



REPRODUCED SOUND 2019

Creating engagement in sound

By Adam Hill

The 35th annual Reproduced Sound conference, organised by the IOA's Electro-Acoustics Group (EAG), took place in Bristol from 19th to 21st November, 2019. The conference represents the cutting edge of modern audio and acoustics in an informal environment that allows consultants, manufacturers, contractors, end users, academics and students to mingle and share insights and information.

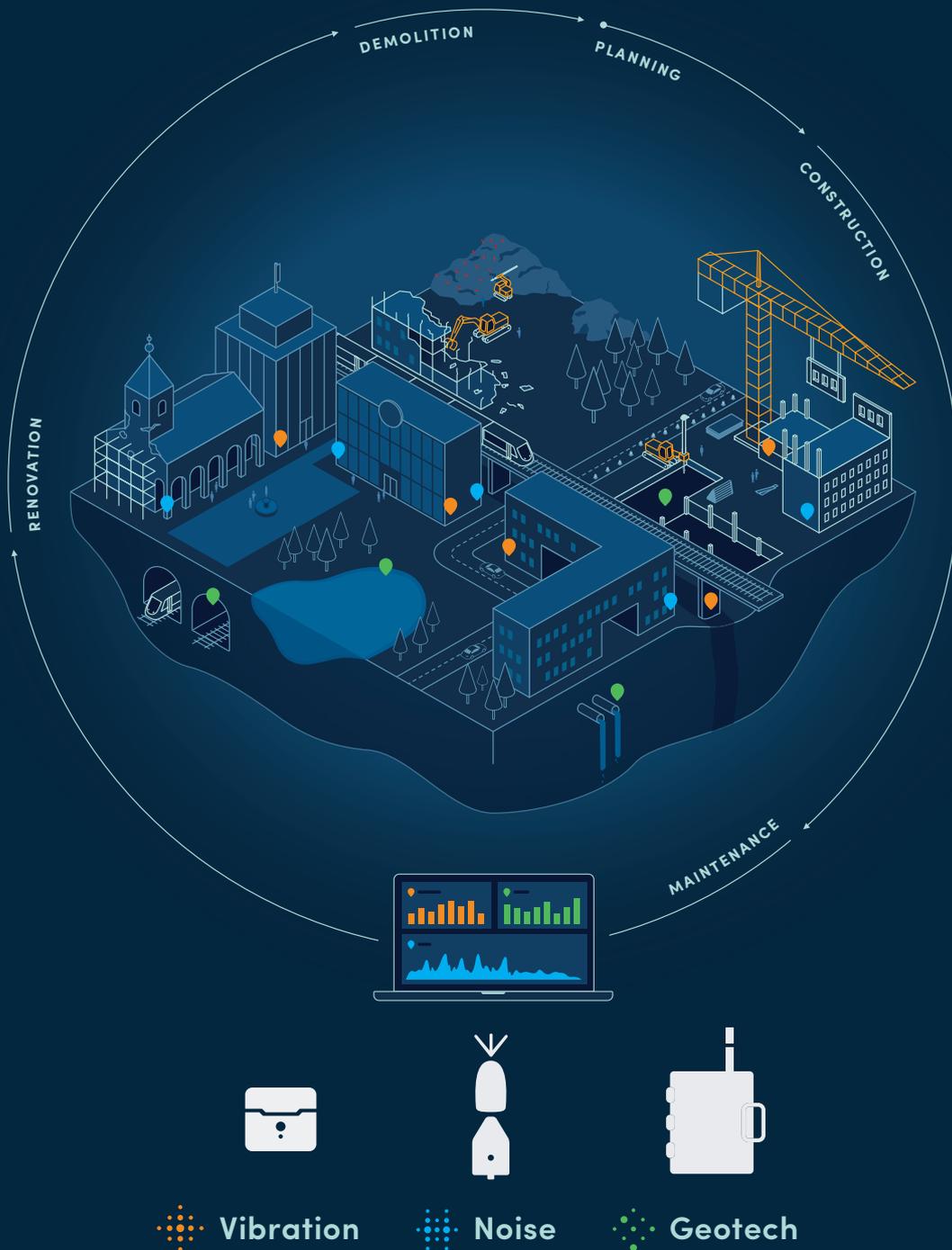
Organisation of the conference was led by EAG chair, Keith Holland (ISVR, University of Southampton), supported by the 10 committee members and the IOA's Linda Canty. A full audio-visual system was provided by EAG

Above:
The conference dinner was held aboard Brunel's S.S. Great Britain

committee member, John Taylor (d&b audiotechnik), along with a number of his associates. d&b audiotechnik have generously supported Reproduced Sound in this manner for a number of years, to the great benefit of the conference.

