shape of the space
- Sound absorption and scattering of surfaces
- Background noise temporal and spectral characteristics
- Loudspeaker–receiver distance
- Loudspeaker and receiver directivity
- Loudspeaker non-linear distortions
- Frequency response / tonality balance of the transmission channel

Other factors affecting VA design and performance

Compliance with other station operational requirements becomes a significant constraint in the design and testing. Logistical and practical considerations in a "live transit system" are numerous for each stage of the onsite processes: acoustic surveys, installation, benchmarking, commissioning and maintenance of the system. Compliance with other station operational requirements becomes a significant constraint in the design and onsite processes. These constraints typically include limited site accessibility, minimum test duration, test conditions, installation, maintenance, health and safety regulations, material/equipment certification, cost, aesthetics and heritage restrictions. P40

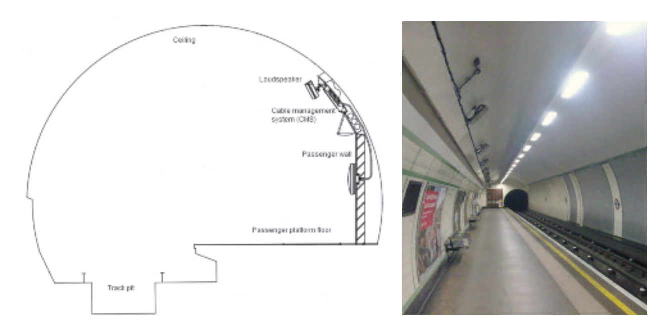

Figure 4 London Underground station subsurface platform cross section representation (left) and corresponding actual platform space.

Parameter	Performance requirement
SNR	10 dBA
Max SPL	90 dBA
Direct sound Coverage uniformity	±2dBA over 90% area
STI (CIS)	≥ 0.5 (≥ 0.7)
Frequency Response	±2dB (250Hz-6kHz) and level difference between adjacent 1/3 octave bands ≤ 5dB (100Hz to 10kHz)

Table 1. Performance parameters requirements for LU subsurface station VA systems

Acoustic, Fire, Structural and Physical test laboratory
Site acoustic pre-completion testing
Notified body
The Building Test Centre
Fire Acoustics Structures
T: 0115 945 1564
www.btconline.co.uk
btc.testing@saint-gobain.com
UKAS TESTING
0296

◀ P39

Guidance on underground VA systems

Legislation and standards

In the UK except for subsurface underground stations, there is no legislation defining the requirements for the use, specification and performance compliance of PA or VA systems. However national and European standards exist, which provide detailed codes of practice and recommendations on an extensive range of aspects of sound systems applications including PA/VA. These standards do not explicitly indicate when a system is required. For instance the need for a voice alarm system is normally determined by the relevant building licensing authorities or on completion of a risk assessment by the owner[12].

Relevant standards in the PA and VA industry are often adopted as reference and/or guidance for compliance purposes[12-19].

Operator performance specifications

Railway companies, operators and/or suppliers, normally develop their own sets of technical and performance specifications. These are used for self reference and as contractual guidelines for compliance for the duration of projects. These documents are written using guidance from relevant standards and from practical experience.

It is usual practice that a supplier company responsible for the renovation and maintenance works of VA systems produces its own document as a re-definition, interpretation and expansion of the details and requirements of the parent performance specifications document handed by the railway company. The supplier document is used in turn as a contractual reference to be followed by sub-contractor companies. Table 1 shows the current electro-acoustic and speech intelligibility related performance specifications for sub surface LU station VA systems.

Findings and discussion

Electro-acoustic design

Commercial computer simulation programs are currently the most suitable and reliable prediction tool for the design of deep platform VA systems[3]. However, performing systematic acoustic surveys and acoustic computer simulations for each station VA zone can be costly and time consuming. Many platform and circulation spaces tend to have similar geometrical, architectural and environmental noise characteristics. Validated design templates based on previous surveys, computer simulation results and experience could provide a reliable and cost-efficient way to deliver VA design for qualifying spaces.

In the design of the electro-acoustic transmission part of VA systems and without the option of introducing acoustic treatment, factors relative to the loudspeaker configuration become the only controllable design variables available to overcome the inherent acoustic difficulties of the space and achieve the required system performance. However even those variables can be severely constrained by practical installation and maintenance priorities (e.g. cabling routes, vandalism protection, accessibility, aesthetics, heritage issues, cost).

Loudspeakers commissioned to be used in stations must satisfy strict minimum performance specifications for optimal speech reproduction, safety, fire and dust ingress resistance, aesthetics and other mechanical and installation requirements. Those requirements limit the selection of loudspeakers commercially available.

Moreover the loudspeaker configuration options are limited to a conventional design approach for long and highly reverberant spaces. This effective approach involves the installation of an array of low-powered and rather directional loudspeakers along the platform length, all equally spaced and connected in parallel without signal delay, (figure 5).

Using validated computer simulations it was shown that variations of the conventional configuration involving different loudspeaker positions, aim and density did not affect the reverberation in the platform space. Furthermore, variations of the loudspeaker array configuration including different types of wide dispersion loudspeaker, aim and speaker density did not significantly increase the STI/STIPA.

Assuming an optimal loudspeaker configuration under the constraints expounded above, the main degrading factors to platform VA speech intelligibility are reduced to background noise and reverberation. Background noise is, under normal conditions, dominated by occupancy noise or by distant background noise sources when the platform has minimum occupancy. If those noise levels are overcome by an adequate announcement signal level (ensured in practice by a dynamic gain system), then the only degrading and limiting factor to speech intelligibility is the platform reverberation.

From a large set of design predictions and actual measurements it was found that speech intelligibility from conventional distributed VA systems on deep platforms is limited to the maximum achievable (typically 0.40 - 0.45 STI) in the dominating reverberation condition. Only drastic approaches such as significantly reducing the loudspeaker-receiver distance, or the use of highly directional loudspeakers were able to achieve the specified performance target (0.53 and 0.50 STI respectively) in design predictions. Those configurations would present the added economic benefit that they would reduce the amplifier power requirement by a factor of 6 and ▶

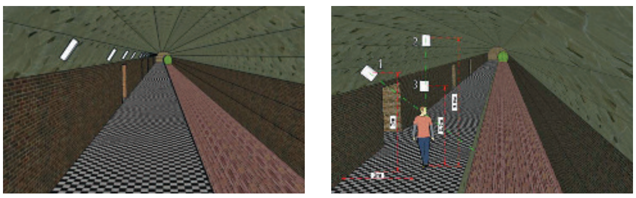

Figure 5. Conventional VA loudspeaker configuration options shown on a computer simulated underground platform

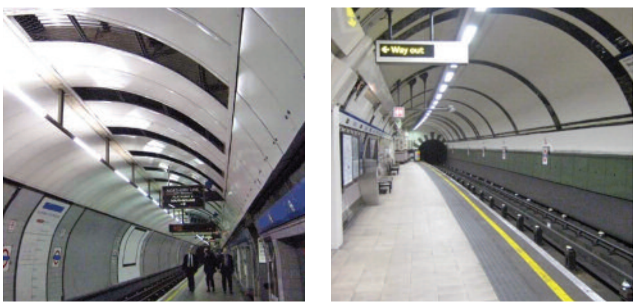

Figure 6. Station platform featuring metal panel cladding on the ceiling (left) and bare ceiling (right)

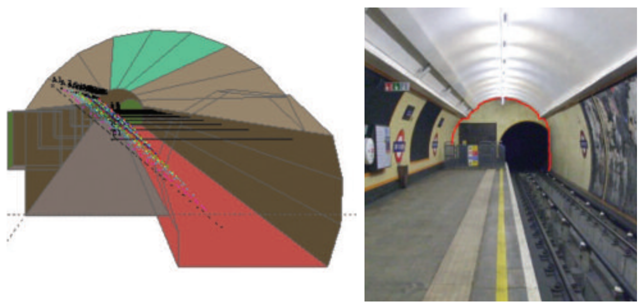

Figure 7. Left: Acoustic simulation showing the position and coverage of three strips of acoustic treatment in a deep platform. Right: Platform end wall and tunnel opening.

4 respectively. However they would reduce coverage uniformity, perceived sound quality and aesthetics.

From measurements it was also observed that metal panels forming the ceiling cladding in some deep platforms act as diaphragmatic sound absorbers, (figure 6). The significant reverberation reduction (1.0 - 1.5 sec) observed on clad platforms at low and mid frequencies (125Hz - 500Hz) resulted in measured STI scores being typically 0.05 higher than on similar platforms with bare ceilings, (figure 6).

A study on the effectiveness of the application of acoustic absorption treatment on deep platforms showed that these spaces are highly sensitive to variations in sound absorption. This fact makes the application of acoustic treatment the most effective solution to reduce reverberation and therefore enable platform VA systems to achieve the specified 0.5 STI target.

The platform end walls (figure 7) were shown to be a highly effective and efficient complementary treatment location to increase the STI score, by reducing general reverberation and strong late reflections. Furthermore, the introduction of acoustic treatment on platform areas would provide the added benefit of reducing background noise and controlling the acoustic field which would in turn enable the utilization of simple design templates.

