Characterization of Signal Propagation through Limb Joints for Intrabody Communication

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ABSTRACT

Intrabody communication (IBC) is one of the recent physical layers of the IEEE 802.15.6 Wireless Body Area Networks (WBAN) communication standard. It is employed for data transmission in low frequency bands (21 MHz as per standard, 0.3-120 MHz in literature), providing up to 10 Mbps data throughput. An effective way to increase data rate communication is to determine higher operation frequency bands. This paper reports empirical studies which explore signal propagation through the human body including limb joints within the 0.3-200 MHz frequency range. Results show that minimum signal attenuation points occur at 50 MHz and 150 MHz within the range of investigation. The presence of the joint segments along the signal propagation path causes on average 2.0 dB loss (at 50 MHz and 150 MHz), 6.0 dB loss (<1 MHz) and less than 3.0 dB (>150 MHz) compared to limb segments.

Keywords: Attenuation, Coupling Method, Data Rate, Human Body Tissue, Intrabody Communication (IBC), Joint Segment, Medical Applications, Signal Propagation, Wireless Body Area Network (WBAN)

INTRODUCTION

Nowadays, the main focus of healthcare technological development is to improve the quality of ubiquitous healthcare monitoring while decreasing costs. The new generation of health monitoring devices employs wireless communication technologies to transmit physiological data between patients and health services (Yoo, 2013). Human vital signs such as heart rate, blood pulse pressure, and blood glucose levels are monitored through on-body wearable or implanted lightweight medical sensors (Patel, Park, Bonato, Chan, & Rodgers, 2012). Vital sign monitoring may require patients to wear or implant several numbers of sensors. To avoid
data interference or collision among the multiple sensors as well as with a decision maker (hub node), a protocol framework is necessary.

In February 2012, IEEE 802.15.6 or wireless body area network (WBAN) standard, specific to medical healthcare applications was released by the IEEE (“IEEE Standard for Local and metropolitan area networks - Part 15.6: Wireless Body Area Networks,” 2012). WBAN is a short-range, low-power wireless communication standard for transmissions within the vicinity of, or inside, a human body. It consists of three physical (PHY) layers including Narrow-band (NB) PHY, Ultra-wideband (UWB) PHY, and Human body communication (HBC) PHY. The first two PHY layers operate in different radio frequency (RF) bands between 400 MHz to 10.6 GHz (Keong, Thotahewa, & Yuce, 2013). The main concern with RF propagation is that it consumes battery life quickly and decreases the usefulness of portable health monitoring devices (Seyedi, Kibret, Lai, & Faulkner, 2013). For example, the IEEE 802.15.6 NB transceiver chip, which provides a wireless solution, was recently proposed for biotelemetry applications. The power consumption of the WBAN chip was 5.9 mW for the bit rate of 750 kbps (Wong, et al., 2013). A 1.0 V button cell which has typically a battery life of a year in continuous operation was employed in the chip. On the other hand, the last PHY (HBC), when a data rate was 8.5 Mbps, has power consumption less than 3 mW (Fazzi, Ouzounov, & Homberg, 2009). This makes it more enticing for WBAN medical applications.

Successful deployment of IBC technology in portable healthcare monitoring, e.g. Body Area Networks (BAN), requires the technology to have acceptable data rates and to be energy efficient. At the same time, small size and light weight transceiver nodes are required to make them suitable for a wide variety of medical applications (Lin, et al., 2011). The maximum IBC data rate is reported as 1312.5 kbps in the 21 MHz frequency band by IEEE WBAN standard. Although, this data rate is suitable for medical data transmission, e.g. capsule endoscope and glucose monitoring, some healthcare applications such as medical imaging require higher data rates above 10 Mbps (Bae, Song, Lee, Cho, & Yoo, 2012). The operation frequency band therefore needs to be enhanced in order to increase the WBAN IBC data rate.

IBC can be classified into two basic procedures based on how data is propagated through the body. The first method is called capacitive coupling (electric field) or near-field coupling. The initial prototype of capacitive coupling IBC, i.e. personal area network (PAN), was proposed by Zimmerman (1996). The early PAN transceiver consists of battery powered transmitter and receiver units. The optimum carrier frequency range was determined between 100 to 500 kHz and a suitable data rate was considered to be 2.4 kbps. Although low power consumption of 1.5 mW was achieved for PAN, the proposed transmission rate was not desirable for medical monitoring systems (Adibi, 2012). Following several attempts to increase the IBC system data rate (Partridge, et al., 2002; Sasaki, Shinagawa, & Ochiai, 2009), in 2012, Kang et al. (2012) proposed a new method to enhance the data throughput for WBAN standard. A modified frequency selective digital transmission (MFSDT) was employed in the IBC transmitter. This method spread the digital transmitted data over the selective frequency range. It provided thrice the data rate (3.9375 Mbps) than current WBAN IBC (1312.5 kbps). Recently, several energy and data rate efficient implementations of IBC system were proposed by KAIST (Korea Advanced Institute of Science and Technology) research group. The group reduced the
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