The conference primarily took place at the Bristol Hotel (Reproduced Sound's second year at this location), with visits to Brunel's S.S. Great Britain and Colston Hall. The delegates numbered nearly 100, representing a good balance between industry and academia. **P22**

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Pre-conference activities

Although the conference wasn't set to officially open until the following morning, Reproduced Sound often includes a special event the evening before the conference, consisting of a more informal talk and demonstration from a member of industry or academia.

This year, the evening session was hosted by Funktion One, led by company founder, Tony Andrews. Tony opened the evening by talking about Funktion One's design philosophy, their view is that speakers should sound good from

their inherent design, not heavily relying on corrective equalisation.

The audience was able to listen to a number of tracks through each of the Funktion One systems that were set up in the room. This began with a compact system consisting of two 5" full range speakers and an 8" subwoofer. The subwoofer performed well for its size, producing bass that could be felt as well as heard. The audience was encouraged to walk around the room as the speakers were auditioned.

The demonstration then moved on to audition a 10" two-way stereo pair

Below:
Prof. Francis Rumsey addresses the conference after receiving the Peter Barnett Memorial Award.

of loudspeakers with an 18" subwoofer, followed by a recently developed, full-range horn-loaded system. Before playing the new system, Tony alluded to the importance of speaker efficiency as part of the design process – a topic later covered in one of the conference papers presented by Funktion One engineer, James Hipperson. Finally, there was a demonstration of two large-format horn-loaded loudspeakers with a single 24" horn-loaded subwoofer. This had no problem shaking the room.

The event was well attended and had the usual convivial Reproduced Sound atmosphere, providing a great opening to the conference.

Conference – day one

The first formal day of the conference was kicked off by EAG chairman, Keith Holland, welcoming delegates and giving them a general background and history of the event, including its organising committee from the EAG. Keith noted that he was particularly pleased to see a good balance between familiar and new Reproduced Sound attendees. This certainly bodes well for the future of this conference.

Peter Barnett Memorial Award – Professor Francis Rumsey

Keith handed over the floor over to IOA president, Professor Barry Gibbs, for the presentation of the Peter Barnett Memorial Award. This award, which is made annually, recognises advancements and technical excellence in the fields of electro-acoustics, speech intelligibility, and education in acoustics and electro-acoustics. The recipient of this year's award was Professor Francis Rumsey for his significant contributions to knowledge and education surrounding the areas of sound quality, spatial audio and psychoacoustics.

After the award presentation, Francis delivered a captivating talk entitled 'Psychoacoustic quality evaluation in the context of interactive sound and virtual reality'. Francis focused his talk on sound quality in regard to emerging virtual/augmented/cross reality formats, stressing that audio quality must be evaluated in respect to how it impacts on the overall (often interactive, multi-modal) experience. **P24**



Safe and sound learning environments

77%
of students
identify noise
as a disturbing
factor

Up to **77%**
of the consonants
spoken by
teachers cannot
be heard by
pupils



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10%
more words are
correctly
identified by
students in
classrooms with
acoustic panels

Ultimately, we need to shift from a focus on quality, to a focus on quality of experience (QoE) when dealing with multi-modal immersive media platforms.

Numerous issues exist with audio quality evaluation, where in many cases the experimenters are evaluating characteristics that normal people don't find important. It has been found that in some cases it is most instructive to let test participants decide what's important (although this may lead to more difficult results analysis). It's also important to note that what listeners do in these evaluations is often more important than what they say.

Ultimately, we need to shift from a focus on quality, to a focus on quality of experience (QoE) when dealing with multi-modal immersive media platforms. In such situations it has been found that audio adequacy

is often more important than audio fidelity, which is quite different from the approach taken by most audio professionals.

Overall, Francis pointed towards a collection of current and future research spanning many different disciplines that is showing promise of resolving current issues with psychoacoustic quality evaluations. Francis' talk was followed by questions and comments from the audience, sparking an engaging discussion, which flowed nicely into the first refreshments break of the day. (A full report of Francis' award was published in the January/February 2020 issue of Acoustics Bulletin).

Session 1 – Room acoustics and measurement (Chair – Paul Malpas)

Acoustic and audio survey of English churches

The first paper of the day was given by Peter Mapp on a recent survey he had conducted on small English churches. The survey was carried out due to the lack of data on such churches, which are commonly found in most small towns and villages. Inspecting data from the 11 churches measured, it was clear that the RT60 characteristics weren't comparable to those of large churches.

