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Wireless Implant Communications Using the Human Body

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INTRODUCTION

Advancements in medical diagnostics and biosensing technology opened up a great venue for research in electronic medical implant. To improve accuracy and timeliness of diagnosis, electronic devices could be implanted inside human body to provide various real-time diagnostics information. However, effective technique for implant communication is still an open problem. Early efforts based on radio wave propagation are standardised as the Medical Implant Communication Services (MICS) for 402– 405 MHz frequency range which was later adopted as Medical Devices Radio Communications Services (MedRadio) for 401–406 MHz frequency range (Hanna, 2009).

Currently, the radio-frequency (RF) implant wireless communication is enabled by utilizing small antennas that radiate radio waves inside the human body. As a bid to find alternative wireless implant communication mechanisms within the Wireless Body Area Network (WBAN), in this work, the authors explored two complementary techniques. The first uses galvanically coupled Intra-body communication (IBC) for implant-to-surface communication. IBC is a relatively new technique that uses the human body as a channel with communication frequencies not exceeding several MHz. The second technique uses the human body itself as an antenna by feeding an RF current into the tissues.

This chapter first examines a new analytical electromagnetic model that uses galvanically coupled IBC where the implant transmitter differentially injects current into the tissue via its anode and cathode electrodes. A wearable receiver on the surface of the skin samples the resulting potential difference using its two electrodes. Frequencies ranging from hundreds of kHz up to a few MHz are considered under quasi-static assumptions. The model is unified in the sense that it is based on multilayered ellipsoidal geometry that can be applied to any part of the body (i.e., head, torso, limbs etc.). It also effectively describes influences of tissue properties and geometry of the body part. The security and low power consumption of IBC are also apparent in this model. The path loss characterisation of IBC implants shows lower values compared to their MICS counterparts.

In addition, the chapter also elaborates on the scenario when the RF current is fed by a tiny toriodal inductor that is implanted and clamped around the tissues in the ankle. The frequency range of 1-70 MHz is considered, which includes the resonance frequency of the human body. Theoretical results show that the system exhibit broadband characteristics with a maximum gain of - 25 dB between 20 to 40 MHz, assuming an isotropic radiation from human body. However, for the case of the small toroidal inductors considered, the radiation resistance of the system is very small, which increases the power consumption.

DOI: 10.4018/978-1-5225-2255-3.ch550

BACKGROUND: IMPLANT COMMUNICATION IN THE WBAN ARCHITECTURE

To improve accuracy and timeliness of diagnosis, and hence improve quality of life, sophisticated actuators and biosensors are emerging for various diagnostic applications; for example, glucose sensors for continuous diabetes monitoring (Heo et al., 2013). In broad terms, implant communication technique explored in literature use radio wave propagation, magnetic induction and volume conduction(Poon, 2010), (Bjorninen et al., 2012), (Yang, 2006).

For implant communication it is important that the transmitter consumes small power to conserve battery life. The implant should also be miniaturized for a minimal invasive embedding. Besides, due to sensitive nature of medical data, security is a paramount requirement of implant communication. To achieve security either the signal needs to be encrypted at the transmitter or be confined to within the body detectable by as far as an on-body receiver. In the case of MedRadio based implant, the signal is radiated outside the human body; hence, requires all security features be implemented right at the transmitter which increases the transmitter complexity. Hence, the transmitter consumes large power and is difficult to miniaturise.

Implant communication scenario can be divided as implant-to-implant, implant-to-surface, and human body to external environment. The authors explored the use of galvanically coupled IBC for implant-to-implant and implant-to-surface scenario; and the use of the human body itself as an antenna for a possible scenario of communicating implant inside human body to external environment.

The general architecture of body area sensor networks, as shown in Figure 1, is that a link node wearable on the surface talks to and listens from the implanted and other surface mounted devices. It then combines and relays the signal to devices external to the body – mainly a monitoring or controlling device away from the body. Another likely scenario is the possibility of two implants talking to each other; for example, a glucose sensor and an insulin pump. To reduce complexity and power consumption it is better to implement advanced security features at the link node rather than each individual implanted or on-body device. To avoid eavesdropping attempts to listen or talk to sensors in and on the body by any transceiver external to the body, the signal needs to be confined to within the body. For frequencies ranging from a few hundreds of kHz to tens of MHz, the human body hardly radiates radio waves. Thus, this band is suitable for body confined (intra-body) transmissions – implant-to-implant, implant-to-surface and surface-to-surface communications.

To communicate the signal to outside the body wirelessly, radio wave propagation of RF signals is required. Such is the case for the link node or possibly an individual implant desired to directly communicate with the outside environment. For this scenario, the authors explored using the human body as an antenna. Specifically, frequency ranging from 10 – 110 MHz was considered. If the human body is excited by an RF current in this frequency range, the human body radiates electromagnetic signals. Furthermore, the human body resonance frequency is found to be between 30 – 70 MHz which falls within the frequency of interest. Transmission power levels within human tissues considered in this chapter arein accordance with the safety recommendations of Specific Absorption Rate (SAR) levels by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (ICNIRP, 1994).

THE HUMAN BODY AS A CHANNEL FOR IMPLANT COMMUNICATIONS

The HBC uses an electric field communication (EFC) where the human body is effectively a volume conductor. It exploits the lossy dielectric nature of the conductive tissue layers to induce a current, and hence a potential distribution, as a

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