However, until recently, the use of acoustic treatment in the design of underground stations has been discouraged due to cost constraints and installation and maintenance difficulties.

Recent research work by the author[20] has showed that assuming temperature and humidity conditions to be constant and/or negligible in the electro-acoustic design of platform VA systems can lead to performance prediction errors of up to 0.06 STI which could become critical in marginal compliance situations.

Standards and guidance

From a critical review of the relevant standards and guidance available to the station VA designer it appears that information is not well harmonised and interconnected among the different standards. Information is frequently generic, overlaps with different levels of detail and guidance is occasionally not applicable. The standards provide only limited guidance on specific aspects of the electro-acoustic design such as survey and test methodologies. Performance specifications were found too generic, imbalanced and occasionally unsuitable. These specifications require generic compliance with standards which cater for different purposes and areas of application. Attempting to meet all performance requirements as laid out in performance specifications and applicable standards can be conflicting across contractual documents, prove unattainable and counter–productive.

The specification of a minimum sound pressure level (SPL) of at least 10dBA above the average inherent background noise on subsurface platforms at the time of an announcement, is not a truly indicative ratio of effective audibility to achieve acceptable speech intelligibility since the signal measured at the receiver positions will be mostly comprised by degrading reverberant sound and background noise. On the other hand, the required operational maximum SPL level (90dBA) could be insufficient to overcome occupancy noise levels under emergency conditions (for example, crowd panic and emergency fans); hence the announcement might become inaudible and unintelligible.

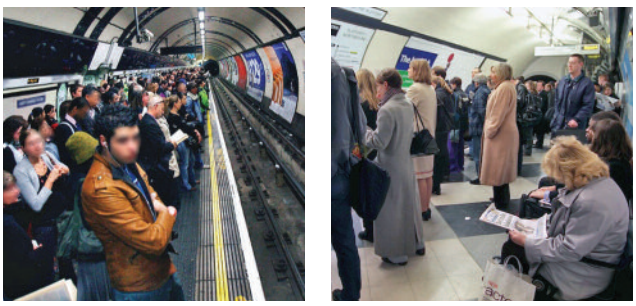

Figure 8. Examples of different occupancy density on deep platforms

Predicted uniformity of the direct field level coverage is not indicative of potential speech intelligibility or suitable to calculate useful speech signal to noise ratio (SSNR), since the direct field becomes swamped by the reverberant field in realistic situations. If knowledge of useful SPL sound coverage is needed for the strategic placement of loudspeakers, the author proposes that a direct plus early reflections level (DERL) coverage parameter would be a more relevant and realistic design indicator of useful sound energy coverage.

DERL can be defined as the SPL (dB) resultant from the useful speech energy registered at the receiver during the time window comprising the direct sound arrival and the subsequent 50ms of early reflections. From the impulse response this parameter could be calculated as expressed in Eq 1.

$$DERL = 10 * log_{10}[\int_0^{50} p^2(t)\,dt] \quad (dB) \qquad \text{Eq.1}$$

where p^2 is the square of the instantaneous sound pressure of the impulse response and t is time.

It is assumed from the relevant standards and guidance that subsurface VA systems are to be designed to provide satisfactory performance for the worst case scenarios. This currently concerns speech intelligibility predictions (STI) involving a combination of maximum possible reverberation and representative rush hour occupancy noise levels (figure 8). This scenario is simulated by synthetically adding representative occupancy noise (rush hour) levels to the intelligibility predictions (STI) undertaken for maximum reverberation[2,12]. P42

P41 However this combination of conditions cannot exist in reality as the maximum reverberation occurs when the platform presents minimum occupancy, therefore this scenario is not representative of real life situations.

Also it is important to note that occupancy background noise levels under normal traffic conditions including rush hours, may not be representative of emergency situations.

Current research is being conducted by the author to determine the multiple effects and their interrelations of different levels of occupancy on platform VA performance. This study will include occupancy effects under a range of simulated emergency scenarios.

Most of the relevant standards and companies' performance specifications only mention fire and emergency evacuation as the intended applications of VA systems. However many other types of emergencies can occur equally requiring the assistance of VA systems (e.g. major accident, failure of power or air supply, entrapment, false alarm panic, stampede, terrorist attack, station kidnap/hostage situation).

Recommendations

A summary of recommendations applicable to the design and guidance documents are listed

Design

1. The design predictions should cater for the most likely worst emergency scenarios including effects caused by different levels of occupancy (figure 8) and other expected background noise sources (e.g. emergency ventilation fans).
2. Acoustic absorption treatment should be provided in all key subsurface circulation spaces where achievable speech intelligibility is limited by long reverberation (e.g. deep platforms, concourses).

If acoustic absorption treatment it is not a design option, other less effective measures could be taken to improve speech intelligibility, these include:

3. Using functional and decorative furniture/hardware/art work/ rough textured concrete/ rough textured artistic walls to increase the sound scattering properties of surfaces to help decrease reverberation.
4. Redesigning existing platform billboards (figure 8) ceiling and cable management metallic paneling as well as signage to act as tuned diaphragmatic and/or micro-perforated cavity sound absorbers.
5. Positioning loudspeakers as close to passengers' head level as possible (e.g. loudspeaker integration into cable management box panels or into acoustic treatment).
6. Consideration of limiting the low frequency response of the system. This measure will prevent long low frequency reverberation, diminish upwards masking, avoid the inefficient low frequency reproduction region of the loudspeakers' response and save significant amplification power requirements. However, although this measure can improve the perceived speech intelligibility, it can also reduce the naturalness of the announcement broadcast particularly of male speech.
7. Activation of selected loudspeakers during broadcast relative to occupancy spatial distribution (passenger presence detection (figure 9).

Standards, guidance and specifications

8. Harmonisation and rationalization of information and guidance among relevant national and international standards.
9. Performance specifications should be reviewed to produce tailored, detailed, updated and balanced requirements taking into account practical constraints and design experience.
10. Rationalising of referred standards and generic compliance involved.
11. Provision of specific and carefully balanced requirements for other interrelated VA performance parameters such as total harmonic distortion (THD), inter modulation distortion, coverage uniformity, frequency response range, frequency response flatness and maximum SPL.
12. Provision of detailed test methodology of performance parameters (including STIPA) specific for the environment, and requirements for relevant instrumentation, test equipment and operator competency.
13. Mention of RASTI as a metric of predicted speech intelligibility should be removed.
14. Harmonisation and certification standardisation of STIPA instrumentation.
15. Incorporation of a procedure to demonstrate reliability and accuracy of design predictions processes

Proposal for raising performance specification and a new standard

Underground railway transportation is the most effective and efficient mass transportation means in large cities. Many underground railway stations are currently being built, extended or renovated around the world. However underground stations are highly vulnerable and at high risk of attacks and other incidents which can develop into major disasters.

Overcrowding and the confined space of old subsurface stations (figure 10) would increase the severity of a major incident. In most types of emergency situations, the VA system will be the only means of mass communication between the emergency services and the users.

Current guidance and specifications have provisions to ▶

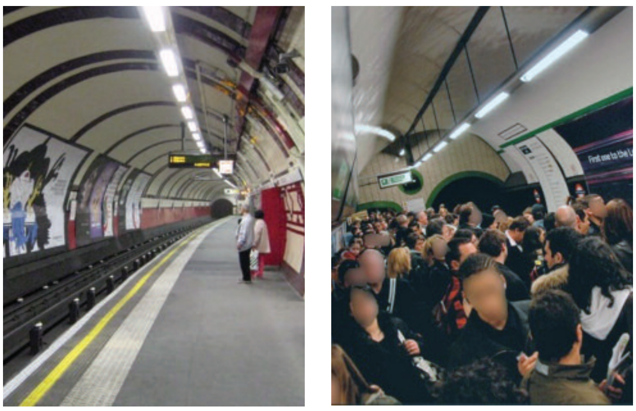

Figure 9. Minimum (left) and crowded (right) occupancy conditions on deep platforms.

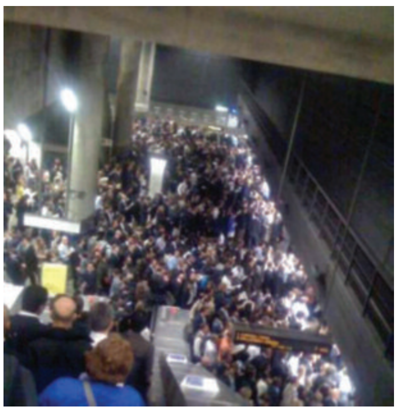

Figure 10. Underground stations exhibiting crowded conditions

relax minimum performance specifications to accommodate for the inherent difficult acoustics of the spaces. In the author's opinion this relaxation should not be contemplated for VA systems particularly those installed in high risk spaces, such as subsurface station platforms. Recognizing the critical importance of the VA systems to public safety in those spaces should prompt decision makers to raise the current minimum specification. The compliance to stricter specification then should drive the stipulation for provision of mitigating measures e.g. acoustic treatment to achieve the raised performance.