In most cases, there were few serious problems identified in terms of the acoustics of the churches (generally around 6-10m³/seat, which is within recommendations, with nave widths of 10-15m). In some cases, surprisingly high STI values were measured in the back row of seating without any sound reinforcement. Problems arose when the sound systems were turned on, where in many cases, the sound reinforcement made intelligibility worse (although it made the STI more even throughout the venue). Additionally, issues were

Below: The 35th annual Reproduced Sound conference was held at the Bristol Hotel



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identified with most assistive listening loop systems tested (generally too low in level with significant mains hum present). Session chair, Paul Malpas, thanked Peter for his “inspiring” talk.

Acoustic design criteria for higher education learning environments

Next on the schedule was a paper given by Sebastian Duran from Solent University. Sebastian spoke about a study that looked into the audio and acoustic performance of five teaching rooms. In most cases, the room measurements were shown to comply with BB93 (although this standard doesn't directly apply to higher education) in terms of STI, sound level and background noise, but nonetheless, were deemed problematic by staff and students (64% of the staff surveyed reported vocal fatigue from teaching in these rooms). While the research pointed to further work required, some general recommendations were suggested, focusing on the need to specify design criteria in relationship to the room volume and use.

Condenser microphones and factors that affect their sound

The final paper of the session was delivered by Hans Riekehof-Böhmer from Schoeps. Hans' presentation was instructive on what influences microphone performance, with an emphasis on practical environments. He stressed the importance of room acoustics and background noise, as well as how essential it is to get the on- and off-axis frequency responses of a microphone to be in agreement (which is easier with small diaphragm microphones). This was highlighted with an instructive comparison of integrated polar responses, which were derived from diffuse field responses of the microphones under test. Supercardioid microphones showed a flat response, indicating they would perform well in most acoustic environments.

Overall, Hans emphasised that a full set of technical information is required to make proper comparisons between microphones, which some manufacturers don't make available. He also noted that non-audio/acoustic-related factors have been shown to influence the perceived sound quality of a microphone (brown microphones

non-audio/acoustic-related factors have been shown to influence the perceived sound quality of a microphone (brown microphones sound the best, green sound the worst).

sound the best, green sound the worst). This specific point caused a very lively discussion in the audience after the paper and carried on into lunch.

Diversity (chair – Mark Bailey)

Prior to the first paper session of the afternoon, Mark Bailey led a discussion on diversity, where the IOA has set out the aim to increase diversity across its membership and for the electroacoustic community in general. Mark (and the rest of the audience) noted that this is a difficult challenge and one which cannot be solved by a single event or organisation. The general consensus was that the key was to provide equality of opportunity, with care taken to avoid unconscious biases whenever possible. It was suggested that reasonable targets should be set (possibly over 10 years) to help the sector move in the right direction. The feeling in the room was that everyone present was supportive of this initiative and would value greater diversification in the workplace.

Session 2 – Signal processing and audio coding (Chair – Glenn Leembruggen)

Optimal source distribution for multiple listener virtual sound imaging

The first paper of the afternoon was presented by Philip Couturier from ISVR, University of Southampton. The primary challenge of this project was to identify the best possible discrete source distribution, based on an approximation of the optimal source distribution for multiple listeners. Philip presented results from simulations using three to five listening location for various loudspeaker layouts. The results indicated that the optimisation

routine showed promise, although there were currently no considerations for room acoustics or head shadowing, which may influence the performance of the system. While some audience members expressed concerns about the practicality of such a system, Philip highlighted the next steps for this research project, which focus on improving the accuracy of the algorithm, making practical implementations more feasible.

HRTF model comparison in inverse filter design for crosstalk cancellation

Jacob Hollebon, also from ISVR, University of Southampton, delivered the next paper, which looked into identifying the best-performing HRTF model for use in crosstalk cancellation. Three types of models were investigated here:

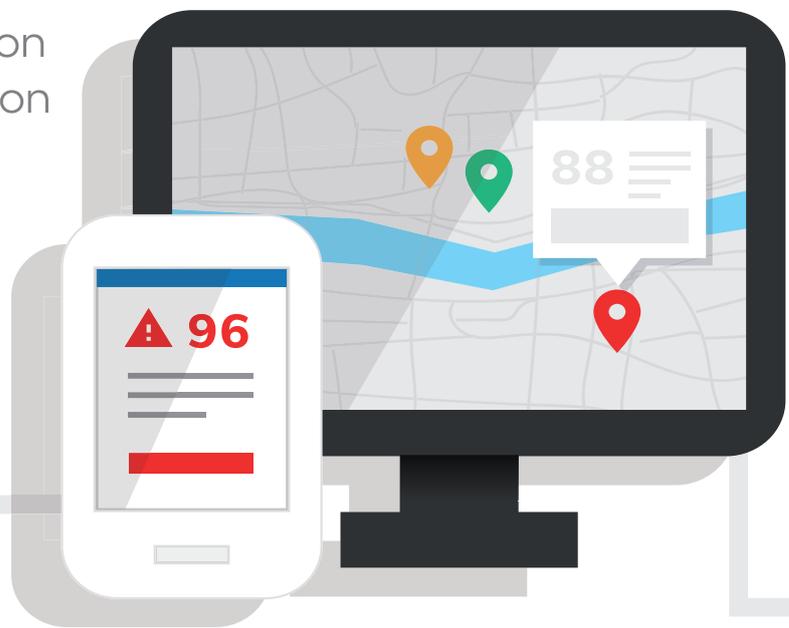
- in-situ;
- free field monopole; and
- rigid sphere.

