Chapter 12

5.8 GHz Portable Wireless Monitoring System for Sleep Apnea Diagnosis in Wireless Body Sensor Network (WBSN) Using Active RFID and MIMO Technology

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ABSTRACT

Sleep apnea is a severe, potentially life-threatening condition that requires immediate medical attention. In this chapter, a novel wireless sleep apnea monitoring system is proposed to avoid uncomfortable sleep in an unfamiliar sleep laboratory in traditional PSG-based wired monitoring systems. In wireless sleep apnea monitoring system, signal propagation paths may be affected by fading because of reflection, diffraction, energy absorption, shadowing by the body, body movement, and the surrounding environment. To combat the fading effect in WBSN, the MIMO technology is introduced in this chapter. In addition, the presented active RFID based system is composed of two main parts. The first is an on-body sensor system; the second is a reader and base station. In order to minimize the physical size of the on-body sensors and to avoid interference with 2.4 GHz wireless applications, the system is designed to operate in the 5.8 GHz ISM band. Each on-body sensor system consists of a physiological signal detection circuit, an analogue-to-digital convertor (ADC), a microcontroller (MCU), a transceiver, a channel selection bandpass filter (BPF), and a narrow band antenna.

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1. INTRODUCTION

The origin of radio frequency identification technology (RFID) can be traced back to a hundred years ago. In the late 18th and early 19th centuries, researchers started investigating radio waves and their propagation. Inventions such as the identification, friend or foe (IFF) transponder for aircraft identification (UK, 1915) and the espionage tool (Theremin) for retransmitted incident radio waves with radio information (Soviet Union, 1945), can be seen as the predecessors of RFID technology. The breakthrough in RFID technology was made at the end of the 20th century. Based on the dramatic development, RFID technology in the applications of healthcare and wireless patient-monitoring have been widely investigated in many countries over recent years. A number of achievements have been introduced in the following papers: Li et al. (Li, Liu, Chen, Wu, Huang, & Chen, 2004) proposed a RFID-based mobile healthcare service system, and the basic RFID system structure and operational procedure are set out in the article. Sangwan et al. (Sangwan, Qiu, & Jessen, 2005) proposed a real-time RFID system for hospital management of facilities, patient monitoring and service organization. The benefits of the utilization of RFID technology in hospitals have also been analyzed. Park et al. (Park, Seol, & Oh, 2005) introduced the new concept of the combination of RFID, mobile and web technology in healthcare services systems. The proposed system employs mobile devices to extend the connectivity to all ubiquitous environments so that the RFID recognizer can identify the patients who visit the hospital and automatically allocate the ‘1 on 1’ service.

Besides the great potential in healthcare service management, RFID also has its advantages in wireless sensor design. Alippi et al. (Alippi & Vanini, 2005) provide a methodology for reducing power consumption by implementing passive RFID tags. The idea of reducing energy consumption by diminishing the received data instances and data resolution depth provides a possible strategy for developers of modern RFID sensors. A joint-research group from Intel Research, Seattle, USA, and the University of Washington, USA, has made progress in RFID sensing which has accelerated the pace of development of battery-free RFID sensors (Philipose, Smith, Jiang, Mamishev, Roy, & Sundara-Rajan, 2005). Marrocco (Marrocco, 2007) has presented a design for UHF RFID planar antennas for biomedical monitoring. This design considers the issues of passive power supply and the effects of radiation on the human body. Another recent achievement in passive RFID sensing has been achieved by Sample et al. (Sample, Yeager, Powledge, & Smith, 2007). Their wireless identification and sensing platform (WISP) is integrated with sensors of light, temperature and rectified voltage. However, this platform still has limitations for human applications. Occhiuzzi and Marrocco (Occhiuzzi & Marrocco, 2010) have published a paper on their research on wireless monitoring by passive RFID systems. Their investigation of the feasibility of UHF band RFID for wireless monitoring of human body movement provides very useful information for other researchers in this frontier. Their particular design for monitoring leg movement during sleep offers significant ideas for sleep monitoring engineers.

Moreover, from the existing research on wireless sleep apnea monitoring systems, it is known that physiological signals such as Electrocardiography (ECG), Electromyography (EMG), Electroencephalography (EEG), Electrooculography (EOG), etc. can be sent wirelessly to the remote base station only in the Single Input Single Output (SISO) environment under the WBSN scenario. However, a wireless signal is severely sensitive to fading. Particularly in WBSN communications, propagation paths can experience fading due to energy absorption, reflection, diffraction, shadowing by the body, body postures (Yazdandoost & Sayrafian-Pour, 2010), body movement, polarization mismatch and scattering of electromagnetic signals due to the body and the surrounding environment (Khan, 2009).
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