The potential life-saving and economical benefits provided by an effective VA system in case of an emergency in underground spaces should outweigh arguments of the high cost of mitigating measures. Hence it is recommended by the author to increase the current minimum speech intelligibility requirement for subsurface circulation spaces to qualification band E (0.56 - 0.6 STI)[5]. The previous minimum STI performance requirement in surface stations areas was 0.6, this was relaxed to 0.5 to minimise environmental noise nuisance. The proposed requirement aims to ensure adequate speech intelligibility and compensate for the following additional difficulties of users in an emergency situation:

- unfamiliarity with the emergency messages (pre-recorded and/or live)
- stress caused to listeners by an emergency situation which may reduce their hearing ability and concentration
- reduced message comprehension by normal hearing non-native listeners, elderly and hearing impaired users[7].

In order to facilitate satisfactory performance of life critical VA systems in subsurface underground stations, it is suggested that there is a need for the creation of a new code of practice, possibly in the form of a British Standard specific for these specific complex and high risk environments.

The new code would consolidate relevant existing guidance, address the concerns and recommendations discussed above and incorporate advice from the relevant industry so as to form a stand-alone and pioneering guidance document which could be also employed outside the UK.

The drafting of the code would also take into account practical, economic, logistical and strategic considerations so that compliance is feasible in all emergency situations.

A possible title is: *Code of practice for designing, specifying, maintaining, installing and operating Voice Alarm systems in Underground Stations*

Conclusions

The vital role of VA systems in subsurface railway stations is currently underrated. A VA system loses its intended life-saving purpose if it is unintelligible and may even become counter-productive in an emergency. Therefore it is essential that improved VA system performance is prioritised by the decision makers when a station is being designed or refurbished.

As subsurface stations are highly vulnerable and at high risk of attacks and diverse types of incidents which could lead to major disasters, particularly in crowded and confined conditions, it is not appropriate that economic considerations prevail and allow substandard VA performance.

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Separating musical audio signals

By Mark D Plumbley, Director of the Centre for Digital Music, Queen Mary University of London

Introduction

As consumers move increasingly to multi-channel and surround-sound reproduction of sound, and also perhaps wish to remix their music to suit their own tastes, there will be an increasing need for high quality automatic source separation to recover sound sources from legacy mono or two-channel stereo recordings. In this contribution, we will give an overview of some for audio source separation, and some of the remaining research challenges in this area.

Separating mixed sounds

A common problem that arises in musical audio is that of *source separation*, where we want to separate one sound from a mixture of many sounds. This is sometimes known as the *cocktail party problem* (Cherry, 1953): we might imagine we are at a party trying to listen to one conversation, while many other noises and other conversations are going on around us.

This full-scale problem, with multiple sources, delays and background noise, is much too difficult for current techniques. Let us therefore start with something much simpler: two source instantaneously mixed in different ways before being picked up by two microphones (Fig. 1). We express this mathematically in matrix/vector form as **x=As** where $\mathbf{s}=[s_1,s_2]^T$ is the pair of sources, $\mathbf{x}=[x_1,x_2]^T$ is the pair of microphones, and **A** is the 2×2 matrix with elements a_{ij} representing how much of the *j*th source is picked up by the *i*th microphone.

Our task is then to try to "unmix" this process to find the original sources **s**, given only the signals **x** picked up at the microphones, but without knowing the mixing matrix **A**. Separating the sources without knowing the mixing process is known as *blind* source separation.

This blind separation problem might seem to be a difficult problem, but we can see how we might try to solve it by turning into a game. Imagine that instead of sound sources s_1 and s_2 we have two dice: Amber (*A*) and Blue (*B*). Then we ask an opponent to think of a pair of secret formulae to mix these to give two observations *X* and *Y*. For example, they might come up with $X=(1/2)A+3B$ and $Y=2A+B$. They then roll the dice only tell us the numbers X and Y (for example, as in Table 1). Can we work out the secret formulae, and the numbers A and B that were rolled?

To proceed, let us plot the values that we get for *X* and *Y* as a scatter plot (Fig 2).

We can see that the outline of the scatter plot forms a lozenge shape, which gives us a clue about how to recover the mixing process. The slopes of the lines formed by the sides of the lozenge tell us the numbers that appear in the two formulae, which tells us how the numbers on the dice *A* and *B* were mixed to give *X* and *Y* (Fig. 3). We can then solve these two simultaneous equations (i.e. multiply by the inverse mixing matrix) to get back to the original numbers *A* and *B*.

In fact, there are two ambiguities that remain after we recover the formulae. The first is a *scaling ambiguity*: A slope of 2 in ½ is the same as a slope of 4 in 1 or 1 in ¼, so we can only discover the relative amounts of *A* mixed in *X* and *Y*. For a die roll we will know that *A* can only take integer values between 1 and 6, so we can work out which is the correct scaling, but for more general

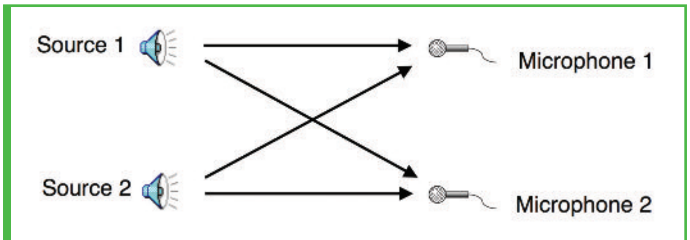

Figure 1: Mixing process of two sources into two microphones.

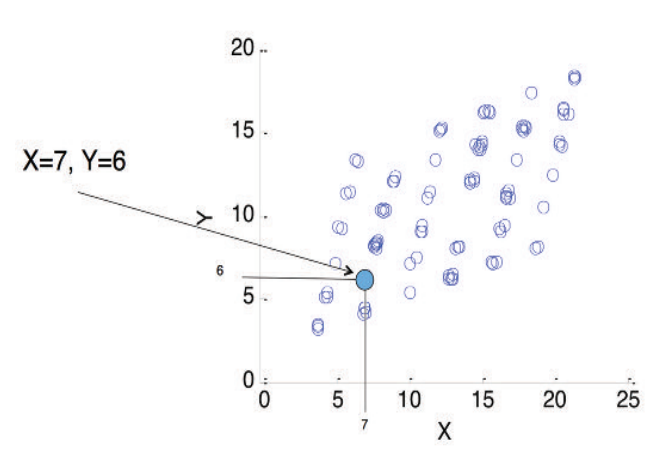

Figure 2: Scatter plot of secret formula values Y against X, highlighting the point X=7, Y=6.

X	Y
7	6
10.5	7
6	9
18.5	12
(etc…)	(etc…)

Table 1: Example results of applying the secret formulae to die rolls.

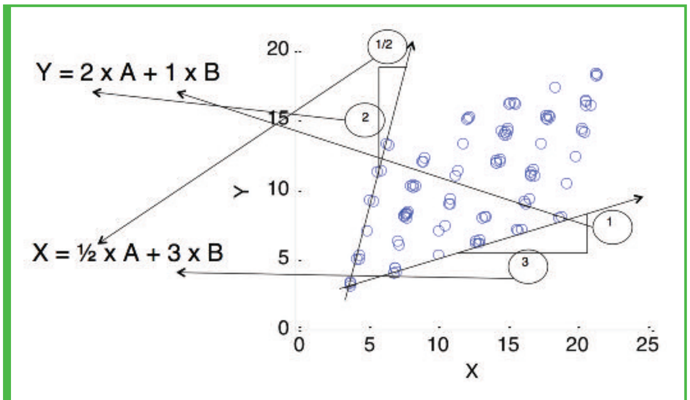

Figure 3: Reading off the mixtures from the scatter plot

signals this scaling ambiguity will remain. The second is a *permutation ambiguity*: we cannot tell the labels (colours) of the original dice from the mixtures *X* and *Y*. So we cannot tell if the original mixing formulae were (a) $X=(1/2)A+3B$ and $Y=2A+B$ or $X=(1/2)B+3A$ and $Y=2B+A$. So, while we might recover the values for A and B, the values that we get back might be swapped and/or scaled from their original values.

What we have seen is a simple example of *independent component analysis* (ICA) (Hyvärinen et al, 2001). While we solved this unmixing problem visually, ICA uses the statistical independence of the sources to solve the unmixing process, searching for an unmixing matrix **B** such that the elements y_i in the vector **y**=**Bx**=**BAs** are independent. When they are, **B** will be an inverse matrix for **A**, subject to a scaling and permutation ambiguity.

Separating *more* mixed sounds

The ICA method is very useful, but since it uses the inverse of the mixing matrix (or equivalently, the solution of a set of simultaneous equations), it is limited to the case where the number of sound sources is the same as the number of observations (microphones). If instead we had more sound sources than microphones, such as a set of three instruments picked up by a 2-channel stereo microphone pair, then we cannot use the ICA method.

Going back to our dice game again: if we have three dice (Amber, Blue, Cherry) but only two mixtures, we cannot see the lines on the scatter plot that would help us to recover the mixtures (Fig 4.). This is not a game we can win, so let us play with a new set of rules based on the concept of *sparsity*.

One feature of many audio signals is that, if represent the signal into the time-frequency domain instead of the time domain, its representation is dominated by a small number of time-frequency components. When a signal can be represented or using a small number of non-zero components in this way, we say that it has a *sparse* representation.

