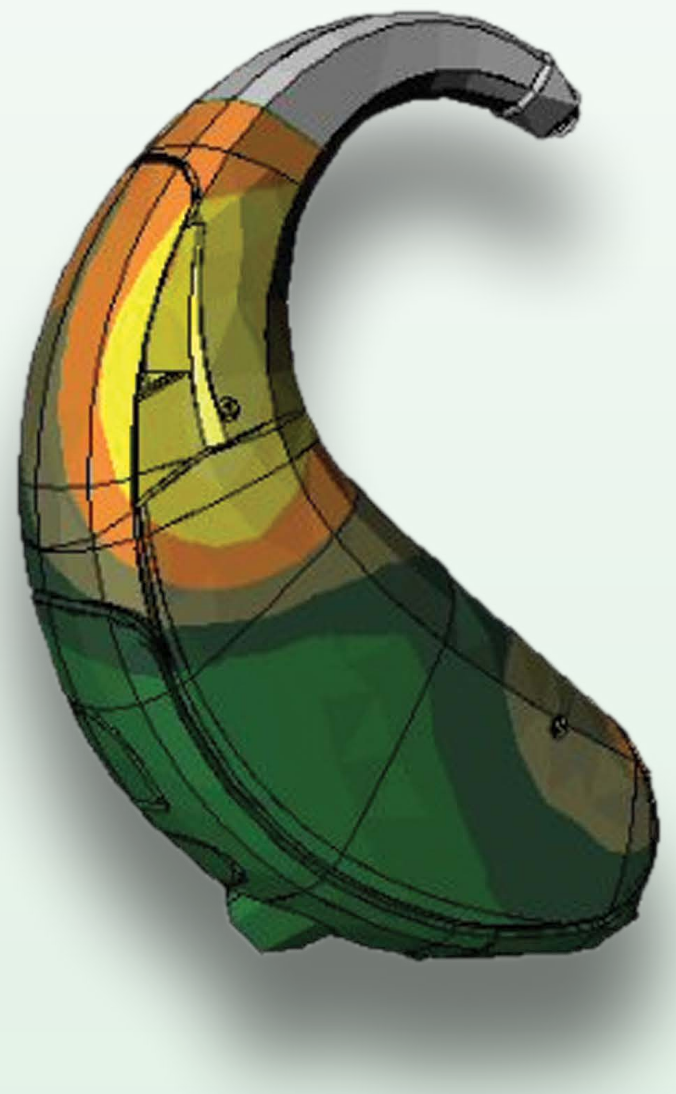
CASE STUDY

ReSound
rediscover hearing

Robot-controlled acoustic holography for hearing aid development

For identifying feedback due to leakage or vibration in hearing aids, a special turnkey solution using robot-controlled measurements and Statistically Optimised Near-field Acoustic Holography (SONAH) has stabilised development time requirements and provided improved insights to build GN ReSound's knowledge base.



