I HEAR YOU

Simulation improves hearing aid performance while saving time and money by quickly iterating through design alternatives.

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▲ Starkey Hearing Technologies' Halo™, a made-for-iPhone® hearing aid

Today, we usually think of smart watches and fitness devices as the premier wearable electronics, but hearing aids are wearable electronic devices that have long improved quality of life for millions (if not billions) worldwide. The hearing aid market has rapidly evolved recently with the introduction of wireless hearing aids that incorporate settings that can be changed while being worn; the aids also can communicate with electronic devices such as smartphones. Design of these products is complex because the antenna and other wireless components must be integrated inside a tiny package. Conforming the antenna to fit these constraints can degrade antenna performance and creates the potential for near-field coupling effects with other electronic components. Starkey Hearing Technologies RF engineers overcame these challenges by using an ANSYS HFSS simulation tool to optimize antenna design while considering the effects of other components and the wearer's body. The result is substantial improvement in hearing aid performance combined with reductions in product development time and expenses.

DESIGN CHALLENGES

With the advent of Starkey Hearing Technologies' 900 MHz wireless hearing aid technology, hearing aid wearers have new options to wirelessly connect with multimedia devices and easily change hearing aid settings. Accessories connecting hearing aids to electronic devices such as televisions and

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Starkey Hearing Technologies increased the use of HPC licenses to reduce simulation time by over 90 percent.

smartphones are a few examples. These hearing aid products also utilize wireless accessories that enable users or medical professionals to make adjustments to the hearing aid without having to remove it from the ear. Beyond accessory communication capabilities, 900 MHz signals are used for communication between the hearing aids (ear-to-ear communication). This technology allows user controls on the left and right hearing aids to be configured for different operations (e.g., left is for volume, right is for memory) since the hearing aids will remain synced via ear-to-ear commands.

In addition to Starkey Hearing Technologies' 900 MHz products, Halo™, a made-for-iPhone® 2.4 GHz wireless product, was recently introduced to the market. Halo communicates directly with an iPhone using Bluetooth® wireless technology, so users can stream telephone calls and music to their hearing aids and control their experiences through an app on their phones.

Manufacturers are adding wireless technology and other features while hearing aids are becoming smaller than ever. This creates major design challenges. The hearing aid consists of many components, including microphones, a flexible printed circuit board, a battery, a receiver, an antenna and, in many cases, a telecoil. The flexible printed circuit board incorporates more than 60 different components and integrated circuits. The RF designer must manage all these components in a constrained space where the potential for the performance of the antenna to degrade is very high. Traditionally, antennas were designed based on textbooks and literature, but that approach addresses only very simple geometries and does not consider potential interactions generated by other components in the hearing aid and the wearer's body. The toughest challenge involves hearing aids that are designed to fit inside the ear because of their exceptionally small size. The outer package for these products is custom-designed to fit the wearer's ear. This means that the electronics must be small enough to fit into the smallest ear size that the hearing aid is designed to accommodate.

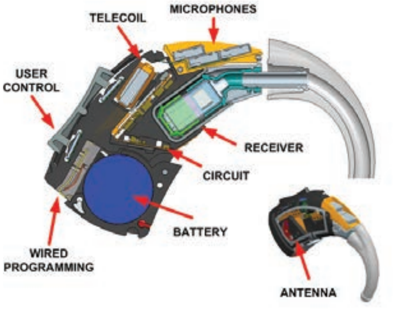
SIMULATION PROCESS

Starkey Hearing Technologies RF designers address these design challenges by using ANSYS HFSS to simulate a wide range of design alternatives that take into account the actual geometry of the antenna, components within the hearing aid, and the user's body. Engineers must generate concept designs for the antenna to fit within the packaging constraints. The greatest modeling obstacle is meshing large features, such as the human head, in conjunction with small features, such as hearing aid circuitry. Starkey Hearing Technologies engineers worked closely with ANSYS application engineers to develop a process that creates consistently meshable models. The Starkey Hearing Technologies team has also developed scripts for pre-processing, running simulations and post-processing that ensure simulation results are comparable across different designers and projects.

