Application Sheet

# FEKO

Comprehensive Electromagnetic Solutions

# RF Design and Safety for Biotechnology

## Introduction

Systems for the healthcare industry are at the forefront of technology development. These drive the growing trend of ubiquitous computing - where computers are embedded and an invisible part of our lives. Applications include remote patient monitoring, drug delivery and sophisticated imaging systems like magnetic resonance imaging (MRI). In many cases, wireless telemetry making use of spectrums that range from low MHz to GHz is embraced.

From vital sensor networks to active implanted devices, each technology has its own set of challenges. Devices tend to be compact and must comply with the comfort requirements of a patient. Antenna performance is degraded by body tissue losses that result in the absorption of electromagnetic signals. Furthermore, safety is paramount and strictly regulated by the relevant standards.

## Antenna Design and Link Budget

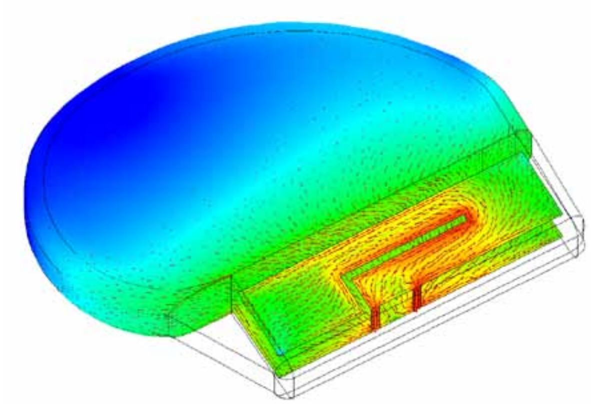
The electrically small antennas typically used for body mounted or implanted devices must achieve the gain requirements to sustain robust and reliable telemetry.

Performance of the initial antenna design can be efficiently simulated and optimised using planar multilayer media or homogeneous phantoms. If a suitable prototype is obtained, realistic anatomical models can be included for a more accurate assessment of the RF performance and final link budget calculations.

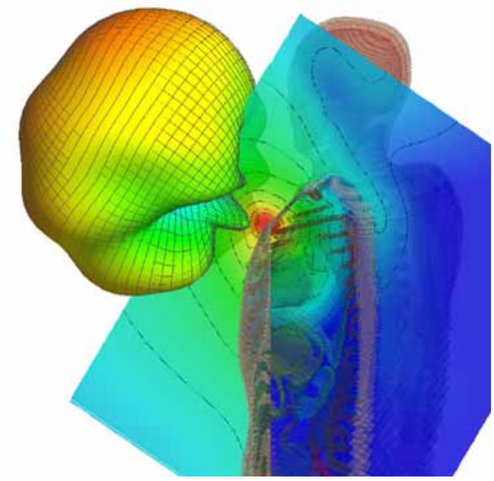
The most suitable simulation method will depend on the application or design stage. While the method of moments (MoM) might offer superior computational efficiency for initial designs using homogenous phantoms, a volume-based method like the finite element method (FEM) or the finite difference time domain (FDTD) method will be more suited to complex models where anatomical phantoms are included. However, applying different solvers for cross-validation purposes offers a great advantage and builds confidence in the simulation results. This is especially true for implants, where obtaining measurements might be difficult.

## EM and Thermal MRI Safety Considerations

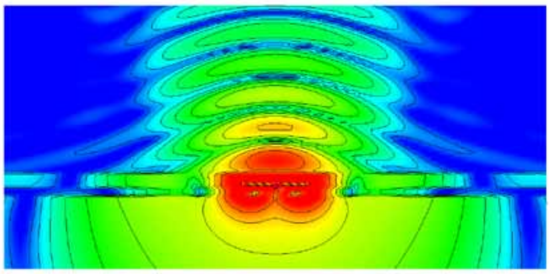
The number of people with medical implants, such as pacemakers, joint replacements or monitoring devices, is steadily increasing. Concurrently, the number of people that need to undergo MRI examinations for diagnostic purposes, is also on the rise. During an MRI scan, high radio frequency (RF) fields are applied, which may induce strong currents on the metallic implants. It can lead to increases in both the temperature and local averaged specific absorption rate (SAR) in the proximity of the



*Surface current on a high gain planar inverted F antenna (PIFA) design (ISM band, 40 x 40 x 8 mm) for a cardiac pacemaker*



*Pacemaker performance with anatomical model. The link budget indicates telemetry will be possible up to 10 m with a -31 dB source power*



