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Optimization of Transmitting Banks for Implantable Medical Devices

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Introduction: Long-term implantable medical devices including cardiac pacemakers and neurostimulators have been widely used. Device miniaturization and longevity are inherently limited by the size and capacity of the internal battery needed to drive the circuits. Inductive wireless power transfer has been demonstrated for recharging batteries or as an alternative for powering implanted devices. It reduces the device size and enables less invasive implantation surgeries. We have previously shown wireless power transfer through tissues at 1.3 MHz to power a gastroesophageal reflux sensor in esophagus or a gastrostimulator in stomach. In this work, we propose to implement a bank of tuning capacitors to optimize power transfer since the coupling coefficient is dependent on the tissue thickness between the transmitting and receiving coils.

Materials and Methods: The wireless power transfer setup consisted of a class-E amplifier to drive the transmitter circuit and transmitting resonant coil, and a receiving resonant coil to deliver power to a 500-Ω resistive load. The transmitter was a spiral antenna with a radius of 6 cm and 52 turns, made of 24 AWG wires. The receiver consisted of a rectangular coil measuring 1.5 cm × 1.9 cm at 18 turns made of 24 AWG wires. Each resonant bank was initially tuned to 1.3 MHz in air with a separation distance of 4 cm between the antennas as the default. The distance between the receiving and transmitting coils then was varied from 1 to 7 cm in 1 cm increments. Received power was measured while the total input power was monitored. The experiments were conducted in air and with pork belly mimicking human tissues. The receiver was not re-tuned since the implant inside the body could not be re-tuned. The external transmitter was retuned until the load received a maximum power.

Results and Discussion: Shifts of the resonant frequency were observed as the tissues varied the effective dielectric constant between the transmitting and receiving coils, as shown in the top panel of Figure 1. As the thickness of tissues increased, the resonant frequency shift deviated farther from 1.3 MHz. To correct the deviation, the transmitter was retuned with the capacitor bank. The bottom panel of Figure 1 shows the retuned resonant frequencies at different tissue thicknesses. The received powers were greatly increased from 53, 15, 4, 2.6 and 1 mW at 1.3 MHz before retuning, to 292, 156, 92, 43, and 22 mW after retuning for the tissue thicknesses of 1, 2, 3, 4, and 5 cm, respectively. The quality factors at different thicknesses of tissues were 34, 38.5, 20.1, 24.7 and 19.2 prior to tuning and 43.2, 33.3, 20.5, 23.7 and 24.9 after tuning. The small changes in quality factors indicated that the tuning bank did not add additional losses to the transmitter coil.

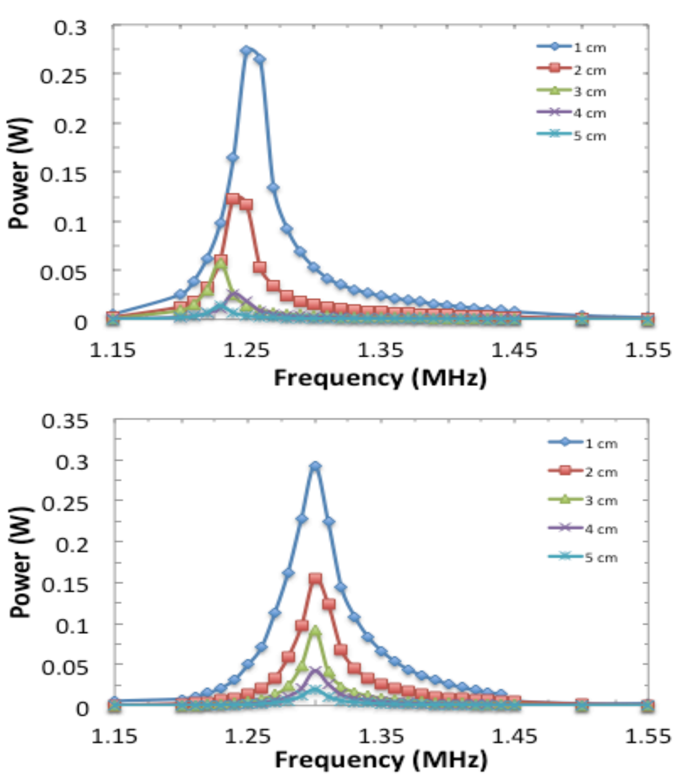

Figure 1. (Top) The received powers with different thicknesses of pork belly between the transmitting and receiving coils as a function of frequency. **(Bottom)** The power received after the transmitter was retuned to reach maximum powers at 1.3 MHz.

Conclusion: The results show that the deviations in the resonant frequency can be corrected when the wireless power transfer system was implemented for different tissue thicknesses mimicking different body types. Retuning the resonant frequency with a tuning capacitor bank can recover the power losses making implant devices more suitable for practical scenarios.