SOUND AND VIBRATION NEWS

WAVES

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SONY: GREAT MINDS THINK ALIKE

EFFECTIVE COMMUNICATION BY ONE AND ALL

FUSING FORM AND FUNCTION IN HOME THEATRES

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CONTENTS

Shaking up the status quo **12**

Striving for effective communication by one and all **08**

75 years of progress **24**

Testing for clarity **26**

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FRONT COVER IMAGE
High-frequency HATS Type 5128

Brüel & Kjær
BEYOND MEASURE

LETTER FROM OUR PRESIDENT

WELCOME TO BEYOND TOMORROW

On 4 December 2017, we celebrate our 75th anniversary. It's exciting to approach this significant milestone, and I'm proud to represent a company that has led the sound and vibration industry for the past 75 years and that is widely recognized for its achievements.

Our ambition is to continue to lead the way in the field of sound and vibration. As we get ready to celebrate our anniversary, it's a very good opportunity to look forward and to think about how we can continue to be innovative and pioneering – at the forefront of progress. With this in mind, we have initiated, together with the Copenhagen Institute for Futures Studies, the Beyond Tomorrow project.

The Beyond Tomorrow project is a vision study, looking towards the year 2030 at the future of product development and the role that sound and vibration plays. How are companies planning for their product development in the future, and what do they see as vital to continue developing products? We are identifying some key trends and asking an expert panel of leaders in product development to help us develop a vision report containing realistic business scenarios. To read more about the project, please visit www.beyondtomorrow.dk.

I know that many of our Waves readers are heavily involved in product development and are helping to shape the future, with an interest in being forward-thinking and visionary. We are privileged that many of you take the time to share your knowledge and insights with us. In this issue of Waves, you will find articles covering a range of interesting topics, from helping children with communication disorders to independent test houses testing packaging construction, as well as some perspectives on testing in the telecom/audio industry.

We are excited about looking forward – towards the next 75 years – and helping to set the agenda of tomorrow. Enjoy reading!

SØREN HOLST
PRESIDENT

FUSING FORM AND FUNCTION

Keith Yates and his team have been engineering purpose-built director screening rooms and private theatres for 26 years, serving an international client base that ranges from well known directors, to private, unknown movie lovers.

> "IT'S NOT JUST ABOUT THE THINGS THAT ELEVATE THE YOU-ARE-THERE EXPERIENCE, IT'S ALSO ABOUT TACKLING THE DOZENS OF THINGS CONSPIRING TO DIMINISH OR PREVENT IT."
>
> MARK GLAZIER, DIRECTOR OF BUSINESS DEVELOPMENT

Keith Yates Design (KYD) works with each client to create spaces where acoustics, architecture, indoor air quality (IAQ) and light control are optimized in an aesthetically designed room you actually want in your home – not sacrificing function for form or vice versa, but creating an environment where they exist together in harmony.

KYD does not sell or install A/V equipment, their involvement ranges from basic architectural, acoustic, electroacoustic and audiovisual layout design in their Essentials package, to comprehensive computer modelling and optimization in their Red projects, to all-out theatre experience that pushes the state-of-the-art boundaries in their Black Label projects. And the venue they designed for Rob Hahn, a retired cinematographer, has become a poster child for their Black Label program.

THE HAHN THEATRE CONCEPT

All KYD projects begin with the mandate to maximize sonic and visual signal-to-noise ratios. As a frame of reference (using noise criteria, balanced (NCB) curves as measurement standards), the Essentials package specifies NCB 15, the same background noise level as major recording studios; Red specifies NCB 10; and Black Label specifies NCB 5 but aims for NCB 0 or less.

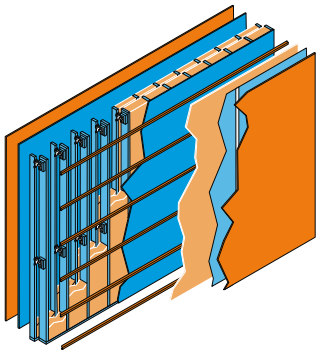
Then additional customer requirements are added in. The Hahn theatre, for example, is sandwiched between two potentially intrusive low-frequency noise sources: garage door motor and vehicle rumble below, and a huge heating, ventilation and air conditioning (HVAC) system in the attic above.

Aside from noise coming into the theatre, the deep bass had to be prevented from escaping into the master bedroom just 18 feet away, where his wife wanted to sleep without disturbance even during *War of the Worlds* or *Apocalypse Now* at theatrical levels. This was particularly difficult given KYD's proprietary UberSub system that can generate thuds and infrasonic rumbles at 125 – 133 dB, well below 10 Hz.

HVAC – COZY AND … CLEAN?

The HVAC system design goes beyond simply maintaining a comfortable temperature and humidity levels. The currents, velocity field, thermal gradients, and air 'aging' are modelled in-house in computational fluid dynamics (CFD) software to comply with their IAQ standards and ensure that breathing-related carbon dioxide and other human 'bio-effluents' are quickly moved away from the audience. This is particularly important in private theatres because they are typically tightly sealed to prevent noise transmission; are stuffed with soft, volatile organic compound- (VOC-) emitting materials; have high occupant densities; and lack windows or sunlight to inhibit microbial growth. Yates quips that "too many home theatres amount to a large, expensive Petri dish with a loud TV." In Black Label projects, the target is 7 to 10 HEPA-filtered air changes per hour, with fresh, outside air accounting for 30 – 50 percent of that air volume. ▶

FUSING FUNCTION AND FORM



Specification for one of the twelve different wall types

Two-microphone coherent power measurement technique set-up

NOISE FLOOR AND ROOM ACOUSTICS

Once the Hahn theatre concept and layout were approved, the 3D model was brought into finite element and various acoustic simulation packages. The isolated room envelope was tuned, detailed, dimensioned and issued as a stack of construction drawings. The blueprints are very detailed and specific, and they need to be. To isolate the theatre from garage rumble below, the structure had to support a six-inch-thick concrete pan deck, two inches of isolation material, then a floating three-inch-thick reinforced concrete floor, upon which the theatre's interior shell rests. Twelve different wall types, each with different acoustical properties, were specified, detailed, installed and tested. Two sets of massive tandem doors function as sound and lightlocks rather than just doors.

Of course, there is the testing to ensure that the room reaches its target levels. Initially they used a Brüel & Kjær 1-inch low-noise microphone for measuring ultra-low sound pressure levels. With it they were capable of measuring down to NCB –1 (the hearing threshold), at which point the microphone was limited by its own self-noise. Recently, however, a new measurement method (the two-microphone coherent power measurement technique has been developed. Yates and his team returned and used that method with two Type 4179 microphones. They measured the Hahn theatre at NCB –6 with the HVAC on high.

The room's isolation and acoustics were checked throughout the construction process, including a Brüel & Kjær Type 3207 tapping machine for vibration from above. With the room shell built, a complex array of acoustic treatments was installed to ensure that the audience received the intended spectrum of reflected sound from the intended places at the intended times.

SIGNAL-TO-NOISE RATIO

Achieving the signal-to-noise ratio specification requires a multidisciplinary approach that includes:

- Extremely low noise floor (NCB as the measurement standard)
- Isolated room-within-a-room design
- Extensive absorptive and diffusive acoustic treatments to foster high signal clarity and speech intelligibility across the full range of human hearing
- Careful attention to speaker radiation patterns and locations
- Rigorous testing protocols to ensure that performance goals are met throughout the construction process

Mr HATS watching *Mannequin*?

WHAT DO YOU GET?

What is the result when the primary noise concerns are now coming from the lights? You get the movie's deepest infrasonic vibrations, clarity, speech intelligibility, listener envelopment and more that lead to immersive experiences. This brings the audience into the movie, and that inspires passion for the art. Imagine *Das Boot*, an entire crew trapped in a sub, where they all stop, listening, straining to hear a destroyer above, and in that stillness, holding your breath, the only sound you hear is your own heart beating anxiously along with theirs.

> "IF THE ROOM'S ACOUSTIC TREATMENT SCHEME DOESN'T TARGET THE RANGE FROM ABOUT MIDDLE-C DOWN TO AT LEAST THE 31 HZ BAND, YOU GET A MUDDLED, OPAQUE MESS … – IMMERSION ISN'T JUST ABOUT LOUD."
>
> KEITH YATES, FOUNDER AND PRINCIPAL PROJECT DESIGNER, KEITH YATES DESIGN

Backlights showcase the speakers behind the acoustically transparent materials

STRIVING FOR EFFECTIVE COMMUNICATION BY ONE AND ALL

The All India Institute of Speech and Hearing develops methods for assessing and rehabilitating people with communication disorders across India.

We humans are bestowed with five senses: sight, hearing, taste, smell and touch. What we feel or experience, we express or communicate. But not everyone is fortunate enough to communicate, and it takes a lot of effort to serve people suffering with communication disorders. The All India Institute of Speech and Hearing (AIISH), a national institute under the Ministry of Health and Family Welfare, Govt. of India, is an institution that has been relentlessly working towards the betterment of lives for more than 52 years. During this time, AIISH has established itself as a world-class institute for human resource development, conducting need-based research, striving for excellence in clinical services, and creating awareness and public education in the field of communication disorders. From April 2016 to March 2017, the institute assessed 70,000 people for communication disorders. Recognized as a centre of excellence in deafness by the World Health Organization (WHO), the institute includes speech, language, hearing sciences and disorders as its main areas of research.

BY: **DR AJISH K. ABRAHAM**
Professor of Electronics and Acoustics
Head, Dept. of Electronics
All India Institute of Speech and Hearing

EARLY IDENTIFICATION OF COMMUNICATION DISORDERS

The communication of a newborn begins at birth through interacting with the mother. Infants receive inputs for language development through child-parent interactions, which require a perfect speech production system and a normal hearing mechanism. Articulation conveys meanings, thoughts, ideas, concepts and attitudes through sounds, words, phrases and sentences and forms the most important activity in speech production. Phonology refers to the adjustments made in the speech production mechanism that result in different speech sounds. Defects in these processes lead to articulatory and phonologic disorders and are treatable if they are identified at an early stage. Infant screening is an important activity at AIISH, where infants at a high risk for communication disorders are identified. 55,000 newborns were screened by clinicians at AIISH between April 2016 and March 2017. The otoacoustic emission (OAE) test has been in use to identify infants with hearing disorders, whereas no such objective tests were previously available to identify those with speech disorders.

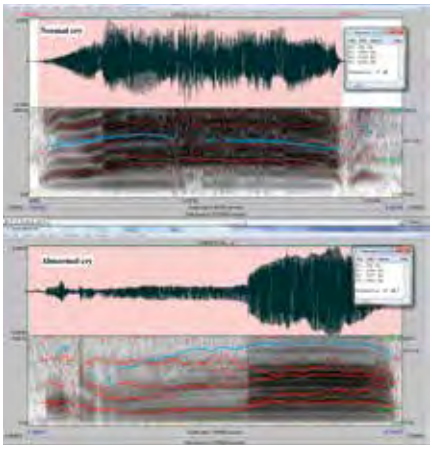
I-CRY – A MILESTONE IN INFANT SCREENING

A team of researchers led by Dr N. Sreedevi at AIISH recently developed a tool for infant cry analysis that has the potential to be used as a screening tool to identify infants with a risk of speech disorders. A cry is an infant´s first verbal communication and is a product of the respiratory and phonatory systems. The tool developed at AIISH, called i-cry, records and measures the cries of healthy and high-risk newborns. Recording is done using an Olympus LS-100 Multi-track Linear PCM Recorder at 48 kS/s, positioned in front of each new born with an external directional microphone placed 10 cm away from the newborn's mouth.

Fifteen seconds of the recorded cries are measured on twenty acoustic parameters including duration of the cry, fundamental and formant frequencies, noise-related parameters, number of pulses, number of periods, number of voice breaks and degree of voice breaks. Using PULSE Reflex™ analysis software, the values of the parameters are estimated from the time domain waveform and spectrogram of the recorded cries. The values obtained are then compared with the normative values and the cry of high-risk newborns are identified. The aim of the screening tool is to aid in early detection of any pathological conditions the infant is susceptible to and to facilitate further investigations leading to early rehabilitation of such high-risk infants.

HELPING CHILDREN WITH CLEFT LIP AND PALATE

One in 700 children born in the world has a cleft lip and one in 2,000 children has a cleft palate. The speech of people with cleft lip and palate (CLP) is often unintelligible and they often face difficulty in communicating with others. Surgery along with several sessions of speech and language therapy helps them to overcome this problem to a large extent. However, it is a time-consuming process and improvement in intelligibility is measured subjectively by speech-language pathologists. ▶



Comparison of normal and abnormal cries

STRIVING FOR EFFECTIVE COMMUNICATION BY ONE AND ALL

Dr N. Sreedevi at AIISH led the recent development of i-cry – a tool for infant cry analysis

There is a lack of experts in this field and this leads to difficulty in appropriately assessing, at adequate intervals, the rehabilitation of people with CLP, even those who have undergone early surgical intervention.

