WEARING A WIRE

Simulation helps to optimize body-worn wireless devices for an emerging class of applications.

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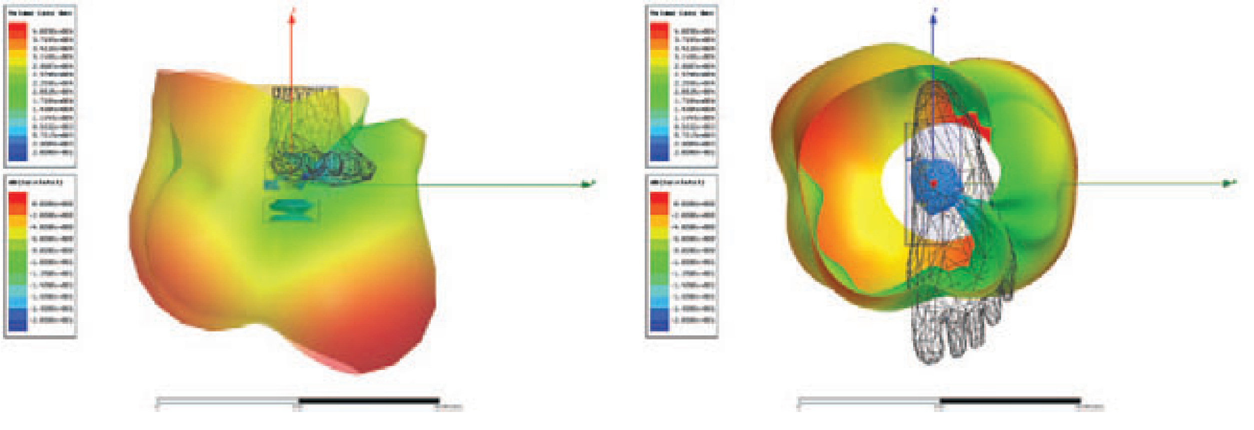
Interest in body-worn wireless devices has grown in recent years because of actual and potential applications in healthcare, sports, law enforcement, entertainment and other areas. For example, the U.S. Department of Defense is working on a wireless device to be worn by soldiers that will allow medics to measure vital signs and collect other medical information from the troops. Body-worn wireless devices have been developed to measure and record an athlete's performance, such as running speed and the number of strides.

Regardless of the application, using a wireless device in close proximity to the human body creates a number of major design challenges. The radiated power of the device must be kept below levels that can create a health hazard. The device's power consumption, size, aspect ratio and weight must be minimized to make it suitable for wearing. Yet the device must be designed to deliver a signal of sufficient power to the right location, with good reception by the target device — despite the fact that the human body may absorb a significant portion of the signal.

MODELING THE SYSTEM

Synapse Product Development solves such difficult engineering challenges from concept through manufacturing for leading consumer electronics and life-sciences companies. One of the company's specialties is developing body-worn wireless devices for a wide range of applications. The design of the antenna is often a major challenge in these devices because the body absorbs so much energy. Synapse uses the ANSYS HFSS 3-D full-wave electromagnetic (EM) simulator and the ANSYS human body model

Synapse uses ANSYS HFSS and the ANSYS human body model to evaluate performance of various antenna designs by modeling the complete system, including the wireless device and antenna and their interactions with the human body.

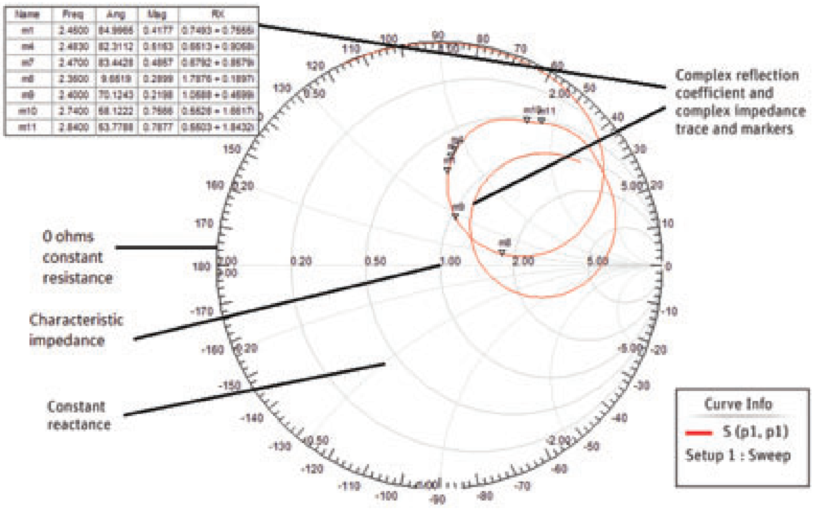


ANSYS HFSS simulation output shows power absorbed by foot and ground.

to evaluate the performance of various antenna designs by modeling the complete system, including the wireless device and antenna and their interactions with the human body. The ability to evaluate designs without building physical prototypes typically helps Synapse engineers to increase the performance of the antenna by a factor of five compared to the original design concept.