The in-situ would give perfectly accurate results, with the other two providing imperfect solutions. Since in-situ isn't necessarily practical for everyday use, it was essential to determine if either of the other two models were sufficient for these purposes. The results were best demonstrated with a live auralisation presented to the audience over headphones. All three models were auditioned without the audience being aware which was which. After listening to the three samples, the delegates were polled to determine the favourite. There was a 50/50 split in the audience. Half preferred the in-situ HRTF (which wasn't surprising), while the other half preferred the rigid sphere model, thus giving strong indication that this model may be sufficient for practical applications of crosstalk cancellation. [P28](#)



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Introduction to sparse, or compressive, sampling for audio and acoustics

The third paper of this session was presented by Professor Jamie Angus from the University of Salford. Jamie's paper was in the format of a tutorial, looking into the possibilities of sampling an audio signal below twice the Nyquist frequency, where she stressed that Shannon's sampling theory has terms and conditions and it isn't the only possible method for signal sampling. The key for this so-called sparse sampling is the density of the audio signals. Sparsity of the signal leads to predictability. The term 'innovation' was used to represent the surprise factor of an audio signal, where the rate of innovation defines the required sampling rate. Essentially, the question is what is the minimum number of samples required to explain an observation. Jamie noted that such an approach is regularly used for sampling of images. The key here is to use incoherent sampling, rather than regular sampling, along with a reconstruction optimiser.

Extended-band audio coding exploiting spectral-domain sampling-rate conversion with embedded ultrasonic data

The final paper of the session was delivered by Professor Malcolm Hawksford from the University of Essex. Malcolm described a new audio coding technique that he developed which does away with the need for an anti-aliasing filter and allows for spectral content

above the Nyquist frequency to be embedded in the digital signal. To achieve this, spectral matching was utilised over short audio frames (16-32 samples). 16 bits of the digital signal are dedicated to the audio content below Nyquist (so that the coded audio will be compatible with standard PCM coding for CDs) with an additional eight bits used for the ultrasonic content (which can be scrambled to act as dither within a DAC). Malcolm showed how down sampling using this approach is virtually immune to aliasing distortion due to this spectral matching approach.

Session 3 – Assisted listening (Chair – Robin Cross)

Assistive listening systems in theatres

Ian Rees from Adrian James Acoustics kicked off the next session on assisted listening with a paper looking into the use of assistive listening systems in theatres. Ian highlighted the widespread issue with such systems at present, where it has been found that many people requiring assisted listening systems attend theatre less than they would like due to frustrations stemming from poor sound quality. There are a number of factors contributing to the poor quality sound coming from these systems. Problems stem from inappropriate mixes from the sound desk, poorly positioned microphones, and lack of audience microphones (making users of these systems feel isolated). A simple way to start making these systems more useable is to actually listen to the

system (it is surprising to learn how rarely this actually happens). Ian's presentation sparked a lively discussion from the audience, where various points were made on the practical issues faced with assisted listening systems and some suggestions for possible improvements. The audience agreed, though, that the situation at present is dire.

Quality evaluation of microphones used for lecture capture in universities

The second paper of the session focused on the common issue of poor speech intelligibility on university lecture recordings. The paper was presented by Rodrigo Sanchez-Pizani from London South Bank University. Rodrigo presented the results of tests he and his team carried out looking into how various microphone types and placements impact the quality of lecture recordings. The tests gave unclear results, indicating that there is more to learn in this area. One practical issue that was brought up was that it's currently very difficult to automatically judge sound quality on recordings manually, as most universities generate roughly 36,000 hours of lecture recordings every week. This may open the door for an AI-based solution. There were a number of suggestions from the audience, most coming from university lecturers who have struggled with this issue for a number of years.

Accessible broadcast audio customisation

Lauren Ward from the University of Salford presented the final paper of the session, which was focused on improving accessibility of broadcast audio. Lauren began by highlighting that audio audibility must be acceptable to the average viewers, while accessibility must be acceptable to all viewers. The key to improving accessibility for all appears to be in providing control to each individual user. This ties in nicely with current innovations in broadcast audio surrounding object-based audio. This allows an individual user to create their own personalised mix of the various elements in a programme, putting them back in control rather than someone in a studio deciding what they should hear. While there is still

Below:
Prof. Malcolm Hawksford explains a novel form of audio coding.





