WIRELESS CHARGER FOR BIOMEDICAL DEVICES

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ABSTRACT : Wireless power transmission (WPT) is a critical technology that provides an alternative for power transfer and communication with implantable medical devices (IMDs). The basics of wireless power transmission include the inductive energy that can be transmitted from a transmitter coil to a receiver coil through an oscillating magnetic field. The AC current supplied by a power source is transformed into high-frequency AC current by particularly designed electronics that are built into the transmitter.In the TX (transmitter) section, the high frequency AC current in the copper coil creates a magnetic field. Once an RX (Receiver) coil is located near to the magnetic field, the magnetic field can induce an AC current in the receiving coil which is to be then converted into DC current in the form of output voltage which is to be used to charge the and thus becomes working power.

Keywords -capacitive coupling, electromagnetic wave, inductive coupling, magnetic resonant coupling, near-field, wireless power transfer (WPT)

I.INTRODUCTION

Diagnosis and treatment of human diseases using an implantable electronic device presents new possibilities in modern medicine. While the developments of biosensors, bioelectric stimulators and drug release mechanisms are important in the designs of medical implants, these developments are application specific. Therefore, they cannot be studied in a unified manner. On the other hand, all implantable devices essentially require a common component: a power supply, which is usually a battery. Recent advances in wireless power transfer (WPT) provide an alternative method to power implantable electronic devices. The WPT technology not only eliminates the need of repeated surgical replacements of a depleted battery within the human body, but also reduces the size of the implant, simplifies the implantation procedure, and enables the device to be placed in restricted anatomic locations prohibitive to large implants [1].

A medical device is considered to be implantable if it is either partly or totally inserted, surgically into the human body and remains there after the procedure. Implantable Medical Devices (IMDs) offer several advantages for diagnostic and therapeutic purposes including sensing, stimulation, and drug delivery. Since the first implementation of pacemakers in 1958, numerous researches have been conducted around the world to apply state-of-the-art techniques to implantable medical devices (IMDs). In recent times, implantable devices are designed to be compact and are expected to avoid any harmful interactions with human body as much as possible. In order to do that, a device with or without embedded rechargeable batteries is desired. The biggest problem facing scientists and engineers is to reduce the harmful effect of corrosion of batteries as

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well as the potential risks of replacing them. Wireless power transfer (WPT) emerges as a potential candidate to solve this problem.

WPT can be categorized into two types, namely, far-field and near-field WPT. Microwave energy transfer falls under the far-field category, in which a large amount of energy can be transmitted between two positions. A WPT system involves a transmitter unit that is connected to the main source of power or battery, which transforms the electrical power into an electromagnetic field. This field may be received by one or multiple receivers to convert it back into electrical power, to be used by the electrical load. On the transmitter side, the power signal and information are carried by the same radio frequency (RF) signal. The information can be recovered at the information receiver and the electromagnetic energy is recovered by the harvester section of the receiver to supply the power to the receiver. The oscillator circuit of the transmitter converts the input power to the electromagnetic field that can be transmitted via the transmitter antenna or coupling systems. At the receiver side, similar coupling systems or antennas are used to alter the received electromagnetic field into electrical current that can be harvested to run the receiver devices. Near-field WPT refers to the distance of transfer energy within the wavelength (λ) of the transmitter antenna. The near-field mechanisms can be categorized into four groups depending on the type of coupling technique used: (i) magnetic resonant coupling; (ii) inductive coupling; (iii) capacitive coupling; and (iv) magneto dynamic coupling. The most suitable methods are magnetic resonant coupling and inductive coupling because the amount of transfer power in capacitive coupling increases with the capacitance between the plates and frequency. Therefore, the total surface area of the capacitor will be increased and accordingly, the size will be large and high voltages on the capacitor plates are required. In magneto dynamic coupling, two energy conversions occur, namely: (i) electrical to mechanical energy in the transmitter; and (ii) mechanical to electrical energy again in the receiver. This process makes magneto dynamic coupling less efficient relative to electrical conversion methods such as inductive coupling. However, the magnetic resonant coupling and inductive coupling methods are suitable for short and midrange distances and rely on the shape and size of the antenna or coil of the transmitter and receiver. In the past few years, portable and wireless devices have become prevalent. This has resulted in a significant diversity of battery chargers on the market, which can be considered a serious problem. Conventionally, charging these devices is performed based on wired technology that requires a wire connected to an electrical wall outlet. Charging can also be achieved wirelessly to achieve similar efficiency by using WPT technology. WPT is a promising method to solve the particular power-charging problems ingrained in several wireless platforms. When the electromagnetic energy (EM) is available, such as in a Tesla coil, WPT can be produced without a physical connection.[2,3]

The wireless power transfer (WPT) technology is often utilized because it provides an alternative to the battery as the energy source and eliminates repeated surgeries for battery replacement. It reduces the size of implant substantially which allows the implant to be placed in a restricted space within the body. This reduces both medical cost and chances of complications. In this work, we present our recent studies on WPT for miniature implants.