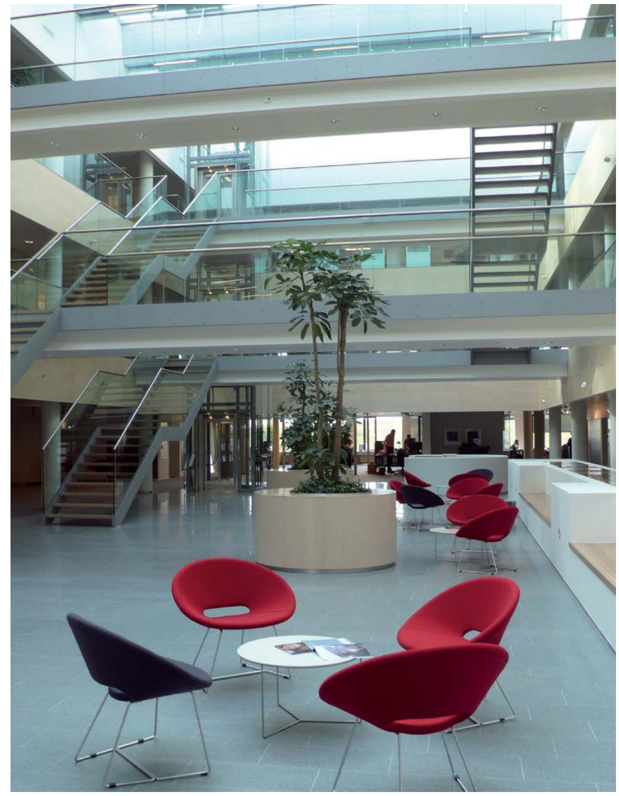
Brüel & Kjær

The company

GN ReSound's headquarters

With headquarters in Ballerup, Denmark, ReSound is part of The GN ReSound Group, one of the world's largest providers of hearing aids and diagnostic audiological instrumentation, which in turn is part of GN Store Nord. GN ReSound is represented in more than 80 countries, including development centres in China and the USA, in addition to Denmark.

GN ReSound's history dates back to 1943, and over the years it has been responsible for a number of hearing industry firsts. Their Wide Dynamic Range Compression technology broke new ground for sound processing, and their Digital Feedback Suppression technology was the first system to effectively reduce howling and sound distortion in hearing aids. They developed the world's first open-standard digital chip, setting a new standard for flexibility in programming. And the introduction of their 'ReSoundAIR' heralded the creation of an entirely new type of hearing instrument, providing more natural sound and doing away with the discomfort associated with plugging the ear canal.



Hearing aid challenges

Acoustical and mechanical feedback are one of the main factors limiting hearing aid design

Hearing aid basics

A hearing aid has three basic parts: a microphone, an amplifier, and a speaker. It receives sound waves through a microphone, which converts them into electrical signals and sends them to an amplifier. The amplifier increases the power of the signals and then sends them to the ear through a speaker.

Hearing aid manufacturers are constantly striving to improve speech intelligibility and comfortable listening, with researchers investigating computer-aided technology to design better hearing aids by improving sound transmission and reducing noise interference and feedback.

The performance of electro-acoustic devices such as hearing aids is severely limited by the amount of acoustical and mechanical feedback typically experienced within the electro-acoustic system. During the design phase, parts need to be identified in the electro-acoustic system assemblies that cause acoustical leakage, thus possibly creating an acoustic feedback path, and also creating resonances that create a mechanical feedback path.

According to a Senior Acoustic Engineer at GN ReSound, Poul Kristensen, "The big challenge in hearing aids is to have high gain, and to have that you need to be able to control your feedback. It's a very small device for gain that is sometimes up to 80 dB, so you need many different tools to understand the feedback patterns."

Analysing feedback patterns

In hearing aids there are different vibration-borne feedback patterns, meaning the small speaker inside generates high pressure sound that makes the whole device vibrate. This vibration generates sound, and if the sound path from the speaker to the output is not insulated you can also have direct sound feedback. For development prototypes this is especially important.

"The vibration of the surface generates sound, so we have to understand if it is vibration of the surface making sounds, or just the vibration of the microphone's membrane. So we use both a laser vibrometer and SONAH acoustic holography to understand the dominant source of the feedback."

"The time taken for the development process involving modelling, simulation and verification using laser measurements and the acoustic holography system has been reduced by 20%"

Morten Birkmose Søndergaard, Senior Acoustic Engineer

Sound pressure level *is displayed at all calculation points as the sum of the contributions, but does not show the source.*

Sound intensity *is primarily used to identify the feedback sources*

Particle velocity *is used in combination with laser velocity measurements to separate leakage sound sources from vibration structure sources.*

"There are also air-borne feedback patterns, so we also measure particle velocity to see whether it is generated by the surface or not. If it is created by the surface then the particle velocity will correspond, whereas if there is acoustic leakage then there is no direct correlation between particles and physical vibrations."

"This is all done during development," says Poul, "and of course we can check production devices if we need to, but it is normally limited to prototypes. If we don't get the gain we expect then we want to know why. And it could be that one assembly is not sealed properly."

GN ReSound's requirements

GN ReSound looked for a solution that could provide accurate conformal mapping on the small scale that they were looking for, and do so automatically and unattended. Seeing a robotic system already made for another customer by Brüel & Kjær's Customised Project Department was important to GN ReSound's decision, as it demonstrated the effectiveness of the system in action.

