Noninvasive Wireless Chargers for Implantable Devices and Epidermal Electronics

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***Abstract*—Conventional powering of implanted medical devices like pacemakers requires periodic invasive surgery for battery replacement. These surgeries can be a physical, psychological, and financial burden on patients. In the case of epidermal health monitoring electronics, power is supplied through large invasive wires which can damage the fragile skin of neonatal babies. This wiring also reduces human interaction for these infants, a vital component in development after birth. Wireless charging presents a solution to these problems by providing a convenient, noninvasive, and elegant alternative power source. Wireless charging promises to eliminate the need for battery replacement surgeries and the network of messy wires involved in epidermal electronics. This wireless charging solution will work overnight, not requiring for the user to spend any additional time to charge their device. The goal of this project is the development of biocompatible charging configurations which show sufficient wireless power transfer through bone and tissue analogues. A key result is that a five-centimeter outer diameter coil receives sufficient power at a realistic distance for a pacemaker application.**

Keywords-wireless charging; pacemaker; magnetic induction

I. INTRODUCTION

Wireless charging works on the principle of magnetic induction. If a conductive receiver coil is exposed to a time-varying magnetic field produced by a larger transmitter coil, then the receiver coil will have an alternating current induced within it. Thus, power transfer is possible between two electrically isolated coils through the medium of air. Although this method of power transfer is less efficient than common wired power transfer, it presents distinct advantages in certain situations.

For example, implanted medical devices like pacemakers and bone-anchored hearing aids require regular invasive surgery for battery replacement. This surgery is an additional cost for patients and occurs every 5 to 7 years. Wireless charging has the potential to greatly reduce or eliminate the need for these periodic invasive surgeries. This would increase the quality of life of about 7 million Americans[2]. Another technology which wireless charging can revolutionize is epidermal health monitoring electronics. These epidermal devices are typically powered by large and messy wires which can cause physical damage to the fragile skin of neonatal babies. Eliminating these wires allows for these babies to have the essential skin on skin contact they need for their development and health. Approximately 10-15% of babies in the U.S. are born into the NICU (neotnatal intensive care unit) and require some type of epidermal health monitoring[1].

The project features two main objectives in pursuit of solving these problems. First, to design a wireless charging configuration which uses coils appropriately sized for the relevant biomedical applications. Second, to demonstrate sufficient power transfer within such a configuration through human bone and tissue. An essential component of both goals is safety. The materials selected must be biocompatible and not present any hinderance or danger to the patient.

II. MATERIALS

The quality of materials and components are important for minimizing losses and attaining maximum efficiency in a wireless charging configuration. It is also important that the materials be safe for users. Frequency is a key consideration in the design. The transmitter coil is selected to operate around 180 kHz (kilo Hertz). Avoiding the GHz (giga Hertz) range is a goal of the project in light of concerns raised over the safety of GHz frequencies when in close proximity to users. Radiation exposure must be kept to a minimum when working with wireless charger technology. The transmitter coil selected is manufactured by Taidacent and has an outer diameter of twenty centimeters. A coil of this size can be placed underneath a bed, assuming a typical measurement of resting 53 cm to 83 cm above the ground, and a user with an implanted receiver coil can then charge to a full 100% of power for seven to eight hours every night while sleeping or resting.

Figure 1. Taidacent Transmitter Coil

Two different types of copper receiver coils are tested with the transmitter coil. A 5-centimeter outer diameter coil made by Taidacent is tested for a pacemaker application, and a 1.27-centimeter outer diameter coil manufactured by Wurth Electronics is tested for an implanted hearing aid application. Both coils are encapsulated in biocompatible PDMS (dimethylpolysiloxane/dimethicone) flexible substrate. This material is safe to be in contact with the human body, as it is biocompatible, and it creates a waterproof barrier between the metal coil and the body. This encapsulation of the coils protects them from corrosion, and also helps protect the coils from any mechanical shock or deformation. The conductive leads of the coils are the only parts which are not covered by PDMS in experimentation.