Battery systems have been developed to provide years of service for implantable medical devices. The primary

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systems utilize lithium metal anodes with cathode systems including iodine, manganese oxide, carbon monofluoride, silver vanadium oxide and hybrid cathodes. Secondary lithium-ion batteries have also been developed for medical applications where the batteries are charged while remaining implanted. While the specific performance requirements of the devices vary, some general requirements are common. These include high safety, reliability and volumetric energy density, long service life, and state of discharge indication. Successful development and implementation of these battery types has helped in the betterment of implanted biomedical devices and their treatment of human disease.

Table 1: Battery specification table

Battery System	**Open Circuit Cell Potential**	**Nominal Cell Potential**	**Theoretical Gravimetric Capacity of Cathode Material (mAh/g)**	**Theoretical Volumetric Capacity of Cathode Material (mAh/cm^3)**	**Theoretical Energy Density of Cathode Material (mWh/g)**	**Energy Density of Battery (mWh/g)**
Li/I_2	2.8	2.8	211	1041	591	210-270
Li/MnO_2	3.3	3.0	308	1540	924	270-230
Li/CFx	3.1	3.0	865	2335	2595	440
Li/SVO	3.2	3.2	315	1510	1008	270
C/LiCoO2	4.2	3.9	155	783	601	155

Batteries developed for implantable biomedical devices have helped enable the successful deployment of the devices and their treatment of human disease. The medical devices are permanently implanted to continually monitor a patient and provide therapy on a predetermined schedule or as needed. Numerous devices have been developed to address diverse human health issues, where some specific examples are shown in. While the functional requirements for the batteries used to power these devices vary with the type of device and therapy, there are some characteristics that are demanded by all applications. The batteries must provide service over many years to minimize surgical frequency, be safe during installation and use, have predictable performance that can be interrogated to provide state of discharge information and be highly reliable. Additionally, the batteries must have volumetric high energy density to enable the design of small devices that minimize discomfort for the patient. Thus, long term stability during use, predictable performance, high volumetric energy density and outstanding reliability are key characteristics that define successful systems for biomedical implants.

II.PROPOSED METHODOLOGY

One of the first demonstrations of WPT was carried out by Nikola Tesla in 1889 through the use of magnetic resonance and near-field coupling-based wireless power transfer coils, also known as Tesla coils. Electromagnetic radiation was previously confirmed 10years earlier in 1888 by H. R. Hertz, when he successfully transmitted electricity over a tiny gap using induction coils. Used on the 1970s for high-frequency heating equipment, WPT systems were applied for short-range applications, such as inductive power transfer systems in the 1990s and wireless charging systems for portable

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equipment in the 2000s.Presently, WPT systems are commercially available for some applications while still being developed and improved for others.

The power requirement associated with some of these devices is, however, a significant challenge. Transdermal or percutaneous wiring is inconvenient because of the large size of these wiring systems and their susceptibility to infect surrounding tissues. For deeper IMDs, a transcutaneous wire-based power source is a medically unacceptable solution as it leads to significant scarring of the tissue surrounding the IMD. Packaged batteries are limited by their operational lifetime, necessitating repeated surgical interventions to replace them. Additionally, any leakage from the battery could pose a severe risk to the patient's health. Batteries also occupy a significant portion of the available internal volume of these miniaturized IMDs, which could reduce the functionality of such devices. Therefore, power requirement, longevity and size of the power supply dictate today's specifications of modern IMDs.

WPT is potentially capable of fulfilling these requirements and enabling seamless and safe operation of IMDs. Over the last two decades, different WPT techniques targeted for IMDs, as shown in, have been studied to improve the performance in terms of power transfer efficiency (PTE), system size and tissue safety. The application of WPT for medical implants started in the 1960s, through the work of Shuder et al., who used inductive coupling to power an artificial heart.

