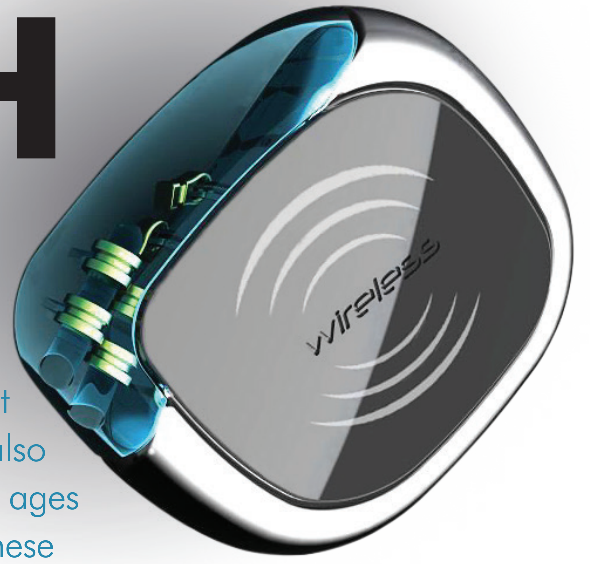
WIRED INTO HEALTH



The Internet of Things for healthcare requires antennas in implantable medical devices to operate safely within the human body, over longer distances than before and at more than one frequency. These devices must also be reliable in the wide range of body types and ages that comprise the human population. To take these many factors into account, Cambridge Consultants uses ANSYS software to model body variations and simulate antenna performance.

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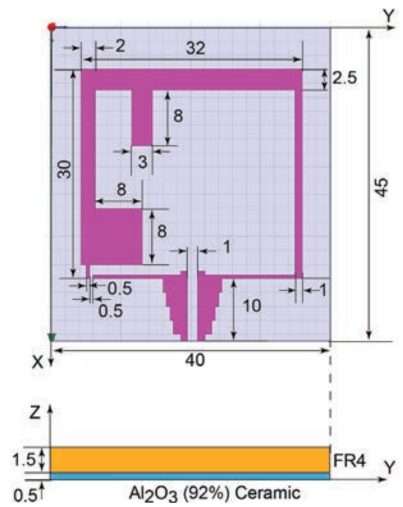
Wireless technology adds a new dimension to medical implants, allowing remote monitoring and treatment optimization. However, to design a successful wireless implant, designers must address many different use cases and regulatory requirements, each of which poses its own unique challenges.

Typically, a smart medical implant must communicate wirelessly with an external handheld device in at least three different environments:

- The operating room, where the implant is programmed before being inserted into the patient.
- The medical office, where a clinician needs to carry out follow-up monitoring by wirelessly communicating with the implant using the external programmer device.
- The home, often using a bedside wireless box that talks to the implant to relay diagnostic information, as well as any alarm conditions, immediately to the doctor/caregiver.

Body tissue affects wireless radio performance by causing reflections and absorbing some of the wireless signal, as well as affecting the operating frequency and bandwidth of the antenna. The patient's body type has a significant effect on the communication distance between the implant and the external device. In recent years, Bluetooth® Smart communication to smartphones has emerged as a popular choice for connectivity. Implantable device manufacturers will no doubt want to explore this option. Bluetooth operates at much higher frequencies than current wireless technologies used in medical devices,

