A Wireless Power Transfer System on Clothes Using Conductive Threads

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***Abstract*—Wireless Power Transmission (WPT) systems today are widely used for charging mobile devices and electric vehicles. Notably, WPT systems will play a critical role in the development of future implantable and wearable devices. In this work, we propose a WPT system that is based on conductive threads. This system can be sewn on clothes and can wirelessly charge/power wearable and implantable devices. Our simulation analysis shows that such a system is efficient and in accordance to the International Commission of Non-Ionizing Radiation Protection (ICNIRP) guidelines on Specific Absorption Rate (SAR).**

I. Introduction

The growing demand for wearable and implantable devices, which range from medical devices (peacemakers, insulin pumps, etc.) to sensors (heart rate, oximeters, etc.), has driven new requirements for Wireless Power Transfer (WPT) systems that need to deliver electrical energy efficiently, quickly and wire-free. Such WPT systems have generated significant attention in recent years due to their great advantages over wired designs. For example, Neuralink Corporation [1] recently announced their prototype of a wireless implant device that will help functions in the brain and spine. Such wearable and implantable devices can significantly be reduced in size when they incorporate the appropriate WPT system. Furthermore, these devices also benefit from longer lifetimes due to their batteries capable of being wirelessly re-charged. Notably, one of the most important challenges that wearable and implantable systems encounter is having a portable charging station to transmit power. In this paper, we propose a wearable WPT charging system that will be able to charge wearable devices and implants. The proposed WPT system is shown in Fig. 1. and it consists of a 2×2 Conformal Strongly Coupled Magnetic Resonator (CSCMR) array connected to a battery. The TX element of the CSCMR is made from an Eliktrisola, Inc., conductive thread, [2], and can be easily sewn on clothes (e.g., vest, shirt, hat, and pants) in order to transmit power wirelessly to multiple wearable or implantable devices. Therefore, having such a WPT system that can facilitate the transfer of power by simply wearing clothes will be extremely advantageous. Even though WPT systems using conductive threads or textiles have been proposed, [3], [4], a complete design as the one proposed here, has yet to be shown.

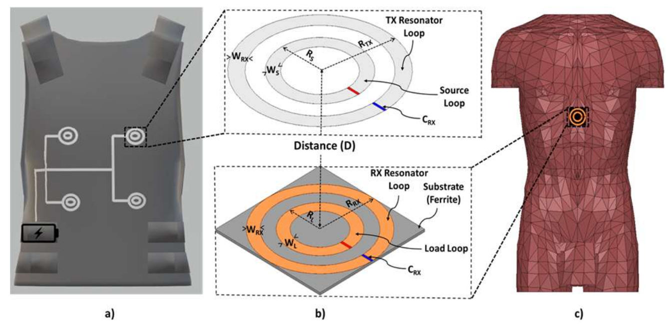

Fig. 1. Proposed system with a) TX element sewn on clothes, b) WPT system TX and RX elements, and c) RX element on the human body.

II. Proposed WPT System Design

A. *Proposed WPT Textile based System Sewn on Clothes*

As wearable and implantable devices incorporate WPT systems, a potential challenge to users is the inconvenience of charging. This is because most WPT systems today require their Transmitting (TX) and Receiving (RX) elements to be directly aligned with each other for the optimal performance and achieve the optimal efficiency, therefore, a transmit device should always be placed in the vicinity of the wearable or implantable device for best results. However, it could be very uncomfortable for users to have a traditional transmit system always perfectly aligned to the receiving device. Consequently, our proposed transmit system uses a conductive textile that can be sewn on clothes (see Fig. 1.) thereby enabling the charging (for battery-operated devices) and powering (for passive battery-free devices) of wearable and implantable systems.