"We wanted to get into a situation where things were more predictable, with a better understanding, so we could be more professional with better tools. This was one of the tools to build up our simulation models, and understanding"

Poul Kristensen, Senior Acoustic Engineer

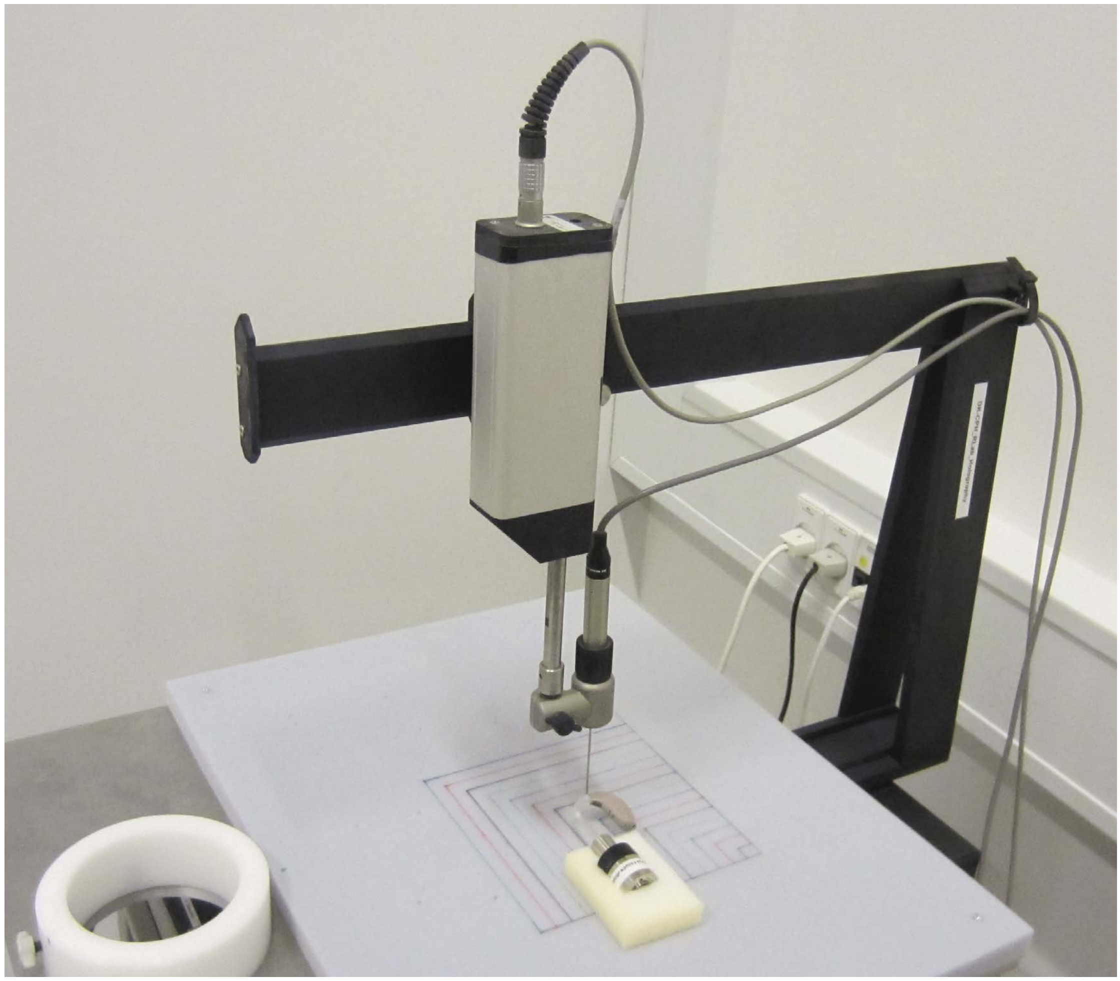
"At the time we were looking for a system, it was taking an unpredictable amount of time in R&D to get the device performance and gain that we were looking for, because the feedback pattern is so difficult to understand," says Poul Kristensen. "We had to do a lot of experiments without seeing the whole picture, so it took us a long time, and the time taken wasn't predictable. We wanted to get into a situation where things were more predictable, with a better understanding, so we could be more professional with better tools. This was one of the tools to build up our simulation models, and understanding."

