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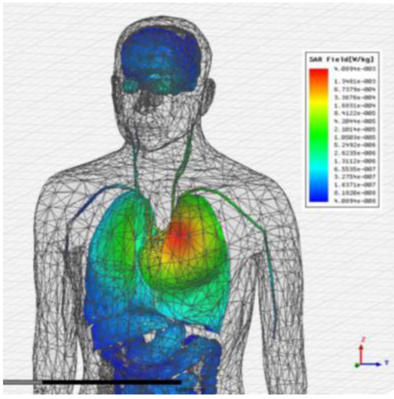
Team 193
Implantable Planar Antenna Simulation with ANSYS HFSS in the Cloud



"ANSYS HFSS in UberCloud's application software container provided an extremely user friendly on-demand computing environment very similar to my own desktop workstation."

THE TEAM

- **End-User**: Mehrnoosh Khabiri, Ozen Engineering, Inc. Sunnyvale, California.
- **Team Expert** – Metin Ozen, Ozen Engineering, Inc. and Burak Yenier, UberCloud, Inc.
- **Software Provider** – Ozen Engineering, Inc. and UberCloud, Inc.
- **Resource Provider** – Nephoscale Cloud, California.

USE CASE

In recent years, with rapid development of wireless communication technology, Wireless Body Area Networks (WBANs) have drawn a great attention. WBAN technology links electronic devices on and in the human body with exterior monitoring or controlling equipment. The common applications for WBAN technology are biomedical devices, sport and fitness monitoring, body sensors, mobile devices, and so on. All of these applications have been categorized in two main areas, namely medical and non-medical, by IEEE 802.15.6 standard. For medical applications, the wireless telemetric links are needed to transmit the diagnostic, therapy, and vital information to the outside of human body. The wide and fast growing application of wireless devices yields to a lot of concerns about their safety standards related to electromagnetic radiation effects on human body. Interaction between human body tissues and Radio Frequency (RF) fields are important. Many researches have been done to investigate the effects of electromagnetic radiation on human body. The Specific Absorption Rate (SAR), which measures the electromagnetic power density absorbed by the human body tissue, is considered as an index by standards to regulate the amount of exposure of the human body to electromagnetic radiation.

In this case study implantable antennas are used for communication purposes in medical devices. Designing antennas for implanted devices is an extremely challenging task. The antennas require to be small, low profile, and multiband. Additionally, antennas need to operate in complex environments. Factors such as small size, low power requirement, and impedance matching play significant role in the design procedure. Although several antennas have been proposed for implantable medical devices, the accurate full human body model has been rarely included in the simulations. An implantable Planar Inverted F Antenna (PIFA) is proposed for communication between implanted medical devices in human body and outside medical equipment. The main aim of this work is to optimize the proposed implanted antenna inside the skin tissue of human body model and characterize the electromagnetic radiation effects on human body tissues as well as the SAR distribution. Simulations have been performed using ANSYS HFSS (High-Frequency Structural Simulator) which is based on the Finite Element Method (FEM), along with ANSYS Optimetrics and High-Performance Computing (HPC) features.

ANSYS HUMAN BODY MODEL AND ANTENNA DESIGN

ANSYS offers the adult-male and adult-female body models in several geometrical accuracy in millimeter scale [17]. Fig. 1 shows a general view of the models. ANSYS human body model contains over 300 muscles, organs, tissues, and bones. The objects of the model have geometrical accuracy of 1-2 mm. The model can be modified by users for the specific applications and parts, and model objects can simply be removed if not needed. For high frequencies, the body model can be electrically large, resulting in huge number of meshes which makes the simulation very time-consuming and computationally complex. The ANSYS HPC technology enables parallel processing, such that one has the ability to model and simulate very large size and detailed geometries with complex physics.

The implantable antenna is placed inside the skin tissue of the left upper chest where most pacemakers and implanted cardiac defibrillators are located, see Figure 1. Incorporating ANSYS Optimetrics and HPC features, optimization iterations can be performed in an efficient manner to simulate the implantable antenna inside the human body model.