For our dice game, one equivalent might be to suppose that we only score something on each of our 3 dice *A,B,C* if we first roll a six, otherwise we score nothing. For example, 4 scores 0, 2 scores 0, but 6 followed by 4 scores 4. This means that most (5 out of 6) of our scores will be zero. If we now plot the scatter plot of the two secret formulae results *X* and *Y*, we can clearly see the mixture lines (Fig. 5).

The high proportion of zeros in the sparse sources has led to a concentration of the scatter plots corresponding to the three cases $B=C=0$, $A=C=0$, and $A=B=0$, where only *A*, *B* and *C* respectively are non-zero. So we can now recover the mixing formulae. We can also determine the values of A, B and C where they are each the only non-zero value, but other cases are more difficult: the points on the scatter plot that are "between" lines could be caused by either two or three non-zero values, so we may not be able to recover them uniquely.

A corresponding situation arises for separation of audio sources. Suppose we have a pan-potted (instantaneous) 2-channel stereo mixture of several sources, where each source is panned to a particular L-R direction by mixing level only (no delays). If we transform the 2-channel mixture into the time-frequency domain (a spectrogram), and plot the resulting scatter plot, we might see something like that in Fig. 6.

We can see three clear signals that show as bidirectional "rods" sticking out from the centre in the scatter plot (a fourth signal is also just visible in this example, at an angle of about 80°/260° from vertical). Each spike corresponds to a sound source coming from a different direction from L to R, which has a different relative weighting of L and R. If we measure the relative L/R weighting for each time-frequency box in the spectrogram, and "colour" the spectrogram according to the nearest source, we can then "tease apart" the spectrogram using *masking* to give its separate component spectrograms (Fig. 7). By transforming those spectrograms back into the time domain, we recover an estimate of the original separated signals. This approach, known as *time-frequency masking*, forms the basis of the Degenerate Unmixing Estimation Technique (DUET) (Yilmaz & Rickard, 2004) and the Azimuth Discrimination and Resynthesis (ADRess) method (Barry et al., 2004).

Separating from a single microphone

The separation problem is even more challenging with only a single microphone, since we no longer have any direction-of-arrival information to estimate which source is present in each time-frequency box. However, if the sound sources are sparse in the time-frequency (spectrogram) domain, they will be approximately disjoint, and we can use the technique of non-negative matrix factorization (NMF) (Lee & Seung, 2001) to try to decompose the sources.

For NMF, we assume that each note *j* has a non-negative spectral profile, so our set of notes can be represented by a frequency x note matrix $\mathbf{W}=[w_{ij}]$, and that the non-negative note activities can be represented by a note x time matrix $\mathbf{H}=[h_{jk}]$. If the frequency profiles of the notes are approximately disjoint, the elements of the "frequency x time" mixture spectrogram $\mathbf{V}=[v_{ik}]$ is approximately given by adding up the contributions due to the frequency profile of each note in the ith frequency bin, P46

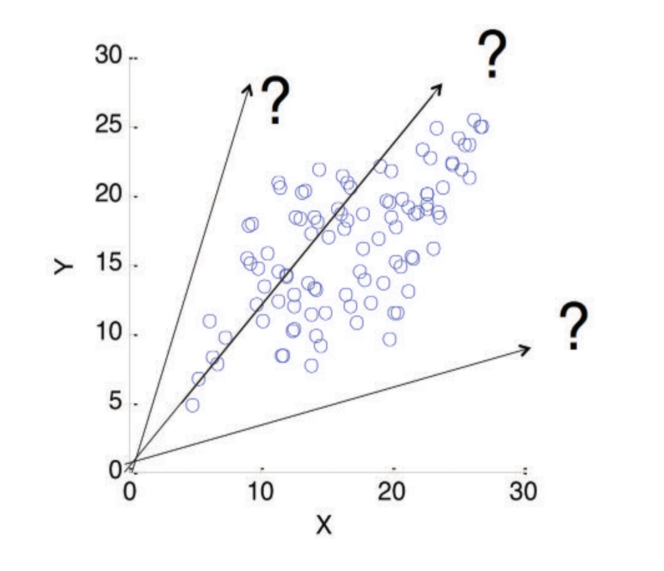

Figure 4: With three sources but only two mixtures, the scatter plot no longer allows us to find the mixtures.

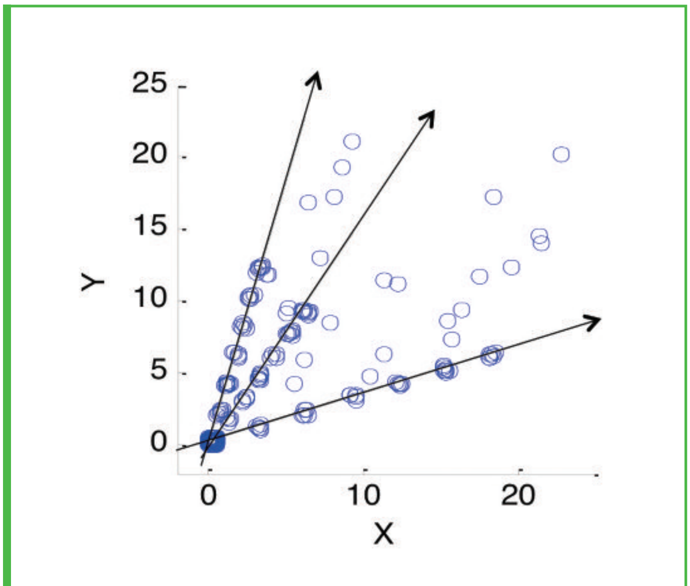

Figure 5: Scatter plot of two mixtures of three sparse sources.

◀ P45 multiplied by its activity at kth time frame, i.e.

$$v_{ik} \approx \sum_j w_{ij} h_{jk}$$

or in matrix notation, $\mathbf{V}\approx\mathbf{WH}$. So if we start with the spectrogram $\mathbf{V}$, we can use the NMF approach to decompose into the separation note spectral profiles and note activities (Fig. 8), resulting in a transcription of the musical notes (Smaragdis & Brown, 2003). While the standard NMF algorithm uses an Euclidean distance, Févotte et al (2009) suggest that approximating using the Itakura-Saito divergence is more suitable for audio sources.

To separate different musical instruments, we then need to group together the notes from the different sound sources. For a simple case we can do this by hand (Wang and Plumbley, 2005) or use convolutive methods (Virtanen, 2004).

We can therefore break our decomposition into sub-matrices corresponding to each of our sources, so our decomposition is split into $\mathbf{V}\approx\mathbf{WH}=\mathbf{W}_1\mathbf{H}_1+\mathbf{W}_2\mathbf{0}_2+\cdots+\mathbf{W}_N\mathbf{H}_N=\mathbf{V}_1+\mathbf{V}_2+\cdots+\mathbf{V}_N$ where $\mathbf{V}_n=\mathbf{W}_n\mathbf{H}_n$ is the estimate of the spectrogram due to the nth source. We then recover the estimated source by transforming back to the time domain.

Research challenges

For time-frequency masking and NMF to work well, the sources must each occupy different boxes in the transform domain, a property that is sometimes known as W-disjoint orthogonality (Yilmaz & Rickard, 2004). In reality, this orthogonality property does not completely hold, so different types of artefacts can be heard in the separated sources. For example, if two source occupy the same time-frequency box, some of one signal will be misallocated to the estimate of a different signal, and we can hear parts of one source signal "bleeding through" to the other.

Another artefact, often called *musical noise* (or *birdies*), arises due to filtering of background noise. In areas where the energy from all sources is low, the value in a time-frequency box may be mostly due to background noise rather than one of the sources. However, the basic algorithm does not detect the difference between noise and signal, and will allocate that noise component to the source with the nearest corresponding L/R ratio. Since each time-frequency box represents a brief burst of energy near the centre frequency for that box, this can be heard as a set of very quiet "bips" at different frequencies, which combine to give a very noticeable "twittering" effect in the background.

Solving these and other problems is a challenge for current researchers. For example, we have been exploring alternative time-frequency transforms to improve separation (Nesbit et al., 2007), the use of additional information such as user input (Smaragdis & Mysore, 2009), knowledge of musical scores (Fritsch & Plumbley, 2013; Ewert et al., 2014), and modelling the local phases and correlations in time-frequency transforms of signals (Badeau & Plumbley, 2014). Many other audio source separation methods are possible, see e.g. (Evangelista et al, 2011) for a review.

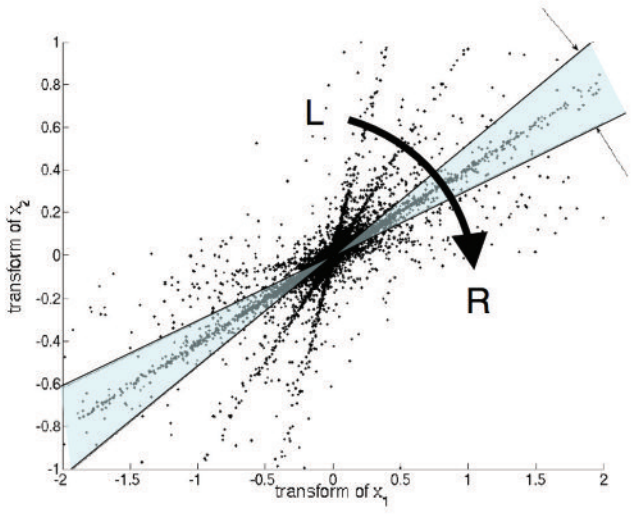

Figure 6: Scatter plot of the real values of a time-frequency transform of panpotted stereo signal.