GN ReSound preferred a robotic solution for the accuracy and repeatability that it could offer, and chose a turnkey solution from Brüel & Kjær using Statistically Optimised Near-field Acoustic Holography (SONAH) made by the Customised Project Department.

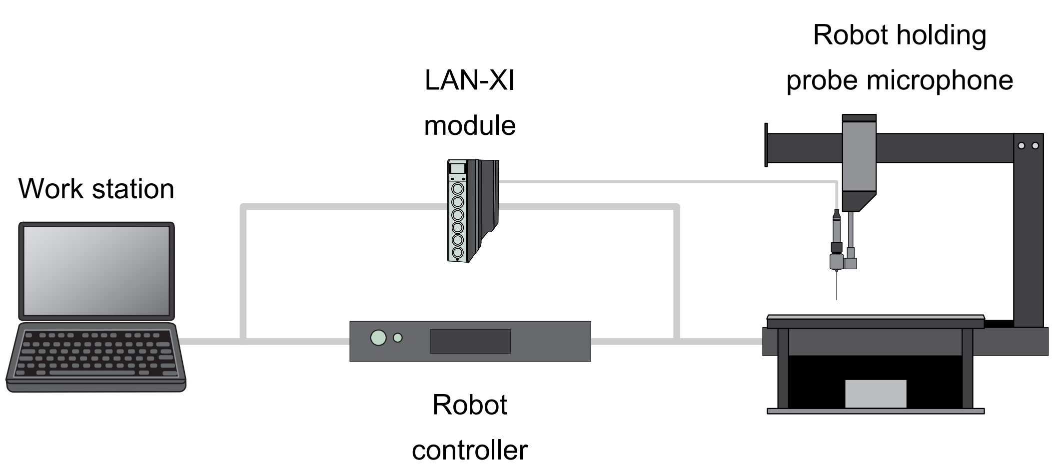
Combining a robot with a conformal calculation

Normally conformal mapping is performed using hand-held arrays, but this approach differs in using a very small robot instead, running on a pre-defined track that is closely aligned with the test object.

The robot with the probe microphone in place. Probe microphones are small, lightweight and perfect for making sound pressure measurements in awkward places close to the sound source.

