

# ROBOT-CONTROLLED ACOUSTIC HOLOGRAPHY FOR HEARING AID DEVELOPMENT

For identifying feedback in hearing aids due to leakage or vibration, a special turnkey solution using robot-controlled measurements and statistically optimized near-field acoustic holography (SONAH) has stabilized development time requirements and provided improved insights to build GN ReSound's knowledge base.

## ReSound

rediscover hearing



### CHALLENGE

Improve the analysis of vibration and acoustic feedback in hearing aids

### SOLUTION

A robot-controlled probe microphone to take grid measurements for sound intensity and acoustic holography calculations

### RESULTS

Higher fidelity measurements performed in a more predictable timeframe with clearly communicable results in 2D and 3D representations

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



### **GN ReSound**

GN ReSound is part of The GN ReSound Group, one of the world's largest providers of hearing aids and diagnostic audiological instrumentation, which is part of GN Store Nord.

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.

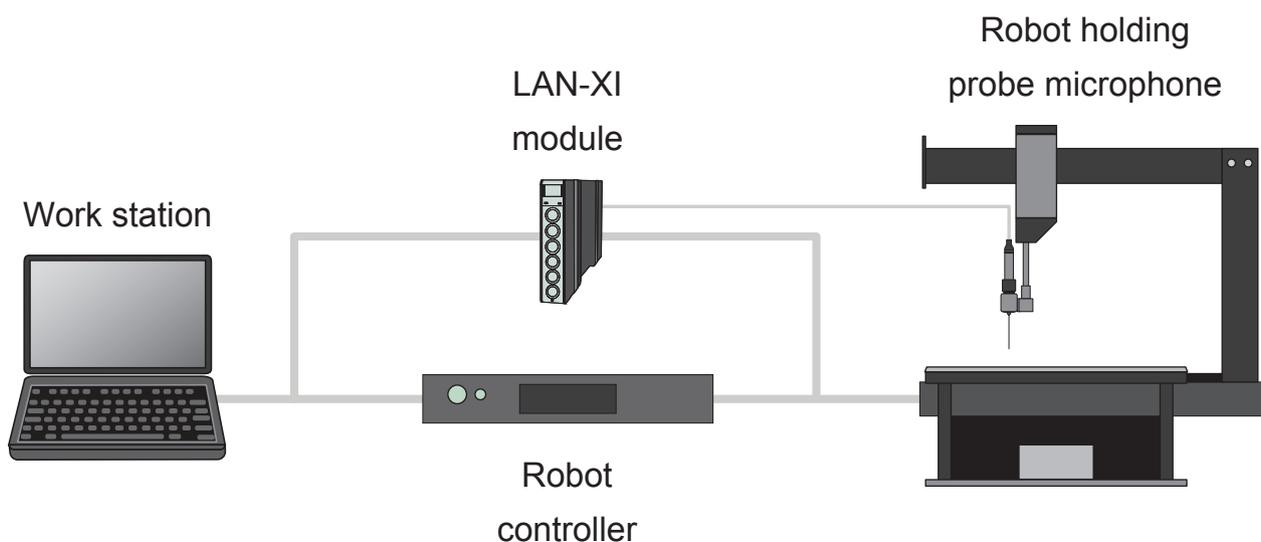
### **BACKGROUND**

GN ReSound is 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 hearing aids is severely limited by the amount of acoustical and mechanical feedback typically experienced within the electroacoustic system. In hearing aids, there are different vibration-borne feedback patterns, meaning the small speaker inside

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*Poul Kristensen, Senior Acoustic Engineer*



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 can also create direct sound feedback.

During the design phase, parts need to be identified in the electroacoustic system assemblies that cause acoustical leakage, thus possibly creating an acoustic feedback path, and also creating resonances that create a mechanical feedback path.

## CHALLENGES

### Analyzing feedback patterns

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.”

“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.”

“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.”