The assessment of speech in people with CLP typically involves using perceptual, acoustic, and aerodynamic methods and estimating the correlation among these. This approach is either manual or semi-automatic and is, therefore, time consuming. Nasospeech, another research activity being conducted by a team led by myself at AIISH, in collaboration with the team led by Prof. S.R.M. Prasanna at the Indian Institute of Technology, Guwahatti, is a solution to this issue. Nasospeech is a computer-assisted diagnostic system for assessing the severity of the speech disorder. Speech samples of the person with CLP are acquired by the computer through its microphone. Nasospeech software analyzes these samples and derives various acoustic and aerodynamic parameters. The values of these parameters are compared with the values of normal speech, and severity is graded based on the extent of deviation.

The scope of the Nasospeech project includes developing a method to automate the assessment process, which would result in a faster and more accurate assessment. This will help professionals involved in the assessment and rehabilitation of people with CLP, such as speech pathologists, plastic surgeons and maxillofacial surgeons. This will also help people with CLP, as well as their caregivers, to take advantage of fast and efficient services that will further enhance their quality of life. According to Dr M. Pushpavathi, an experienced speech-language pathologist, the results at the end of the first phase look very encouraging.

CORRECTION OF MISARTICULATED SOUND

Articulation disorders are commonly found in children with hearing impairment, cerebral palsy, cognitive impairment, CLP and in adults as an after-effect of stroke and accidents. Articulation therapy is a systematic procedure in which a misarticulated sound is corrected at various levels by speech-language pathologists. However, there is lack of trained rehabilitation professionals leading to scarcity of rehabilitation services.

Articulate+, another ongoing research project, which I am coordinating at AIISH, addresses this issue and aims to develop an automated system for articulation assessment and therapy at the level of phonemes, words, phrases and sentences in Hindi and English. Speech samples of the person with articulation disorders are acquired by the computer through its microphone. Then recognition of disordered speech is done using automatic speech recognition. Suitable features are extracted from the normal as well as disordered speech. Dynamic time warping (DTW) matching is then used to match phonemes in normal speech with

Dr Ajish K Abraham, is a professor of electronics and acoustics at AIISH who specializes in acoustic analysis of defective speech, and electroacoustics. As head of the Dept. of Electronics, it is his mandate to develop automated tools and processes that will result in early identification of people with communication disorders and their effective rehabilitation.

The full AIISH team

A state-of-the-art acoustics laboratory equipped with Brüel & Kjær´s PULSE™ multi-analysis system, electracoustic test system, head and torso simulator (HATS), artificial ear and mastoid and hand-held analyzers with sound recording software provides the major infrastructure to support the research activities of Dr Abraham

corresponding phonemes in disordered speech to find a measure of similarity.

The collaborative research team, led by Prof S.R.M. Prasanna of the Indian Institute of Technology, Guwahatti and AIISH, visualizes that Articulate+ will help speech pathologists, special educators and caregivers of people with communication disorders. Using Articulate+, people with articulation disorders could take advantage of fast and efficient rehabilitation services, which will further enhance their quality of life.

BRINGING THE SMILES BACK

As humans, our ability to communicate is essential to our quality of life – no matter who we are or where we come from. Particularly in rural India, communication disorders are very prevalent. Although there are many speech professionals working to help people with communication disorders, there is generally a lack of acoustic research and clinical tools to do this optimally. AIISH is working hard to change this with applied research that impacts the hearts and lives of people with communication disorders. From identifying communication disorders in newborns to helping assess and rehabilitate people suffering with CLP, and helping rehabilitate children with articulation disorders, the tools from Brüel & Kjær have proven essential to this endeavour. The team at AIISH will continuously explore these tools as they work towards their goal of 'promoting quality of life for people with communication disorders'.

"THE V8900 IS EXPANDING THE POSSIBILITIES OF THE PACONSULT GROUP AND IS THE CORE OF OUR LABORATORY IN BERLIN."

INGO HENNIG,
CUSTOMER SERVICE MANAGER, PACONSULT

TESTING EVOLUTION
SHAKING UP THE STATUS QUO

For over 15 years, PAConsult – with laboratories in Germany and Switzerland – has been providing high-quality support and independent test house services. It offers environmental simulation tests on container prototype units as well as transport simulation for packaging systems.

Over the years, since PAConsult tested their first payload, the overall mass and dimensions of packaging systems and the prototypes that need to be tested have increased considerably. Increasingly, customers want their prototypes to be tested in the development phase to ensure that they pass certification tests the first time through. And these trends continue, spurring increased expectations for test equipment performance and the quality of the results. Additionally, this means that entire test systems and real-life assembly test scenarios need to be re-evaluated in order to accommodate the increased dimensions and allowable forces. In plain terms, the capabilities of test equipment must not only be able to reliably handle the mass of the payloads, but also be able to accommodate tall and massive structures under the force loads required to properly test the structure and provide quality results. ▶

"OVER THE YEARS WE HAVE RECEIVED MORE COMPLEX PAYLOADS FOR VIBRATION AND SHOCK TESTS. IN GENERAL WE SEE AN INCREASE IN REQUESTS FOR COMPLEX AND INTERBRANCH TESTS THAT ADDRESS THE CONCERNS OF A VARIETY OF INDUSTRIES."

INGO HENNIG,
CUSTOMER SERVICE MANAGER, PACONSULT

TESTING EVOLUTION
SHAKING UP THE STATUS QUO

These trends are industry wide and particularly visible in the areas of packaging and prototypes. The frequency of testing packaging systems with increased volume and mass has increased considerably. Most industries that are involved in shipping goods (such as specialized shipping companies, automotive suppliers and medical equipment manufacturers and suppliers) have recognized the need for more stringent testing requirements because of data obtained from transport simulation. More frequently, their packaging systems are being tested for mechanical and climatic resistance according to International Safe Transit Association (ISTA) and ASTM International standards.

IN THE MOMENT

To accommodate the trend of increasing test specifications, PAConsult invested in the LDS V8900 shaker. The primary benefits of this addition were the increased force capabilities (80 kN, almost twice their previous test limit) and the high overturning moment restraint. Some commonly tested objects include control cabinets, switchgears and packaging systems based on euro pallets that can be more than two-metres tall. The high overturning moment restraint is particularly beneficial when testing these objects.

The integrated hydrostatic bearing, which is integral to the high overturning moment restraint, also provides other benefits. This stability makes it easy to work with the shaker and quickly switch out various head expanders and attachments, such as driver bars that connect the shaker and slip table together in the horizontal position so that payloads with large footprints, or standing surfaces, can be tested.

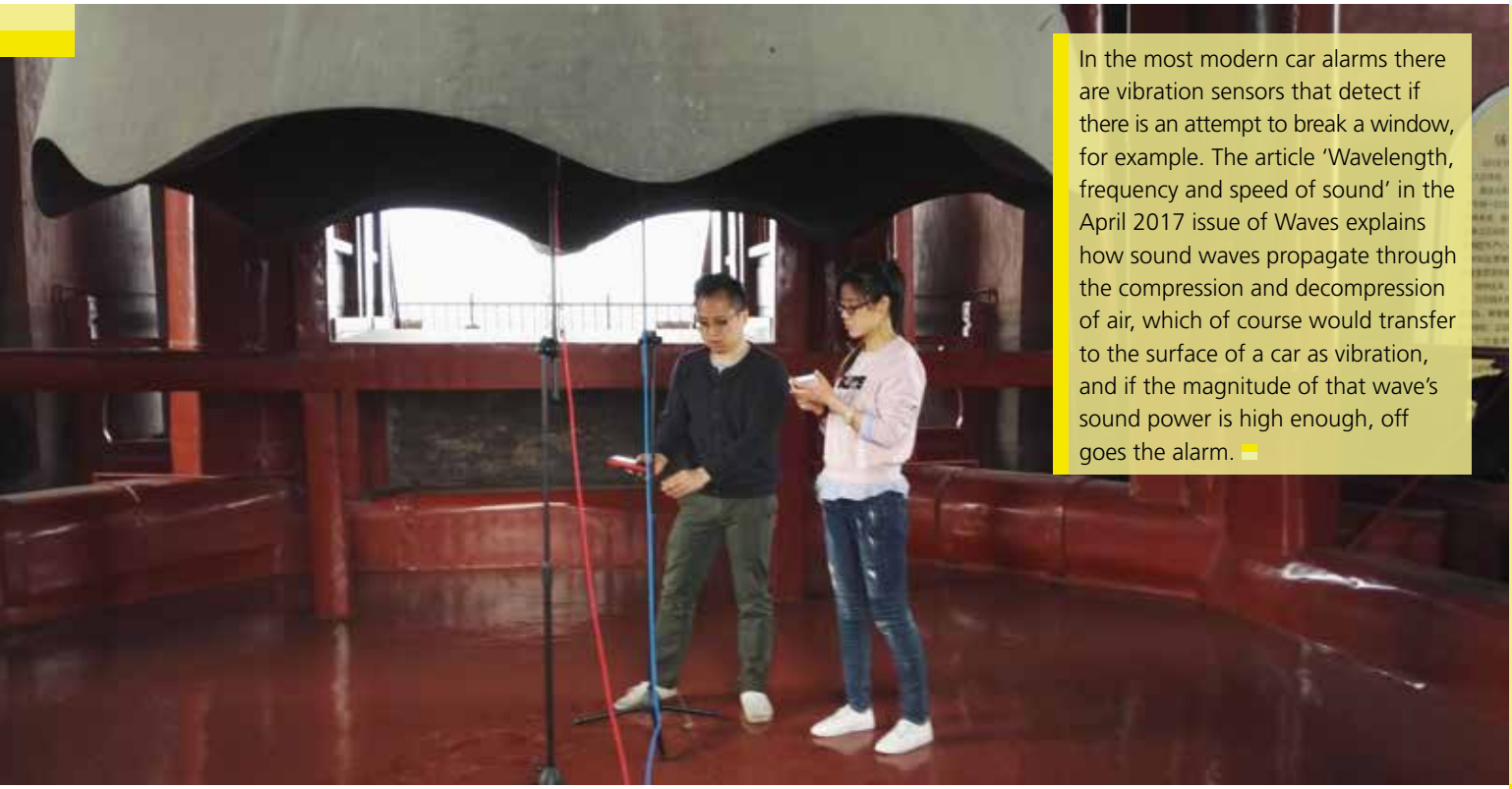
Another very beneficial aspect is how easily the shaker can be modified. The sub-systems interact smoothly and easily, and that results in reduced time between test configurations. The amount of time needed to change the shaker set-up from the z-axis test configuration to the x/y-axis test configuration can be managed by one operator in under 30 minutes, and changing back to the z-axis configuration can be done in under 10 minutes. This reduces the amount of time taken for each test and ultimately reduces the cost to the customer.

WHAT TRENDS MAY COME

Only six months after incorporating the new shaker, the expanded test capabilities have become indispensable. The system's increased force capacity and overturning moment restraint enable tests that customers need and that can currently only be performed by a few independent test laboratories. The speed with which these test capabilities became indispensable demonstrates the need for testing equipment to keep pace with market trends or, better still, stay ahead of the game. Because as market trends generate larger payloads with greater mass, more robust and protective packaging requirements and newer standards, testing must evolve as well.

> "THE TESTING SPECIFICATIONS, FOR WHICH A SHAKER LIKE THE V8900 IS NECESSARY, ARE RAPIDLY BECOMING STANDARD."
>
> INGO HENNIG,
> CUSTOMER SERVICE MANAGER, PACONSULT

BEIJING'S BIG BELL RINGS – LOUDLY

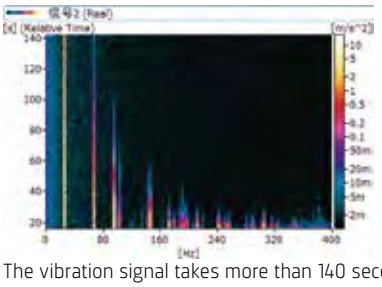


In the most modern car alarms there are vibration sensors that detect if there is an attempt to break a window, for example. The article 'Wavelength, frequency and speed of sound' in the April 2017 issue of Waves explains how sound waves propagate through the compression and decompression of air, which of course would transfer to the surface of a car as vibration, and if the magnitude of that wave's sound power is high enough, off goes the alarm.