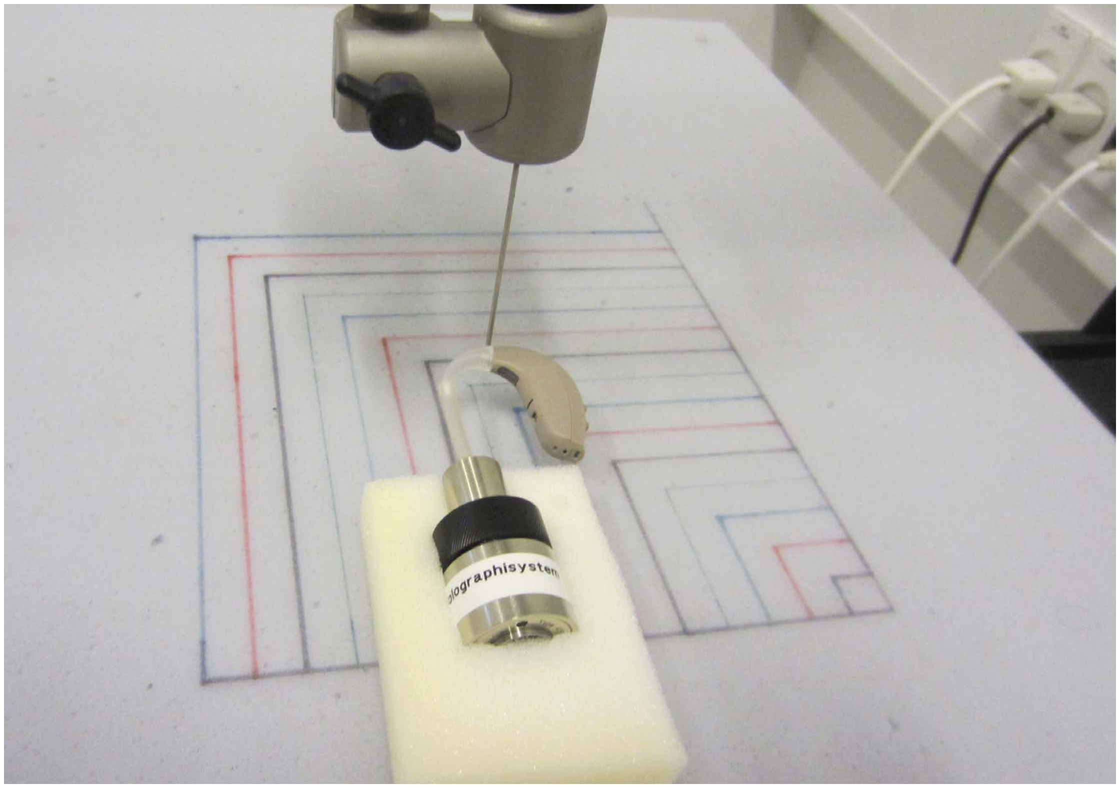


The robot system supplied to GN ReSound



A single Brüel & Kjær probe microphone is positioned by an X-Y-Z robot and measures sound pressure in one or several grids aligned to cover the test object. The robot performs a sine-sweep of all points, moving automatically from point to point at 6 - 7 second intervals.

The robot moves the probe microphone on a pre-defined track to map the sound field



Setting up the system for 3D measurements takes a couple of hours, as Poul Kristensen describes: “We put the device on the test plane and then define the area which the robot is scanning. Then we can cover the whole device and define the size of the steps the robot takes, and then decide on a part of the object where we can measure in smaller amounts if we want to. Typically we look at 16 – 18 mm per square. If we want to go faster, we can do larger steps, and then go into more detail on areas of interest.”

The scan area and the number of positions in each grid are defined by the required frequency range and resolution, but in the beginning the important thing is to look at the sound pressure at the microphone to check for feedback. Then they can analyse the source of this sound.

New capabilities

“With this system we can perform sound intensity measurements,” says Poul, “which we were unable to do before. Thanks to SONAH, this system makes it controllable, as you now have a robot to put the microphone in a specific position. We can now perform a fine mesh of measurements where before we could only analyse sound pressure.”

Before SONAH, we tried to understand the sound by moving the microphone around the hearing aid. But it has to be so precise, and you have to do so many measurements that it really wasn’t very practical. This is much more precise, and gives us much more information.”

What is SONAH?

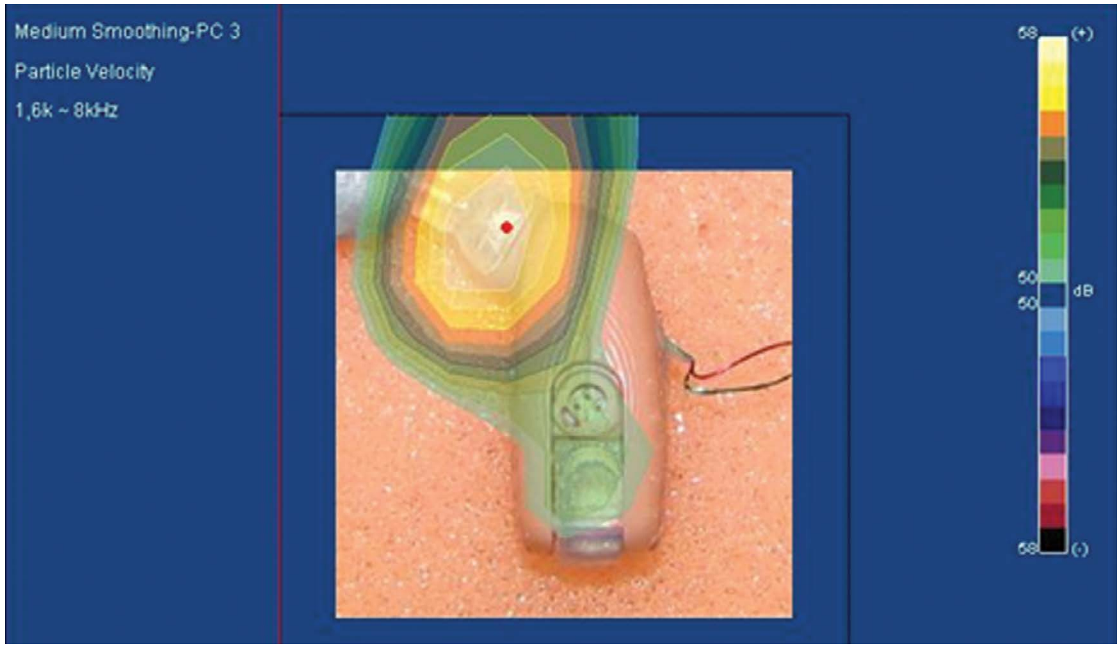
Brüel & Kjær’s patented, advanced holography technique that allows for measurements with arrays smaller than the source, without severe spatial windowing effects. SONAH stands for ‘Statistically Optimised Near-field Acoustic Holography’.