Conclusions

Musical audio source separation is an interesting and challenging area of research. Where we have the same number of microphones as sources to be separated, we can use methods based on *independent component analysis* (ICA). In many cases there are more sound sources than microphones, and for those cases we can use methods based on time-frequency masking, including the well-known non-negative matrix factorization (NMF) approach. However, this is still far from being a solved problem, particularly if we are looking for results with high perceived audio quality, suitable for upmixing or remixing applications, and currently may still require significant manual work to get the best results. Nevertheless, there are some promising areas of current research that suggest that progress is still possible, and it will be interesting to see how far we can go towards the target of fully automatic high quality audio source separation.

Acknowledgements:

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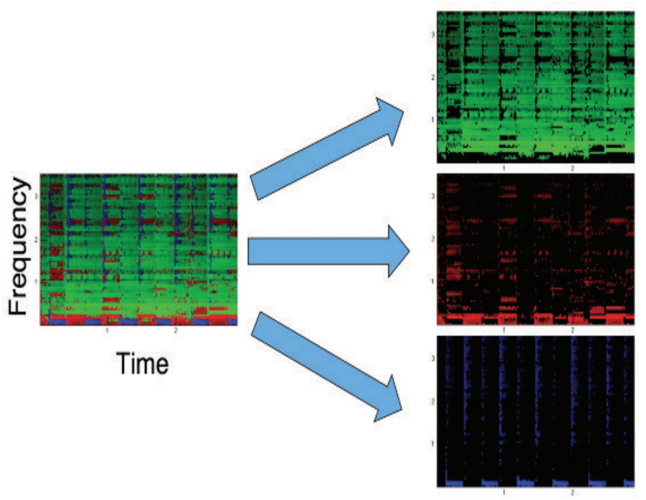

Figure 7: Separation by colour-coding the spectrogram

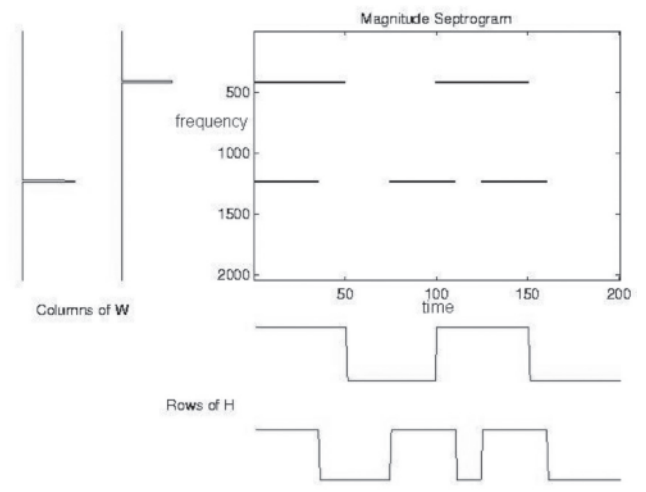

Fig. 8: Illustrative example of decomposition of a spectrogram by non-negative matrix factorization (NMF)

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The Centre for Digital Music (C4DM) at Queen Mary University of London is a world-leading centre for research into digital technologies for new understanding and innovation in music and audio. The Centre consists of over 50 people, including 12 Academic staff, around 35 PhD students and 12 postdoctoral researchers. C4DM has hosted several conferences in music and audio, including DAFx 2003, ISMIR 2005, and CMMR 2012. C4DM has many industry collaborations, including with Yamaha, FXpansion, I Like Music and Audio Analytic, and is a member of the BBC Audio Research Partnership.

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Sales up by nearly a third in two years as AcSoft celebrates 20th anniversary

AcSoft, a leading UK specialist in sound and vibration instrumentation and sensors for a wide range of sectors including environmental, automotive, aerospace, transport and telecommunications, has been celebrating its 20 year anniversary.

Part of the AcSoft Group, which also comprises occupational health and environmental noise and vibration monitoring business Svantek and newly formed GRAS UK, the Aylesbury-based company has marked the milestone by announcing that sales have increased by 30% since 2012.

AcSoft, which was set up in 1994 by Managing Director John Shelton, offers a large portfolio of products from major brands, including HEAD Acoustics, G.R.A.S., GFal, Sinus Messtechnik, Crystal Instruments, Listen Inc, Lookline, Pioneer Hill Software and Delta.

Recent developments include the addition to its portfolio of Microflown, the world's first MEMs (Micro-Electrical Mechanical Systems) technology-based sensor measuring acoustic particle velocity.

John Shelton said: "It seems impossible that 20 years have passed since I started AcSoft. It is most gratifying to see how the business has grown during that time. Our longevity can be attributed to an ongoing commitment to helping organisations, both large and small, solve their sound and vibration challenges."

For more information contact Paul Rubens on **01296 682686** or **07815 087905**, email **prubens@acsoft.co.uk** web: **www.acsoft.co.uk**

John Shelton

Arup opens latest SoundLab in Manchester

Arup has opened another of its auralisation studios, known as SoundLab, at its Manchester office.

SoundLab enables design teams, stakeholders and sound artists to listen to soundscapes of the natural and built environment before they are physically created. It allows users to experience how different locations and spaces sound, the impact of architectural form on sound quality, and how physical interventions can alter the audible environment.

SoundLab uses the latest audio technology to accurately demonstrate changes in the level of sound, its character, and its location relative to the listener. The facility enables informed discussions around design, as well as providing certainty in outcomes and informing cost savings.

The technology developed by Arup has been extensively used in the design of numerous performance venues including Milton Court in London, Kulturkvartelet in Bodo, Norway, and the Bill & Melinda Gates Foundation Headquarters, as well as helping to model complex infrastructure projects such as High Speed 2.

The Manchester SoundLab will also be used for research, including an Arup sponsored PhD with the Manchester Metropolitan University (MMU) Centre for Aviation Transport and the Environment (CATE). The research will investigate aircraft noise to improve communication between airport operators and surrounding communities.

Picture courtesy of Arup

The new Manchester SoundLab

Trials under way of infrasound suppression device

A Canadian company has been conducting field evaluations of an infrasound suppression device (ISD).

The ISD has been developed by Kevin Allan Dooley Inc to remove infrasonic barometric pressure fluctuations from the home.

The device is a small appliance similar to an air conditioner, which once installed in the home, monitors and controls the barometric pressure inside the home to eliminate exposure of the occupants to infrasonic pressure fluctuations.

The ISD is intended to improve the in-home environment of dwellings located in the vicinity of wind turbines or in the path of infrasonic spinning mode influence.

The prototype was temporarily installed in two separate homes varying significantly in size and structure.

The goal was to confirm the functional capacity range of the system at generating effective anti-phase infrasound between 0.2Hz to over 20 Hz throughout the enclosed dwelling. The ISD was located in fixed convenient locations in each of the homes.

The anti-phase infrasound target level was 70 dB from 0.2 Hz to 5Hz and 65 dB from 5Hz to 25 Hz. These levels, says the Toronto-based firm, were "easily achieved" for all conditions at less than 40% drive capacity.

Testing included measurements in the homes with open and closed windows, and in rooms with closed doors, with only minor effects on the anti-phase infrasound levels.

For more details go to **www.kevindooleyinc.com**

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WSP to acquire Parsons Brinckerhoff

Balfour Beatty has agreed to sell professional services division Parsons Brinckerhoff to WSP Global for £820 million.

The deal, which is subject to approval by shareholders and the regulatory authorities, is expected to be completed by the end of 2014.

Montreal-based WSP expects the acquisition will increase its presence in the US and position the company as a player in the US transportation segment.

The deal also will build on WSP's position in the UK, where Parsons Brinckerhoff has 14 offices, and provide a stronger presence in growth regions such as Asia and Australia. The transaction also will expand its capabilities in its core buildings and infrastructure segment, as well as develop the energy segment and further increase its project and programme management services offerings.

WSP expects the combination to generate annual cost savings of about £15 million over two years and to give an immediate boost in the mid-single digits to per-share earnings.

Balfour Executive Chairman Steve Marshall said the sale follows a re-evaluation of the company's portfolio to focus on its core construction and infrastructure businesses.

Balfour Beatty acquired Parsons Brinckerhoff in September 2009 for £382 million.

Chartered Building Consultancy status for Acoustic Associates

Acoustic Associates Sussex has been awarded the title of Chartered Building Consultancy.

Peter Attwood, Managing Director of the Shoreham-based firm, which specialises in noise and vibration problems, said: "We are delighted to be awarded this title. This scheme, administered by the Chartered Institute of Building, is important as it ensures that standards of excellence are both achieved and then maintained for the benefit of our clients.

"We believe that we may be unique: we are not aware of another acoustic consultancy practice which is also a Chartered Building Consultancy. If you are aware of one, please let us know; we'll happily share the accolade!"