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a large amount of work to do, Lauren's experiments have shown that the vast majority of listeners given this control found their viewing experience much more enjoyable. With the predicted rate of hearing impairment in the population looking to accelerate in the coming years/decades, this is an important area to focus on in the world of broadcast audio (and beyond).

Conference reception and dinner

After a short break, the conference resumed aboard Brunel's S.S. Great Britain, which, at one point, was the world's longest passenger ship and the first ship to be constructed of iron that included a screw propeller. The delegates were allowed to explore the ship before a very interesting presentation given by one of the museum staff members about the history of the ship.

Following the presentation, delegates moved down to the first-class dining saloon for the conference dinner. Afterwards, IOA President Barry Gibbs presented Adam Hill from the University of Derby with the IOA Young Persons' Award for Innovation in Acoustical Engineering, sponsored by Cirrus Research (Martin Ellison and Clarke Roberts from Cirrus were on hand for the award presentation). The award was presented to Adam in recognition of his research so far in his career which has aimed to achieve the 'democracy of sound,' giving everyone within a given space the same high-quality listening experience. (A full report of Adam's award was published in the



Above: Lauren Ward explains her research into broadcast audio accessibility.

Below: Conference dinner aboard the S.S. Great Britain.

January/February 2020 issue of Acoustics Bulletin).

Following the award presentation, EAG chair, Keith Holland, formally thanked everyone who made this year's Reproduced Sound possible including: the EAG committee members, specifically John Taylor and d&b audiotechnik for the top-notch audio-visual support, Linda Canty, the staff at the Bristol Hotel and aboard the S.S. Great Britain, and all of the delegates for continuing to support the conference by coming back every year.

After-dinner talk – Jim Griffiths, Vanguardia

Keith then introduced the after-dinner speaker, Jim Griffiths from Vanguardia. Jim delivered a captivating talk on his career spent

managing sound for concerts, festivals and sporting events. He gave a detailed historical overview of how the landscape of the industry has changed over the 40 years that he has been active in the field, highlighting the common challenges he faces at high-profile events in densely populated areas, all punctuated with humorous anecdotes from his experience. Jim also highlighted current developments on both the technological and policy sides of the industry and how these have the potential to positively impact this area of audio and acoustics.

CONFERENCE – DAY TWO
Session 4 – Events and installations
(Chair – Mark Bailey)

Keynote: The Royal Albert Hall – sound of the future

This keynote paper was jointly presented by Steve Jones (d&b audiotechnik), Stephen Stringer (Sandy Brown Associates) and Ollie Jeffery (Royal Albert Hall). Ollie started with the venue's perspective, noting that the RAH goal is to achieve a "life enriching, unforgettable experience". He acknowledged that there had been audio/acoustics issues that had resulted in a poor experience and audience complaints. The goal was not only to address these issues but to go further and to become a "world leader in the quality of sound".

Stephen then gave the consultant's view, outlining some of the past changes to the hall, including acoustical treatments such



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as the famous ‘mushrooms’. Time was taken to speak with stewards on the ground as they were the ones directly hearing complaints if they happened. Out of 382 shows, there were 176 complaints. Almost all of these were for amplified events. In terms of where these were reported, 50% of these (a significant amount) were in the upper levels. Reported issues were speech intelligibility, the sound being muffled and/or unbalanced. The plans for the venue were known to have discrepancies from the actual dimensions. One reported reason was that during construction, the weight of the roof was so significant that it had caused the entire building to twist. In order to obtain a more accurate picture, a laser scan was undertaken.

Steve Jones then gave a perspective from a sound system designer. He covered how d&b had assessed the configuration of the system. Given the dimensions of the building, it was preferable to have speakers slightly lower to give the FOH engineer and audience a good experience. However, this meant that the arrays needed to be angled up, introducing challenges in reaching the upper levels without causing unwanted reflections.

For the array, an LCR solution was decided upon for coverage and flexibility in cinematic use along with a cardioid sub array to avoid unwanted LF build-up. Finally, some delays were added – with great challenges due to the locations of the ‘mushrooms’ not being recorded on the plans and challenges in obtaining permission to drill through Grade I listed plaster.

Ollie came back to note that while they expected 50% of rock shows to

use the system, so far 100% had been happy to do so. He acknowledged that although sound was subjective, the audience response had been positive and that the number of complaints had reduced dramatically. He felt they had achieved their vision.