- *It can operate with irregular arrays and still perform spatial FFT calculations*
- *It can perform conformal – 3D – mapping*
- *It allows mapping at lower frequencies than conventional holography methods*

Clearly communicable results

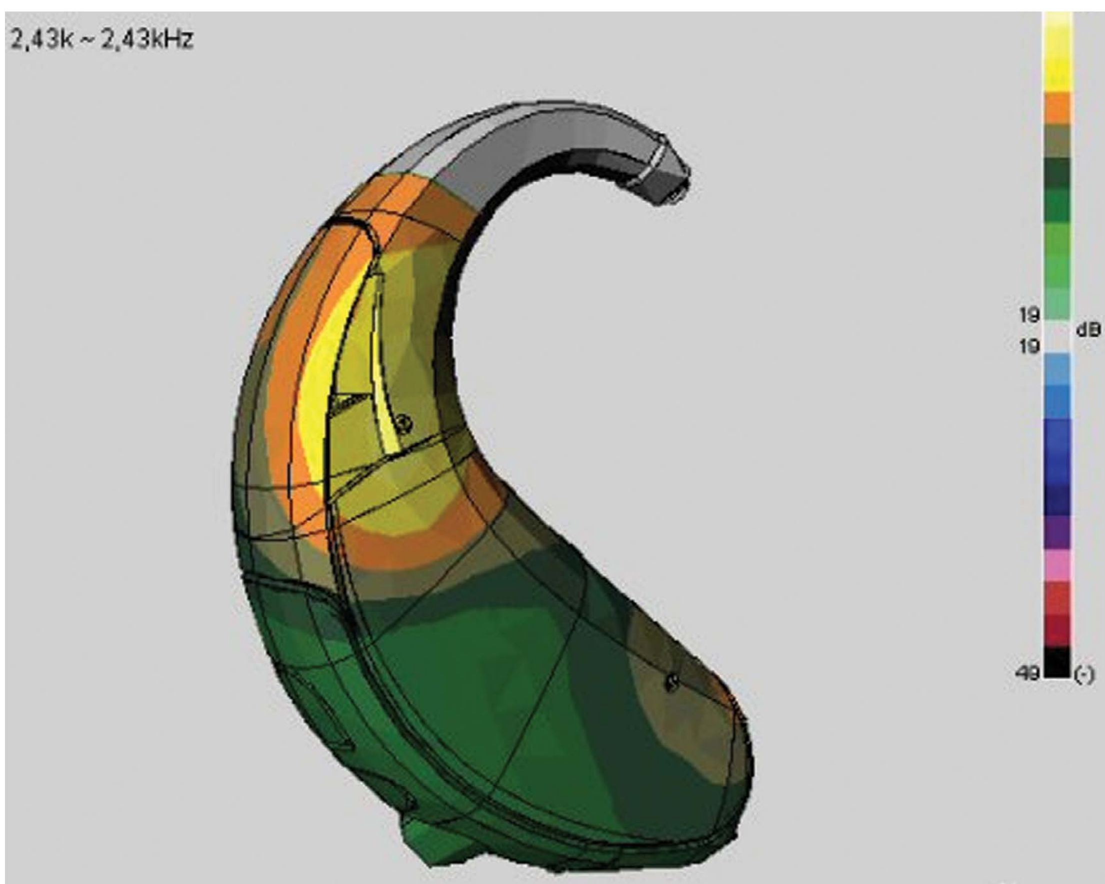
The information can then be represented in 2D planar acoustic maps that can be overlaid on a photo to quickly show the origin of the various sound sources in fine detail.