The 'King of Ancient Bells' is 7 m high, 3.4 m in diameter and weighs 63 tons

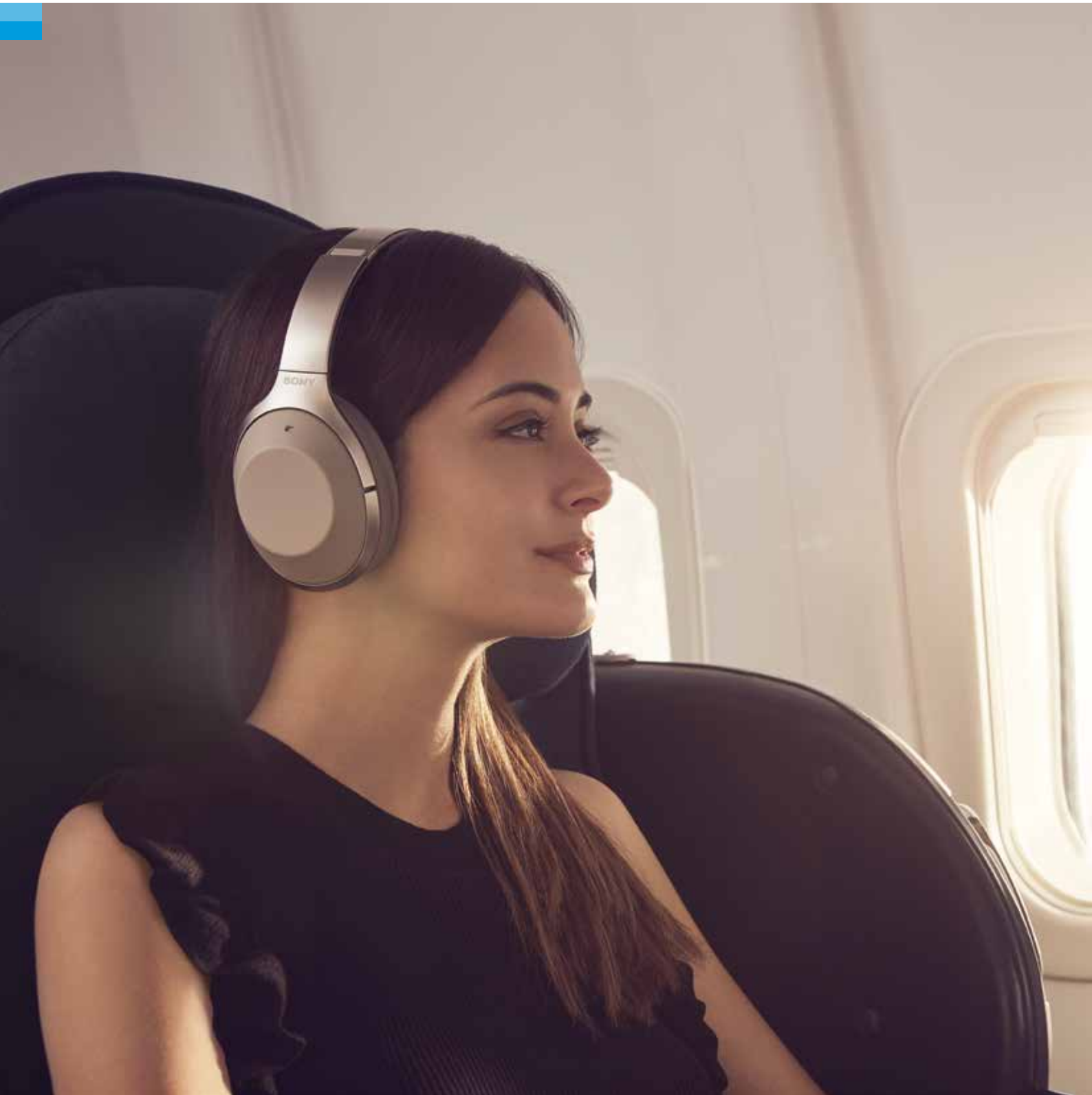
Beijing's Bell Tower and Drum Tower were used to mark time from the 13th century until 1924. The Bell Tower, which could be heard over 20 kilometres away and heralded the morning and opening of the city gates, remained silent until 1990 when it was struck on New Year's Eve to mark the new year. And the great bell has rung again each New Year's Eve, resuming its timekeeping duties.

Professor Yang Yang from Shanxi University's Music Department sought to apply modern acoustic theory to ancient structures. Brüel & Kjær's Liangwei Shen and Ang Li then attempted to capture the sound and vibration qualities of the bell and analyze the room acoustics. Capturing the vibration data of the bell was successful. But the bell's sound power was of such a magnitude that it triggered nearby car alarms, thereby polluting the sound data.



The vibration signal takes more than 140 seconds before decaying, shown by the FFT vs time and total slice, which shows the most prominent tone to be around 26 Hz. Beating frequencies were also found when the bell was vibrating

GREAT MINDS **THINK ALIKE**



SONY

When product development presents you with a challenge you can be sure you're not the only one facing it.

Sony Corporation has always been a pioneer in the design of audio equipment, and its most recent development direction is in Hi-Res audio. It has long been claimed by some audiophiles that digital audio lacks some of the nuances of high-quality, vinyl recordings. Since standard digital-CD-quality audio covers the full audible frequency range, the assumption is that the difference is due to artefacts from the interference of ultrasonic harmonics in the recordings. Hi-Res audio is loosely defined as having a higher sample rate than the standard CD, 44.1 kHz, and/or a higher digital representation than 16-bit.

Early in the new millennium, Sony engineers became convinced of the value of Hi-Res audio; not just for improved clarity and definition of audio reproduction but also for more precise positioning of sounds in binaural space. Research has shown that humans can detect time differences down to five microseconds. This is a key driver for the positioning of audio objects in virtual soundscapes for gaming, music performance reproduction or engineering purposes, as well as improving the quality of the reproduction.

Naotaka Tsunoda has been developing headphones at Sony since his graduation in 1991. His passion for developing the ultimate headphone driver unit combined with his position as Deputy General Manager for Acoustic Technology, Headphones resulted in the design of the ultra-high-end Qualia 010 headphones in 2004. His drive for perfection led him to challenge the tools available for evaluating his product designs. "Early on in our development work, we realized that the Brüel & Kjær head and torso simulator (HATS) we were using was too limited in frequency range and too simplistic in ear canal geometry for accurate measurements in the areas we were trying to optimize – up to 100 kHz and beyond," says Tsunoda. "So, in 2014, we started our own research into how the tools could be improved to achieve the precision we needed."

FINDING THE GOLDEN MIDDLE WAY

The Sony team mapped out the parameters they considered had the most influence on the accurate measurement of human response to sound. Tsunoda continues, "At the frequencies we're working with, the geometry of the human head, in particular the ear pinna and canal, have an immense impact on the accuracy of the measurements, and the biggest challenge is that there are huge differences in the shapes of human heads and especially ear pinnas. We have to find an average or mean geometry that is the best compromise, but if the spread of the variations is too wide, then the measurements made with the average will be meaningless to large parts of the population."

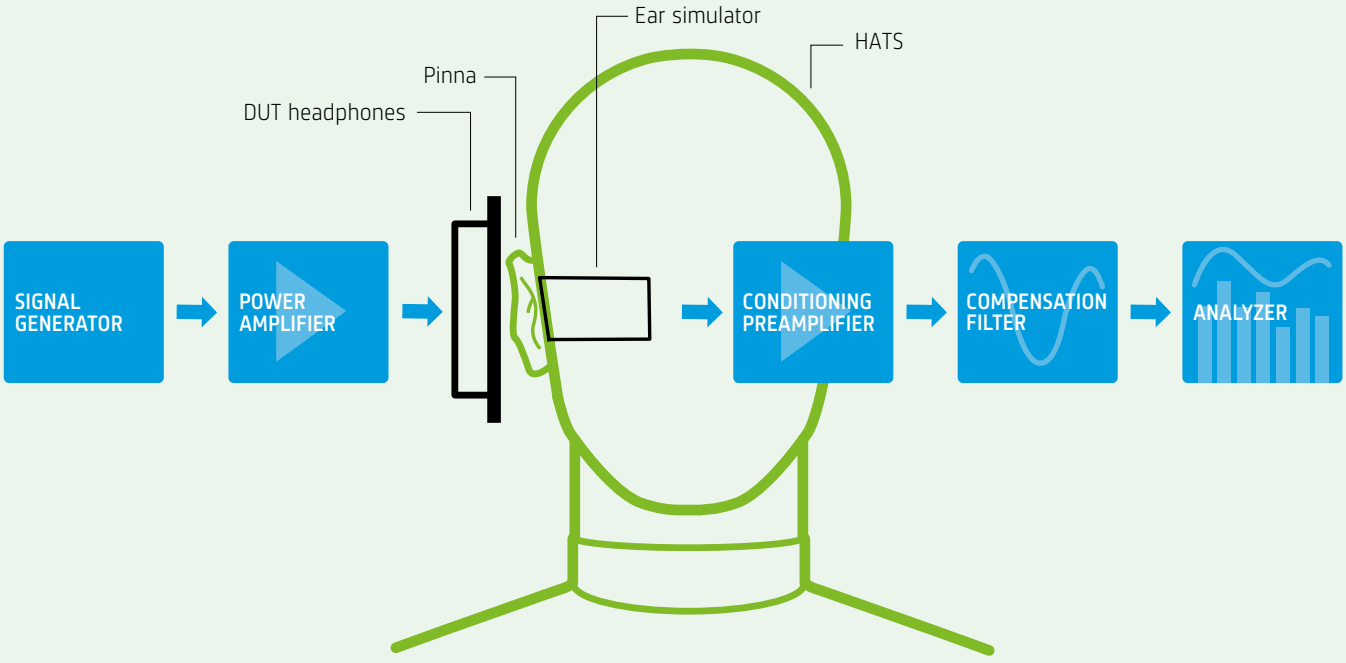
Having reviewed the published data on the subject, the team decided they needed to do their own research on head and ear geometry. Of primary importance was the geometry of the ear canal. To obtain an accurate geometric model, Sony measured several human ear canals using an MRI scanner. They also measured a range of human pinnas and averaged the results to get a mean geometry. Using this data, they used 3D-printer technology to build a human ear simulator to replace the ear simulator and pinna in a standard HATS Type 4128. ▶

> "IT'S OBVIOUSLY BETTER WHEN WE CAN LEVERAGE THE KNOWLEDGE OF OTHERS AND ADD IT TO OUR OWN EXPERIENCE TO REACH A GOAL FASTER."
>
> NAOTAKA TSUNODA
> DEPUTY GENERAL MANAGER
> FOR ACOUSTIC TECHNOLOGY,
> HEADPHONES, SONY

GREAT MINDS
THINK ALIKE

Team members Naotaka Tsunoda, Takeshi Hara, Koji Nageno and HATS

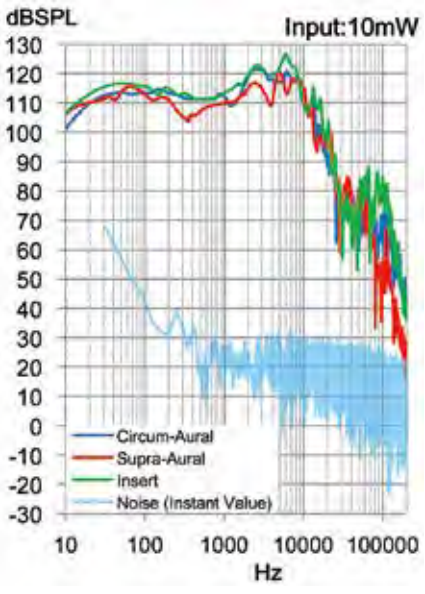
MEASUREMENT SYSTEM



EXPERIMENTAL REDESIGNS

The next challenge was to optimize the measurement system. To try to get close to duplicating the human ear experience, they knew they had to measure close to the ear drum location in the desired frequency range. The microphone in a standard Brüel & Kjær HATS has a frequency range limited to 20 kHz and a half-inch diameter. So, they decided to replace it with a Brüel & Kjær Type 4138 microphone, with a measurement range up to 140 kHz and an eighth-inch diameter, positioned at the location of the ear drum in the manufactured ear canal.

Tests on this configuration showed improved response over the standard HATS at higher frequencies and good correlation at lower frequencies for



HATS output vs background noise spectrum: Instant value

supra-aural (over ear) and circum-aural (on-ear) headphones, but for in-ear headphones they discovered a problem. "We noticed a significantly higher response in the 500 Hz to 4 kHz range for the in-ear headphones and guessed that we had not been able to match the human ear impedance accurately enough with our design" explains Tsunoda. "The in-ear headphone configuration produces a much higher acoustic load on the ear than other designs, and that's when the problem was most apparent."