Effects of low frequency sound on the human condition

The second paper of this session was about an art installation at the Tate Modern and was presented by Richard Grove and Joe McCall of BDP. The installation, entitled ‘10,148,451’, includes a 40kW sub-bass array. Its intention is to “plug straight into the algorithms of fear and anger” of its audience. As part of their evaluation of this exhibit, they measured the system in various locations. This mapped response showed that while some people in the exhibition walked right up to the speaker, it was actually loudest in some other areas of the room, due to room-modes. A short demo was played for the audience to hear – and feel – and indeed the sounds were discomfoting but thankfully, no one showed clear signs of fear or anger. An investigation of what the duration of such exposure might change was noted as something for further work and research.

Sound level monitoring and management at large scale music festivals

Next in this session was Adam Hill from the University of Derby, presenting a case study he conducted at a recent music festival in Chicago. This primarily considered sound exposure to audience

Above left: Steve Jones explains the design of the new Royal Albert Hall system.

Above right: Peter Mapp questions whether there’s a better metric for measuring speech intelligibility.

members, while highlighting the varying regulations across the world. The goal is to do this while maintaining a high-quality listening experience for the audience. Much of the issue is in the LF range – and these levels are quite extreme. At rock concerts, people may be within touching distance of subwoofers capable of 140 dB peak output. At these levels, hearing defenders are largely useless. Adam is part of an AES group working on this, looking to develop a set of recommendations to address these issues of audience sound exposure, where the work is now also being fed into a World Health Organization initiative.

The results of the study showed that if a limit was set, and the mixing engineer could see a level meter, then most engineers mixed to that limit. Other results showed that larger audiences influenced the engineer to mix louder and that a touring engineer would mix louder than one working for the owner of the sound system.

Acoustic design for sport venues and arenas

Oliver Creedy from Vanguardia presented the final paper of the session, about the recently completed Tottenham Hotspur stadium, discussing the requirements for acoustics and sound reinforcement. For Tottenham Hotspur, the brief was that “the atmosphere must be intimidating” and so adding a lot of absorption for the sound reinforcement was not seen as a viable option. Balancing the need for audio performance and speech intelligibility in environments where the RT60 may be around six seconds or more is a notable **P34**

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challenge. Oliver presented some approaches with specific placement of absorption, designed to tackle key reflections rather than RT60 overall. Some auralisations were played to demonstrate the point made.

Session 5 – STI and intelligibility (Chair – Adam Hill)

What would we do if we didn't have STI?

Peter Mapp began the next paper session on speech intelligibility and STI by calling into question whether it would be possible to come up with a new and improved metric to quantify speech intelligibility, expressing that STI should be viewed as a blunt instrument (i.e. it's not very precise).

Peter began by highlighting a number of possible metrics as well as specific acoustic characteristics of a measured signal which are important for intelligibility. He called into question whether 'intelligibility' is the correct term for what we are trying to achieve, suggesting ease of listening, ease or recall, or ease of attention as more accurate descriptors. The term 'engagement' seemed to be appropriate, especially considering Francis Rumsey's talk the day before. All things considered; Peter suggested that we may not be measuring the right thing in this area. Perhaps some form of artificial intelligence including automatic speech recognition would be an appropriate solution? Overall, Peter left the topic open for discussion, but the message was clear — that we shouldn't accept STI as the best solution for quantifying speech intelligibility. The presentation was followed by a lively discussion amongst the delegates.

Another look at the relationship between frequency response and STI

The day didn't get much better for STI, as Glenn Leembruggen from Acoustic Directions presented his paper looking into the effect of frequency response on the metric. Glenn made the point that a number of problems exist with STI when used in noisy and reverberant environments. This was demonstrated by mathematically applying worst-case frequency responses to existing road tunnel measurements. The different

frequency responses didn't significantly alter STI, showing that the metric doesn't adequately consider frequency response, despite this acoustic characteristic being essential for speech intelligibility. This is likely down to the fact that the spectrum of the STI test signal doesn't match the spectrum of individual words in speech. Glenn concluded by echoing Peter Mapp's point from the previous paper, that STI is a blunt instrument and we need to consider alternative approaches for the accurate and efficient quantification of speech intelligibility.

Session 6 – Modelling and auralisation (Chair – Bob Walker)

Modern auralisation routines as design tools

The first paper after lunch was from Wolfgang Ahnert from ADA Acoustic Media Consultants, which looked into the implementation and uses of auralisation within acoustic modelling software. Wolfgang began with a thorough historical overview, spanning physical models through

to modern day computer models. In terms of auralisation, it is essential to include head tracking and HRTFs, otherwise the results won't provide a useful tool for acousticians. Wolfgang then went on to demonstrate an example implementation of auralisation within EASE 5, which now includes that capability of using B-format files and is compatible with virtual reality. While Wolfgang highlighted the current tools available in this area, he stressed that care must be taken to not misuse them. He strongly discouraged auralisation "competitions" during the tender process, pointing out that there can't be such a thing as a perfect comparison in this area.