Wireless power transfer (WPT) is the technology that enables the power to be transmitted through an electromagnetic field in an air gap to an electrical load without interconnecting wires. This technology is widely used for the applications from low power smartphone to high power electric railroad. In this paper, the model of wireless power transfer circuit for the low power system is designed for a resonant frequency of 1.5MHz followed by ICNIRP guidelines. Also, a feedback WPT circuit is proposed, and the methodology for power efficiency improvement is studied as the coupling coefficient increases above 0.01, at which the split frequency is made.

III.MATHEMATICAL MODEL

The fundamental theory of ICWPT systems is governed by Faraday and Ampere's laws. Based on Ampere's law, current I generates a magnetic field H. Some of this magnetic field links the secondary power pickup coil and according to Faraday's law causes a voltage V to be induced. Ampere's law can be mathematically expressed as:

∮H → dl → =I∮H → dl- → =IE1 (1)

Equation (1) states that the line integral of the magnetic field in tensity around a closed loop is equal to the current flowing through it.

Faraday's law, on the other hand, is expressed by:

$$V = -N_2 \, {d\emptyset}/{dt} \; V = -N_2 \, {d\emptyset}/{dt} \, E_2$$
(2)

where N2 is the number of turns of the secondary coil. The negative sign in the equation is described by Lenz's law, which states that the current flow in the secondary coil (when a load is connected) will be such that it creates a magnetic field that opposes the primary magnetic field.

IV.SYSTEM DESIGN

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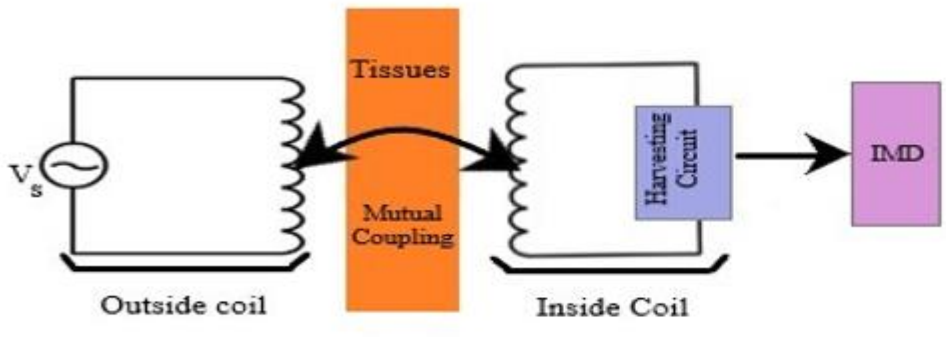

Figure 1: Wireless power system[1,2]

Figure 1 gives the overall idea of wireless power transfer system, where outside coil will be powered by ac source with some frequency which will not harm the tissues of patient. The secondary coil being inductively coupled with the primary coil will have voltage developed across it. This inductively developed voltage needs to be converted into corresponding DC potential which will be used to charge the battery of implanted device.

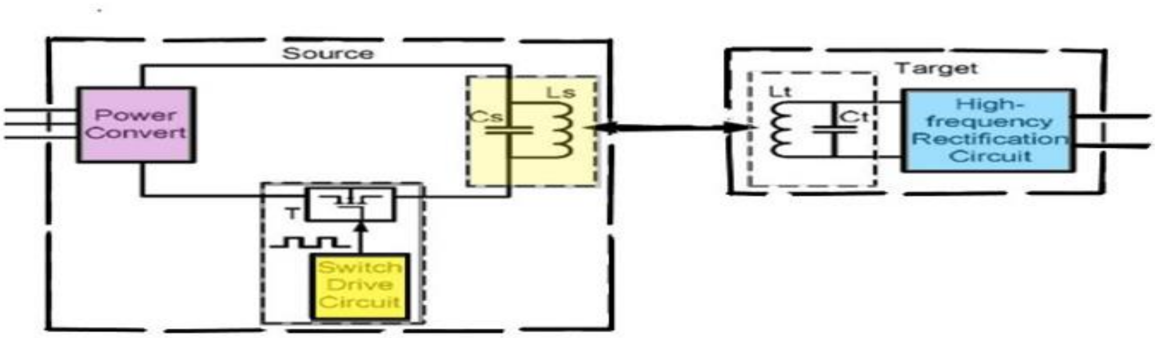

Figure 2: Block diagram of resonant inductive circuit [2,5].

