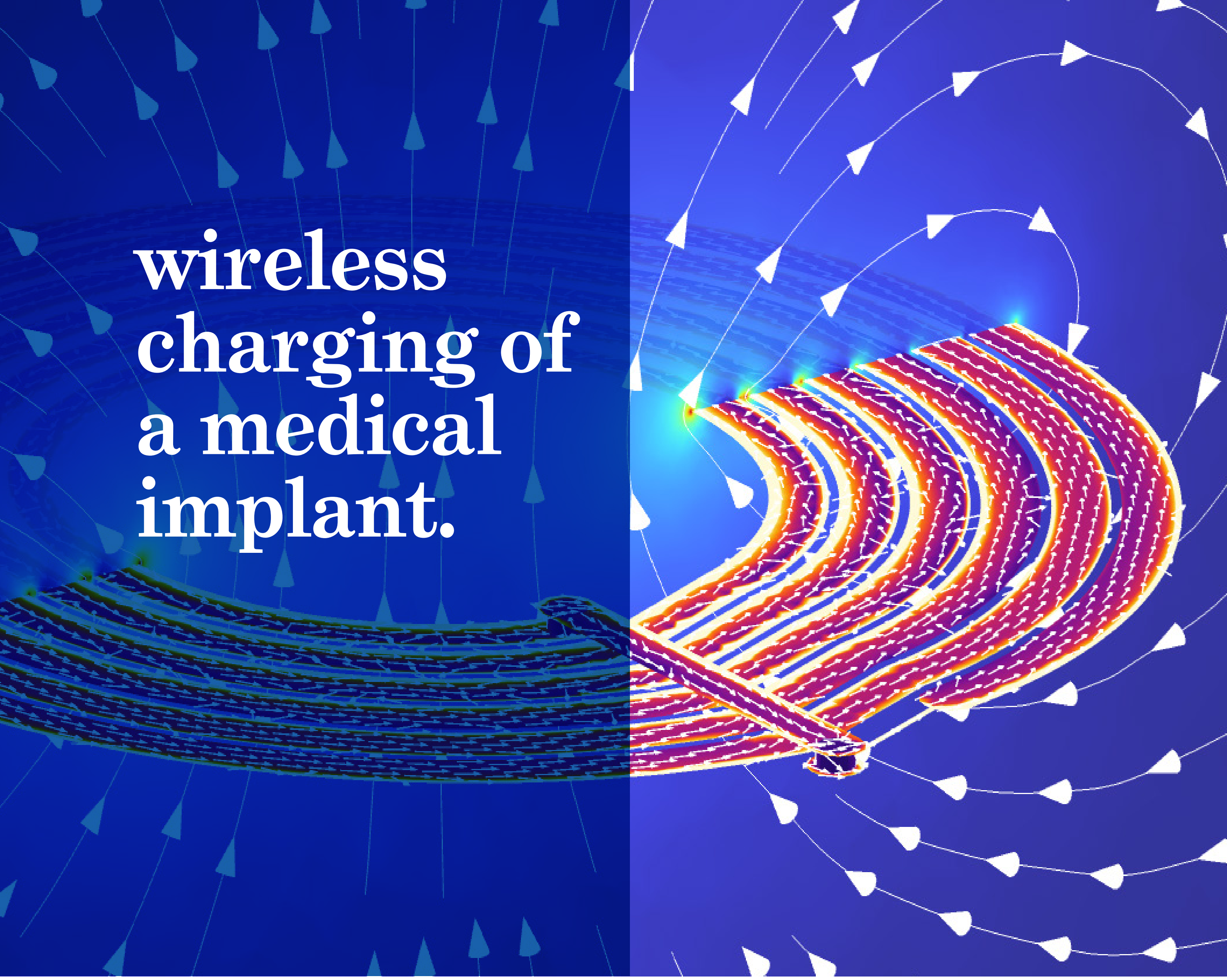
wireless charging of a medical implant.