The block diagram of a WPT system is presented in Fig. 2. The design flow is as follows: 1) a DC voltage supply is required to supply the power amplifier, 2) the power amplifier in combination with an oscillator converts the DC voltage to the required RF power at the frequency of operation of the WPT system, 3) the TX is used to transfer power over a medium, 4) the RX captures the power that was transmitted by the TX, 5) a rectifier circuit is used to transform the high frequency signal to a DC signal that is suitable for the load, and 6) the load consumes the power.

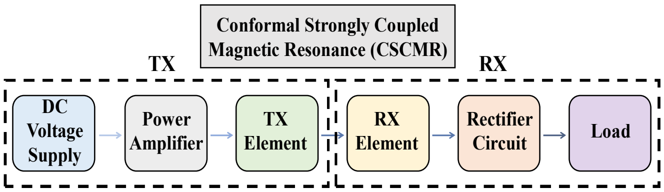

Fig. 2. Block diagram of a WPT system.

B. WPT TX and RX design

Our proposed WPT system is shown in Fig. 1. and it based on the CSCMR method [5][6]. CSCMR systems are especially advantageous for wearable and implantable systems because their source loop and TX resonator (and their RX loop and load resonator) are coplanar thereby providing minimal footprint. In our case, where the TX elements will be sewn on clothes using conductive threads, there is little or no space to have a distance between source/TX and RX/load loops, which is typically required for other Strongly Coupled Magnetic Resonant systems. Therefore, CSCMR systems are very well suited for the applications considered here. Our system was purposely chosen to resonate at the Industrial Scientific and Medical (ISM) band frequency of 40.68 MHz so that the TX and RX elements are substantially smaller than the ones operating at lower ISM frequencies. Also, our proposed systems provide a high WPT efficiency of 75%. All the geometrical parameters of our optimized CSCMR system are given as follows: R_S = 17.81 mm, R_L = 14.25, W_S = 5 mm, W_L = 4.5mm, R_{TX} = 30 mm, R_{RX} = 24 mm, W_{TX} = 5.62 mm, W_{RX} = 5 mm and D = 60 mm and is shown in detail in Fig. 1. Additionally, the conductive thread used here is a silver copper alloy with a conductivity σ =57.5 S·m/mm^2. Also, WPT systems must satisfy the RF exposure levels to humans, which are specified by safety standards. In addition, previous research [7] has shown that safe WPT systems can be developed for wearable and implantable systems due to their very low power requirements. Here, the simulated Specific Absorption Rate (SAR) of our WPT system is calculated using the ANSYS human body model to ensure the ICNIRP guidelines are met. Our SAR results is shown in Fig. 3.

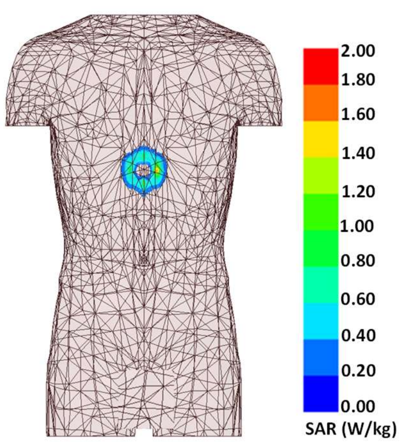

Fig. 3. Simulated SAR of WPT System on ANSYS human body model.

C. Class E Power Amplifier design

In this work, a 40.68MHz class E amplifier [8] was designed. The class E configuration is often used for WPT systems due to their highly efficient nature (from their zero voltage switching properties) as efficiency at each design step is important in WPT system designs. A Wolfspeed cgh60030d gallium Nitride high-electron-mobility transistor is used in our design. The full design of the class E power amplifier will be shown at the conference and it achieves an efficiency of 79%.

III. Conclusions

A conductive thread WPT system, which can be sewn on clothes to power wearable and implantable devices, was proposed. Simulations show that the system will be highly efficient for a wearable system at the ISM frequency band of 40.68 MHz. Additionally, the calculated SAR levels illustrate that our WPT system meet the ICNIRP guidelines.

Acknowledgement

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