Maximizing Wireless Power Transfer Efficiency for mm-scale Implantable Medical Devices

Zhen Su*, Conor O'Sullivan †, Brendan O'Flynn*, John Barton*, Melusine Pigeon*, John L. Buckley*, Eamonn Hawe * and Patrick Sugrue*

*Tyndall National Institute, University College Cork, Dyke Parade, T12R5CP, Cork, Ireland
†Boston Scientific, Model Farm Rd, Cork, Ireland

Tyndall National Institute
Institiúid Náisiúnta

Abstract

- This work presents an Electromagnetic (EM) analysis for a mm-scaled wireless implantable medical device (WIMD) that is implanted in a homogenous human body model.
- The goal is to investigate the key parameters that affect the wireless power transfer efficiency (PTE) performance of the implant system.

A. Introduction

- Wireless power transfer (WPT) based on radio frequency (RF) techniques is investigated with an external reader providing wireless power to the implant.
- The implant is designed to operate at the centre of the licensed medical implant communication system (MICS) band 403.5 MHz [1].

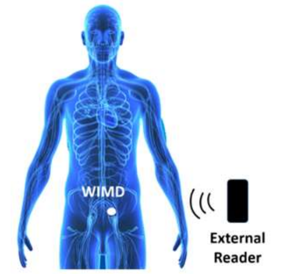

Fig. 1. Wireless modules for WIMD WPT

B. Reader-to-implant WPT Schematic and Key Parameters

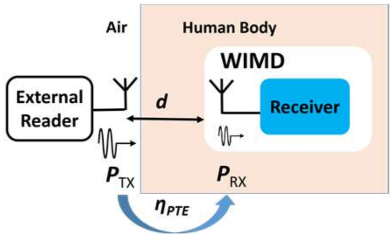

Fig. 2. Reader-to-implant WPT schematic for WIMD system

- P_{TX} is the radiated RF power from the external reader antenna (W)
- P_{RX} is the received RF power at the implanted receiving antenna (W)
- d is the reader-to-implant distance (m). In this work the external reader is placed very close (0.1 mm) to the human body model so the reader-to-implant distance is approximately equal to the implant depth.
- η_{PTE} is the PTE, expressed in dB as follows [2,3]:

$$\eta_{\text{PTE}}\,(dB) = 10 \times \log_{10}\left(\frac{P_{\text{RX}}}{P_{\text{TX}}}\right) \tag{1}$$

C. EM Simulation

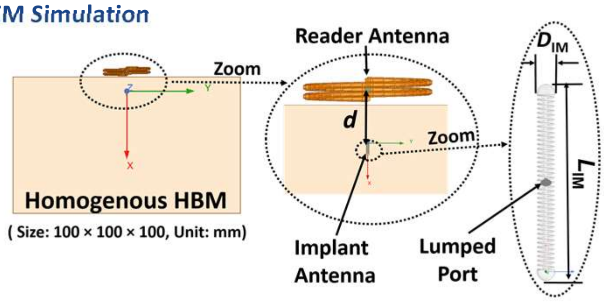

Fig. 3. Reader-to-implant EM simulation setup in the *XY*-plane

- Human body tissue effects are modelled using a 100 × 100 × 100 mm^3 homogenous human body model (HBM) with an electrical conductivity of 0.45 S/m and a dielectric permittivity of 36 at 403.5 MHz [4].
- The effects of the implant depth *d,* implant length L_{IM} and conductor material on the PTE performance are studied at a frequency of 403.5 MHz.

D. Results and Discussion

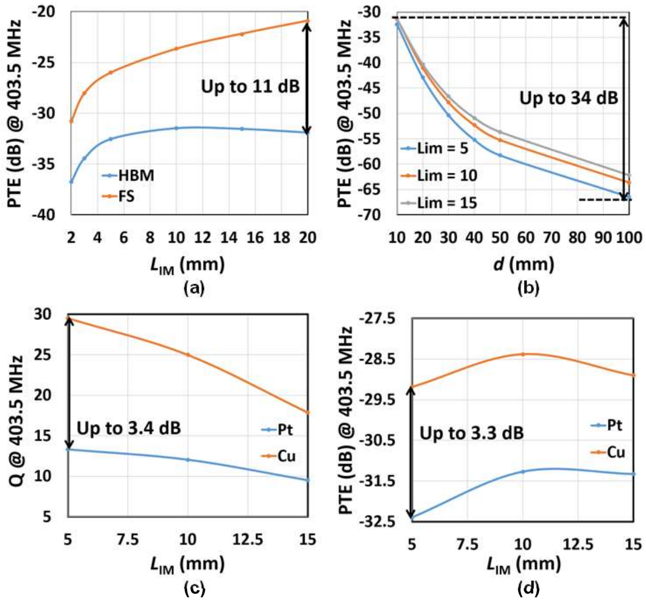

Fig. 4. EM simulation results for WIMD WPT system

Key Observations

- The HBM adds significant power loss (up to 11 dB) at 403.5 MHz.
- Increasing the implant depth *d* from 10 mm to 100 mm decreases the PTE approximately by 34 dB at 403.5 MHz.
- The quality factor of the implanted antenna is more than doubled from approximately 13 to 29 by switching conductor material from Platinum (Pt) to Copper (Cu).
- There is an approximately 3 dB improvement in PTE when using Cu as opposed to Pt.

E. Conclusions and Future Work

- This work presents an EM simulation study and shows that implant antenna length, implant depth and implant antenna conductor material all have a significant effect on the WPT performance of a mm-scaled implantable medical device and need to be optimized for a given configuration.
- Future work will focus on optimization of the PTE for changing transmitter reader antenna geometry and varying frequency of operation for several cases including varying reader-to-implant distances.

References

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[4] Speag phantom arm: SHO-GFPC-V1, Available online: https://speag.swiss/products/em-phantoms/phantoms/sho-gfpc-v1/, Accessed in Feb. 2022.

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