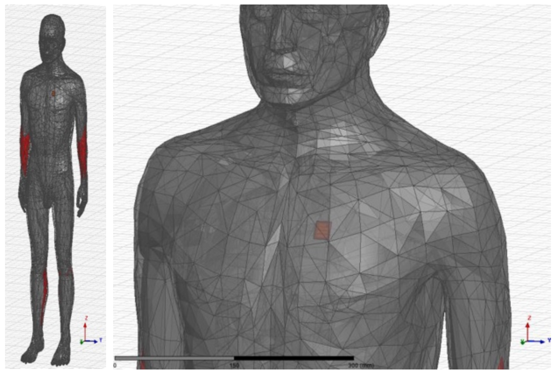


Figure 1: Implanted antenna in ANSYS male human body model.

The antenna is simulated in ANSYS HFSS which is a FEM electromagnetic solver. Top and side view of proposed PIFA is illustrated in Figure 2 (left), the 3D view of the implantable PIFA is demonstrated in Figure 2 (right). The thickness of dielectric layer of both substrate and superstrate is 1.28 mm. The length and width of the substrate and superstrate are L_{sub}=20mm and W_{sub}=24mm, respectively. The width of each radiating strip is W_{strip}=3.8mm. The other parameters of antenna are considered to be changed within the solution space in order to improve the PIFA performance. HFSS Optimetrics, an integrated tool in HFSS for parametric sweeps and optimizations, is used for tuning and improving the antenna characteristics inside the ANSYS human body model.

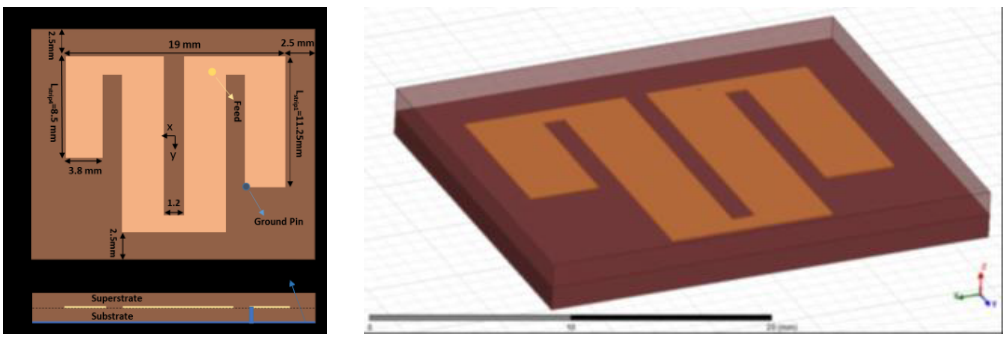


Figure 2: Top and side view of PIFA (left) and 3D view of PIFA geometry in HFSS (right).

RESULTS AND ANALYSIS

Figure 3 illustrates the far-field radiation pattern of the proposed PIFA at 402 MHz. Since the antenna is electrically small and the human body provides a lossy environment, the antenna gain is very small (~-44 dBi) and the EM fields are reactively stored in the human body parts in vicinity.

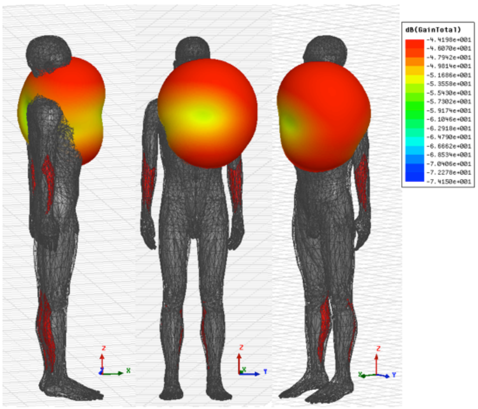


Figure 3: 3D Radiation pattern of implanted PIFA inside the human body model.

Figure 4 shows the simulated electric field distributions around the male human body model at 402 MHz center frequency. The electric field magnitude is large at upper side of the body, and it becomes weaker as going far away from the male body chest.