COLLABORATION

Around this time, in 2015, Tsunoda speculated that the manufacturers of Type 4128 probably had the same issues with which he was wrestling. He contacted Brüel & Kjær to discuss Sony's project

SEE MORE

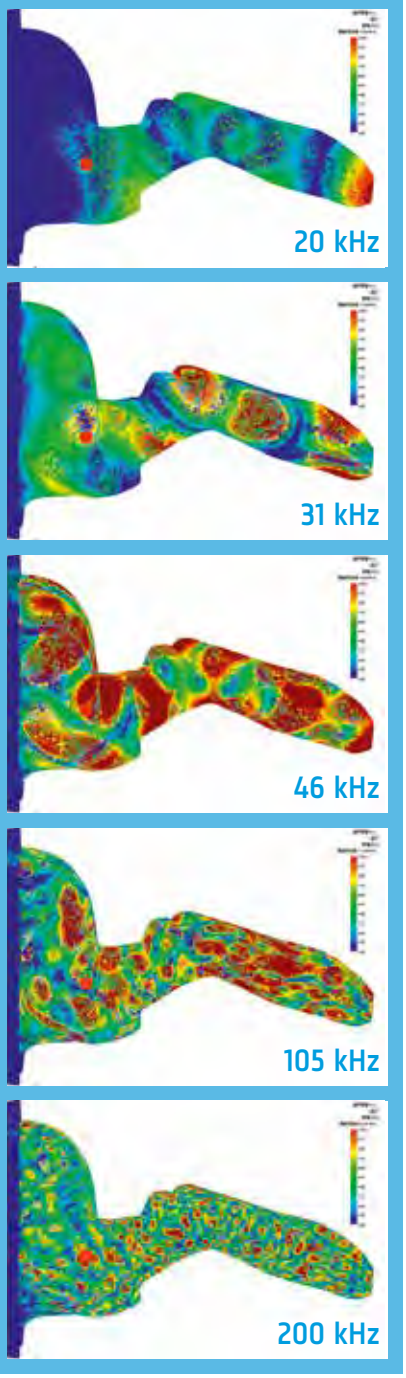
Read Sony's white paper 'A Headphone Measurement System Covers both Audible Frequency and beyond 20 kHz (Part 3)' (presented at the 143rd AES Convention, October 2017) at

www.bksv.com/conference-papers

and share information on future developments. As it happened, Brüel & Kjær had been working for some time on a realistic human geometry ear canal with a focus on optimizing the acoustic impedance of the new design. Under a collaborative agreement with Sony, the Brüel & Kjær team shared information on the prototype they had developed and explained the reason for the in-ear differences Sony was seeing. The Brüel & Kjær design featured a new high-frequency coupler with a ¼" microphone, which best matched the impedance of the human ear. After some discussions, Brüel & Kjær agreed to provide Sony with a prototype of the new HATS for them to use in their experiments. "It's obviously better when we can leverage the knowledge of others and add it to our own experience to reach a goal faster," says Tsunoda. "Our tests of the Brüel & Kjær prototype overcame some of the problems we had with in-ear device measurements."

But are there more improvements to be made? "The pursuit of perfection is a road without destination," comments Tsunoda, "there are still more enhancements we would like to make to the measurement system. For example, the geometry of the HATS head, though an effective standardized shape, doesn't represent the average human head and gives us challenges when testing headphones with a headband. Our measurements indicate that the sides of the head should be tapered slightly towards the face. This would also help with the correct positioning of the headphones. There is still work to do."

Simulation of steady state sound power level inside the human ear canal at different frequencies



SPOT THE DIFFERENCE

Can you spot the five differences between these two pictures?

See the solution on page 33.

EXPERT PROFILE

PASSIONATELY ENGINEERING BEAUTY

"MY HAPPIEST MOMENTS REVOLVE AROUND SNIPE SAILING."

DR MARCO BALLATORE

Born in Turin, the Italian hub of the automotive industry, with an automotive engineer as a father, it's not much of a surprise that Dr Marco Ballatore's curiosity and passion for cars led him to a career in the automotive industry and, eventually, to Bentley.

DR MARCO BALLATORE

Functional Manager Chassis NVH, Bentley Motors Ltd, UK

EDUCATION

2000 – 2005:	Master's degree, Mechanical Engineering Università Politecnica delle Marche
2005:	von Karman Institute for Fluid Dynamics – Trainee
2005 – 2009:	Doctor of Philosophy (Ph.D.) in Mechanical Engineering, Università Politecnica dell e Marche

CAREER

2014:	Technical Manager – NVH & Structural Dynamics, Bentley Motors Ltd
2013 – 2014:	Attribute Leader – Structure-borne Road Noise, Bentley Motors Ltd
2012:	R&D Senior Engineer – EMEA product development, Fiat Spa
2006 – 2012:	NVH engineer – Tyre Research Department, Bridgestone

Why do you do what you do?

I am passionate about car engineering and I like the idea of understanding the engineering problems, applying the right boundary conditions and developing the design around them. The forces will dictate the design, but the shape must come from the physics – when this is applied, beauty manifests itself in the form of the best combination of shape and materials in all the structural components. My challenge is to have the right set of forcing functions for each performance attribute before the car is designed, early enough in the project to develop it to match the performance aspiration.

Were cars a passion of yours as a child?

Yes. My dad, an engineer, once worked for an automotive supplier, making parts for the Fiat and Lancia race cars of the time. In the days before airbags, we had a unique Abarth racing steering wheel prototype in every car we owned.

What was the first indication of your interest for NVH?

I wanted to design vehicle suspensions and thought that a deep understanding of vibration was required for that. In my third year at university, I selected a course on vibration mechanics to learn all about vehicle suspensions but the course contained nothing about that, but was really about structural dynamics and testing. However, the class was small and we ended up performing modal analyses on car parts and having fun! Everything was 'alive' and the professor made us add the CAE analysis of every (simple) part we tested. My ambition to study how to control things started then, while the mechanical design I had originally been so keen on, proved interesting but dull when taken out of the dynamics context.

What drew you to Bentley?

A strong expectation that best-in-class performance should be matched by best-in-class engineering.

What are the unique challenges you face in your work?

Doing it right the first time, every time, means a strong front-loading approach. We try to offset as much work as possible onto CAE and try to move the decision-making upfront. However, the earlier in the programme, the less robust the models are and we run higher risks in steering the design. That often requires more communication than engineering. You need to know the decision-making pattern of each director or executive and adapt the message according to their respective culture and mindset. ▶

PASSIONATELY ENGINEERING BEAUTY

Computers can tell you anything, but to add value with CAE you need to question the results and to do so I see no better way than putting CAE and test engineers under the same roof.

"Vehicle development is much closer to racing – to quote an old saying, if you are feeling comfortable, it means you are not going fast enough"

What's the most challenging thing about what you do?

Moving from design to hardware development needs thorough planning and can be chaotic. Nowadays, product complexity is huge, and the early months of prototype cars are anything but smooth. In many ways, it's not that different from racing, but managing the situation requires continuous insight into the team's state of mind in order to keep things sustainable.

What is your greatest achievement and why?

The work I have done for the development of the Bentley new Continental GT. It's a game changer for Bentley.

Do you have a vision?

It's a thrilling period for NVH, where we are managing the transition towards digital prototyping. This needs a systematic match of CAE-skilled engineers with a great deal of experimental insight and process overview. Computers can tell you anything, but to add value with CAE you need to question the results and to do so I see no better way than putting CAE and test engineers under the same roof. My vision is to shape the NVH business with a streamlined application of these two approaches.

Why is your work important?

It defines one fundamental element of Bentley DNA – refinement at minimal or no compromise to sportiness. Vehicle dynamics are great, but the expertise to allow some more extreme design choices around the chassis without any consequence to comfort and acoustics, can only come from NVH, and for a Bentley customer that can make a huge difference. Ultimately, this is the approach being transferred to electric vehicles. You don't want to listen to a whining e-machine and roaring tyres all journey long – honestly!

What are the major challenges facing automotive NVH?

The transition of electric vehicles from niche to mainstream, and how this will separate the most advanced countries from the others. It will be a revolution for many, but not for all, and not at the same time. Those who can, will realize, when buying their new cars, that things are radically different and simpler, but duller. No flare at the start, no idling noise, no gear changes and transitions, and ultimately, the new sound of the e-machine. It's easy to add extra power train sound synthetically, but will the customer like it? There is a risk of high-end products being fake but we still need to open the doors to further personalization options because electronics now allows plenty of them. ▶

"I still cultivate the dreams of my youth – painting and sketching cars make me happy"

"THE WORST MISTAKE WE COULD MAKE IS NOT TO BE READY."

DR MARCO BALLATORE ON ELECTRIC VEHICLES

We have developed our new full vehicle simulator with Brüel & Kjær after years of practice experiencing CAE results as we would with the real vehicle

How will the shift to hybrid/electric vehicles impact people's perception of NVH?

I guess people will start putting more emphasis on the rolling noise element and there will be a general learning phase. Aside from tyre-road interaction, cooling fan and ancillary noise, these vehicles can be totally silent, so people will focus on a different acoustic profile, or flood the interior with music and/or entertainment systems – NVH-attribute priorities will change.

Apart from the weather, what's the biggest difference between Italy and the UK?

I am a typical Italian – loud, passionate about my work, enthusiastic and with no inner filter to hide my feelings. However, since moving to the UK, I've had to refine my approach. I admire the British people's calmness, understatement, self-control and unique style. Other interesting things about Britain include carbonara with cream, mushy bread and a collective passion for deep frying.

What's your favourite car and why?

The Alfa 156 – I've chosen an affordable car and not a dream car, because the level of handling the 156 provided to the mass market was really revolutionary. Its shape is timeless, the drive is great even by today's standards – the way you feel connected to the front wheels through the steering, the perfectly mastered rear axle, its nimble agility and comfortable ride. Pity it's so loud on the road, but then the body platform is almost 30 years old.

THE DEFINING MOMENT

"Every time the first prototype car rolls out on the track. Those initial minutes tell you whether years of work have been successful. Having pushed for a certain design feature that you can't change, and seeing it 'in the flesh' one year later, gives the team shivers."

75 YEARS OF PROGRESS

For the past 75 years, visionary engineers and inventors at Brüel & Kjær have been responsible for innovative breakthroughs and many world-firsts. We have a long and impressive track record and, as we look back, we wanted to share with you some of the highlights.

Founders Per V. Brüel (middle) and Viggo Kjær (right) with Production Manager Holger Nielsen (left), Final Test Manager Svend Jensen (front) and Engineer John Oberg (back). The product being tested is a Type 2107 analyzer ›

HIGHLIGHTS OF INNOVATION

Here are some of the past highlights that have laid the solid foundation we stand on and which makes it possible for us at Brüel & Kjær to look beyond tomorrow, towards future innovations.

1942 Brüel & Kjær founded

1943 Piezoelectric accelerometer (Type 4301)

1949 Level recorder (Type 2301)

1958 Condenser microphone (Type 4131)

1960 Hand-held sound level meter (Type 2203)

1973 Hydrophone (Type 8101)

1977 Digital filter analyzer (Type 2131)

1981 Sound intensity analyzer (Type 3360)

‹ Celebrating Christmas in 2008, LAN-XI style

Type 2033 presented in Wuhan, China, around 1980 ›

‹ A 1985 print from Type 2032 to graphical writer Type 2313. The print lasted for ever on the special paper that came in rolls and was referred to as "galvanized toilet paper"

"RUNNING A BUSINESS IS ABOUT HAVING FUN. HAVING FUN IS THE BEST WAY TO USE YOUR SKILLS. WE WANTED TALENTED PEOPLE WHO COULD THINK FOR THEMSELVES, WERE CREATIVE AND ALSO A BIT LUCKY."

PER V. BRÜEL AND VIGGO KJÆR'S UNOFFICIAL RULE OF CONDUCT

1975 airport environmental noise management. The results on the back wall are covering the original airport decoration: posters with pin-up girls. And yes, we have photos of that, too

Engineers in the old workshop working, testing – and sweeping!

Exterior and interior view of the Brüel & Kjær demo-bus on tour in Poland in 1972

1983 Modular sound level meter (Type 2231)

1986 Acoustical holography system

1991 Danish Primary Laboratory of Acoustics

1996 Windows®-based multi-analysis system (PULSE)

1997 Hand-held sound intensity system (Type 2260-E)

2004 Colour touch-screen hand-held analyzer (Type 2250)

2009 Multi-field microphone (Type 4961)

2013 Tablet-based app for in-vehicle data noise and vibration recording (Sonoscout)

2013 Wideband holography

2016 New class of air-cooled shaker (LDS V8900)

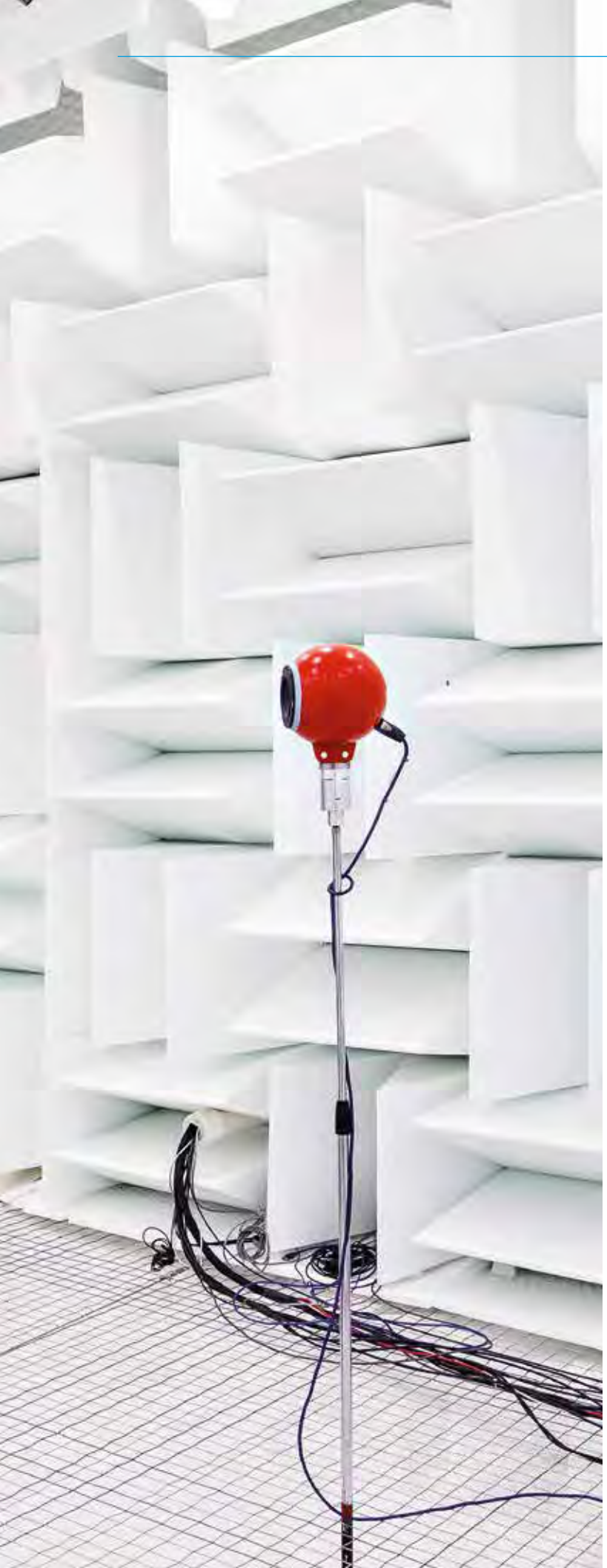
2017 Anatomically correct ear canal (Type 5128)

