Simultaneous Wireless Power & Data Transmission for Wearable Applications

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Abstract— **This paper investigates the possibility of simultaneous digital communication and wireless power for wearable applications. The modulation and demodulation process of an 8-bit Pseudo Random Binary Sequence (PRBS) is presented. Specifically, a 5 Mbps data rate and 57% wireless power transfer efficiency are achieved. This study provides new insights in design trade-offs of wearable systems that provide digital communication and wireless power transfer through the same wireless link.**

Keywords — communication, CSCMR, efficiency, WPT, wearable applications, the human body

I. Introduction

Wireless Power Transfer (WPT) systems have recently attracted significant attention in different fields, such as biomedical devices, structural health monitoring, industrial applications, environmental monitoring, traffic controls, health applications, etc. [1]. WPT technologies can effectively extend the lifespan of devices, reduce the use of battery storage systems and eliminate the challenges of cable connections which makes them the best candidate for next-generation communication and sensing applications [2].

The proposed design simplifies the installation of a simultaneous WPT & data communication link on the vicinity of the human body. The compactness of the design can effectively reduce the costs and also lead to a practical and reliable design with less sensitivity to damage and easy maintenance. Moreover, for in-body applications, this design can eliminate invasive procedures (e.g., surgeries) that are typically needed for replacement of sensors' batteries [3].

II. System Description

Data communication and WPT can be achieved with three possible techniques [3]: a) The use of an independent wireless data link which has an extra resonator. This resonator is used to form an inductive coupling and its major challenge is the cross-coupling between the power and data links. b) The use of two radio frequencies (RF) antennas for transmitting data and the use of an inductive link for the WPT. This method achieves a reduced cross interference but with increased complexity and a possible increase in size and weight. c) The use of a single WPT and data communication channel. This method simplifies the hardware structure and it is the one used in this work.

The scope of this work is to achieve a high data rate of digital communication through a highly efficient WPT link in the presence of the human body. Below the design procedure of the proposed link is given.

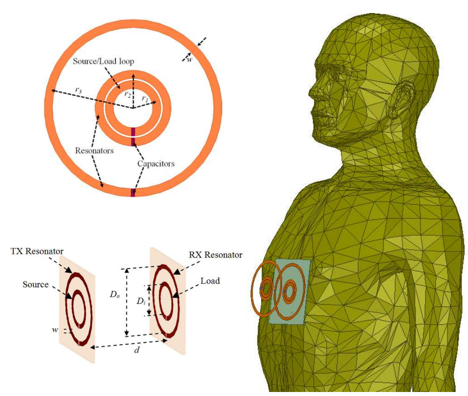

Fig. 1. A typical wearable model of highly efficient broadband CSCMR system in presence of the human body.

As it is shown in Fig. 1, the proposed link is supported by a Conformal Strongly Coupled Magnetic (CSCMR) system, [4-5]. A possible scenario is that the RX is placed on clothes (i.e., wearable devices) and the TX is placed on static hubs placed on top of furniture or it is integrated into furniture. Fig. 2 shows the architecture of the proposed system. The main communication blocks are the electronic circuits (modulator and demodulator), the sensors (here a 50 Ω load), and the CSCMR link (3 loops on each side TX/RX). The wireless power transmission consists of a signal generator, the CSCMR link, and the rectifier supplies DC power to the sensor.

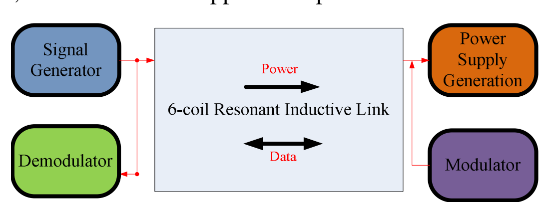

Fig. 2. Schematic representation of a system with WPT & data communication

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Based on our analytical and simulation analysis [5], the geometrical specifications of the resonators are as follows: the radius of the inner loop r_1=14 mm, middle loop r_2=20 *mm*, and outer loop r_3=50 mm; the width of the copper trace w=2.4 mm; the optimum distance between the transmitter and receiver l=47 mm; the capacitors used for r_2 and r_3 are 31.15 pF and 7.6 pF, respectively, and the center operating frequency is 115 MHz. In addition, a typical polyester textile is considered as the substrate for the RX resonator with ε_r=2.122 and $\tan\delta$ =0.0035. As it is shown in Fig. 3, our system's bandwidth for at least 50% efficiency is approximately 24 MHz covering the band from 102 MHz to 126 MHz.