For further information go to **www.aasussex.co.uk**

Peter Attwood (left) receives the firm's accreditation from Stuart Henderson of the Chartered Institute of Building

IAC Acoustics in further US expansion

IAC Acoustics is opening a new factory in the USA for both exhaust silencers and other traditional IAC acoustic products such as doors, windows, louvres duct silencers and panel based rooms and enclosures.

The factory is near its existing GT Exhaust site in Lincoln, Nebraska, which it acquired in October 2012 as part of plans to grow its share of the North American power generation market.

Mark King, Group President and CEO of IAC Acoustics, said: "The new facility is an exciting time for the group, especially for our North American sites.

"The ability to provide multiple product disciplines under one roof is something that few others can come close to. Once fully online, this multi-product production facility will further aid us in our ability to provide larger acoustic packages to different industries."

IAC has also announced that it has achieved "excellent results" by adopting lean manufacturing techniques in producing acoustic louvres, acoustic doors, and duct silencers.

It reports "significant" reductions in lead times, inventory and space utilisation, as well as improvements in manufacturing output and an increase in overall productivity.

Miller Goodall celebrates 10 years in business

An environmental services company which specialises in noise has celebrated its 10th anniversary.

Miller Goodall, which is based in Bolton, was launched by Lesley Goodall and Jo Miller when they spotted a gap in the consultancy market while job-sharing as environmental health officers for Salford City Council.

The team now comprises 10 people who are specialists in either noise control or air quality – and such has been the firm's growth that it plans to move soon to bigger offices.

To celebrate the milestone, the consultancy held a party for staff and clients at a nearby inn.

Echo Barrier eases noise nuisance at World Trade Centre

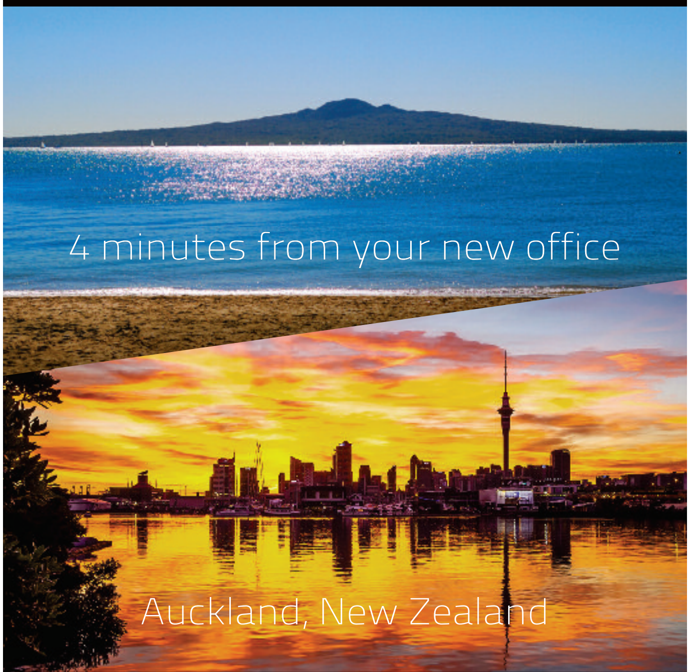
A UK-based company is helping to cut noise nuisance at the World Trade Centre development site in New York City.

Echo Barrier has supplied the H2 Series noise reduction barriers to provide a solution to construction noise on the site and reduce disruption to local residents, businesses and tourists.

Barriers have been erected across the site including around the underpass where a significant difference has been noticed by users.

See the launch of the H3 barrier on page 56.

Time for a change of scenery?



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Cass Allen welcomes two more acoustics consultants

Cass Allen has announced the appointment of two more consultants to join its expanding team.

Tim Ives read electro-acoustics at the University of Salford and was awarded his PhD in psycho-acoustics from the University of Brighton. He has joined the architectural acoustics team and is currently working on the EIA and detailed acoustic design for South Quay Plaza, a Foster & Partners design, which at 73 storeys high is set to change the skyline of London's Canary Wharf.

Francisco Robles holds a BSc in Physics and MSc in Acoustic Engineering, both from Madrid University. He worked as an acoustics consultant in Spain before coming to the UK. He is currently working on One Tower Bridge, a nine-block mixed-use development on the south bank of the Thames between City Hall and Tower Bridge.

Tim Ives

Francisco Robles

Neil Thompson Shade elected to ASA Fellowship

Neil Thompson Shade, President and Principal Consultant at Acoustical Design Collaborative in Ruxton, Maryland, USA, has been elected Fellow of the Acoustical Society of America. He was cited for his "contributions to acoustics education and to the integration of electro-acoustics in architectural acoustics".

Neil, an MIOA, has taught at the University of Maryland School of Architecture (1987 to 1991), American University of Physics and Audio Technology Department (1988 to 2000), and in 2000 established the acoustics studies programme at the Peabody Institute of Johns Hopkins University where he is still on faculty.

In 1998 he was the recipient of the Theodore John Shultz Grant for Advancement of Acoustical Education for his book, *Electronic Sound Systems Design – Equipment, Application, Specification and Installation.*

His work at Acoustical Design Collaborative focuses on consulting in architectural acoustics and audio/visual systems design for cultural and performing arts facilities, education buildings, historic renovation, and places of worship.

Neil Thompson Shade

New Editor-in-Chief for the Acoustical Society of America

James F (Jim) Lynch has been appointed the new Editor-in-Chief of the Acoustical Society of America (ASA). He began his service as Editor-in-Chief Designate in August and will assume the title of Editor-in-Chief on 1 November 2014.

As Editor-in-Chief, he will be responsible for the ASA publications programme, including: the *Journal of the Acoustical Society of America*, *JASA Express Letters*, *Proceedings of Meetings on Acoustics*, and *Acoustics Today* magazine.

Dr Lynch is a Senior Scientist at the Woods Hole Oceanographic Institution in Massachusetts, where he joined the staff in 1982. His earlier employment included a position at the Applied Research Laboratory, the University of Texas at Austin (1977-81).

James F Lynch

Neil Ashton is latest recruit at Environoise

Neil Ashton (AMIOA) has joined the expanding team at Environoise Consulting, which recently moved to new offices at Ellesmere Port.

Miles Wooley, Principal Consultant, said: "We are delighted that Neil has joined us. He brings a wealth of experience to the sound insulation sector of our business."

Neil Ashton

Ray Browne heads up SRL's new Birmingham office

Ray Browne has joined SRL Technical Services to head up its new Birmingham office.

His background in underwater, military and environmental acoustics will add to SRL's existing offerings in acoustic and vibration consultancy, testing, UKAS-accredited laboratories, BREEAM and long and short term monitoring for noise, vibration and dust.

His acoustic experience ranges from large infrastructure projects, such as the Forth replacement crossing and the M25 widening for the Olympics, to residential, further education and retail development, plus experience in providing expert witness testimony at public inquiries.

SRL Managing Director Jack Dalziel said: "We are really pleased to be able to appoint someone with Ray's knowledge and experience to open our Birmingham office."

Ray Browne

COYLE Personnel Plc Recruitment Specialists

Established in 1988, Coyle Personnel Plc is one of the UK's largest independent recruitment agencies, providing expertise to construction, environmental and medical fields. Applications for the following roles should be forwarded in confidence via email to kimberley.powell@coyles.co.uk or alternatively call Kim Powell on 07919696717.

Acoustic Consultant: Manchester or London £28 – 35K + Pension, Health & Dental, Life insurance. An exciting new opportunity for an Acoustic Consultant looking to progress. An award winning international multidisciplinary consultancy renowned for their professionalism and sustainable project delivery, is now looking for self-sufficient candidates, with 2+ years experience. My client has an exceptional portfolio with an array of high profile clients, so applicants must have a sense of pride and exceptional communicative ability. You will receive unparalleled training, an all-inclusive selection of benefits with clear room for professional development.

Technical Director of Acoustics & Vibration: London - £40-55K + Health, Life insurance & Personal Cover, Car. An urgent requirement for an accomplished Acoustics/Noise and Vibration specialist to join an international front-runner in multidisciplinary services. Applicants must be BSc or IoA Dip qualified with 8Yrs+ experience. The successful candidate will be rewarded with an outstanding starting package, creative freedom, flexibility in location and specialised field (Environment or Architectural) and the opportunity to influence one of the world's most reputable Acoustic teams.

Graduate Acoustic Consultant: Surrey - £18K – 22K + Career Progression, flexi benefits package. A fully established and highly successful multidisciplinary consulting firm offering expert services to development, environmental, and infrastructure sectors are now recruiting for a Junior or Graduate Consultant. Offering invaluable training prospects and an outstanding rate of promotion for those that work hard and prove their worth. This role would be perfect for those with an inbuilt sense of professionalism, common sense and an ambition. Acoustic Degree or Diploma, determination to develop professionally, IT competence and full driving licence needed.

Acoustic Consultant – Birmingham - £30K+ Pension, Life Insurance, Medical, 23days Holiday+. A professional and highly-reputable team of acousticians with global recognition in multidisciplinary services is searching for a credible consultant to invest in. Contenders are expected to be skilled in Acoustic consultancy (3Yrs+), and qualified with a quality BSc or IoA Dip. My client holds an outstanding reputation for their input into sustainable design within the build environment. Projects contrast between small/specific to vast multidisciplinary offering variety and an abundance of prospects.