Measurement with Sound Level Meter Type 2203, ca. 1970

In the 1970s, practically everyone in Denmark owned and happily wore an Icelandic sweater, including R&D employees at Brüel & Kjær

TESTING FOR CLARITY:

FROM THE LAB TO THE CONSUMER



Jabra is a Danish company that designs and produces quality headphones, headsets and speakerphones. Its focus is ensuring that its products – headsets, speakerphones, headphones and all their associated accessories – combine to enable clear, accurate and effortless communication.

Life can be stressful enough without trying to figure out what another person, possibly thousands of miles away, is saying because of poor microphone quality or speech intelligibility problems introduced by the speakers.

Jabra shares the test lab with its sister company, GN Hearing (known for the high-quality hearing aid brands ReSound, Beltone and Interton), which is worth mentioning because they share a common goal. Contrary to a common misconception, the goal is not the accurate reproduction of the entire soundscape, the goal is the accurate reproduction of the sounds that convey information. No one wants to hear the wind blasting past the microphone when the hearing aid should be transmitting the sound of an approaching car, and while it is nice to hear bird song, the headset should instead be transmitting the words of the person on the other end of the call. It inspires confidence to know that, while the targets may differ slightly, the testing facilities are designed and used to ensure that the sounds you need to hear are the ones that you will. ▶

"WE CAN MEASURE AND GATHER DATA, BUT IN THE END, WHAT THE USER CARES ABOUT IS GOOD SIGNAL QUALITY."

SØREN W. CHRISTENSEN
TEST ENGINEER, GN STORE NORD
ACOUSTICS RESEARCH LAB

TESTING FOR CLARITY:
FROM THE LAB TO THE CONSUMER

> "HATS IS AN EXCELLENT COLLEAGUE – HE'S ALWAYS IN A GOOD MOOD AND I CAN RELY ON HIM EVERY DAY."
>
> SØREN W. CHRISTENSEN
> TEST ENGINEER, GN STORE NORD
> ACOUSTICS RESEARCH LAB

TEST, TEST, TEST

When new prototype systems are developed, they must be tested to ensure that they perform as expected, they are safe and, in some cases, to fine-tune a proposed design or algorithm. The test lab at Jabra gets a lot of use. While much of the testing revolves around making sure that the intended speakers' voices are what is transmitted, there is also significant testing to safeguard users' hearing – making sure that the system will not transmit signals loud enough to damage hearing, for example.

Testing headset receivers and testing loudspeakers cannot be compared because the headset receiver needs to be placed directly on-ear when testing, so a realistic test ear is needed. With artificial ears, testing can be conducted just as a human will hear with the receiver. Søren quips, "You sometimes use a person, but people can have good and bad days. HATS always has a good day – he's consistent – you can always rely on the data you get from HATS."

WHY TEST IN A WAY THE MICROPHONE WON'T BE USED?

The anechoic chamber is used to test for frequency response in order to characterize the microphone directivity. Though it may seem odd to test a microphone by itself when it will not be used away from a person's face, it is important to test the microphone both on its own, mounted on a pole, and using an artificial head and torso manikin like HATS. The pole-mounted test is used to generate a polar plot, which is where the

There are many tests to perform and many environments in which to test: an anechoic chamber, a reverberation room, a listening (or IEC room) room, a car set up similarly to the IEC room and a wind tunnel. All of these test environments exist to test for specific data and responses, and are used in different ways. The anechoic chamber and wind tunnel test under carefully controlled conditions in accordance with zero interference and under more realistic conditions. The IEC room, reverberation chamber and car are only used to test realistic conditions. In all the rooms, the realistic test conditions are still controlled for repeatability and use a head and torso simulator.

Anechoic chamber

Car set-up

Listening room (IEC room)

Reverberation room

Wind tunnel

directivity of the microphone is characterized. This plot lets engineers see the way the microphone reacts to different frequency bands at different angles. So even though a headset microphone will only be used while worn, characterizing the microphone to find the best orientation for the microphone is an excellent first step in ensuring that the speaker's voice is the most prevalent source, before the introduction of complex algorithms.

Mounting the microphone on a head and torso manikin when measuring for the microphone's directivity would influence the sound field, but once the directivity data is obtained and the preliminary microphone orientation is determined, HATS can be used to get further data in a realistic use configuration. Measuring on HATS with the microphone oriented as indicated by the polar plot can both confirm the test and provide additional data based on how the sound field is altered by the proximity of a face.

TESTING UNDER USE CONDITIONS

In contrast to the anechoic chamber, reverberation room and wind tunnel, testing in the IEC room and car focus purely on realistic use to ensure, for example, that the day-to-day noise of an open-office environment neither disturbs the listener nor hijacks the microphone. Testing here focuses on isolating the subject from the environment. Building on previous tests where the microphone was characterized, the IEC room can introduce a variety of background noises, such as an office space or cafeteria, and confirm that the system is properly designed and set up or provide data for further fine-tuning.

TOMORROW, TOMORROW AND TOMORROW

According to Søren, test equipment like HATS will be important in the future because there will be more automated test systems needed as there will be more and more standards to meet that will require more tests. These tests will require good reliable test equipment. Also, it will require more realistic background noise testing. For example, Søren points out that they currently use a number of speakers in their IEC room, and technology is progressing to the point where the test systems can pinpoint the speaker positions. With the ever-increasing quality of computers and test systems, there will be an increased emphasis on creating realistic environments with versatile and reliable equipment, high-quality microphones, loudspeakers, analyzers and software.

SOUNDS ABOUT RIGHT...

By Lars Kroman

LISTENING IN 3D

One of the remarkable abilities of our auditory system is that it can pinpoint the location of sound sources. This is vital in many situations in life, such as safe navigation in traffic. But the spatial properties of sound are just as important to achieve a realistic acoustic environment in gaming and home cinema set-ups. So how does it work and what does it take to recreate an authentic experience?

INTERAURAL TIME AND PHASE DIFFERENCE

INTERAURAL TIME DIFFERENCE

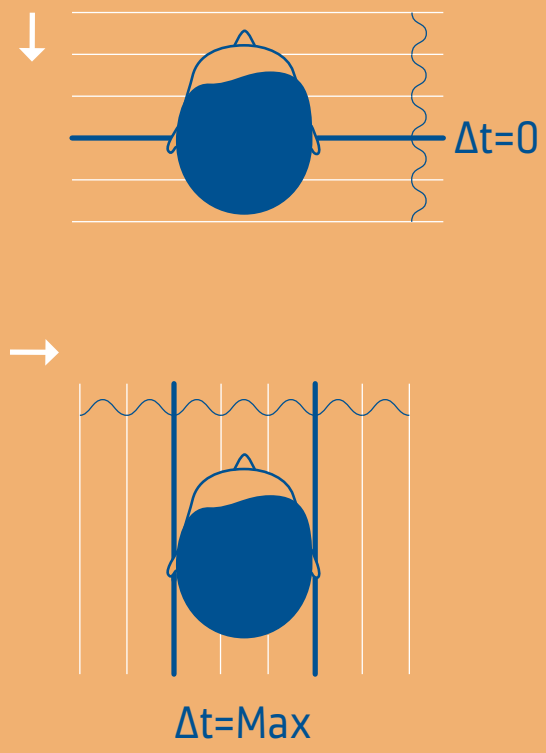


Fig. 1a: With sound coming from the front, the interaural time difference is zero (top). Coming from the side, with a head size of about 20 cm and a sound speed of 340 m/s, the maximum time difference is 0.58 ms

INTERAURAL PHASE DIFFERENCE

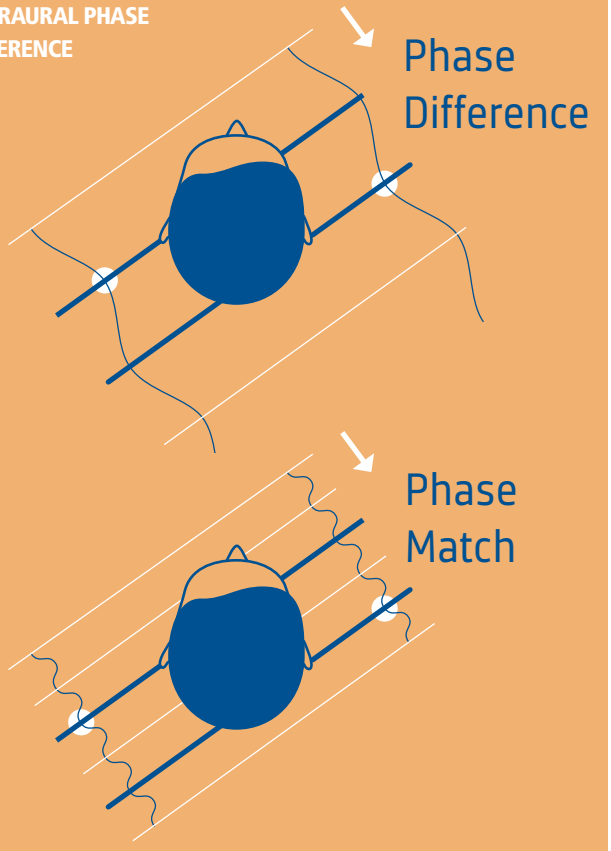


Fig. 1b: While usually the ears will sense a phase difference (top), depending on frequency and angle of incident they may detect a false phase match (bottom)

BY: **MATTHIAS SCHOLZ**
User Interface Designer
PhD Applied Acoustics
Brüel & Kjær

HOW DO WE LOCALIZE SOUND?

The first clue our hearing uses is interaural time difference (fig. 1a). Sound from a source directly in front of or behind us will arrive simultaneously at both ears. If the source moves to the left or right, our auditory system recognizes that the sound from the same source arrived at both ears, but with a certain delay, or seen the other way around, the two ears pick up different phases of the same signal.

We decipher phase differences best at low frequencies. At higher frequencies, the wavelengths can be so short compared to the size of the head, that the pattern repeats itself and both ears may coincidentally pick up the same phase (fig. 1b).

Fortunately, the auditory system has another clue to work with: the acoustic shadow created by our head when sound arrives from the side, a phenomenon that increases with frequency. At very low frequencies, the size of our head is small compared to the wavelength of sound in air. Consequently, the sound pressure is essentially the same at the left and right ear, no matter from which direction the sound arrives. However, with increasing frequency the wavelength decreases and the size of our head is no longer negligible. It becomes an obstacle that shields and reflects sound, so that in comparison to the ear which faces towards the source, higher frequency content will be attenuated when it arrives at the ear on the opposite side of the head.

The shape of our pinnae also provides a wealth of spectral (frequency-dependent) clues. Like the acoustic shadow of the head, the pinna functions like a shield attenuating the higher frequencies of sound that does not enter straight from the front. You can experience this by turning away from and again towards a source. While doing so you should sense a slight change at high frequencies, something you would normally not pay attention to.

In addition, dependent on the frequency and direction of incident, the pinna's shape affects sound as it is reflected into the ear canals, enhancing some frequencies and attenuating others.