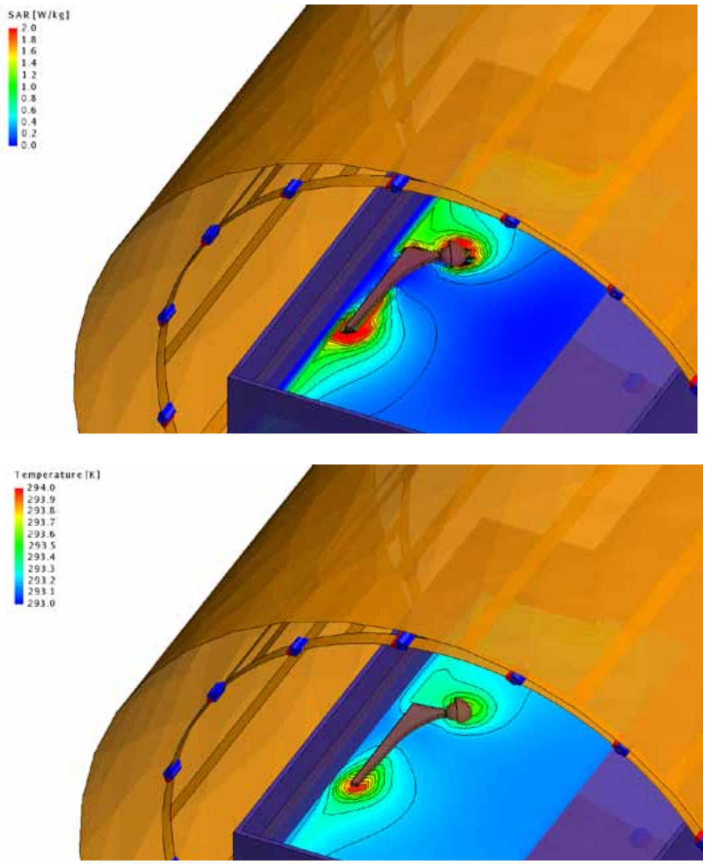
*2.45 GHz simulation of injectable biosensor in a layered skin, fat, muscle phantom* device. This can result in localised tissue damage or burns in a patient. For this reason, rigorous compliance testing is required in order to certify that an implant is MRI compatible. The same also applies for tools that are used for interventional MRI.

Simulation of a prototype offers a straightforward means to quantify the relevant parameters for MRI safe devices. This case study illustrates an experimental setup for a titanium hip implant in a 1.5 T body coil MRI system, operating at 64 MHz. The hip implant is placed in an ASTM phantom, which is based on the 2002 standard for testing passive implants. It is filled with gel with material properties based on averaged human tissue parameters. The implant is positioned near the edge of the phantom where the field gradients are higher. The phantom is then placed in the MRI.

The RF coil is fed with a quadrature (IQ) feed, excited with 38 W power. The implant influences the fields, and localised peaks in the SAR distribution are seen at the tips of the implant. The peak spatial average SAR can be calculated to check if it is compliant with safety standards.

A thermal analysis can be performed to calculate the temperature increase for the setup. The Lua script implementation is based on the classic Pennes' Bioheat equation, taking into account heat transfer through absorbed (electromagnetic) EM power, thermal conductivity, perfusion and metabolic heat generation. Convection and thermal radiation boundaries are used to describe the heat transfer to the surrounding air at ambient temperature.

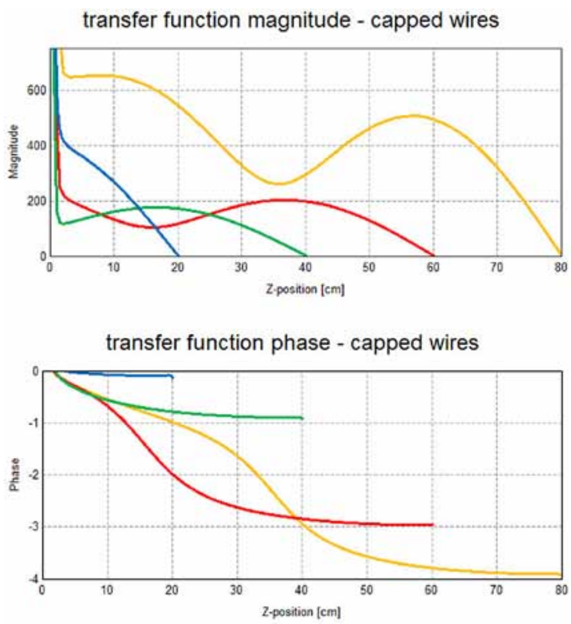
In this case, the metabolic heat and blood perfusion rates are set to zero for the gel and the simulation is initialised with a temperature of 293.15 K. The temperature distribution after 10 minutes shows a temperature increase of 0.8 K near the tip of the implant. The expected temperature increase would most likely be lower if the phantom was replaced with an anatomical model and the effects of blood perfusion were taken into account. The Lua script and example files for the thermal calculation can be downloaded from the FEKO website at www.feko.info/support/lua-scripts.




*SAR distribution for the titanium hip implant placed in an ASTM phantom within a 1.5 T body coil (top). The resulting temperature distribution (bottom) after 10 minutes shows an increase of about 0.8 K at the tip of the implant*

## Transfer Function Calculations

Due to the geometric complexity of active implants (for example pacemakers and neuro-stimulators), complete simulation of MRI, patient and implant geometry might either be challenging or unfeasible to solve. In this case, an approach based on the transfer function [1] can be used to estimate the SAR and thermal MRI safety for the implant. The implant and lead is simulated in a homogenous background medium with an applied tangential excitation, and the transfer function is derived. FEKO's MoM solver is well suited to resolve the complex geometry that is typical of realistic leads.




*Magnitude and phase transfer functions calculated for 20, 40, 60, 80 cm capped wire are in good agreement with the results published in [1]*

## References

*[1] "Calculation of MRI-Induced Heating of an Implanted Medical Lead Wire with an Electric Field Transfer Function", Park et al., Journal of Magnetic Resonance Imaging, 2007*

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