Goal

This project focused on the design of a wireless power transfer for a medical implant. This battery-powered implant is permanently placed in a patients body, and must be powered wirelessly every few days. We simulated the electrical circuit of the implant, as well as the interaction of the implant with an external wireless charger and the surrounding skin tissue. Furthermore, two important characteristics were assessed: how much the temperature of the tissue around the implant increases due to electromagnetic field absorption and what the temperature of the implant itself is. In other words, how much energy is absorbed by the skin tissue around the implant, and can local overheating of the implant can occur? A measure of the amount of energy dissipated in the skin is the Specific Absorption Rate (SAR). The maximum allowed value of the SAR is 10 milliwatts per 10 grams. The restriction on local overheating of the implant is that the implant itself is not allowed to be more than 2 degrees warmer than the surrounding tissue.

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Approach

The charging mechanism of the battery is based on two coils: a receiver (Rx) and a transmitter (Tx) coil. The Rx coil is embedded in the electrical circuit of the implant, and the Tx coil is positioned inside the external charger. COMSOL Multiphysics was used to design and optimize both coils (Fig. 1). The objective was to ensure that enough current is generated in the Rx coil to charge the implant, while minimizing the power losses in the Rx and Tx coils and circuits. The energy that is dissipated in the surrounding skin tissue was one of the limiting design constrains.

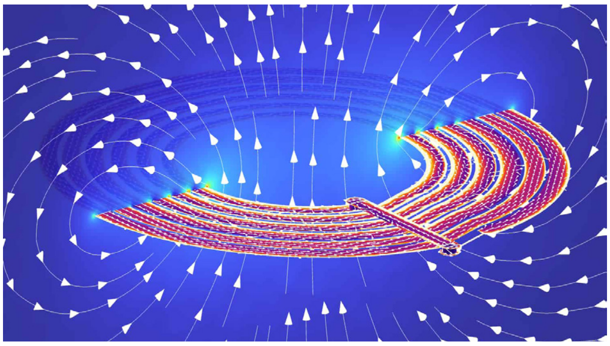

Fig 1. Magnetic field lines and currents in an electromagnetic simulation of the transmitter coil.

In the COMSOL model, the Rx coil was placed 3 cm below the transmitter. The centers of the Rx and Tx coils were displaced with respect to each other by 3 cm, to mimic the real-life situation. The electrical circuit of the implant was simulated with LTspice, and experimentally verified using a breadboard.

Finally, simulations of local heating of the implant and the surrounding tissue were performed for several skin depths of the implant (Fig. 2). For these simulations, it was needed to make a coupled EM-thermal simulation using COMSOL.

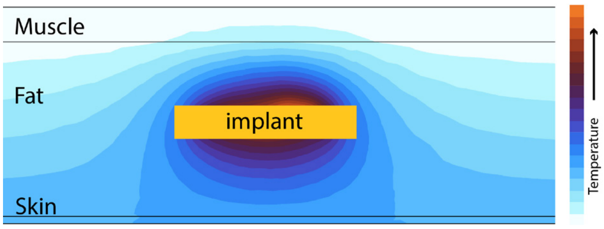

Fig 2. Body heating due to implant dissipation.

Results

Using simulations in COMSOL Multiphysics, the Tx and Rx coils were designed such that enough current can be generated in the receiver, without exceeding the SAR restriction (Fig. 3). The SAR value, which may be averaged over a volume of 10g of tissue surrounding the peak value, the SAR was found to be an order of magnitude below the maximum allowed value.

A breadboard verification of the electric circuit of the implant, including the designed coils, demonstrated a good match with the LTspice simulation and proved that sufficient energy can be transferred to the receiver coil and the battery.

Simulations of the thermal behaviour were performed for several depths of the implant, enabling us to quantify for which depth under the skin, the local heating is less than 2 degrees. Succeeding the experimental verification of the final design, the charging mechanism is ready to be integrated in the implant design.

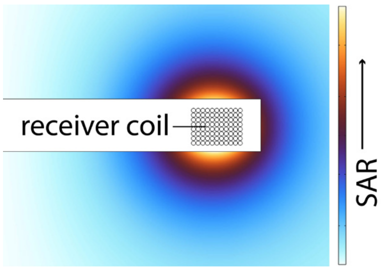

Fig 3. Specific Absorption Rate (SAR) from the receiver coil only. The SAR is maximal at the center of the coil. The SAR caused by the receiver coil turned out to be low compared to the SAR originating from the transmitter field.