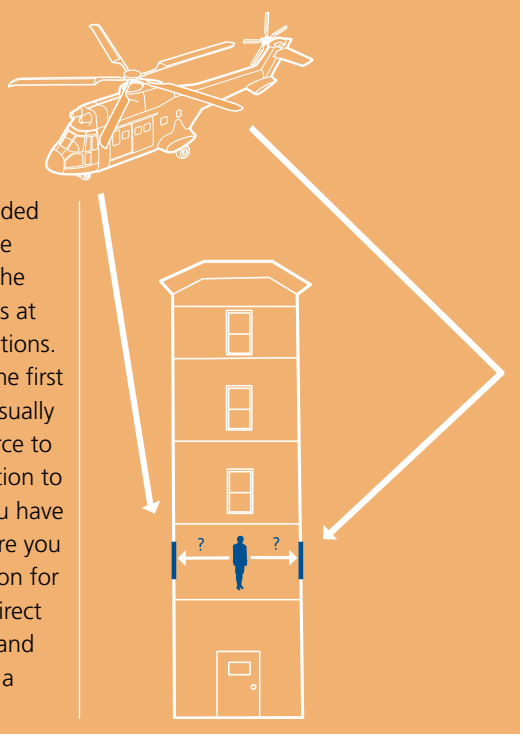
BINAURAL HEARING AND REPRODUCTION OF SOUND

Generally, for a correct spatial acoustic experience we need both ears (binaural), since the comparison between left and right ear gives the strongest clues about source locations. It may not come as a surprise that we have the most difficulty in localizing sources on the median plane, where there is almost no interaural difference.

However, a lot of our directional sense is built on experience, which is linked to our own physiology – the size and shape of our head, pinnae and ear canals. Over time, our auditory system builds up a pool of references, such as noticing that sound from behind sounds slightly duller.

Therefore, to create a convincing spatial experience, where it is possible to sense the exact location of sound sources, the reproduction of sound must provide all the information our auditory system is used to. There are basically two ways to do so. ▶

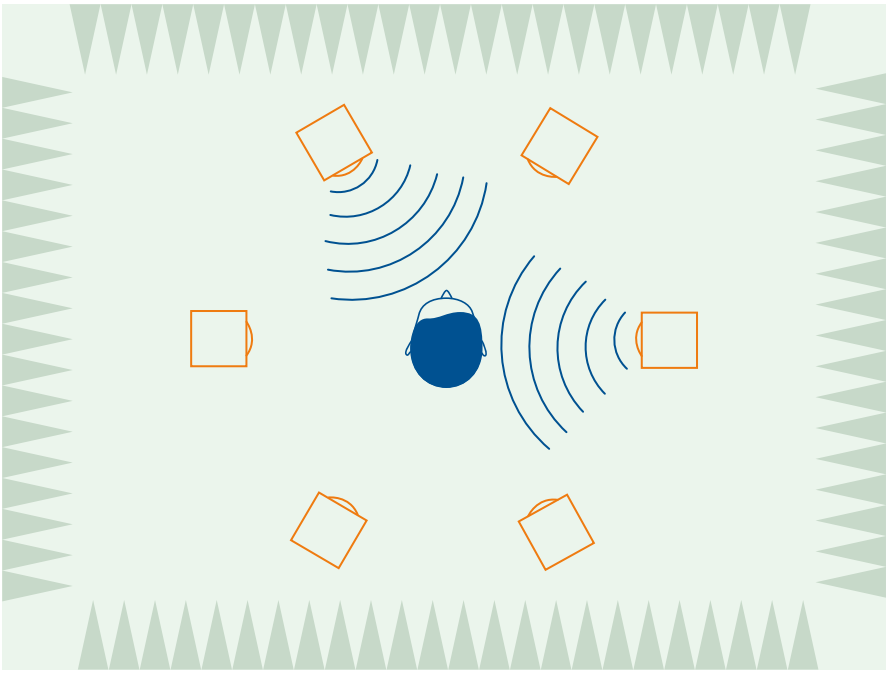
LOCALIZATION AND ECHOES



Most of the time we are surrounded by objects that cause sound to be reflected. This means a copy of the same signal arrives multiple times at our ears and from different directions. Our auditory system recognizes the first occurrence of a signal – which usually is the direct sound from the source to our ears – and uses the information to identify the source. However, you have certainly been in situations, where you initially look in the wrong direction for the source. This is because the direct path to the source was blocked and the first occurrence was, in fact, a reflection. ■

LISTENING **IN 3D**

Fig. 2: Exact reproduction of three dimensional soundscapes using loudspeakers requires highly sound absorbing rooms to avoid reflections



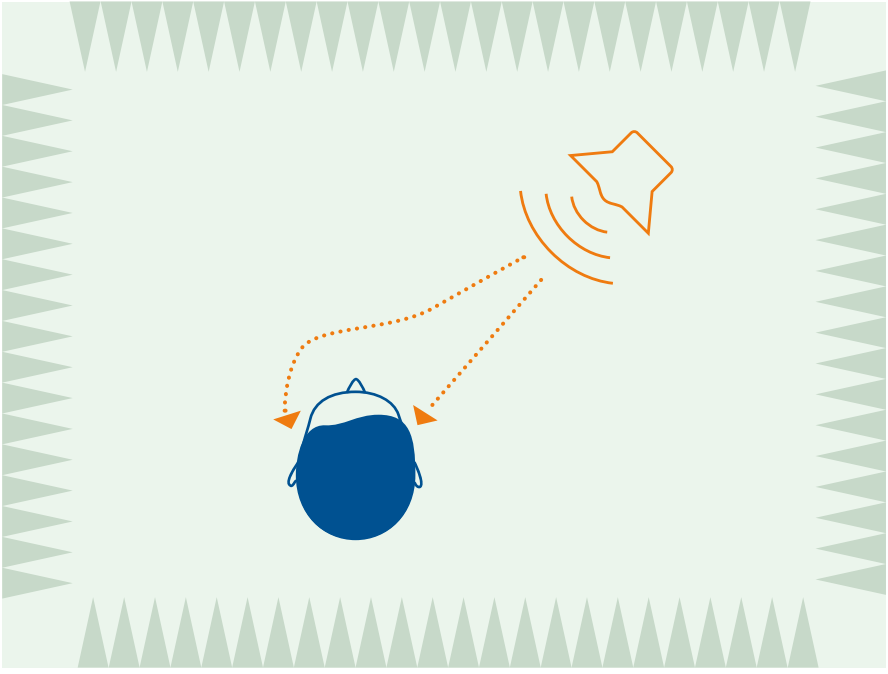


Fig. 3: Measurement of the HRTF for a source at a specific angle

1: Binaural recording

A binaural recording can be made with a pair of microphones carried close to the ears or – as it is usually done – using an artificial head with the microphones placed at the entrance of the ear canals. Such a recording is intended for direct playback over high-quality headphones; that is, the sound is reproduced as close as possible at the same point where it was captured. Playing it back over loudspeakers without further signal processing, such as cross-talk cancellation, would not work, since the signal would be sent through the room and around the listener's head, creating a completely different experience.

2: Microphone array

In this approach, one uses an array of microphones arranged in a closely spaced, three-dimensional pattern. This will record sound in a point, but with spatial information about the direction of incident. With the help of sophisticated algorithms, it is then possible to reproduce a similar sound field using an arrangement of speakers around the listener. The result is best if the listening room is highly sound absorbing, so that sound, which has passed the listener, is not reflected. Otherwise, the characteristics of the room would be added (fig. 2). This technique requires the listener to remain in a fixed position, or at least within a limited area. However, the experience would feel authentic; turning towards the different loudspeakers would make you feel like you were facing the actual sound sources.

HEAD-RELATED TRANSFER FUNCTIONS

We can combine the two techniques, and play back sound through headphones, even though it was recorded with a microphone array. This too requires some processing to convert the array recording to a binaural

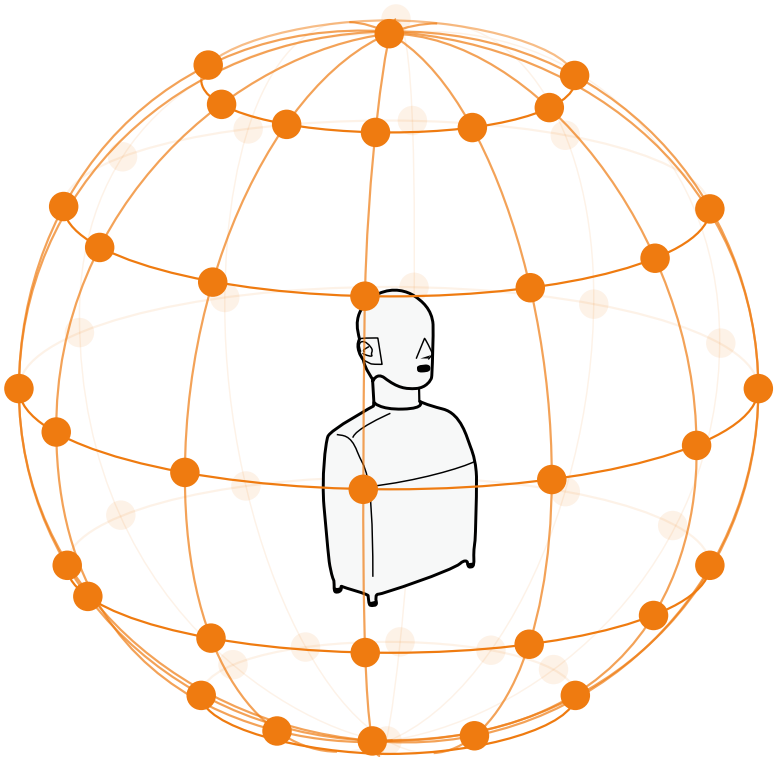
signal. To do so, we need to take the presence of the listener's head into account and how it influences sound as it impinges from the various directions.

This relation is described by the head-related transfer function (HRTF). A single HRTF describes how a sound created at a specific point will be perceived at the right or left ear. You could say that it is the acoustical fingerprint of your head and torso.

To measure an HRTF, one places a loudspeaker in a source location and a microphone at the ear (fig. 3). While this is a manageable task for a single or few source locations, covering all possible angles will require a vast set of HRTFs and one set for each ear (fig. 4), but the result is rewarding.

Compared to listening to a straight binaural recording, the advantage of using a signal, which was recorded with an array and processed through an HRTF, is that the playback set-up can utilize a sensor to pick up the orientation of your head and correct the processing accordingly. As an example, as you turn your head to the left, a sound source that was originally in front of you would then appear to your right and vice versa. This then gives a similar sense of 'being present' as in the loudspeaker set-up, but without the limitations of having to be in a special room, since the sound goes straight from the headset into your ears.

Fig. 4: To process sound from any direction, the HRTF measurement must be repeated for many source points around the head



SPOT THE DIFFERENCE

Our new High-frequency HATS on page 19 had been modified in five places.

Did you get it right?

The new High-frequency HATS Type 5128 provides a realistic reproduction of the acoustic properties of an average adult human head and torso.

It is fully compliant with the established human ear response, but in addition has known and documented response at high frequencies.

SEE MORE
Sony has evaluated the new High-frequency HATS, pp 16 - 19

The history of HATS, pp 34 - 36

OUTSOURCE OR IN-HOUSE?

For the past 20 years, Pro-Plan Ltd. has provided architectural and engineering services to support sound and vibration testing, including tailor-made, turnkey acoustic test rooms and cabins, on-site training and in-house testing.

Testing is a fact of life in manufacturing. It must be done. The question is: how to go about it? Should testing be in-house or outsourced? Does the solution require an entire room or a cabin? Pro-Plan specializes in providing architectural and engineering services to support sound and vibration testing and the decisions that need to be made.

Many factors go into the decision-making process for testing, such as frequency of testing, repeatability of test types and the need for specialized testing. For example, acoustic rooms are required for well-defined and standardized measurements like sound power or material testing, whereas cabins are primarily for non-standard work like quality control and comparison tests. For product manufacturers, benefits include reduced testing costs and times for testing variants of products and alterations made during research and development, as compared to outsourcing. For testing houses, benefits would include increasing the range of test capabilities for items that a single company might test infrequently but many companies need, updating for compliance with standards or improving the quality of the test facility.

EVERY PROJECT IS UNIQUE

In some cases, a single one-size-fits-all box solution may suffice, but few test items are the same, and even if they are similar, they can have very different test parameters. To properly test, the correct equipment is required, and that includes the environment to test. Pro-Plan has delivered more than 20 test rooms and chambers, and none of them is a duplicate: different test object size requirements, cut-off frequencies, background noise levels, installation areas and clear areas – each project is unique.

"Many customers also do not know exactly what they should do and when we guide them through the process and suggest options during design, they are more than happy," says Alper Akgül.

There are also many alternative options for the equipment that, depending on the testing requirements, the optimum solution in terms of cost and capability can range anywhere from a single sound level meter with customized software to a multi-channel LAN-XI data acquisition system.

The differences in the required complexity of the rooms, such as size, installation workspace, construction materials (panel or concrete), single- or double-shell (room within a room) system, auxiliary equipment (heat, ventilation and air conditioning (HVAC) systems, etc.) mean that construction time can take anywhere from 2 to 12 months and the cost is not insignificant.

TESTING THE TEST ROOM

Ensuring that the test environment is correct is the first step to confirming the accuracy of the test data. For sound power and material testing, qualification procedures are given in accordance with relevant test codes. Tübitak UME (the Turkish National Metrology Institute) is generally contracted to verify the rooms. For non-standard applications, the qualification specifications are agreed upon beforehand and Pro-Plan equipment is used to perform the tests.