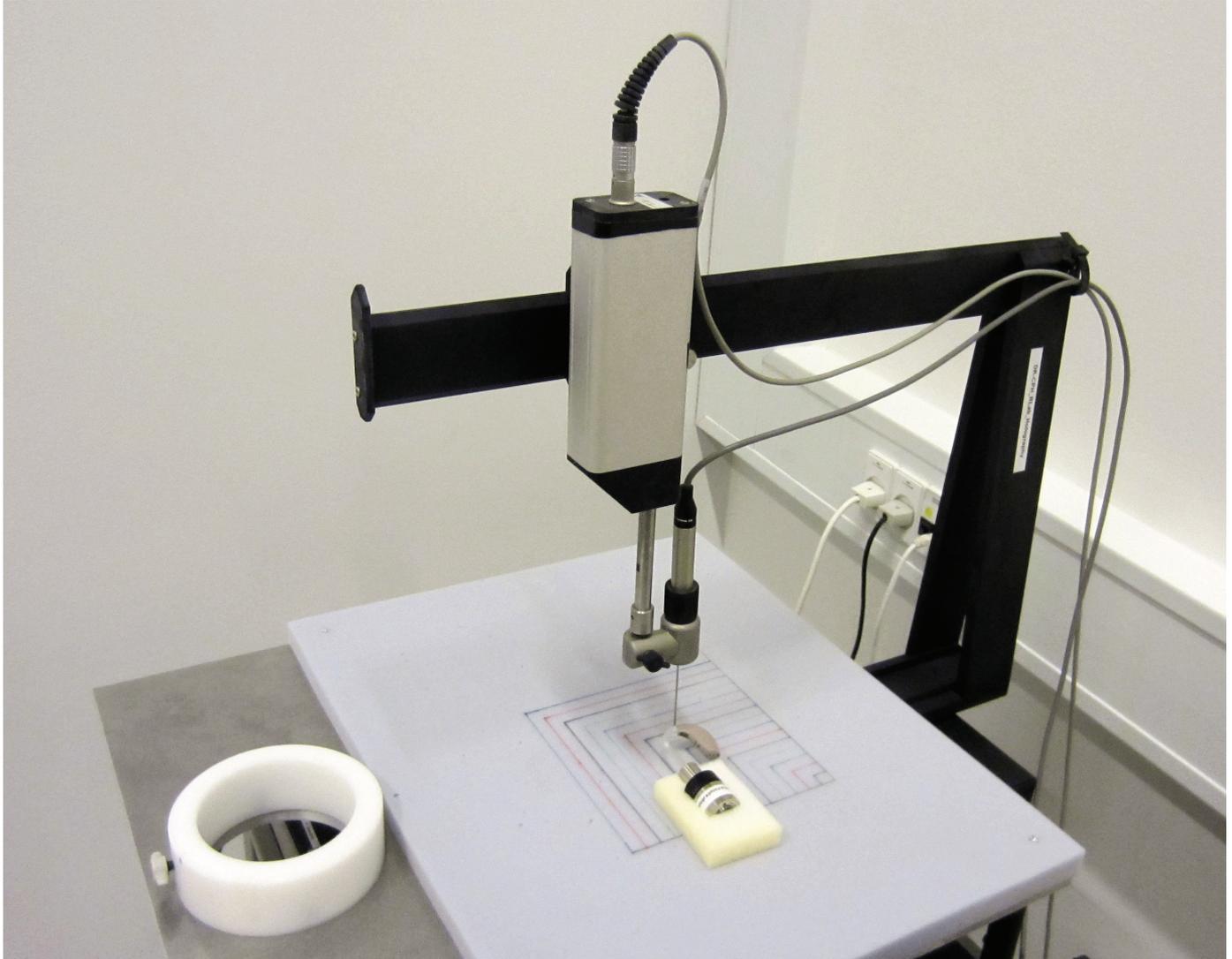
“This is all done during development,” says Poul, “and of course we can check production devices if we need to, but it is normally limited to prototypes. If we don’t get the gain we expect then we want to know why. And it could be that one assembly is not sealed properly.”

### Predictable testing time

“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

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



a lot of experiments without seeing the whole picture, so it took us a long time, and the time taken wasn't predictable.

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.

## **SOLUTION**

Normally, conformal mapping is performed using hand-held arrays, but 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 optimized near-field acoustic holography (SONAH).

## **Hearing aid components**

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.

This approach uses a very small X-Y-Z robot running on a pre-defined track that is closely aligned with the test object.

A single Brüel & Kjær probe microphone 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 to 7 second intervals.

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.