Senior / Principal Acoustic Consultant: Scotland -£37-48K + Life Insurance, Pension, Health & Dental, Car. One of the UK's largest Acoustic teams is currently searching for a Senior/Principal Consultant (6Yrs+). In exchange for your business development and team leadership expertise, and as an esteemed acoustic specialist (Environmental or Building focused) you will gain inventive freedom, an inspiring starting salary and an inclusive benefits package. Requirements: BSc/MSc, IoA Membership, 6Yrs+ experience, full driving licence, proven ability to win and deliver a multitude of large scale projects.

Acoustic (Building Specialist) Consultant: North West -£28-32K – 25 Days Holiday, Pension, Health Insurance+. A reputable and independent team of Acoustic specialists in the North West immediately require an Acoustic Consultant (5Yrs+) with adept knowledge in building specific acoustics and a proven project winning record. As a dynamic and flexible office, you will become a respected and influential member of a friendly and supportive working environment, and gain a variety of benefits as well as fantastic starting salary and opportunities for progress. Recent projects have included education, health, retail, and office developments.

For all current Acoustic vacancies visit: www.coyles.co.uk/h/sectors/environmental/102/ Or contact Kim via kimberley.powell@coyles.co.uk - 07919696717

GRAS launches new kit for aero-acoustic testing in wind tunnels

GRAS Sound and Vibration UK has launched a compact flush mount turbulence screen microphone kit for improved aero-acoustic testing in wind tunnels.

By attenuating the hydrodynamic component of turbulence up to as much as 25 dB, the acoustic signals of interest can now be identified and diagnosed with a much more reliable resolution.

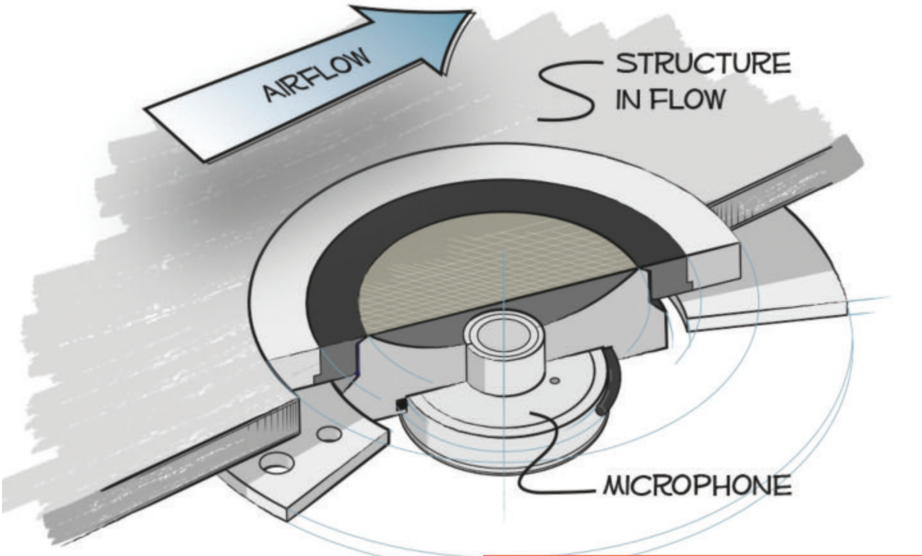
The turbulence screen integrates the flush and recessed mounting techniques with a special wire mesh into one single unit and allows for adaptation of several mounting options. Key features and benefits, says GRAS, include very high induced flow noise reduction, extremely low acoustic attenuation, low installation height, front or rear mounting options and flush-mount and standard microphone accommodation.

The kit features a 47BX / ¼" flush mount microphone set which combines high precision and reliable noise measurement with the need for fitting sensors into very confined spaces and narrow structures. With an installation height of less than 10mm, thin coax wiring and front venting, this flush-mount microphone can be integrated into any design and application.

It also includes mounting flanges and a USB stick with calibration data, angle and wind speed dependency data and CAD drawings of mountable parts. It features a standard CCP connection so will be compatible with existing equipment.

In addition, the kit offers a turbulence frequency range between 500Hz – 10KhZ; acoustic attenuation less than 3db; acoustic frequency range between 100Hz – 70kHz; dynamic range between 44dBA – 166dB; approach ±60Degrees and front venting.

For more information contact Emily Howarth on **01296 681891** or via **emilyhowarth@gras.co.uk** or go to **www.gras.co.uk**



The new flush mount turbulence screen

New probe microphone gets into the tiniest of spaces


The new 377B26 probe microphone

The new 377B26 probe microphone from PCB Piezotronics has been designed for R&D engineers needing to measure sound pressure in confined spaces.

The probe tip diameter measures 1.3mm, which enables white goods, telephone, loudspeaker and musical instrument manufacturers to make measurements in small, confined and difficult-to-access spaces that cannot be accessed using traditional microphones.

The microphone comprises four components: pre-polarised microphone, preamplifier, housing and several probe tips of different lengths. The components work together to provide a maximum operating temperature of 800° Centigrade, much greater than traditional test and measurement microphones.

Innovations in high temperature accelerometer technology for gas turbine monitoring have led to the development of the series 357D90, a charge output sensor that enables vibration measurement in extreme heat environments up to 650°C. It has a sensitivity of 5pC/g ±10%, a measurement range of ±1000g peak and a frequency range of 2.5kHz.

The accelerometer is housed in an Inconel welded hermetically sealed package and features an integral hardline 3m cable. Weighing 50 grams without cable, it features through-hole mounting and can interface directly with handheld data collectors for both permanent and route based applications.

For more information go to **http://www.pcbsensors.co.uk** or email **ukinfo@pcb.com**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New sound reduction barrier from Echo Barrier

A new version of the Echo Barrier H2 sound reduction barrier that achieves noise reduction of up to 30dB has been launched.

The launch of the H3 comes at a time of growth and innovation for the company as it expands into new markets in Europe and the US. A number of other new products are also in production, including an acoustic tent and a transparent barrier.

Peter Wilson, Technical Director, said: “The number of contractors now specifying noise reduction solutions as part of their site management credentials is increasing rapidly, as the impact of noise on local communities becomes more of an issue.”

For more information visit **www.echobarrier.co.uk**

The H3 in action

Outdoor measurement microphone for XL2 SLM

NTi Audio has introduced an outdoor measurement microphone for the XL2 sound level meter.

The M2230-WP has corrosion-free polymer housing, windscreen, water-repellent membrane and bird spike to provide protection from rain, wind, dust and perching birds.

The microphone fulfils IEC 61672 Class 1 as well as the ANSI S1.4 Type 1 requirements. It features a residual noise floor of 16 dB(A) and supports precise and linear measurements up to 139 dBSPL.

Available for the XL2 is a heavy duty outdoor case that also has space for batteries and further accessories. The connection cable to the outdoor microphone runs into the case through a rain-protected aperture.

For more details go to **http://www.nti-audio.com/en/solutions/noise-monitoring/environmental-noise.aspx**

The XL2 outdoor measurement kit

Acoustic ceiling design aims to reach new heights

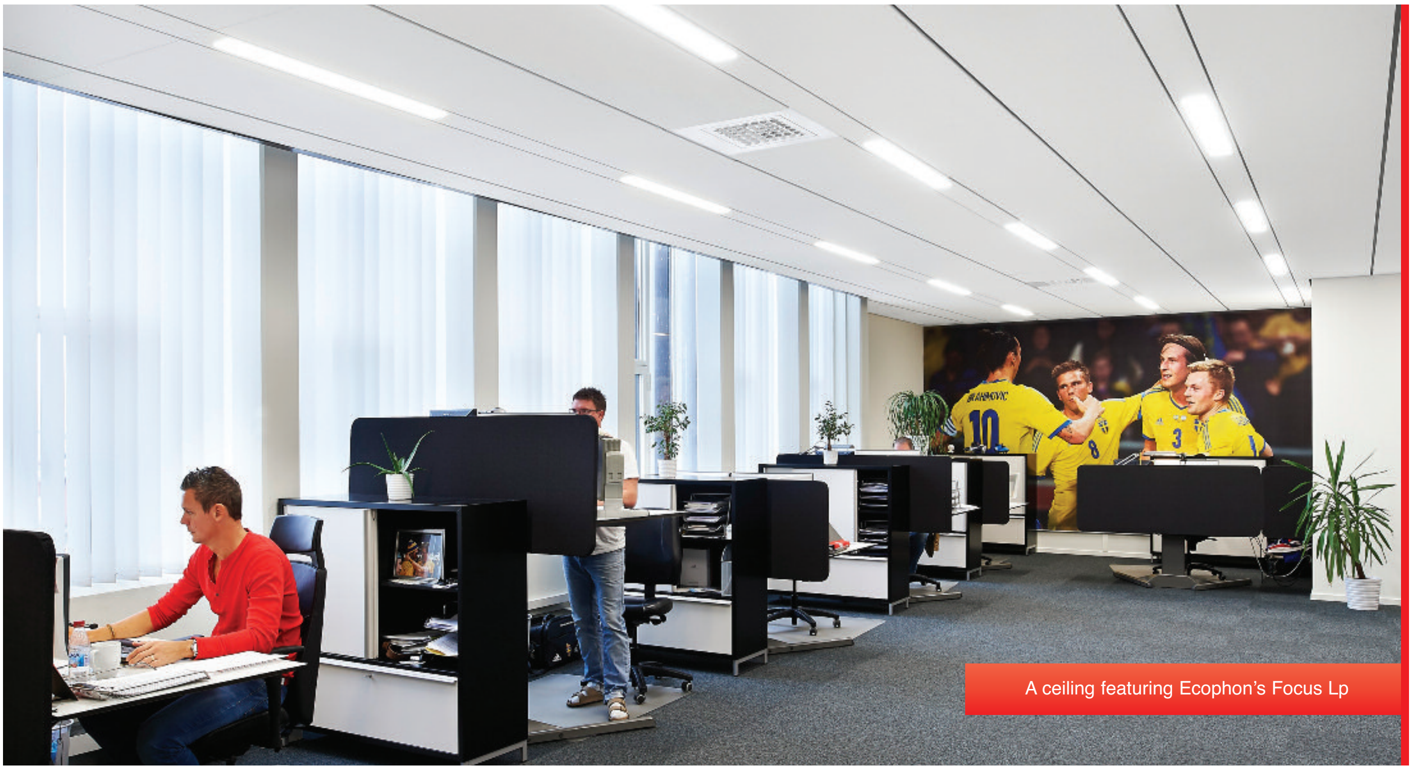
Focus Lp, Ecophon's acoustic ceiling design, now features a Connect Wall spring and Connect Space bar connector aimed at sharpening accuracy and stability.