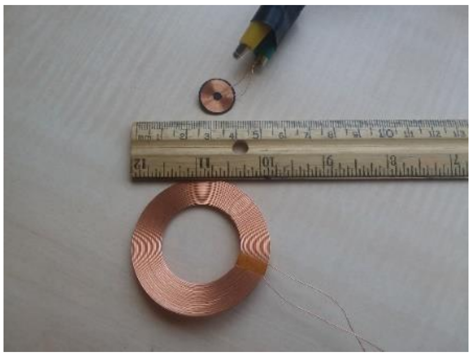


Figure 2. Receiver Coils

III. METHODS

Multiple charging configurations are designed, and the received voltage is measured with an oscilloscope. Preliminary testing is done with only air between the coils. The receiver coils are kept flat and parallel with the plane of the transmitter coil as the distance is varied. The receiver coils are moved vertically upward until power transfer is no longer detectable with the oscilloscope. Each coil must be tuned in order to achieve resonance. This is done by placing an appropriate capacitance in parallel with the receiver coil. This forms an LC tank circuit where the resonant frequency, f_r, is given by the following equation.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

In order to charge a battery, the received voltage must be converted to direct current. This is done by using a diode bridge rectifier. Schottky diodes are selected for their lower forward voltage compared to ordinary silicon diodes.

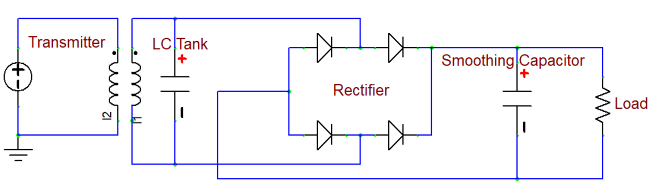
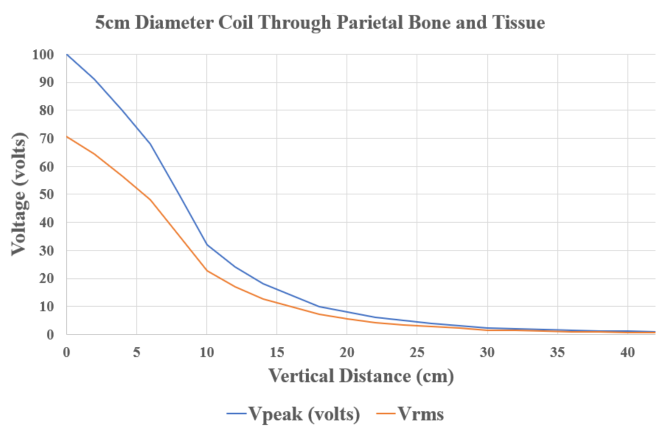


Figure 3. Wireless Charging Circuit

Both coils are tested through the medium of synthetic human tissue, real human parietal bone, and real baboon skull.

IV. RESULTS

Through the variety of experiments performed, testing shows that the 5-centimeter diameter coil is able to receive sufficient power at realistic distances for a pacemaker application to be charged through a bed overnight. The 5-centimeter diameter coil picks up around 0.7 volts RMS even at 46 centimeters above the transmitter coil. This distance is more than enough for a successful charging configuration with the transmitter coil attached under the bed of a user. The smaller 1.27-centimeter diameter coil loses voltage too rapidly with distance to work for an implanted hearing aid application. The smaller coil can only receive sufficient voltage at very close distances which are unrealistic for a user to achieve for significant amounts of time. However, future modifications could overcome this. A larger and more powerful transmitter could potentially solve this problem. Another modification to be considered is increasing the number of turns in the coil or modifying the shape of the coil into a square. Research has shown that these changes may be successful in increasing power.



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REFERENCES

[1] Which Babies Need Care in the NICU? (n.d.). from https://www.oakbendmedcenter.org/which-babies-need-care-in-the-nicu/

[2] Silvestrini, E. (2017, October 17). Medical devices & Procedures, surgical tools & FDA recalls - DRUGWATCH (1298790930 956175376 K. Connolly & 1298790931 956175376 D. A. Daller, Eds.). from https://www.drugwatch.com/devices/