The simulation sequence normally begins with modeling the antenna alone as a subsystem, and then modeling the antenna with other hearing aid components. Finally, the antenna and hearing aid are simulated in place on the wearer's head as a full system to understand how the absorption of power by the wearer's body affects antenna performance. Engineers evaluate the ability of proposed designs to meet performance requirements despite variations in the wearer's head size, ear shape and position in which the hearing aid is worn. Simulation lets engineers explore the design's sensitivity to parameters such as antenna topology, the line width of the copper that makes up the antenna, and antenna excitation locations. Engineers can easily add and remove components of the hearing aid from the model to understand their impact on antenna performance.

▲ For hearing aids worn in the ear, all the components must fit within a package that accommodates the smallest ear size.

▲ Starkey Hearing Technologies' SurfLink® Mobile accessory device communicates with a hearing aid.



▲ Hearing aid components

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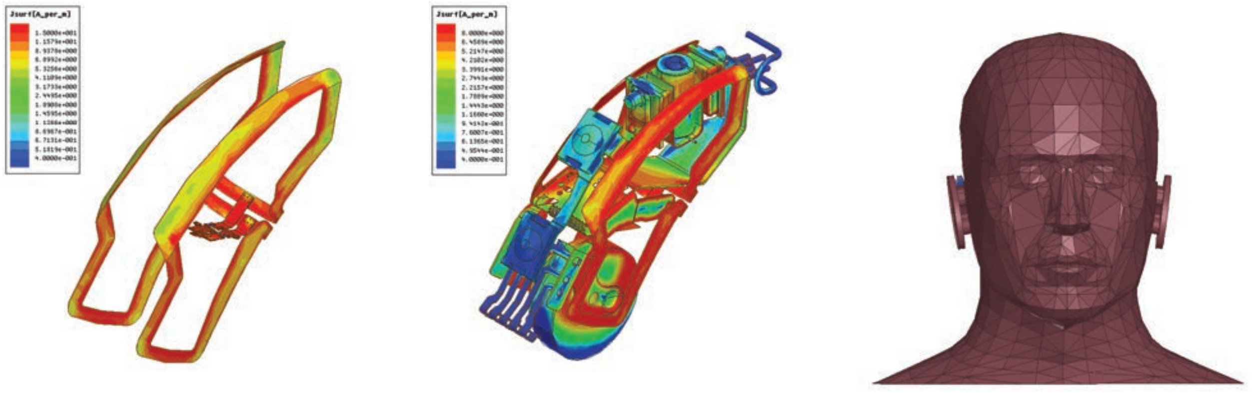
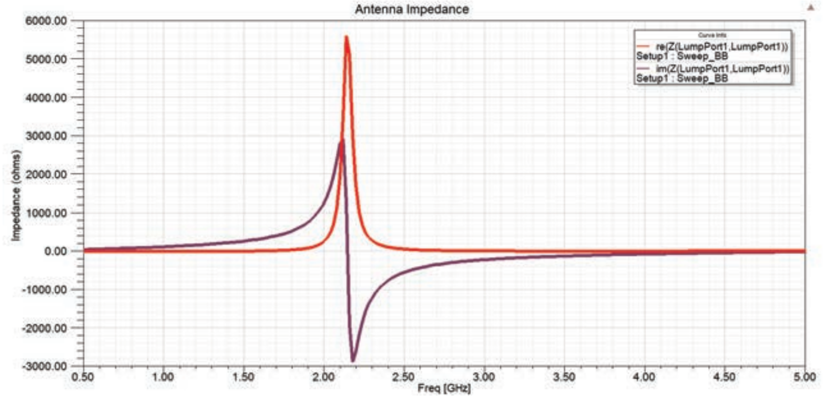