A 2D holographic sound map overlaid on an image of the measurement object. This planar approach also uses a robot and the same system as above.



Combining conformal sound maps with CAD models gives an even more detailed, 3D image.

3D conformal mapping results from meshing a CAD model with the sound map calulated with SONAH



In collaboration with Brüel & Kjær's Customised Project Department, GN ReSound's engineers combined the precision of the robot-controlled probe microphone with 3D CAD models of the hearing aids they were measuring.

Calculating in this way to a surface rather than a plane is normally done using a hand-held array, but as with the 2D mapping, the approach here uses a small robot for greater accuracy and repeatability.

Rather than a conformal technique, measurements on hearing aids with a robot can be configured with a resolution to 1x1 mm intervals, before the software makes holography calculations from which they can calculate the sound intensity, and get an overview of the acoustic leakage and crosstalk. They then make a conformal calculation onto the structure.

"It has improved the product. It is one of tools that has decreased time and increased predictability. Now we have better tools and can understand the problems better, and get to the root causes of issues faster."

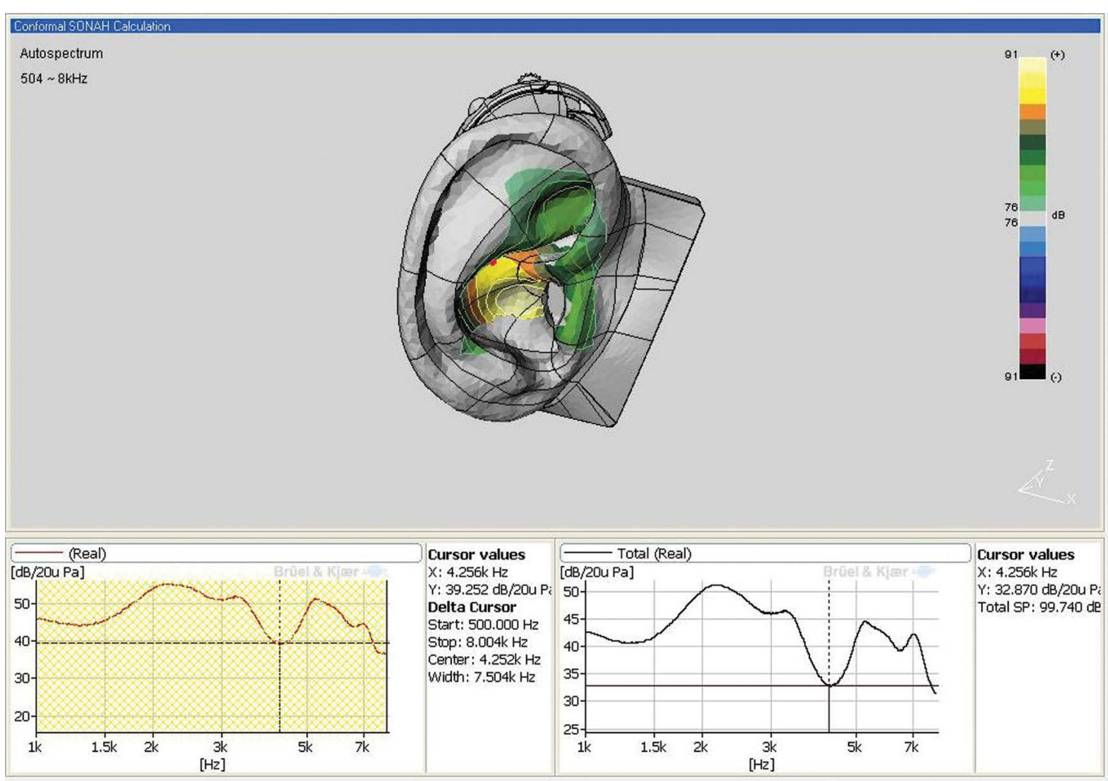
Poul Kristensen, Senior Acoustic Engineer

The resultant 3D images overlay conformal sound mapping on a 3D computer image of the test object, giving the advantage of showing the full picture in one step instead of having to look at many different 2D planes to get the whole picture. On a computer the model can actually be turned around to see what happens from every different perspective.

This unification of CAD models and acoustic holography is achieved by meshing the imported CAD model of the hearing aid with the holography result, using a triangular-mesh, high-density mapping system.