> "CUSTOMERS GENERALLY LIKE THE IDEA OF WORKING WITH A SINGLE SUPPLIER AND GETTING A TURNKEY PRODUCT."
>
> ALPER AKGÜL, PRO-PLAN LTD., TURKEY

OUTSOURCE
OR IN-HOUSE?

A CASE IN POINT

Last year Pro-Plan completed a project for the Turkish Standards Institute (TSE). The project resulted in a double-reverberation room (side by side) plus a third room for testing ducted units with twin rooms, each with a volume of 250 m^3.

It was a complicated project with a 15 dBA background noise level requirement on a noisy first floor, and the design incorporated many openings in the rooms (air inlet/outlet, water inlet/outlet, test duct and pressure equalization ductwork connections between rooms, cable passages, etc.). The HVAC system (run from a different computer) also needed an interface, and the relevant temperature/humidity/pressure data had to be input to customized software. And because the customer was a test house, they required standard software interfaces for a large variety of equipment types, such as fans, air conditioners, fan coils, washing machines, refrigerators, vacuum cleaners and heaters.

"We emphasize that acoustics are in the details, and you should get the job done right the first time. You cannot gamble with such an investment of money and time," says Alper Akgül.

VALUE IN THE DETAILS

The investment of capital and time is not insignificant, and the entire process, from the initial decisions up to the first test can require additional man-hours dedicated to determining the correct facilities, equipment and accessories. But in return, the convenience and time and money saved on having a complete and finished test room or chamber with the right testing capabilities and the training to use them – be they for expanding the services of a test hour or for in-house testing during product development – can be substantial.

Test room under construction

Test room completed

KEEPING A LID ON NIGHTLIFE NOISE

Photo © Jens Dresling

It's summer, it's hot, people vie for places to sit outside restaurants and cafés and people spill out from the bars onto the pavement – the weekend is kicking off in Copenhagen. A noise complaints unit and its two small electric vehicles patrols the city streets until the early hours. And the focus is not on rowdy, anti-social behaviour – that's police territory – the focus is on helping fed-up residents by keeping down the noise emanating from the revelries.

Copenhagen's noise complaints unit is not new – it's been around since 2014, but the number of noise complaints has increased so dramatically, that in March 2017, Copenhagen City Council decided to set aside one million Danish kroner to deal with the problem. From July 2017, instead of the usual Friday and Saturday night, the noise unit, with its extra seven officers, has been patrolling the streets of Copenhagen seven days a week. While noise-plagued residents are pleased with the initiative, they remain sceptical, and doubt whether the additional manpower will really help. As one unhappy resident put it, "When the noise patrol officers drive away, they just turn the music up again."

However, the team itself believes that the addition of extra staff has already made a difference, allowing them to deal with more complaints. And apparently, they do go back and check if noise offenders pump up the volume as soon as they drive away. More people on the job also means more time to focus on preventing noise issues. Engaging with outdoor event organizers, restaurateurs and street vendors, explaining the noise rules and offering advice on how to uphold them, all help towards nipping potential problems in the bud. And if that doesn't work? The answer is simple. "We'll just close the party down," says Johnny Svendsen.

** The ground rule is that the noise from a nearby nightclub, restaurant, or music venue, etc., must be ≤ 30 dB before 10 pm and ≤ 25 dB after 10 pm at the nearest residence.*

WHO SAID WHAT?

Photo by Marcin Wichary from San Francisco, U.S.A.

"THE BEST WAY TO PREDICT THE FUTURE IS TO INVENT IT."

ALAN KAY
(BORN 1940)

Alan Curtis Kay is an American computer scientist, best known for his pioneering work on object-oriented programming and windowing graphical user interface design.

It is impossible to predict the exact future. However, if you look in the right places, it is possible to make some educated guesses. Together with the Copenhagen Institute for Futures Studies, Brüel & Kjær is investigating key trends and predictions for product creation towards 2030 and the role of sound and vibration in this.

You can read more about the Beyond Tomorrow project in the enclosed brochure and register your contact information on **beyondtomorrow.dk** to receive a copy of the vision study when it is published.

BY: **ALUN CREWE**
Vice President
Telecom Audio
Brüel & Kjær

THE GREEN MAN –

While there are several manufacturers of HATS, the one you're most likely to notice is Brüel & Kjær's Type 4128, often referred to as 'the green man' – not only because it sports the largest area of Brüel & Kjær's ubiquitous green of any current product, but also because it is market leader in terms of numbers sold.

THE NEXT CHAPTER

Walk into any acoustic laboratory and you will inevitably see a device that stands out because, unlike most of the boxy instruments in the room, it has the shape of a human head and torso. No surprise then that it's called a head and torso simulator, or HATS for short.

HATS Type 4128 was first released in 1986, but its origins go back a quarter of a century earlier when Per Brüel responded to a market need for better ways to evaluate hearing aid devices and participated in research related to artificial ears. This resulted in the development of Artificial Ear Type 4152. Roll on to the 1980s and the proliferation of personal stereos, initiated by the Sony Walkman, together with the emergence of the mobile phone concept, drove the need for a more holistic method of audio performance beyond the hearing aid market – a need to consider more than just a better representation of the human ear but also the influence of the head and torso.

The HATS concept can be traced back to work done by Knowles Electronics in the early 1970s in pursuit of improved hearing aid evaluation and resulting in the development of the KEMAR head and torso simulator. But while the concept evolved the science of audio product evaluation, it suffered from a lack of symmetry in left/right ear response and had no 'mouth' restricting the application in communication products. When considering the design for Type 4128, Brüel & Kjær engineers aimed at an average head geometry that could be defined in international standards while maintaining the accuracy and realism of human hearing. The style of today's HATS reflects that. Type 4128 also included a version of the recently developed and standardized IEC 711 coupler which, for the first time, provided accurate acoustic impedance matching the human ear up to 8 kHz.

The part of the design that couldn't be simplified was the pinna – the part of the ear external to the head. The geometry of the pinna is crucial in obtaining the correct head-related transfer functions (HRTFs), which provide the coding of the directionality of the sound and must have a very precise geometry. ▶

THE GREEN MAN – THE NEXT CHAPTER

Telephone Test Head Type 4905 – shown testing Ericsson's 'Eriocofon', also known as the cobra telephone (photo ca. 1970)

In addition, the material had to be of the same relative stiffness as a human ear. Not an easy balance to achieve.

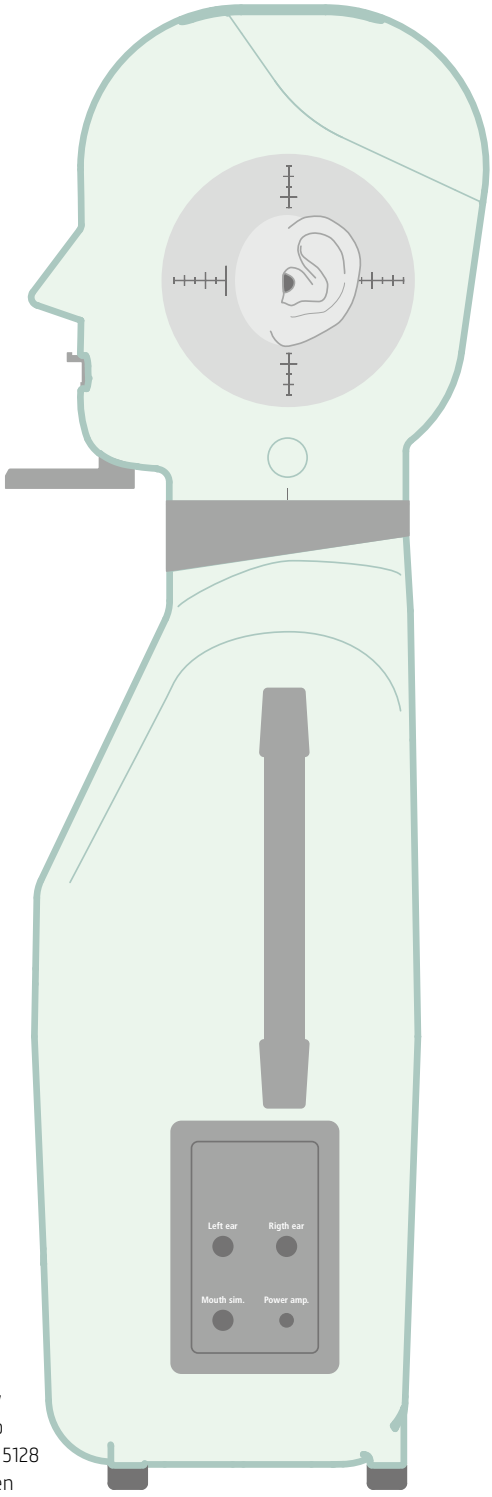
The product was an instant success and found supporters beyond the target markets of communication and hearing aids. Manufacturers in the rapidly growing high-end audio headphone market found the HATS invaluable to optimizing their products.

THE DIGITAL AGE

By the turn of the millennium, the digital audio age was already in full swing, transitioning from CD discs to MP3 players and then the Apple® iPod® revolution. The improvement in quality of source material and audio reproduction was continuous and the design limitations of Type 4128 were being challenged by these developments. Early in the new decade, Brüel & Kjær's R&D team had been mapping out the research needed to expand the fidelity of a Type 4128 successor, but it was the launch of the Apple iPhone® in 2007 that added urgency to the need for a new product. The iPhone finally brought together mobile phone, entertainment system and personal computer into a single device, requiring new, integrated methods of measurement.

The maximum frequency limit of 8 kHz was fine for the previous generation of communication devices, which were limited to a bandwidth closer to 3 kHz, but incapable of accurately assessing the performance of devices that claimed playback up to 15 kHz or even 20 kHz.

The key to successfully achieving the higher performance lay in better matching the acoustic impedance of the human ear. This meant a new coupler design, abandoning the simplified ear canal (a simple tube, 7.5 mm diameter by 8.4 mm long) and replacing it with an accurate geometric representation of a human ear. Brüel & Kjær engineers accurately measured the ear canal geometries of over forty people and then averaged the measurements to produce a target model. The correct geometry was, however, only part of the story as the materials comprising the walls of the ear canal had to be optimized for the correct and variable damping characteristics of the ear as it transitioned from soft pinna to the hard, bony structure towards the ear drum. Much numerical simulation of acoustic properties and many prototypes later, the new ear simulator achieved the goal of producing an accurate ear response measurement extending to 20 kHz and led to the birth of High-frequency HATS Type 5128 – a worthy successor to the original green man.



High-frequency Head and Torso Simulator Type 5128 – new and green

A NEW WHITE PAPER FROM THE STACKS

GOLF CART NOISE AND VIBRATION TROUBLESHOOTING

Expectations for noise and vibration performance of personal vehicles such as golf carts, ATVs, and side-by-side vehicles continue to evolve, requiring additional efforts from manufacturers to meet customer expectations in comfort and the ability to converse with passengers.

SEE MORE
Read the full white paper at
www.bksv.com/whitepapers

As the marketplace for personal vehicles continues to grow, so does the need for additional refinements as manufacturers look for opportunities to differentiate their products from competitors. Noise and vibration performance has become a selling point, offering customers additional comfort and a sense of quality.

Currently, the golf cart market is comprised of two segments – electric- and petrol/gasoline-powered vehicles. The electric power train is very quiet in operation but costlier and more complex than its counterpart. Petrol-powered carts are cheaper and easier to maintain, but they are also significantly louder. In general, this cost-vs-NVH performance is leveraged in marketing quieter petrol-powered carts, touting them as the low-cost/same-performance alternative to electric.

While the problems generated by golf carts resemble those of other ground vehicles, the low speeds of golf carts means that most of the problems are power train related. This paper focuses on the power train source and describes the combined efforts of Brüel & Kjær Engineering Services and a golf cart manufacturer to identify opportunities within two different product types to improve the noise and vibration signature. The main goal was to reduce the overall sound pressure level as much as possible. The most objectionable operating condition identified for further troubleshooting was the full-throttle start from standstill. For the operational data, baseline measurements on the golf cart were made outdoors in a parking lot, in a grass lot and up a grassy hill. As the NVH performance was similar for all operating conditions, the parking lot was chosen for ease of access. To evaluate potential countermeasures, the vehicle was operated on a hemi-anechoic chassis dynamometer to ensure repeatability.

The investigations were used to identify design recommendations, providing the manufacturer with several opportunities to improve both product and customer experience.

THE SOUND OF SUMMER

BY: **LIANGWEI SHEN**
Technical Training Manager
Brüel & Kjær China

Summer is watermelons, rainstorms, mosquitoes, burning sunshine and air conditioning. But a summer is not a summer without the chirping of cicadas.

Cicada chirp, the sound of summer

Cicadas are born underground, and after 2 to 17 years, the nymphs emerge, climb to the nearest tree, shed their old skins and become adults. Regardless of species, adult cicadas perish within a season or two and do not live multiple years in their adult form.

Cicadas live in groups, so it's not easy to find a single individual. However, I was lucky enough to record an interview with a Mr. Cicada in Haidian, Beijing, using Hand-held Analyzer Type 2250 in high resolution setting with a sampling rate of 24 bits.