In its standard form, the product is available in various panel sizes; most recently, a 300mm panel has also been added. The premium option allows designers to integrate all technical ceiling components such as lighting, ventilation, sprinklers and smoke detectors.

There is also the option to integrate Ecophon's own Line LED lighting, a recessed luminaire suitable for various applications including open-plan work spaces and walkways

Ecophon says Focus Lp helps to minimise unnecessary distraction in open plan offices by reducing both sound levels and shortening the distance speech travels. Articulation Class (AC) value specifies how well the product reduces sound levels for speech and with an AC value of 180 Focus Lp is ideal for open-plan offices.

For more information go to **www.ecophon.com/uk/Product-Web/Focus/Focus-Lp/**



A ceiling featuring Ecophon's Focus Lp

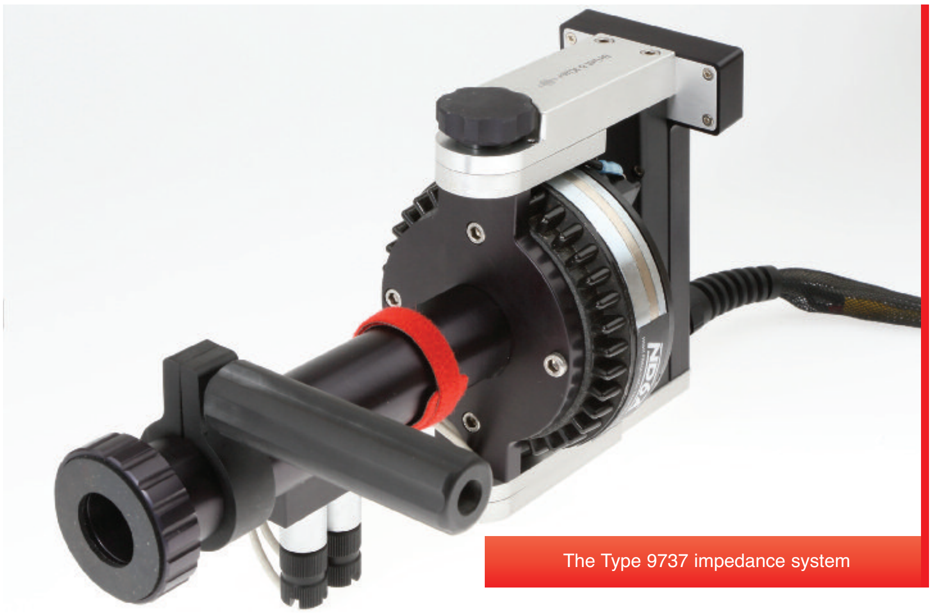
Portable impedance meter system from B&K

Brüel & Kjær created a portable impedance meter system, Type 9737

The firm says it provides aerospace engineers with a user-friendly system, suitable for carrying out research and production quality control impedance measurements, up to 150 dB SPL on engine nacelle liners.

The system allows key acoustic parameters, such as impedance spectra vs. OASPL and acoustic resistance versus acoustic velocity, to be extracted in-situ.

An automated pass/fail routine allows non-acoustic specialists to carry out production quality control measurements.



The Type 9737 impedance system

The system is based on the two-microphone, transfer function test method, which means measurements take only a fraction of the time required by traditional, standing-wave ratio systems.

For more details go to **http://www.bksv.com/doc/bn**

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Committee meetings 2014/15

DAY	DATE	TIME	MEETING
Tuesday	4 November	10.30	ASBA Examiners
Tuesday	4 November	1.30	ASBA Committee
Thursday	6 November	11.30	Meetings
Friday	7 November	10.30	Executive
Tuesday	**25 November**	**10.30**	**Council**
Wednesday	26 November	9.30	CCBAM Examiners and Committee
Wednesday	26 November	10.30	CCENM Examiners
Wednesday	26 November	1.30	CCENM Committee
Thursday	27 November	10.30	Diploma Tutors and Examiners
Thursday	27 November	1.30	Education
Tuesday	2 December	10.30	CCWPNA Examiners
Tuesday	2 December	1.30	CCWPNA Committee
Thursday	8 January	11.30	Meetings
Tuesday	20 January	10.30	Diploma Tutors and Examiners
Tuesday	20 January	1.30	Education
Thursday	22 January	10.30	Membership
Thursday	5 February	11.00	Publications
Thursday	12 February	11.00	Medals & Awards
Tuesday	10 February	10.30	Executive
Tuesday	3 March	10.30	Diploma Examiners
Tuesday	**10 March**	**10.30**	**Council**
Thursday	26 March	10.30	Engineering Div
Tuesday	7 April	10.30	CCWPNA Examiners
Tuesday	7 April	1.30	CCWPNA Committee
Wednesday	8 April	11.00	Research Co-ordination
Thursday	9 April	11.30	Meetings
Thursday	7 May	10.30	Membership
Thursday	14 May	11.00	Publications
Tuesday	19 May	10.30	CCHAV Examiners
Tuesday	19 May	1.30	CCHAV Committee
Tuesday	26 May	10.30	Executive

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

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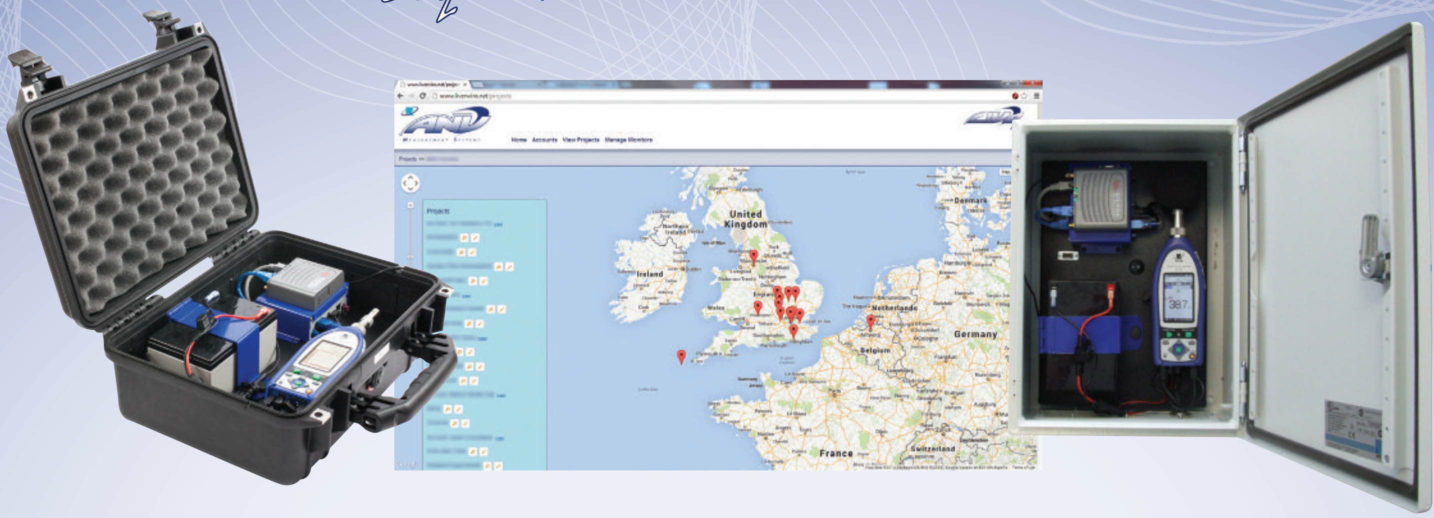

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