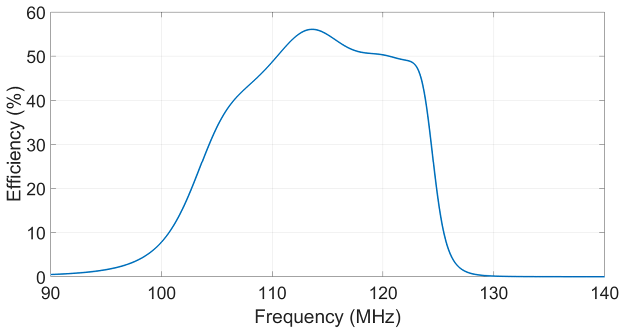

Fig. 3. Simulated efficiency for broadband CSCMR system in presence of the human body.

A. Communication System

The signal generator creates an RF signal which is transmitted from the TX to power up the RX. In the RX a 5 MHz bit rate pseudo-random signal (with bit sequence 10001100) is used to modulate the RF signal. The modulation is achieved using Load Shift Keying (LSK). The RF signal is converted to DC by a full wave rectifier (under the power supply generator of the schematic in Fig. 2). Note that the DC output of the rectifier contains ripple at the operation frequency. To reduce or eliminate these ripples, and to achieve a DC voltage independent of the input voltage, a capacitor is connected at the output of the rectifier. The rectifier uses Schottky diodes taking advantage of their low level of power consumption and their low switching time. Fig. 4 shows that with this set up the output voltage is kept at 0.884 V. Also, the modulated signal will reflect back to TX.

In the TX an envelope detector is used as a demodulator. The circuit used here can detect an AM waveform with a very low modulation index. It consists of two main elements; a diode and a low pass filter which is needed to eliminate the high-frequency components of the modulated signal after the detection/demodulation. For edge detection of the modulated signal, a cascaded envelope detector is designed which can detect the envelope of the passed signal (see Fig. 5).

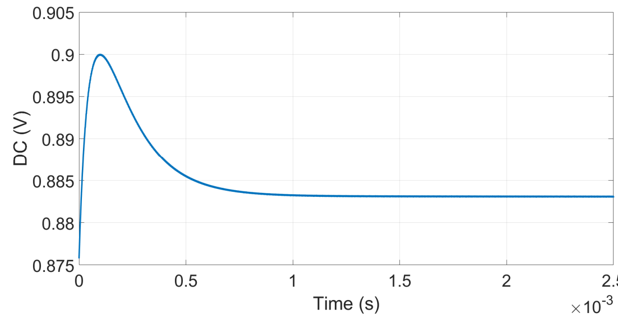

Fig. 4. DC voltage generated by the full-wave rectifier.

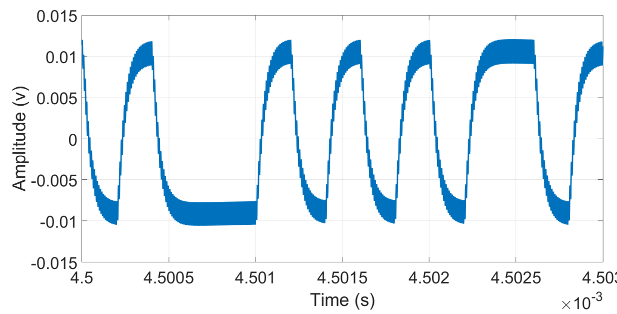

Fig. 5. The demodulated pseudo-random signal

III. Conclusions

A wireless system that provides simultaneous highly efficient power transfer and high data rate communication was proposed for wearable applications. By considering the right settings for the input power and with a proper selection of the elements, a ripple-free DC voltage was achieved. This system can be used in various wearable applications, such as biosensing.

References

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