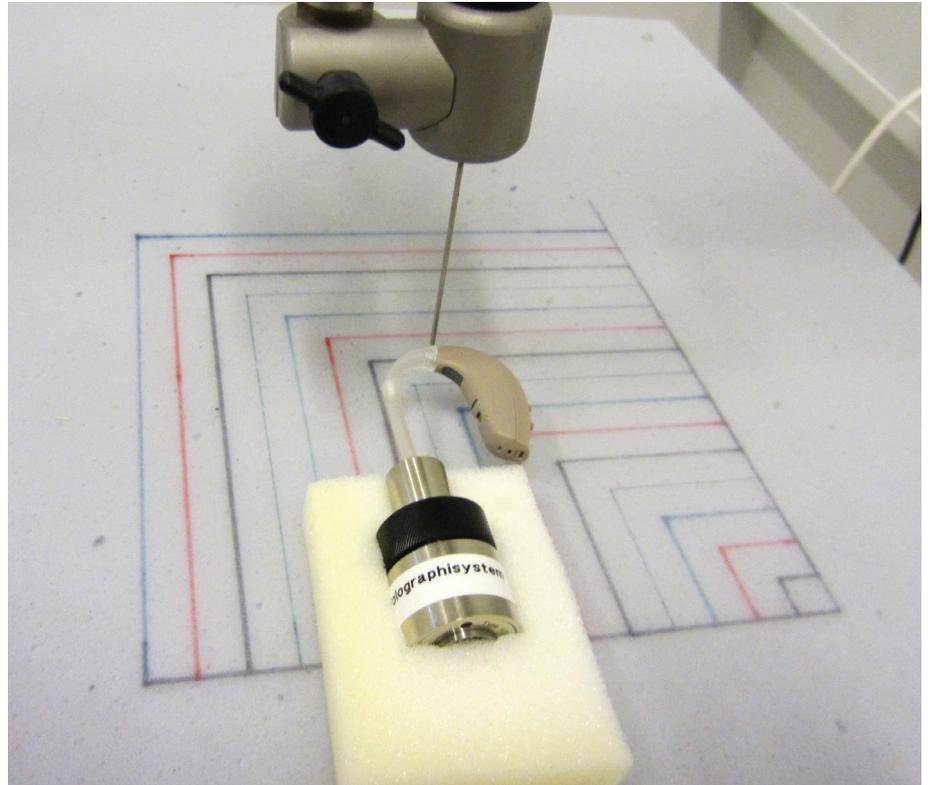
Setting up the system for 3D measurements takes a couple of hours, as Poul Kristensen describes: “We put the device on the test plane and then define the area which the robot is scanning. Then we can cover the whole device and define the size of the steps the robot takes, and then decide on a part of 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 analyze the source of this sound.

## RESULTS

### Higher fidelity measurements

“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.”



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

### 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

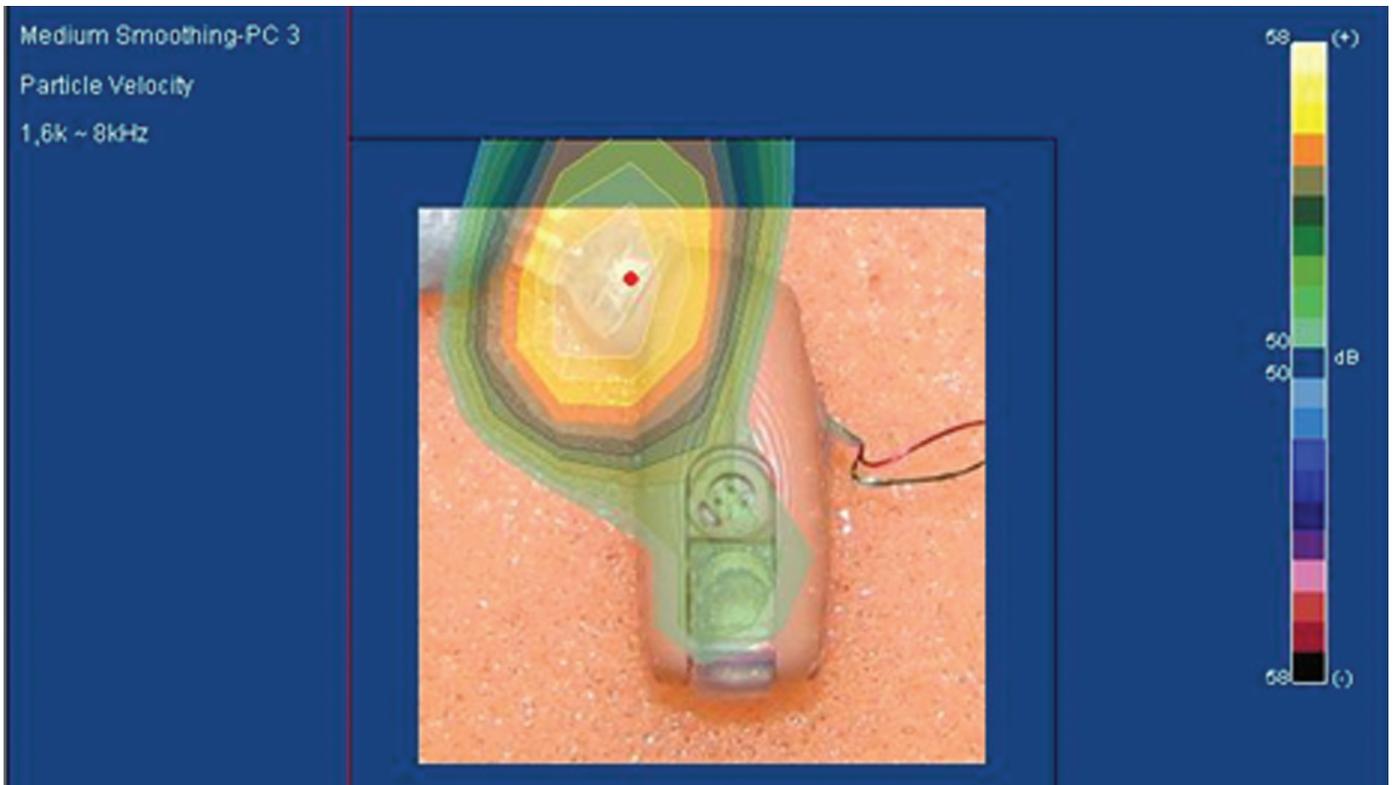
“With this system, we can perform sound intensity measurements, which we were unable to do before, says Poul. “And thanks to SONAH, this system makes it controllable, as you now have a robot to put the microphone in a specific position. We can now perform a fine mesh of measurements where before we could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

