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Simultaneous Wireless Power Transfer and Data Communication Using Synchronous Pulse-Controlled Load Modulation

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Abstract

Wireless Power Transfer (WPT) and wireless data communication are both important problems of research with various applications, especially in medicine. However, these two problems are usually studied separately. In this work, we present a joint study of both problems. Most medical electronic devices, such as smart implants, must have both a power supply to allow continuous operation and a communication link to pass information. Traditionally, separate wireless channels for power transfer and communication are utilized, which complicate the system structure, increase power consumption and make device miniaturization difficult. A more effective approach is to use a single wireless link with both functions of delivering power and passing information. We present a design of such a wireless link in which power and data travel in opposite directions. In order to aggressively miniaturize the implant and reduce power consumption, we eliminate the traditional multi-bit Analog-to-Digital Converter (ADC), digital memory and data transmission circuits all together. Instead, we use a pulse stream, which is obtained from the original biological signal, by a sigma-delta converter and an edge detector, to alter the load properties of the WPT channel. The resulting WPT signal is synchronized with the load changes therefore requiring no memory elements to record inter-pulse intervals. We take advantage of the high sensitivity of the resonant WPT to the load change, and the system dynamic response is used to transfer each pulse. The transient time of the WPT system is analyzed using the coupling mode theory (CMT). Our experimental results show that the memoryless approach works well for both power delivery and data transmission, providing a new wireless platform for the design of future miniaturized medical implants.

***Keywords*—Wireless power transfer; data communication; load modulation; transient process; coupling mode theory.**

Introduction

The Wireless Power Transfer (WPT) technology can extend the lifetime of the battery operated device and eliminate the complications due to cable connection. With an advanced concept of strongly coupled magnetic resonances, which was proposed in 2007[1, 2], the WPT has become a promising method to address the problem of power delivery in highly constrained environment. One of the most popular application areas of WPT is wirelessly powering biosensors or implants within the bodies of humans or animals [3-5]. The non-invasive solution has attracted a great deal of attention in diverse applications, such as electric stimulators for muscles and neural tissues, endoscopic capsules, cardiac pacemakers, and cochlear implants [6-14].

One additional challenge associated with medical implants is the transmission of data acquired by these devices to the outside of the biological body[4, 5]. The methods of data transmission usually involve an independent wireless data link. A typical data link consists of an extra coil operated using inductive coupling [15-19]. Such a system must deal with the problem of the cross-coupling between the data and power links. Another method uses a pair of radio frequency (RF) antenna to transmit data and an inductive link for WPT [20-23]. Such a hybrid system reduces cross-interferences but is more complicated and size/weight demanding.

Unifying the WPT and communication channels into a single channel would be a desirable approach because it simplifies the hardware structure. Previous studies use an on-off switch to change the load of an inductive power link for data transmission [9, 19, 24, 25], and it can be considered as a load shift keying (LSK) technique where the modulation is achieved by shifting the switch based on the data stream [24]. In addition, each switching state (on or off) must be held for a relatively long period of time to ensure the system to reach a steady state. This approach has serious drawbacks that the data rate is low, and the on/off states affect the power transfer efficiency due to frequent mistuning. Beside the problem in the RF transmitter, many systems