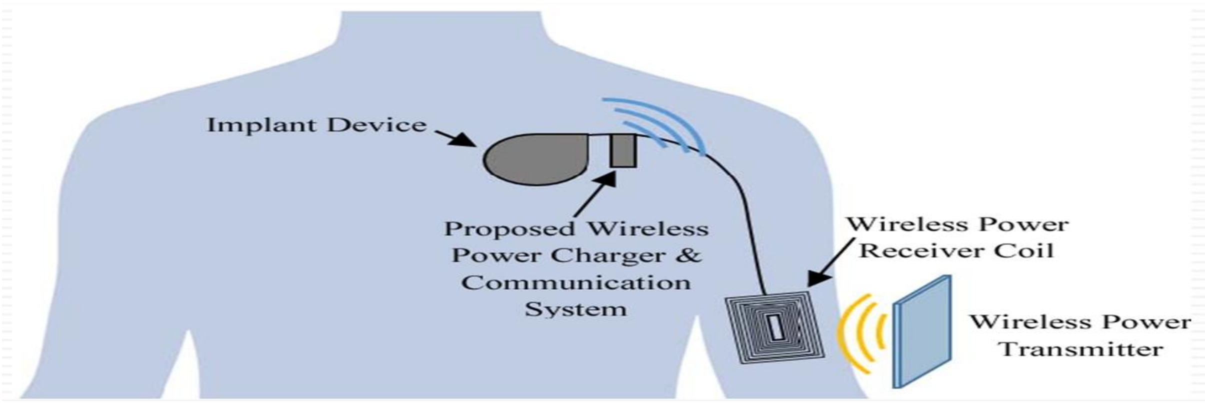

Figure 3: Basic working of power transfer showing the positions for installation of the device in the human body.

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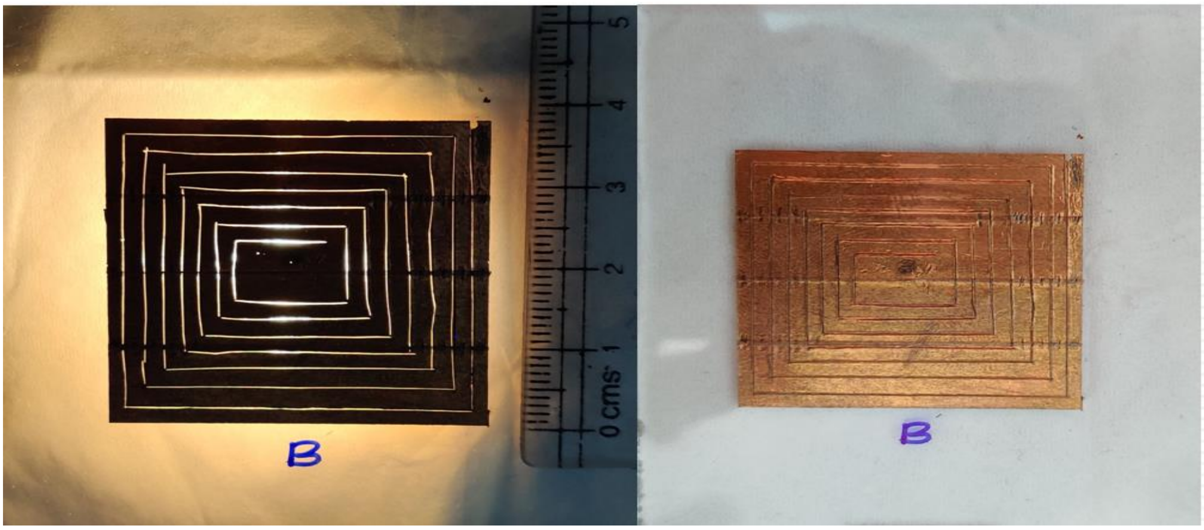

Figure 4: Receiver Coil

Figure 3 shows the position of the implanted device inside the human body and the proposed technique for wireless charging having secondary coil inside the human body. Figure 4 shows the receiver coil which can be mounted on the device itself.

V. Conclusion

In this work, an investigation of the wireless energy transfer for implantable medical devices has been presented. Several techniques were used in order to understand and analyze the inductive coupling between coils as well as the influence of the devices on the tissue.

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