### Clearly communicable results

The information can be represented in 2D

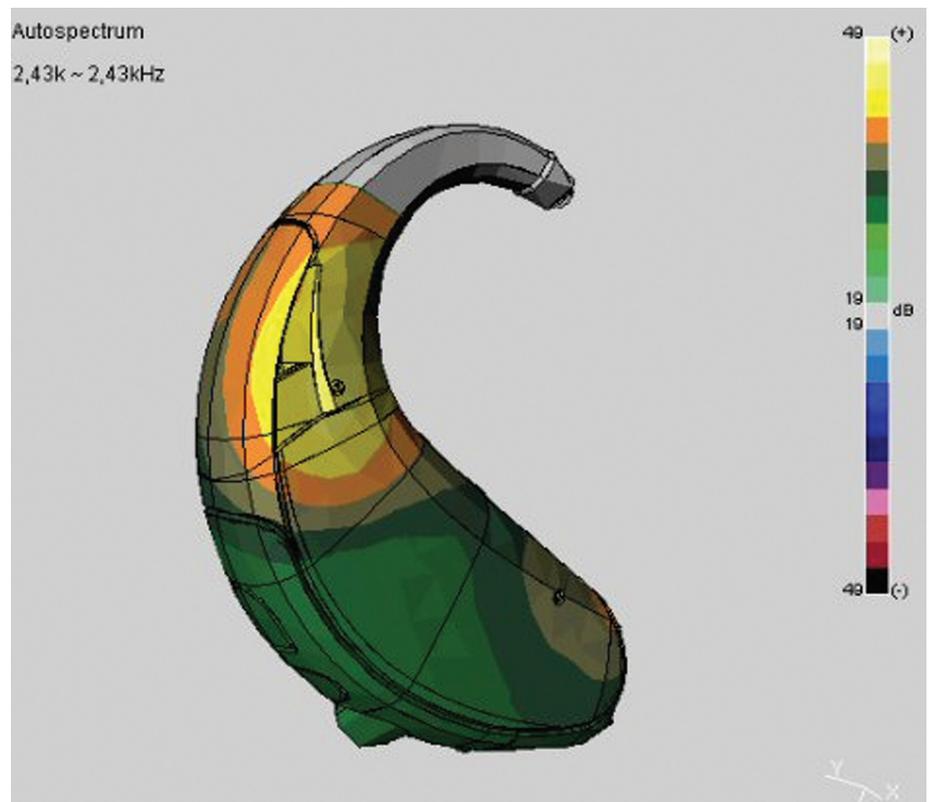
planar acoustic maps that can be overlaid on a photo to quickly show the origin of the various sound sources in fine detail.

