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 technical summary for the recently funded MCCI project concerning the design of a custom RFIC design for a highly integrated Wireless Powered Implantable Medical Device (WPIMD). This project has been mainly driven by the lack of suitable commercial RFIC solutions on the market for highly integrated implantable applications in particular that has a rapidly growing application base. The need for a custom RFIC solution has been identified to address key challenges with current commercial solutions including antenna integration challenges, the need for battery-less operation using wireless power transfer (WPT) and also challenges associated with low power sensing and ultra-low-power wireless communications. The remainder of this document presents a short background on WPIMS applications, details on key issues and challenges for these applications as well as the proposed solution that is planned for this research work. This research will focus specifically in the areas of Antenna and RFIC Design, EM Simulation and in-body testing/characterization using an EM phantom.

1. Background

WPIMD are miniaturized devices that can be implanted in the human body to enable continuous monitoring of physiological parameters such as blood glucose level, blood pressure and neural activity recording as well as neural stimulation and drug delivery. As illustrated in Fig. 1, these devices use an external reader to provide RF power to the implant and also enable wireless transfer of measured sensor data from the implant.

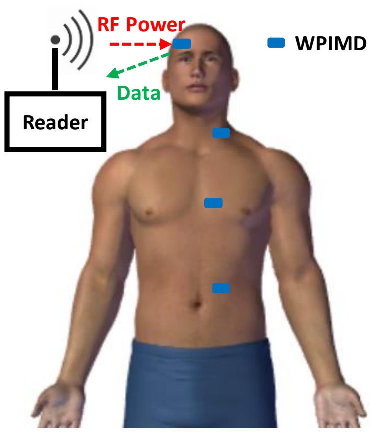

Fig.1 WPIMD concept

The provision of Wireless Power Transfer (WPT) has the advantage of removing the requirement for an integrated battery within the sensor which is undesirable from the point of view of bio-compatibility and bio-degradability but removal of an integrated battery also presents several key research challenges in powering the implant as well as other key challenges that are now outlined in Section 2.

2. WPIMD Design Challenges

1. One of the key challenges associated with the design of miniaturized WPIMD devices is the need for highly integrated or electrically small antennas (ESAs). Due to their size limitations, ESAs suffer from low gain and radiation efficiency, limiting the amount of RF energy available to power the WPIMD.

2. ESAs are also sensitive to human body effects such as sensor location and tissue type as each tissue type has varying dielectric properties. Current WPIMD devices have no capacity to adapt to their surroundings such as varying sensor location in the human body and varying tissue types due to implant location or patient physiology.

3. Also there is currently a lack of commercial ultra-low-power radio ICs for WPIMD applications. Commercial radio standards like Bluetooth low energy (BLE) are available but these devices require battery power are not optimised for in-vivo operation.

3. The Prosed WPIMD Solution

This work will develop a highly integrated WPIMD device using a custom RFIC design to address some of the key design challenges outlined above. The architecture of the RFIC is depicted in Fig. 2.

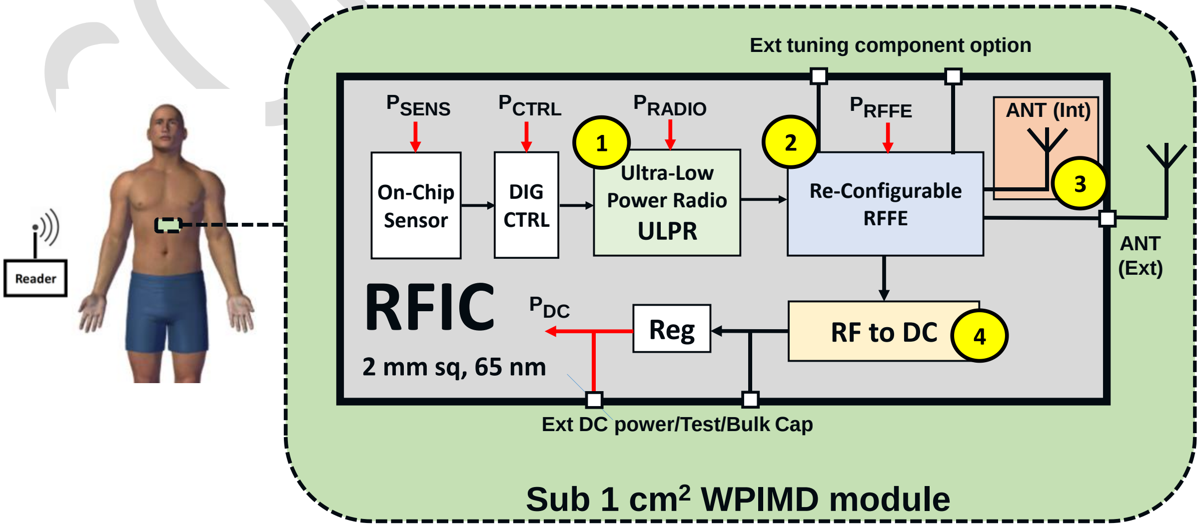

Fig. 2. Overview of proposed WPIMD design

4. The RFIC will feature 4 key sub-blocks

1. An integrated radio designed for ultra-low-power operation.

2. An integrated on-chip antenna for standalone operation with the provision for an external antenna as part of a Multi-Chip-Module (MCM) solution.

3. A reconfigurable front-end that will provide tunable impedance matching to enable the sensor to adapt to different placements of the implant, different tissue types and patients with different body mass index values.

4. An integrated RFtoDC converter to convert received power from the internal or external antenna and provide DC power to the sensor from an external RF power source.

5. Key Advantages over the state-of-the-art

1. The proposed WPIMD will provide a wirelessly powered alternative to battery powered commercial wireless solutions e.g. BLE where battery power is required. Similarly, there are very few commercially available implantable radio modules available on the market (e.g. Microsemi ZL70103) but this device requires battery power and dual antennas are also required and this poses challenges for integration.

2. RFFE re-configurability will enable multi-modal capability (i.e. ability to cover multiple frequency bands such as LF, HF and UHF bands) whereas current devices cover a single frequency band.

3. The RFFE will enable dynamic, antenna load impedances to be catered for rather than being limited to 50 Ω impedances typical in commercial radio ICs.

4. Provision of Internal and External antenna options for standalone and multi-chip implementation (e.g. MCM solution) will enable a large variety of antenna types to be interfaced with and tested during the integration stage with the final demonstrator.

6. Current work

The official start of this project was April 1st 2021 and current activities are focused on CV reviews for a suitable PhD candidate. A total of 32 applicants have been received and reviewed with 4 candidates having been shortlisted for interview on the dates of 12th to 16th April, 2021.