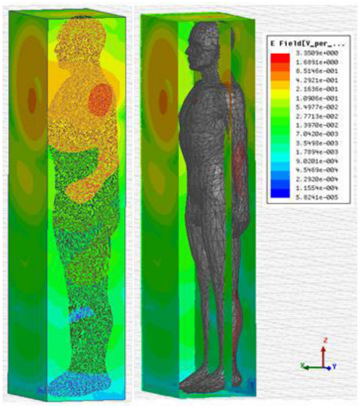


Fig. 4 Electric Field distribution around male body model at 402 MHz.

The electromagnetic power absorbed by tissues surrounding the antenna inside the human body model is a critical parameter. Hence, SAR analysis is required to evaluate the antenna performance. SAR measures the electromagnetic power density absorbed by the human body tissue. SAR measurement makes it possible to evaluate if a wireless medical device satisfies the safety limits.

SAR is averaged either over the whole body or a small volume (typically 1 g or 10 g of tissue). ANSYS HFSS offers SAR calculations according to standards. The 3D plots of the local SAR distribution are shown in Figure 5 and Figure 6. In Figure 5, the detailed male body model with heart, lungs, liver, stomach, intestines, and brain are included. It can be observed that the left upper chest region where SAR is significant is relatively small. The peak SAR of the PIFA is smaller than the regulated SAR limitation. Figure 5 shows the SAR distribution on the skin tissue of the full human body model.

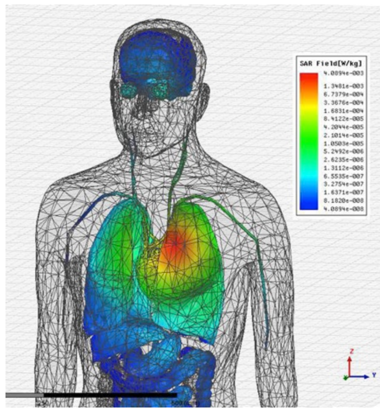


Figure 5: Local SAR distribution on upper side of male body model at 402 MHz.

A more detailed discussion of this use case by Mehrnoosh Khabiri can be found in the Ozen Engineering white paper about "Design and Simulation of Implantable PIFA in Presence of ANSYS Human Body Model for Biomedical Telemetry Using ANSYS HFSS", http://www.ozeninc.com/wp-content/uploads/2015/05/QEI Biomedical WhitePaper Final.pdf.

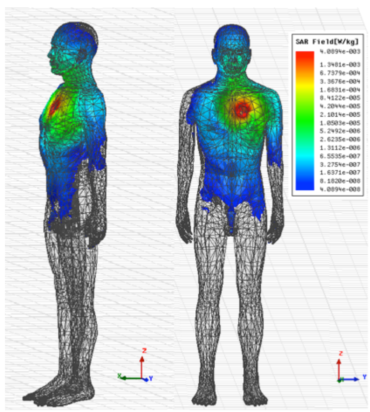


Figure 6: Local SAR distribution on the skin tissue of male body model at 402 MHz.

CONCLUSION & RECOMMENDATIONS

- Design modification and tuning of antenna performance were studied with the implantable antenna placed inside the skin tissue of ANSYS human body model. The resonance, radiation, and Specific Absorption Rate (SAR) of implantable PIFA were evaluated. Simulations were performed with ANSYS HFSS (High-Frequency Structural Simulator) which is based on Finite Element Method (FEM). All simulations have been performed on a 40-core Nephoscale cloud server with 256 GB RAM. These simulations were about 4 times faster than on the local 16-core desktop workstation.

- ANSYS HFSS has been packaged in an UberCloud HPC software container which is a ready-to-execute package of software designed to deliver the tools that an engineer needs to complete his task in hand. In this experiment, ANSYS HFSS has been pre-installed, configured, and tested, and running on bare metal, without loss of performance. The software was ready to execute literally in an instant with no need to install software, deal with complex OS commands, or configure.

- This technology also provides hardware abstraction, where the container is not tightly coupled with the server (the container and the software inside isn't installed on the server in the traditional sense). Abstraction between the hardware and software stacks provides the ease of use and agility that bare metal environments lack.

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