A simple model for horn coverage angle

Next in the session was Keith Holland from ISVR, University of Southampton, talking about his approach to creating an efficient and compact model of horn coverage angle. To achieve this, Keith took the audience through how it was [P36](#)

Below: EAG Chair, Keith Holland, takes a question from the audience.



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necessary to separately handle the low-, mid- and high-frequency bands. For the mid-frequency range, it was shown that constant directivity can be observed, with more complicated radiation characteristics outside of this band. Measurements of symmetrical horns helped to validate this model, but Keith mentioned that further work was necessary to include the effects of diffraction in the model.

Transparency of binaural auralisation using very high order circular harmonics

The last paper of the modelling and auralisation session was delivered as a joint presentation by Mark Dring and Bruce Wiggins from the University of Derby. The focus of their work was to identify the point when increasing the ambisonics order results in no further perceptual improvement to the reproduced sound within an auralisation. At present, the current standard used is third order. The experiments in this work were based on modelled binaural room impulse responses and investigated ambisonics orders from 1-31. The results clearly indicate that there is no perceptual difference above 20th order

ambisonics, pointing towards a reduced set of BRIRs needed to accurately model an acoustic space for the purpose of auralisation. Further work requires checking these findings with real room measurements to see if the trends are upheld.

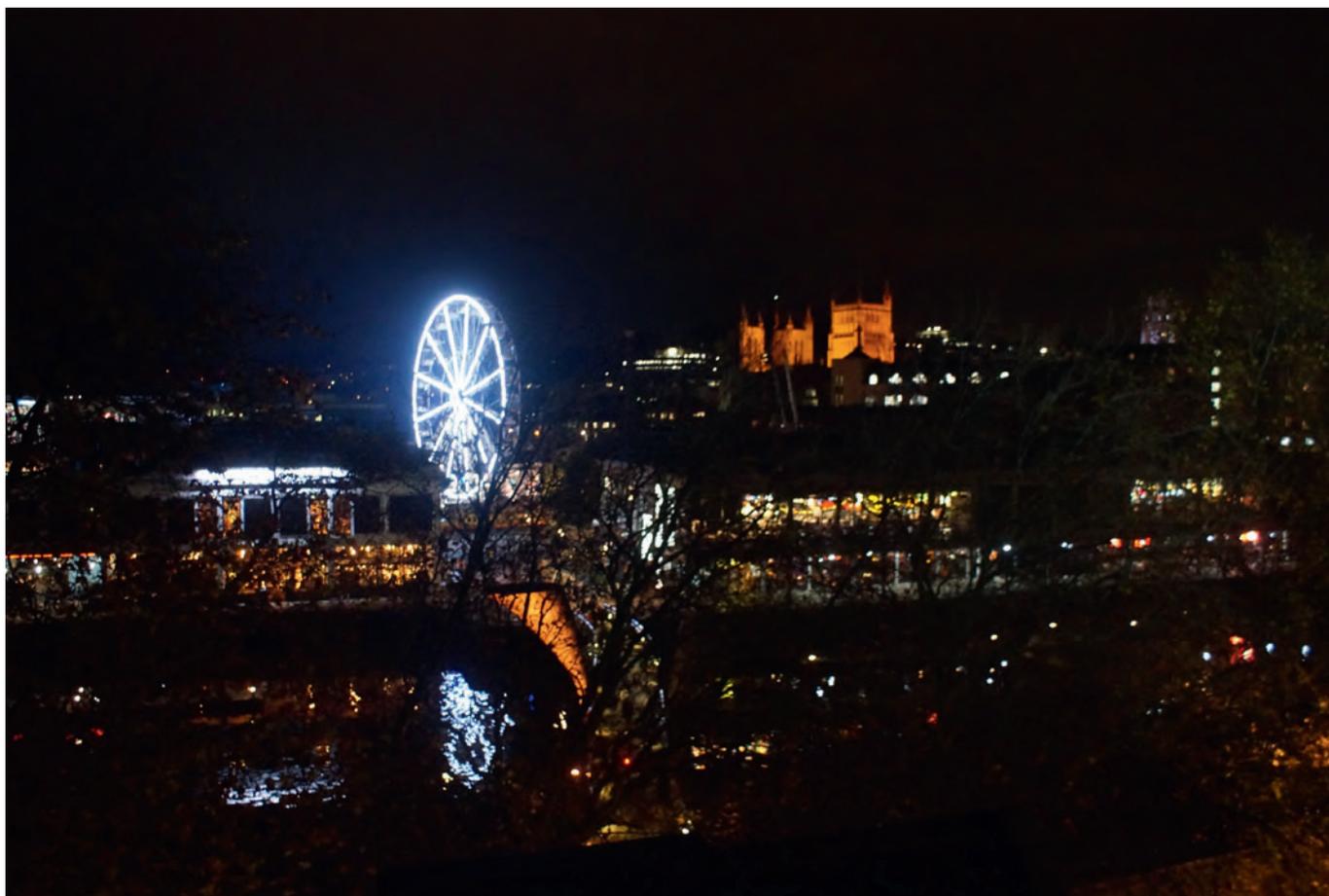
Electroacoustics Group AGM

Prior to the final paper session of the conference, was the annual general meeting of the Electro-Acoustics Group (EAG). This meeting was chaired by Keith Holland and was attended by 27 delegates, including eight EAG committee members. Keith delivered the chairman's report, describing all activities of the group over the past year,

He also noted that Reproduced Sound is one of the rare audio/acoustics conferences that actually has high quality audio.

the central focus being the organisation of this conference. Following the election of officers and confirmation of committee members, IOA President Elect, Stephen Turner, thanked the committee for the great conference and highlighted outreach activities being done at local schools to raise awareness of these fields of work. He also noted that Reproduced Sound is one of the rare audio/acoustics conferences that actually has high quality audio. He expressed an interest in the EAG to disseminate any tips and tricks to other IOA groups. It was noted that the superior audio at the conference is thanks to the ongoing support from John Taylor and d&b audiotechnik. **P38**

Below:
Nighttime view of Bristol from the conference venue.





architectural acoustic finishes

SonaSpray fcx in the Hard Rock Hotel, London.

"Our experience over the years teaches us that architecture & interior design are so much more than just looks. We consider every factor with each project we work on & acoustics is no exception. We knew we needed a premium acoustic product that would also work with our designs, which is why we chose Oscar Acoustics."

David Mason, Director of Scott Brownrigg Architects.



OSCAR
acoustics

Session 7 – Loudspeakers (Chair – John Taylor)