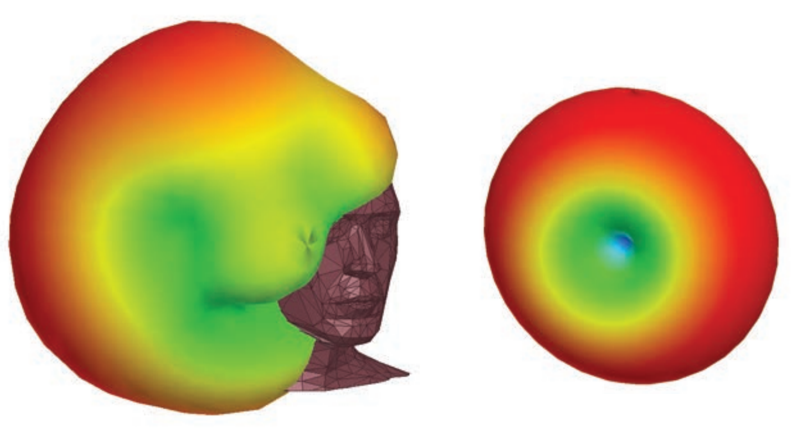
▲ Typical simulation sequence (from left to right): antenna only, antenna with some hearing aid components, antenna with some hearing aid components on head

ITERATING TO AN OPTIMIZED DESIGN

The antenna design process typically starts with developing a link budget from which hearing aid performance requirements are derived. These are defined by two key metrics: total radiated power (TRP) (for hearing-aid-to-accessory communication) and receive sensitivity (for accessory-to-hearing-aid communication). With an understanding of the radio performance connected to the antenna, requirements are derived from these two metrics. Engineers use HFSS to calculate the radiation efficiency of the antenna, which is added to the power sent into the antenna to yield the TRP. There are other key antenna parameters that the designer needs to consider to understand antenna radiation properties. One example is effective isotropic radiated power (EIRP), which is the amount of power radiated at a single angle. This quantity is usually quoted in the direction of maximum antenna gain. The designer can obtain the hearing aid's predicted EIRP by using peak realized gain from HFSS and adding the power incident at the antenna. HFSS enables the designer to make comparisons between different antenna designs regardless of type, size or form based on these key metrics.