Antenna design focuses on transferring power from transmitter to receiver. A dipole antenna is a well-established reference for performance and has the perfect geometry to optimize the power transfer of the antenna. For a 2.45 GHz antenna built with an FR4 printed circuit board, the wavelength is 60 mm, so the total length of the dipole should be 30 mm. This is too long for most body-worn wireless devices. So instead, electrical engineers design a smaller antenna with properties as similar to a dipole as possible. For example, they attempt to match the antenna's radiation resistance to the optimal load impedance of the transceiver. Radiation resistance is that part of an antenna's feedpoint resistance that is caused by the radiation of electromagnetic waves from the antenna.

The complexity of the antenna geometry required for body-worn wireless devices makes it very difficult to create an acceptable design in a reasonable amount of time using the traditional build-and-test design process. Facing this and many other difficult design challenges, Synapse engineers evaluated a number of different simulation products. ANSYS provides a solution for nearly all of their design challenges, including circuit, electromagnetic, mechanical and thermal simulation. ANSYS software enables automatic data transfer to simultaneously optimize the product over multiple disciplines and domains. Synapse's management staff concluded that purchasing all of its simulation tools from a single vendor would deliver great benefit, such as a single-support contact for questions and training.



Smith chart helps engineers to match impedance of antenna and transmitter.

THE DESIGN PROCESS

The design process typically begins with the industrial designer providing a concept that incorporates the electronics and antenna. Synapse electrical engineers then use ANSYS HFSS to optimize the wireless antenna design. The engineer starts the modeling process by importing the geometry of the initial design from a SAT file. The next step is defining the electrical properties of the materials, such as permittivity and dielectric loss tangent, permeability and magnetic loss tangent, bulk electrical conductivity, and magnetic saturation.

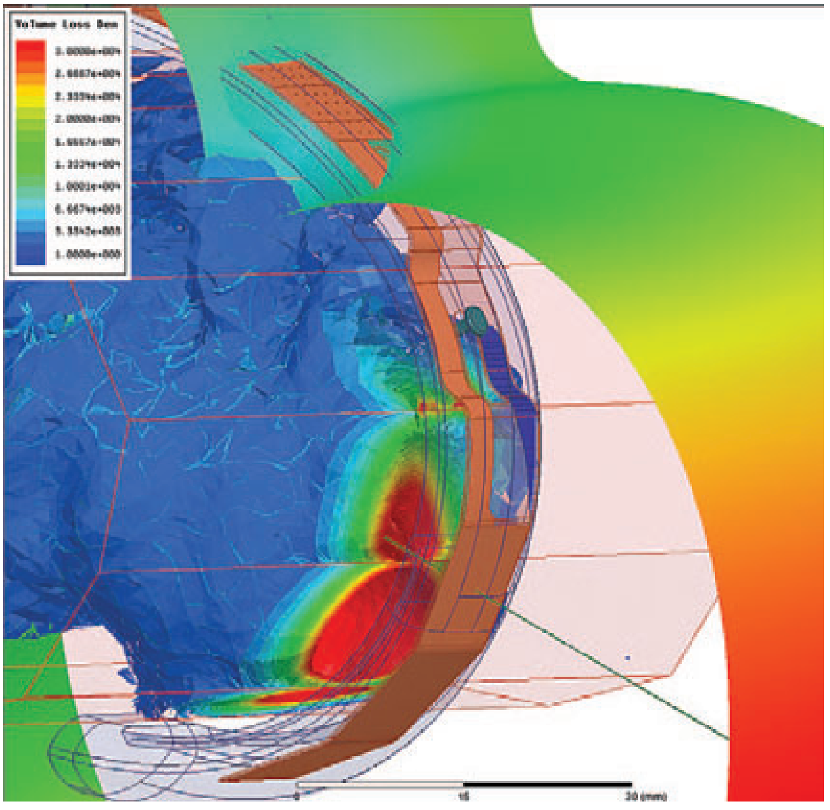
Optimizing the performance of the antenna requires close attention to the way in which the human body affects antenna performance — thus the need for a systems approach to analysis. The ANSYS software's human body model enables users to set the dielectric constant for different parts of the body. Typically, Synapse engineers vary skin thickness from 0.4 mm to 2.6 mm and assign it a dielectric constant of 38. The thickness of the fat layer is chosen to account for all impedance-matched effects, typically half of the wavelength, with a dielectric constant of 5.3. The muscle serves as a termination to the model with a thickness of approximately 20 mm and a dielectric constant of 53.