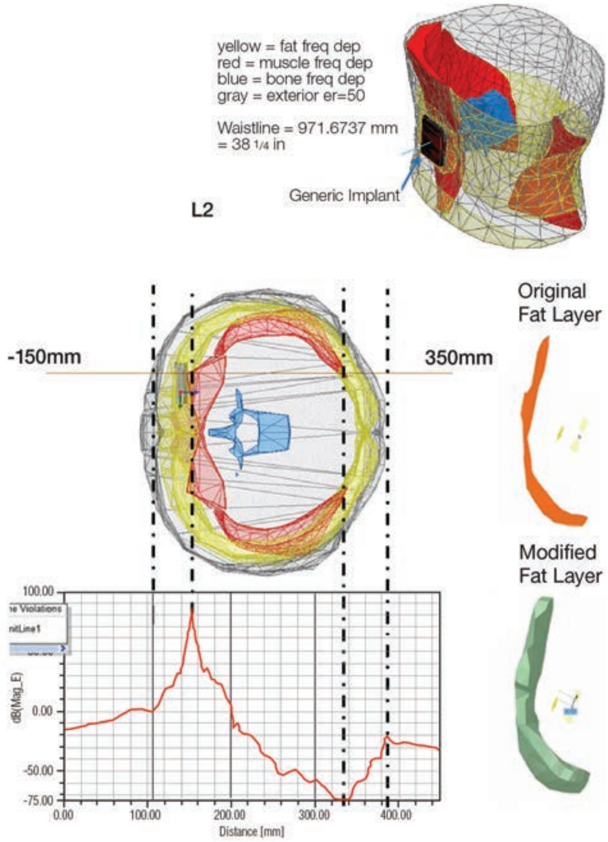


^ Model of the antenna for an implantable device

> **“Engineering simulation tools from ANSYS enable Cambridge Consultants to design innovative medical devices faster.”**

which means that the body absorbs an even higher proportion of this energy, making the range problem even more difficult. The antenna may need tuning from time to time to accommodate patient physiology changes — for example, if the patient gains or loses weight. Finally, regulatory bodies place stringent restrictions on the radiated power, the specific absorption rate, and the rate and amount of data that can be transmitted over the air.

Cambridge Consultants, a world-class supplier of innovative product development engineering and technology consulting, uses ANSYS simulation tools to overcome these challenges. Simulation allows engineers to optimize the design of implanted device antennas to increase their range, enable them to operate at desired frequencies, and validate their performance in advance for a wide range of body types.



^ The ANSYS HFSS human body model was modified with ANSYS SpaceClaim Direct Modeler to represent different body types. ANSYS SpaceClaim can easily change the geometry of an object.

DESIGNING AN IMPLANTABLE ANTENNA

Cambridge Consultants’ engineers recently designed a small antenna that works on both the 402 to 405 MHz (medical implant communications service [MICS]) and 2.4 to 2.5 GHz (industrial, scientific and medical [ISM]) bands, and enables wireless communication at a range of 2 meters or more so that it can be used outside the sterile zone in the operating room. The capacitive nature of human tissue, along with the large capacitive reactance of traditional electric dipole antennas, produces a residual negative reactance that must be compensated with a lumped inductive load to match the microchip impedance. So engineers used a relatively new antenna design approach — a compound field antenna that employs both magnetic loop radiators and co-located electric field radiators. This approach provides an intrinsic inductive reactance that enables engineers to match impedance to the implanted electronics much more easily, and better supports miniaturization and biocompatibility.

Fat, muscle, various types of bone, skin and blood all have different dielectric properties. The dielectric properties of the surrounding tissue strongly affect the behavior of the antenna, for example, lowering the resonant frequency compared with the free-space performance of an antenna with the same dimensions. But the effect of the body on the antenna differs depending on the location of the antenna in the body and on the patient’s body type. Nearly all engineers who design antennas for implantable devices perform electromagnetic simulation using a human body model with elements designed to match the relative permittivity and conductivity of various body materials such as skin, fat, compact bone, spongy bone, muscle and blood. The problem with many of these models is that they are difficult to change to match different body types. So engineers usually optimize the antenna for one average body type, which often leads to antenna performance issues when the device is implanted into a patient with an atypical body type.

Internet of Things: Wearables and Medical Devices
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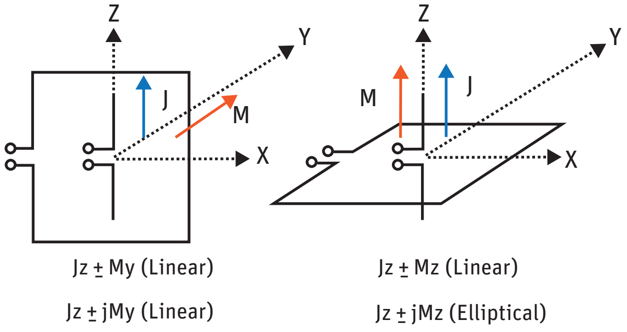
> "Cambridge Consultants' engineers use ANSYS SpaceClaim Direct Modeler software to rapidly modify the ANSYS HFSS human body model to represent changes in body morphology."



Cambridge Consultants developed a compound field antenna that uses both magnetic loop radiators and co-located electric field radiators.