▲ Impedance plot

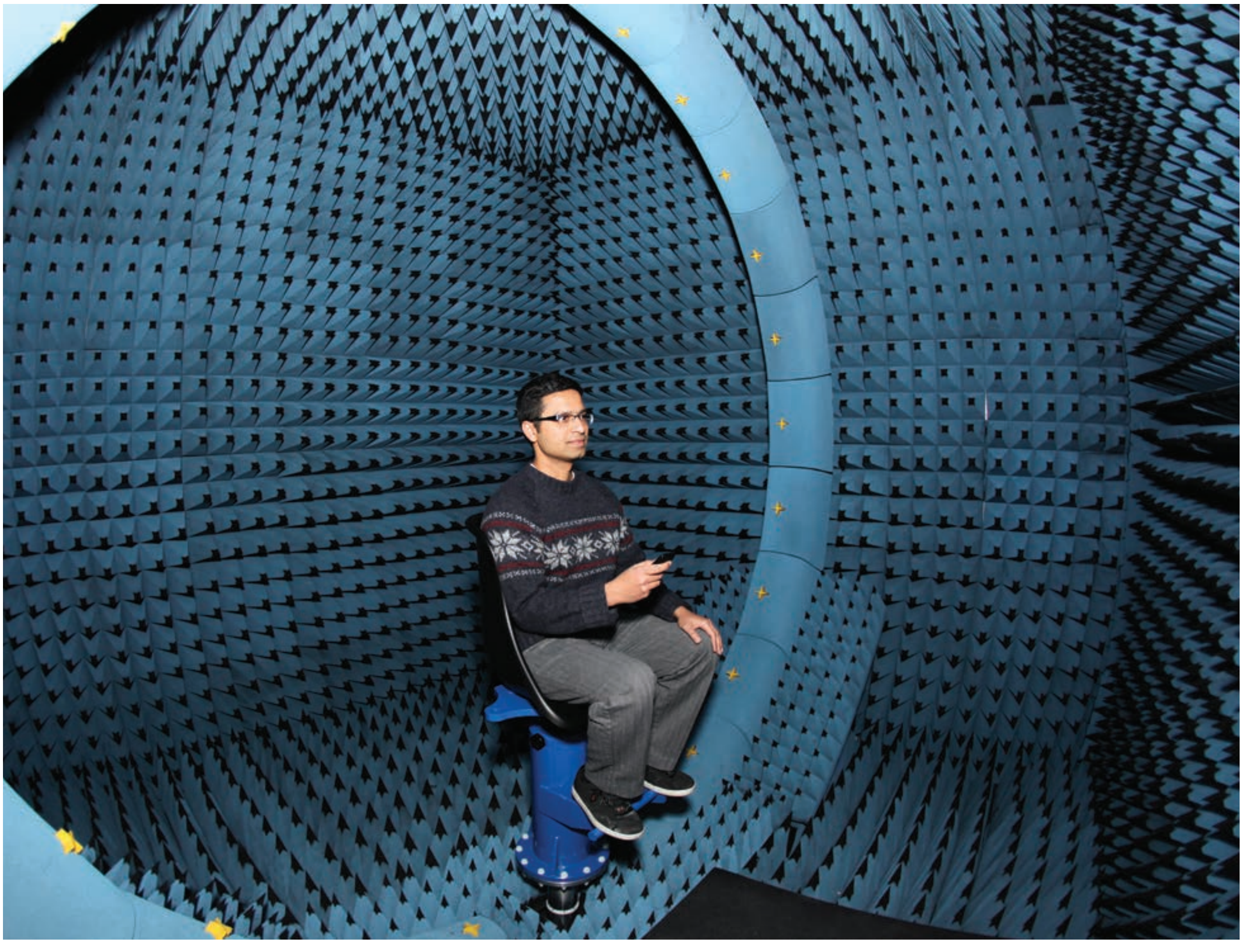


▲ Radiation patterns

Simulation is also used to diagnose the performance of a proposed design and gain insight into how it can be improved. For example:

- Impedance plots predict the impedance of the antenna across a range of frequencies and are used to match the load impedance (antenna impedance) to source impedance to achieve maximum power transfer.
- Radiation patterns are used to tune the direction in which the antenna power is radiated to minimize power wasted by radiating into the body and maximize power directed toward the accessory or smartphone.
- Current density plots show the potential for interaction between each of the hearing aid components and the antenna.

Simulation results are verified by testing in an anechoic chamber (a room



Testing on a human in an anechoic chamber

with walls that completely absorb electromagnetic radiation), isolating the device under test from outside sources of energy. Measured results correlate well with simulation predictions, typically within 1 dB to 3 dB.

In the past, HFSS simulations were performed on high-performance computing (HPC) towers with 8 to 16 cores each taking about 11.5 hours to complete. Starkey Hearing Technologies recently transitioned to an HPC cluster that can be accessed easily by all the company's designers and provides efficient use of ANSYS HPC licenses. The HPC cluster hardware includes one virtual node for scheduling and three computational nodes, each with 48 cores and 192 GB of RAM. The HPC cluster uses 48 cores to reduce simulation time to less than one hour. This greater-than 90 percent reduction in simulation time enables Starkey Hearing Technologies designers to iterate through more design variations in a project time frame, ultimately resulting in a more robust product for the end user.

With the growing use of wireless technology in today's hearing aids, electromagnetic performance is becoming more and more critical to hearing aid performance and reliability. Simulation makes it possible to consider the impact of various antenna designs and component placement strategies in the early stages of the design process. Simulation also enables engineers to consider the effects of different head geometries and wearing positions on the performance of proposed designs prior to the prototyping phase. Simulation saves months of testing time and tens of thousands of dollars in resources for each design project by refining antenna options through virtual prototypes rather than physical prototypes. Using engineering simulation also reduces the risk of expensive mechanical tool iterations. Starkey Hearing Technologies has plans to increase its deployment of simulation by using a wider range of head models and incorporating full-body simulations.

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