3D conformal mapping has also been used to determine the feedback pattern for the sound generated in the actual ear canal by a hearing aid, shown on top of the ear. Sound is transmitted from the hearing instrument via tubing and an ear-mould that is inserted into the ear canal, both of which are not shown in the image.

Conformal mapping on a physical ear model



Benefits

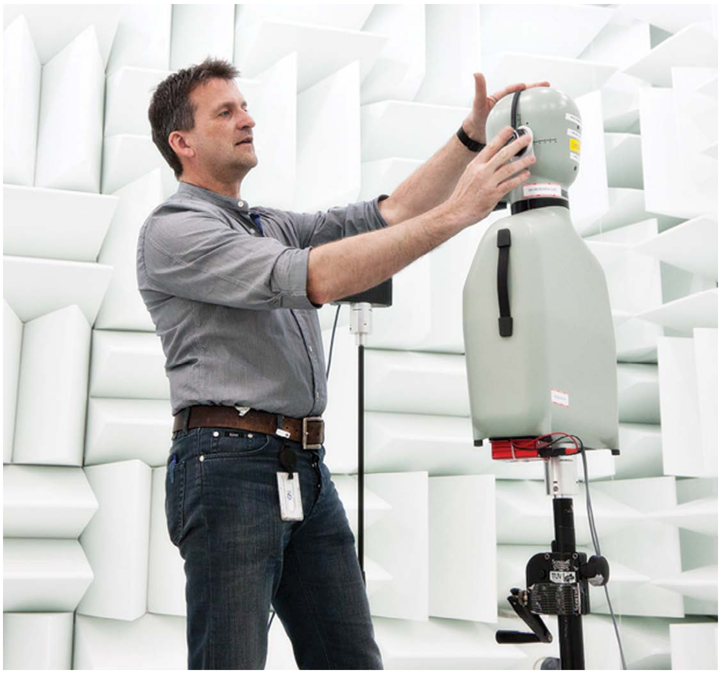
The ability of the system to provide high resolution mapping on a small object, and to do so with excellent repeatability and a dependable timescale has brought great benefits to GN ReSound's development process, as Poul Kristensen says. "It has improved the product. It is one of tools that has decreased time and increased predictability. Now we have better tools and can understand the problems better, and get to the root causes of issues faster."

Morten Søndergaard, another Senior Acoustic Engineer involved with the development of the system and building simulation models is also pleased with the increased development speed that it has brought. "The time taken for the development process involving modelling, simulation and verification using laser measurements and the acoustic holography system has been reduced by 20%," he says.

All of GN ReSound's Senior Acoustic Engineers are able to use the system, and with a floating PULSE licence, it can also be used by their Chinese and American R&D facilities. As Poul Kristensen says, "We have floating licence so they can analyse measurements in China that have been made in Denmark, so we can do the measurements and then they can perform the analysis when they have the data locally."

Future

GN ReSound's Head And Torso Simulator (HATS) at work



Much will continue to happen in the direction of simulation, where the increased experience will help improve their products' capabilities, as they carry experience from one project to the next. But simulation can't stand alone, and real measurements have to support simulation models, meaning the tools for finding out why physical models don't behave as expected will continue to be vital.

As with most technology, and especially with portable devices such as these, the trend is towards smaller and smaller units. And as devices shrink, the challenges become even more difficult, so the contemporary challenge is to keep or reduce the amount of feedback, even with smaller devices.

Software development is also critical as they work with sound and processing sound to improve speech intelligibility, mainly by processing of the signal. As Poul Kristensen says, "Hearing aids consist of a lot of sound processing software. Hardware plays a role, but the big difference is in sound processing software."

Denmark. Hearing Aid Industry, telecom and audio. PULSE, 2D & 3D robot, probe microphone, SONAH.
Photos courtesy of GN ReSound.

www.bksv.com/CaseStudies

BN 1155 – 11 2012-07

HEADQUARTERS: Brüel & Kjær Sound & Vibration Measurement A/S · DK-2850 Nærum · Denmark
Telephone: +45 7741 2000 · Fax: +45 4580 1405 · www.bksv.com · info@bksv.com
Local representatives and service organisations worldwide

Brüel & Kjær