ANTENNA PERFORMANCE AND BODY WEIGHT CHANGE

Cambridge Consultants designs its antennas by simulating performance using ANSYS HFSS electromagnetic software with the HFSS human body model to represent the antenna's use environment. Recognizing the critical importance of developing an antenna design that is robust to changing body morphology (weight), Cambridge Consultants' engineers use ANSYS SpaceClaim Direct Modeler software to rapidly modify the HFSS human body model to represent changes in body morphology.

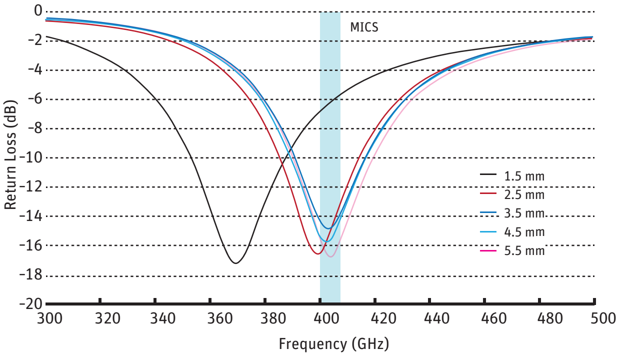
SpaceClaim enables users to create, edit and repair geometry without worrying about underlying technology, thereby speeding up time to analysis. Users can pull, move, fill and combine features of a model to, for example, create rounds, move a feature to another face or change the size of a face. If they prefer, users can enter explicit body dimensions.

This allows Cambridge Consultants to alter fat layer thickness and surrounding skin and muscle layer contours to scale a single body model. This capability is currently not available in other software packages in which a family of body types is provided rather than a single scalable body model.

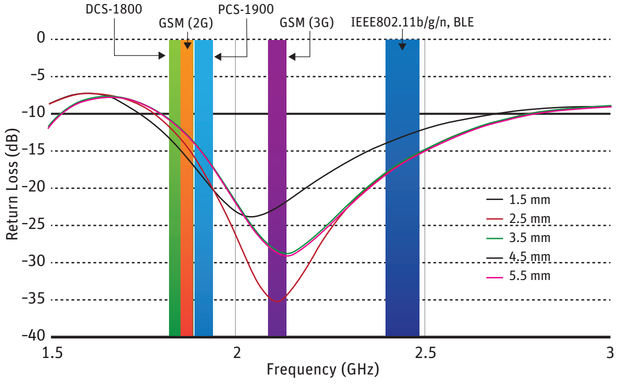
OPERATING IN TWO FREQUENCY BANDS

Nearly all modern wireless implants operate in the MICS band, but recently manufacturers are interested in developing devices that can operate in the ISM band. Using the ISM band can enable devices to communicate with smartphones, eliminating the need for a custom external communications component, and making it possible to take advantage of the powerful capabilities of smartphone technology. Cambridge Consultants engineers designed a new antenna from the ground up to work with both bands.

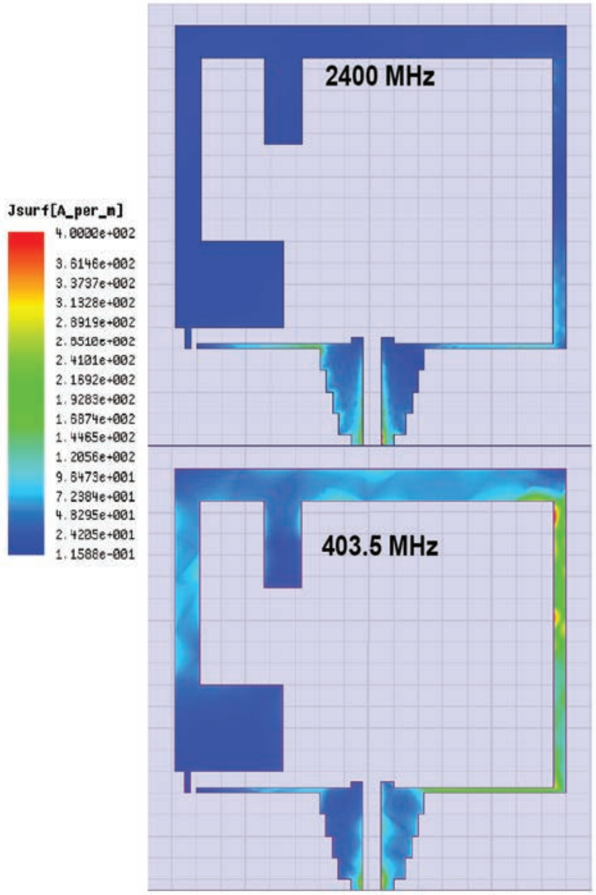
The dual band compound antenna topology was simulated on a 1.5 mm FR4 (glass-reinforced epoxy laminate printed circuit board) substrate with a 0.5 mm Al_2O_3 (aluminum oxide) substrate backing. The fat thickness in the HFSS human body model was varied between 1.5 mm and 5.5 mm in 0.5 mm steps. The antenna return loss was