HFSS automatically specifies the field behavior on object interfaces and defines a geometrically conforming tetrahedral mesh. Adaptive meshing refines the mesh automatically in regions in which field accuracy needs to be improved. The software computes the full electromagnetic field pattern inside the solution domain. The next step is computing the generalized S-matrix from fields calculated in the solution volume. The resulting S-matrix allows the magnitude of transmitted and reflected signals to be computed directly from a given set of input signals, reducing the full 3-D electromagnetic behavior of a structure to a set of high-frequency circuit parameters.

The HFSS simulation shows the power absorbed by the body and the gain of the antenna in the form of a color map incorporating both the body and surrounding airspace. In the typical case, simulation results show that the areas of the body closer to the antenna absorb more power. In the case of a device worn in a shoe, for example, the results will identify the amount of power absorbed by the ground as well, which sometimes turns out to be even larger than the energy absorbed by the foot. Based on these results, electrical engineers provide feedback to the industrial designers and system engineers, including information about the geometry of the antenna as well as how close and where on the body it can be positioned.

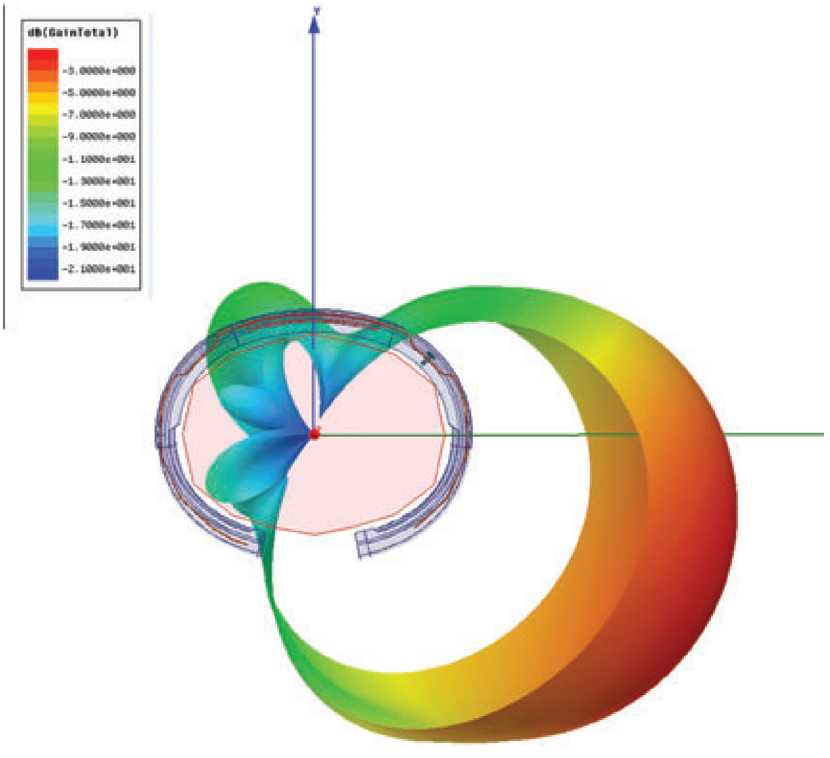
INCREASING RANGE WHILE SAVING TIME

The antenna performance information provided by simulation plays an important role in the system design of a body-worn wireless product. The antenna gain results are critical in link analysis, which



Power absorption of a product worn specifically on the wrist

Guided by simulation, electrical engineers typically can increase the range of the product by a factor of five while saving an estimated three months of development time.



3-D gain of product worn on the wrist

determines the range and throughput. The antenna gain also helps to determine how much transmit power is required, which, in turn, impacts battery life. In the typical case in which more than one device is worn on the body, the antennas of all devices are optimized simultaneously to align the gain between them and to minimize battery power consumption.

In addition, simulation is used to make the antenna smaller to meet industrial design and mechanical design objectives while achieving the required level of performance. As the size of the antenna is reduced, it works over a narrower bandwidth of frequencies. Simulation predicts not only in-band performance but also out-of-band performance, and it helps to avoid radiating at frequencies that would interfere with other devices. Guided by simulation, electrical engineers typically can increase the range of the product by a factor of five, relative to the initial concept, while saving an estimated three months out of a traditional 12-month development cycle.