Development of a Highly Integrated (sub 1 cm^2) Wirelessly Powered Implantable Medical Device (WPIMD) using a custom RFIC design

Abstract

This document presents a short summary of recent work in the MCCI funded WPIMD project.

Introduction

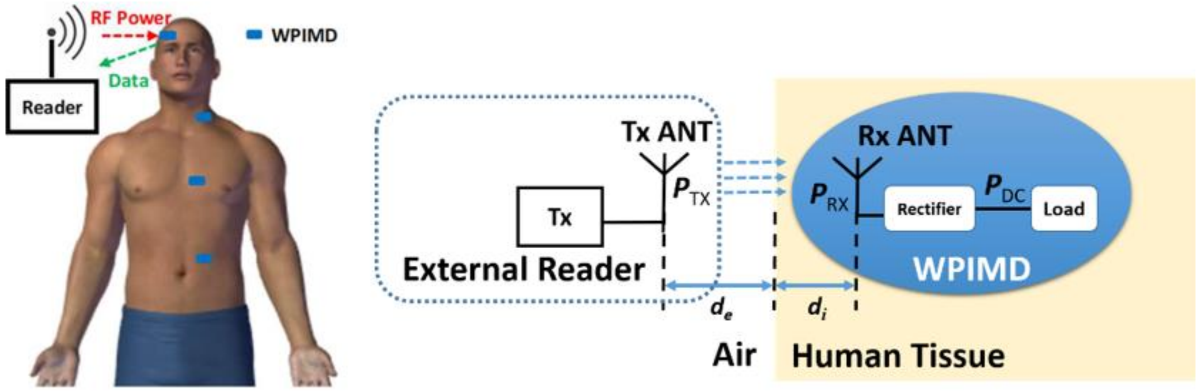
Wireless Implantable Medical Devices (WIMDs) are an emerging area for wireless sensing that have applications in a wide range of medical applications. WPIMDs can be used in applications such as cochlear implants, cardiac defibrillators, electrocardiogram (ECG) devices and pacemakers. WPIMDs are emerging as they have great potential to improve medical care treatment for patients. WIMDs interact with and monitor physiological processes including sensing, drug delivery, and stimulation, to monitor or influence the progression of these physical processes.

In order to make WIMDs less invasive to the human body and decrease surgical complexity as well as decreasing the risk of after-effects post-surgery, the minimization of WPIMD device size is of significant importance. While recent progress in device fabrication has dramatically decreased the size of electronic and mechanical components, electrochemical energy storage has been much slower to miniaturize. Energy harvesting is possible from several types of ambient energy sources such as light, radio frequency, thermo-electric and ultrasound. A key challenge however for these technologies is that these energy sources provide much less power compared to what is possible with a typical battery.

The use of wireless power transfer (WPT) methods to power medical implants is gaining increasing attention in recent years due to several potential advantages. These advantages include the facilitation of implanting devices that do not require interconnecting wires which are not desirable in a surgical scenario in order to enhance both the healthcare professionals' and patients' safety. With the increasing need for patient safety, the possibility to decrease the risks associated with battery replacement using WPT methods is a key advantage with potential to enable a new generation of medical applications.

High-level model for WPIMD analysis

Figure 1(a) illustrates a high-level WPT scenario. The WPIMD device is implanted in the patient and uses WPT methods to harvest RF energy to recharge or replace batteries as power supply and to power the sensing and wireless communications blocks within the WPIMD. The external reader transmits RF energy towards the implant WPIMD where this power is then converted to DC and used to charge a battery or to power the sensor independently without the use of a battery. The sensor then wirelessly transmits the measured sensor data back to the reader using an integrated radio transceiver and integrated antenna within the WPIMD.



(a) (b)

Figure 1 (a) Wireless power transfer for WPIMD, (b) WPIMD High-level model

Figure 1(b) shows a block diagram of a WPIMD system developed for WPIMD analysis. It consists of an external reader with a wireless transmitter (Tx), a transmitting antenna (Tx Ant), a WPIMD implant embedded in human tissue that contains a receiving antenna (Rx Ant) and an RF to DC, or rectifier circuit, whose DC output is used to power the sensor. In this case the sensor electronics is denoted as a simple load (resistance). The external reader is placed outside the human body at a distance d_e away from surface of the skin and the implant is placed inside the human tissue at a depth denoted d_i beneath the skin. The implant depth d_i is determined by the target medical application for the implant. The external reader antenna radiates an RF signal with a power level denoted P_{TX} from the transmitting antenna and the implant antenna intercepts a portion of this power P_{RX} using the receiving antenna. This received RF power P_{RX} is then converted to DC (P_{DC}) using an internal rectifier circuit within the implant. This model can be used to analyse the limits of power delivery to the implant.

Conclusions

- The main achievement for the last quarter have been the development of a high-level architecture for WPIMD power-level analysis. This model shows that the DC power delivered to the implant depends on several key parameters such as implant antenna volumetric dimensions, implant location in the human body, implant depth and tissue type as well as the nominal operating frequency. Follow-on work will use this model to estimate the limits of implant performance versus key parameters based on data from the literature.

- The key challenge of this work-to-date has been in identifying a suitable PhD candidate for this work. Particularly, a candidate with the required RFIC design skills.

- The goals for the next quarter are a more detailed analysis of the high-level WPT model using the literature as a source of data. In addition, a key ongoing focus is interviewing for a suitable PhD candidate.