Frequency response of antenna in MICS band for different amounts of body fat



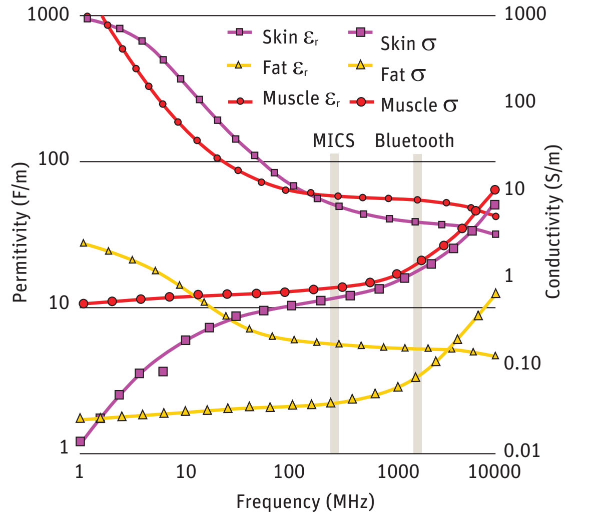
Frequency response of antenna in ISM band for different amounts of body fat



^ Surface current density for 2.4 GHz and 403.5 MHz, two of the bands in which the antenna must operate

optimized for both frequency bands. The surface current density for the antenna structure was plotted for excitations at the two center design frequencies. The antenna demonstrated a peak gain of –11.42 dBi in the ISM band and –14.62 dBi in the MICS band.

The coupled electric and magnetic dipole antenna provides sufficient gain, radiation efficiency and broadband response in both the 402 to 405 MHz and 2.4 to 2.5 GHz bands in a wide range of body types and dimensions to enable the external communications component to operate outside the sterilized zone. The single planar structure is easily fabricated on a single 40 mm by 45 mm bilayer substrate (FR4/Al_2O_3). This antenna and others developed using similar simulation methods will help to improve healthcare by enabling the design of a new generation of medical devices that operate at a longer range to collect patient data for many body types.

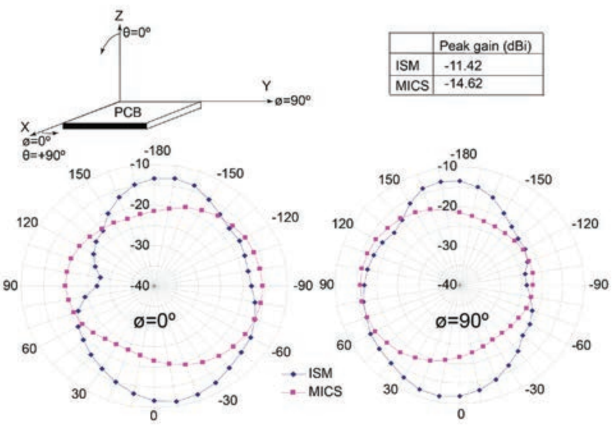


^ Dielectric properties of fat, muscle and skin

DELIVERING INNOVATION FASTER

Modern implantable devices are very complex and require engineers to balance performance, safety, reliability, cost and time-to-market constraints. Engineering simulation tools from ANSYS enable Cambridge Consultants to design innovative medical devices faster.

Developing a scalable human body model helps Cambridge Consultant engineers to perform regression analysis on antenna designs right from the beginning of the design process. This halves the number of iterations needed and reduces the design time by 25 percent. The company has been able to increase the radio range for its novel antenna designs by 45 percent compared with traditional PIFA and loop antennas. Field data shows a very close correlation between the simulated and finished product results.



^ Antenna radiation patterns showing gain vs. radiation angle