VOCALISM PRINCIPLE

The male cicada chirp is generated by the vibration of the tympanic membrane, which is pulled and compressed by the tensor tympani muscle. The cicada chirp lasts for tens of seconds at a time, reaching deafening levels before fading out again.

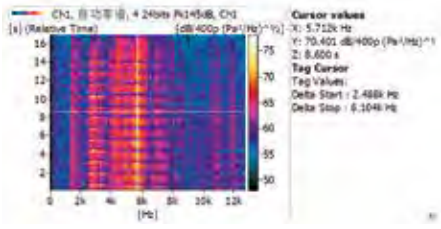
PERIOD AND PEAK VIEW

Our recording covers the final part of a chirp. By dragging the file into a display in PULSE Reflex™ Core, we can clearly see several 1 s periods in the chirp signal. The peak value is about 0.7 Pa, around 90 dB.

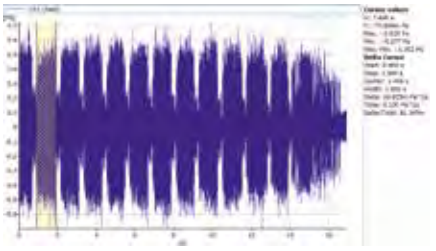
FFT VS TIME ANALYSIS

Zooming in on the 1 s period shows that the period signal is composed of pulse trains. We carried out an FFT vs Time analysis to obtain an RMS spectral density spectrogram. The spectrum's frequency range – from 20 Hz to 12.8 kHz – dominates between 2.5 kHz and 6.1 kHz, with the highest peak occurring at around 5.7 kHz.

Soon, leaves will fall from the autumn wind and the air will cool. It will become hard for cicadas to chirp as their lives come to an end; their song turns sad, as winter is upon us.



We carried out an FFT vs Time analysis to obtain an RMS spectral density spectrogram



Final part of the cicada chirp signal

NEW HATS EXTENDS FREQUENCY RANGE

The development of high-quality audio in mobile phones and the increasing popularity of headphones and headsets for communication and entertainment has driven the demand for measurement of product audio performance to higher frequency ranges than those in the currently available head and torso simulators, or HATS for short.

High-frequency HATS Type 5128 addresses that need for realistic, accurate and repeatable acoustic measurements across the full range of human hearing, significantly improving the correlation between subjective and objective evaluation of the audio performance of smart devices and accessories.

By accurately replicating the audio response of the human ear, High-frequency HATS provides unprecedented precision in high-frequency audio testing of consumer products, reducing the development time and ensuring industry-leading audio quality for new products in the marketplace.

High-frequency HATS features a human like ear canal that enables the correct acoustic impedance across the full audio frequency range and ear simulators with associated electronic calibration information (TEDS).

The head has also been redesigned to provide easier access to internal components and a larger area of silicon rubber around the pinna to better accommodate circumaural (over the ear) headphones.

SONY HAS EVALUATED THE NEW HIGH-FREQUENCY HATS, SEE PAGES 16 – 19

Some of the engineers behind the development of High-frequency HATS Type 5128

BRÜEL & KJÆR NEWS

BEYOND TOMORROW

December 4, 2017, is the 75th anniversary for Brüel & Kjær. The celebration of our accomplishments and how far we have come (see pages 24 – 25) present a great opportunity to think of the future: where is Brüel & Kjær headed and what will we accomplish? To that end, we have initiated the Beyond Tomorrow project. The goal of this project is to develop trend predictions and market intelligence in order to start a conversation with the sound and vibration community about what role sound and vibration will have in the 2030 production and development environment.

We conducted video interviews with Søren Holst (President of Brüel & Kjær) and Carsten Beck (Director of Copenhagen Institute for Futures Studies) to get their perspectives on the project.

VSound

Responding to market needs, Brüel & Kjær has introduced VSound™ Type 3115, a vehicle sound-generation system – for both interior and exterior perspectives – that enables virtual NVH prototype evaluation in the context of a real vehicle. This system can be used to evaluate targets, candidate sounds and sound delivery strategies for real vehicles, demonstrations and final sign-off by senior management.

VSound uses vehicle parameters such as throttle, rpm and speed from the CAN bus system and seamlessly integrates with the NVH Simulator's Desktop Simulator and Exterior Sound Simulator. Engineers can use this system to design, check, evaluate and deliver interior and exterior vehicle sounds for vehicles of any configuration: electric, hybrid, conventional internal combustion power trains, or any other vehicle/power train design.

Single-channel Universal Signal Conditioner Type 1708

Customers have been asking us for a portable signal conditioner that supports both constant current line drive (CCLD) transducers and classic microphones. We are happy to announce Single-channel Universal Signal Conditioner Type 1708. The new signal conditioner power module is low-cost, lightweight and portable with a built-in, rechargeable battery. This conditioner is optimized for in situ measurements in the lab or the field.

Type 1708's unique features include:

- Supplies up to ± 60 V, covering the maximum dynamic range of all Brüel & Kjær classic microphones
- Can be powered and charged from a 5 V DC adapter or connected to a PC's USB port
- Provides a wide range of gains (×0.1, ×1, ×10 and ×100) to improve noise floor
- Offers three different filter types: Linear, A-weighted and 22.4 Hz – 22.4 kHz

Sonoscout CAN bus

Sonoscout, our ultra-portable NVH recorder, has been updated. One of the primary new features is the integrated CAN bus data interface, negating the need for third-party hardware.

Real-time data, such as throttle position and engine rpm, via the CAN bus maximizes engineer confidence during testing and brings simple control and analysis to tasks such as comparing vehicles and data sets. When used with a binaural recording headset, a Sound Quality HATS Type 4100 or a digital HEAD acoustics HATS, Sonoscout can capture cabin sounds in real-time.

Sonoscout's capabilities now include:

- Automated calibration procedure
- TEDS support for automatic CCLD transducer recognition
- FFT, order analysis, spectrogram analysis, sound quality metrics
- Data from a vehicle's CAN bus (OBD-II or J1939)

SEE MORE
To find out more about Sonoscout, visit

www.bksv.com/sonoscout

PULSE Reflex Stepped Sine

Stepped sine is a dedicated excitation and analysis technique used in structural testing, where measurements are made at predefined, fixed step frequencies, one at a time. Stepped sine testing has many advantages compared to broadband random testing.

Typical applications include:

- Leakage-free, high-quality FRF measurements as input to modal analysis
- Control and study of non-linearities
- Resonance surveys
- Forced response ODS analysis

Find out more about PULSE Reflex Stepped Sine from these four videos

BRÜEL & KJÆR NEWS

"MY OWN INTEREST IN WAVES [...] IS INSPIRED BY A BREADTH OF ARTICLES RATHER THAN DEPTH OF ANY ONE ARTICLE."

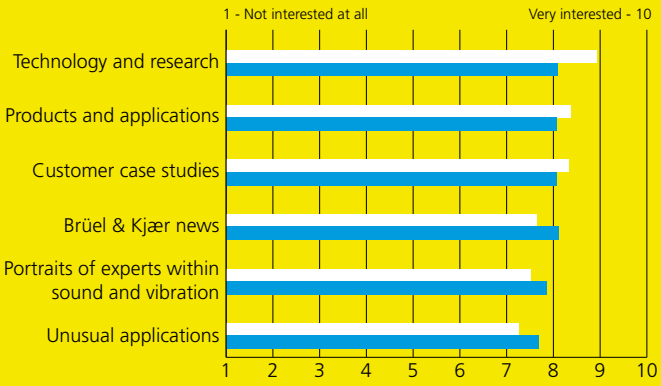
YOUR VIEW ON WAVES

Every six months, we deliver Waves to more than 40,000 subscribers worldwide, so we want to make sure we deliver a magazine that sparks your interest, inspires you and lives up to your expectations.

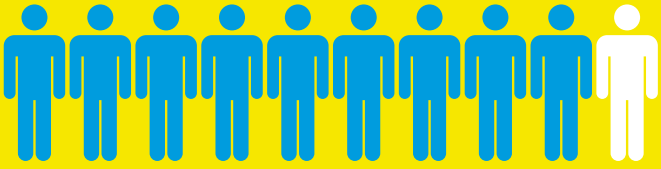
To get a little more insight into this, we sent a survey to Waves subscribers in June 2017. We would like to share some of the results with you.

Areas of interest

How interested are you in the following topics in Waves?
How well do you feel the following topics are covered in Waves?

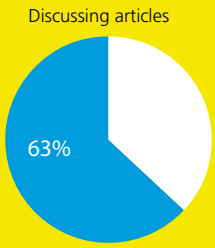


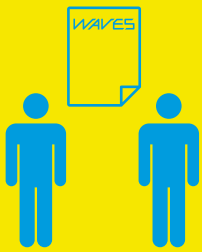
9 OUT OF 10 READERS READ ARTICLES NOT DIRECTLY RELATED TO THEIR AREA OF EXPERTISE



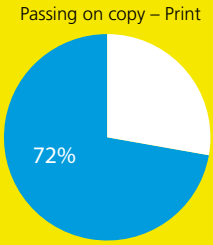
Discussing and sharing

Do you discuss Waves articles with colleagues or peers?

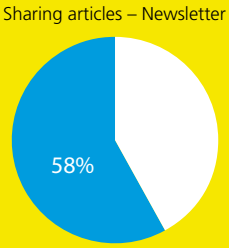




Have you ever passed on your copy of Waves to colleagues or peers?



Have you ever shared an article with colleagues or peers?



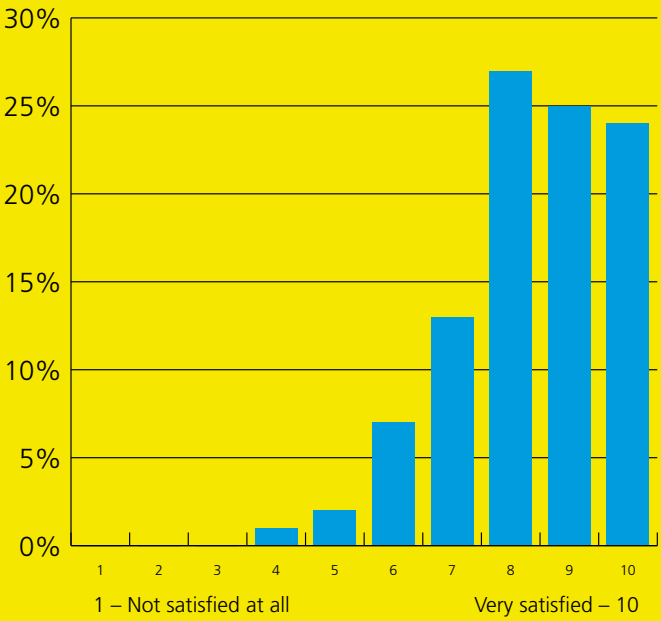
FEEDBACK WELCOME

Nearly 700 of you, from 69 different countries, took the time to answer our questions and give us feedback and comments. Thank you so much for this.

If you have comments, feedback or suggestions for articles for Waves, please email us at waves@bksv.com.

Satisfaction

HOW SATISFIED ARE YOU WITH WAVES?



Actions

As part of the survey, we have received many positive and constructive comments for changes and enhancements. Based on this, we will focus on:

ARTICLE LINKING

- More extensive reference lists in articles
- Better linking from articles to background information, related information, etc.

INTRO TO SOUND AND VIBRATION

- Basic introductory article to a sound or vibration topic in each issue

"The print journal is unique these days among companies. It singles out Brüel & Kjær in the field and is well received in the industry."

"The breadth of stories in Waves is always interesting and I look forward to receiving each edition of the magazine with great anticipation."

"I would welcome a series of 'basics of sound and vibration analysis' articles."

FIVE QUESTIONS FOR NIELS-JØRGEN

Born on the Danish island of Bornholm, Niels-Jørgen Jacobsen is Brüel & Kjær's Product Manager for Structural Dynamics. This Wagner aficionado is also a self-confessed foodie with a dream of starting his own winery. He also runs marathons, believing that good health is synonymous with a good life.

MOTTO:

"IT'S ALL ABOUT PASSION AND DEDICATION"

What attracted you to Brüel & Kjær?

When I studied engineering, my main interests were acoustics and digital signal processing. There was no doubt in my mind that Brüel & Kjær was the place to work.

What drives you in your work?

Educating people in the fascinating world of sound and vibration, and working with passionate, inspirational people to create outstanding solutions, which help our customers fulfil their goals. Strong customer interaction is essential to me.

Who do you admire most?

Visionaries who motivate and guide others to create outstanding results and generous people who invest not only money, but also time, to make life better for others.

What are the future challenges?

Due to the fast increase in new emerging technologies, the risk of disruption is inevitable. As a company – and individual – it is essential to possess the skills and willingness to constantly change to counter these challenges.

If you had all the money and time in the world, what would you do?

I would set myself an ambitious physical goal such as completing a Triple Iron Man – yes, there is such a thing. But according to my wife, I will never leave Brüel & Kjær.

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