Non-minimum phase behaviour of loudspeaker at low frequencies

The final session of the conference began with a paper from Keith Holland from ISVR, University of Southampton, where the question of why non-minimum phase behaviour is observed in loudspeakers when no such behaviour is predicted by their lumped sum models. This was investigated by creating an extended model of a ported loudspeaker that included the observation point. Using this model, it became clear that the signal from the port arrives at the observation point before the signal from the drive unit. In the measurement, this is observed as an echo which is louder than the direct sound from the drive-unit. This was the cause of the non-minimum phase characteristics, which made it clear why it wasn't turning up in conventional models. To overcome this issue, Keith stressed that the position of the drive-unit and the port must be included in lumped parameter models.

Energy efficiency in sound reinforcement

Fittingly, the final paper of the conference was from the company that started the conference, Funktion One. The paper was presented by James Hipperson where he highlighted the current movement in the live event industry



to limit its carbon footprint. Loudspeaker technology is generally one of the worst offenders in terms of efficiency, where we regularly put in kilowatts of electrical power into loudspeakers in order to generate watts of acoustic power. There are ways to increase a direct radiating loudspeaker's efficiency, such as maximizing Thiele-Small parameters: β , l , S , and d , capturing back-EMF when using Class-D amplifiers or, quite-simply, using a horn.

James showed a recent example from his work where 24 horn-loaded subwoofers were driven at concert levels while the three amplifiers only drew 9A, representing a significant increase in efficiency over what a direct-radiator equipped system could supply. James concluded by emphasising that we must strive to

increase efficiency of all technology, loudspeakers included, which is why he (and Funktion One) believe horn-loaded loudspeakers are the way forward.

Conference close

EAG chair, Keith Holland, closed the formal proceedings of Reproduced Sound 2019, by thanking all those who were involved with the organisation and running of the event as well as the delegates for attending.

Post-conference activities

Another tradition of the Reproduced Sound conference is to arrange for an off-site visit to a local venue, museum or university after the formal proceedings of the conference have concluded. This year's visit was to Colston Hall in Bristol.

Despite it not being possible to view the auditorium because it was covered with scaffolding, the evening was highly enjoyable to those who attended. Nick Craney from Colston Hall opened the proceedings with a short history of the hall and an explanation that sound quality has been prioritised over architectural considerations.

Joe Stansfield from theatre consultant, Charcoal Blue, talked about the electroacoustic considerations and the issues of future-proofing the infrastructure. The evening was rounded off by Bob Essert from acoustic consultancy, Sound Space Vision, who explained his design for the auditorium acoustics. Numerous pictures of the hall, past and present, were shown followed by a lively question and answer session. ©

Above: Conference delegates on the visit to Colston Hall.

Below: A full audio-visual system was provided by EAG committee member, John Taylor (d&b audiotechnik)

