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Wireless Charging of Implantable Pacemaker's Battery

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Abstract

Many of the modern bio-sensors and bio-implants are placed inside a patient's body. Hence a question arises for the supply of device which is placed for a long term basis. To overcome the limitation of artificial cardiac pacemaker in terms of source replacement after expiry, this paper present a method to eradicate the surgical technique in order to place a rechargeable source for artificial cardiac pacemaker. For this, a transmitter, which is outside patient's body, and receiver which is inside circuit of pacemaker, is used to deliver power to artificial cardiac pacemaker based on principle of magnetic induction.

Keywords: Wireless charging; Pacemaker; Magnetic induction; Wireless power transmission; Non-invasive charging

Introduction

The basic function of the pacemaker is to pace the heart in the absence of intrinsic impulses and to recognize intrinsic cardiac electrical activity if present and restrain pacing consequently. Systems such as implantable cardiac pacemaker have benefited millions of people. These devices are usually used to treat patient who suffers from a disease called arrhythmia (irregularity in the heart beat). However, there is a constraint for power supply [1].

The current implantable pacemaker are powered with lithium-iodine battery, which can last from 5 to 10 years or more – on the average about seven years. Once, the battery is fully drained, patient must be advised to replace the pacemaker with a new unit, which is carried out by a surgery [1]. To overcome this limitation, Inductive coupling wireless power transmission(IC-WPT) is introduced. The IC-WPT works on principle of magnetic induction, where an electromotive force is produced due to varying magnetic field in an electrical conductor [2]. The IC-WPT technique with rechargeable lithium-iodine battery can solve our problems of power supply. And it also avoids the risk related to surgery and post-surgery infection.

Materials and Methods

System block diagram

Inductive coupling works on principle of magnetic field induction between two coils [3]. Primary coil is placed outside the human body, whereas secondary coil is located inside body near to the heart. Primary coil of an energy transmitter that generates a varying magnetic field across the secondary coil of the energy receiver within the field. The secondary coil should be tuned at the operating frequency to enhance charging efficiency [4]. The quality factor is usually designed in small values usually below 10 [5], because the transferred power attenuates quickly for larger quality factor values. Direct current is needed to charge a battery. Hence, secondary coil is attached to a rectifier, in order to convert alternating current directly into direct current. A charging circuit is added for regulation the voltage and current to charge the battery of pacemaker (Figure 1).

Circuit designing

To establish an efficient wireless energy transfer, there are three major design aspects which need to be looked, they are as stated: coil design, battery selection and charging aspects.

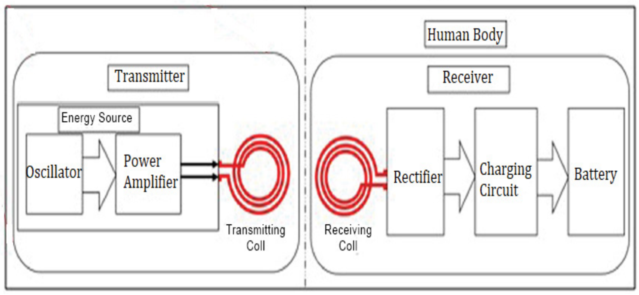

Figure 1: Block diagram of Inductive charging aspects.

Coil design

Most implantable medical devices (IMD) has size limitations, for instance, a typical pacemaker has a size of 44 × 59 × 7.9 mm^3; hence, in order to realize a practical wireless charging system for IMD, both the receiver resonator coil and the load loop should be small, and the wireless power should be transferred efficiently from the transmitter coils to the small receiver coils with reasonable transfer distances. To improve the transfer efficiency, [6] suggests the application of multi-turn coils for the receiver, whereas [7] uses the rectangular shaped receiver coil with a size of 10 cm × 5 cm. However, those designs are still too large to be applied to IMDs.

Battery selection

Considering the heat of coils and the psychological states of patients, the charging process should not last too long. Actually, 30 minutes could be suitable, so the capacity of lithium-ion battery should be chosen considerately. From the data, the 0.92Ah lithium battery for single-chamber pacemaker could last 10.4 years and the 1.3Ah lithium battery for dual-chamber pacemaker could last 11.3 years. So according

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Implementation	Output	Maximum Charging Efficiency	Maximum Charging Distance (mm)	Distance Frequency
Yoo et al.	1.8V	54.9%	10	13.56MHz
Lee et al.	3.1V	77%	80	13.56MHz
Lee et al.	3V	87%	20	13.56MHz
Lazaro et al.	1.5V	82%	11.35	100-50KHz

Table 1: Comparison of hardware implementations of inductive coupling.

to our requirement 1050mAh lithium-ion battery would be efficient and also consumes less time to charge [8].

Charging aspects

Various attempts and trials are done to study the behaviour of charging capacity of a battery under different conditions such as distance between coils, frequency and output [9]. To describe given point, Table 1 shows the comparision on hardware implementation of inductive coupling. Overall, it can be seen that the output power and maximum charging distance are directly responsible for the charging efficiency (Table 1) [10].

Standard for Wireless Charging

Qi is a wireless charging standard developed by Wireless Power Consortium (WPC). Qi standard specifies interoperable wireless power transfer and data communication between a wireless charger and a charging device [11]. Qi allows the charging device to be in control of the charging procedure. The Qi compliant charger is capable of adjusting the transmit power density as requested by the charging device through signaling. Qi uses magnetic inductive coupling, typically within the range of 5 millimeters to 40 millimeters [12,13]. Hence this range defined by Qi standard matches our criteria.

Results and Discussion

To charge pacemaker's lithium-ion battery with the help of coils in effect of inductive coupling, the result of experiments were promising and as accurate as expected. The total time to charge the battery of current rating 1050mAh from 50% to 100% is 56 minutes. Hence it charges as quickly as same as a latest wireless charging mobile phone. Also the longevity of battery is about 11.59 years if calculated according to

$$L = Q\,del/\,8766I$$

Where I is the current output of pacemaker which is generally 10 μA [13].

Conclusion

In this paper, a thorough investigation of minute detail for wireless charging to charge implantable pacemaker's battery is given. Also, various aspect to choose an appropriate battery, charging compliant charger for desired outcome and the charging aspects with effect of frequency and charging distant are also stated. Thus, it provides every vital and basic knowledge to be implemented while designing and experimenting a wireless power transmission for pacemaker's battery and ease the life of patient by eradicating the need of surgical method of replacing battery.

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