In collaboration with Brüel & Kjær, GN ReSound’s engineers combined the precision of the robot-controlled probe microphone with 3D CAD models of the hearing aids they were measuring. This unification of CAD models and acoustic holography is achieved by meshing the imported CAD model of the



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

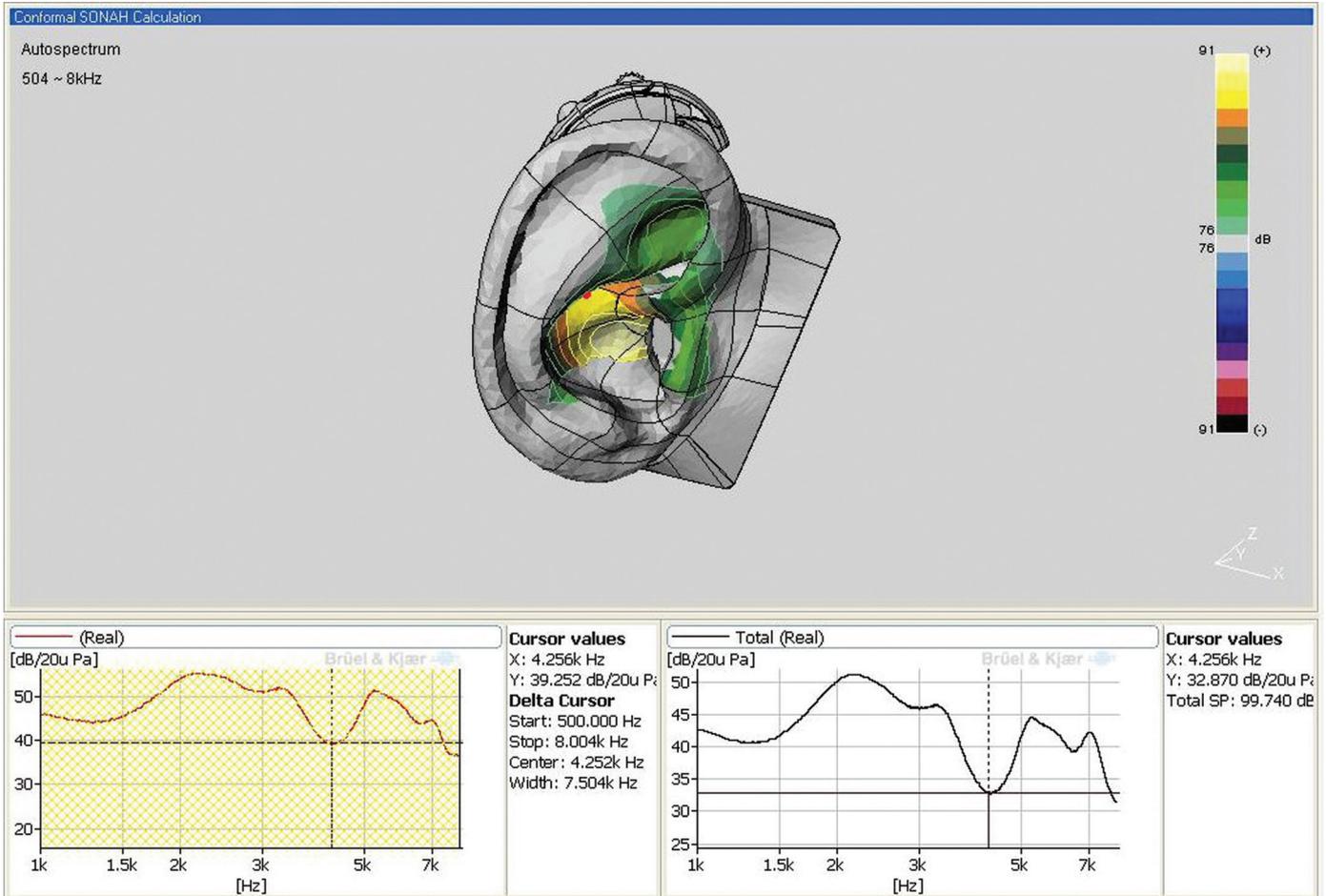
3D conformal mapping results from meshing a CAD model with the sound map calculated with SONAH



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.



Conformal mapping on a physical ear model

hearing aid with the holography result, using a triangular-mesh, high-density mapping system.

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.

3D conformal mapping has 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.

“THE TIME TAKEN FOR THE DEVELOPMENT PROCESS USING LASER MEASUREMENTS AND THE ACOUSTIC HOLOGRAPHY SYSTEM HAS BEEN REDUCED BY 20%.”

*Morten Birkmose Søndergaard,  
Senior Acoustic Engineer*

“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*

## CONCLUSION

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. “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,” says Poul.

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 meas-

urements and the acoustic holography system has been reduced by 20%,” he says.

Overall, as Poul Kristensen says, “It has improved the product. It is one of the 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.”



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