OSA evaluation by using clinical parameters monitoring system based on Radar Technology

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Abstract

The detection of Obstructive Sleep Apnea (OSA) is essential for assessing sleep quality and for supporting cardiovascular diagnosis. Recent studies have shown that radar-based monitoring system can remotely measure the vital signs (respiration and heart rates) aiming to detect OSA events. In this work, a non-contact radar sensor is proposed for remote vital signs monitoring in a sleeping subject to detect OSA events. An experimental setup has been implemented in a bedroom with the radar fixed to the ceiling above human volunteers. Preliminary results show accurate measurement of the subject's vital signs.

Keywords

Obstructive Sleep Apnea, clinical parameters, radar sensor

1 Introduction

Obstructive Sleep Apnea (OSA) is a sleep-related breathing disorder characterized by repeated partial or complete upper airway obstructions which occur during sleep [1]. The standard method for sleep apnea diagnosis is polysomnography (PSG) [2]. It requires skilled technicians to perform optimal data recording; moreover, it is also uncomfortable, unsuitable and expensive to be used by general population. To overcame these limitations and to improve patient comfort, contactless sleep monitoring came into being [3, 4]. Recently, many studies using microwave biomedical radar for non-contact vital sign monitoring, such as Frequency Modulation Continuous Wave (FMCW) radars, have been proposed [5, 6, 7]. They present several advantages: (i) contactless measurements free individuals from additional electrodes used in existing sleep monitoring devices, (ii) the high sensitivity and accuracy of microwaves ensure to capture even subtle changes in the vital signs signatures and to detect body movement changes during sleep, (iii) there are no privacy concerns associated with biomedical radar, (iv) radar sensors can be mounted in privacy-sensitive areas within typical room sizes, facilitating a number of highly relevant clinical applications, both in home and clinical environments[7].

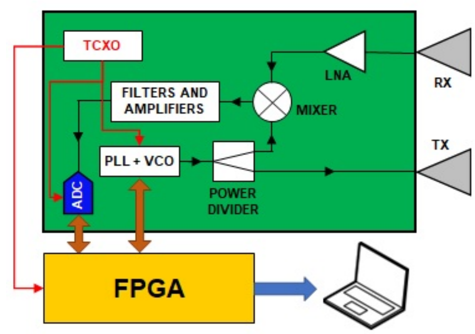

Figure 1. Block diagram of the system with radar sensor.

Due to the above-mentioned advantages of bio-radar, in this work, a radar sensor, based on an FMCW architecture, and a signal processing algorithm have been proposed for remote in-bed monitoring of the patient's vital signs aiming to detect OSA events. Experimental results show the ability of the radar in accurately monitoring the vital signs parameters (respiration and heart rates) of a sleeping subject.

2 Methods

The block diagram of the proposed radar system is shown in Figure 1. The radar unit is depicted in green.

The radar transmits linear chirps with instantaneous frequency ranging from 7.3 GHz to 8.05 GHz. The total bandwidth of 750 MHz results in a range resolution of 20 cm, which is sufficient for localization due the typical dimensions of the human body. Each chirp lasts 102.4 μs and

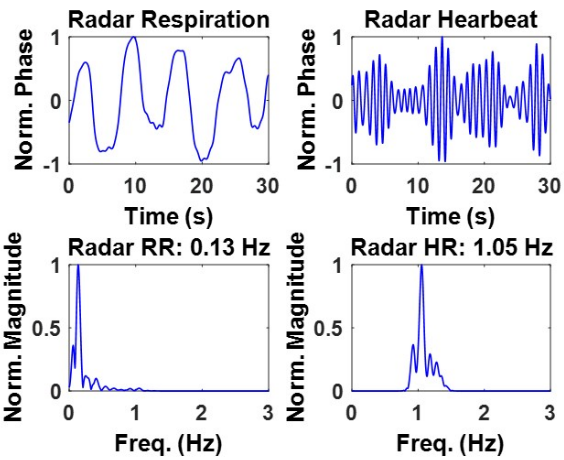

Figure 2. Example of the acquired heartbeat and respiration signals by radar.

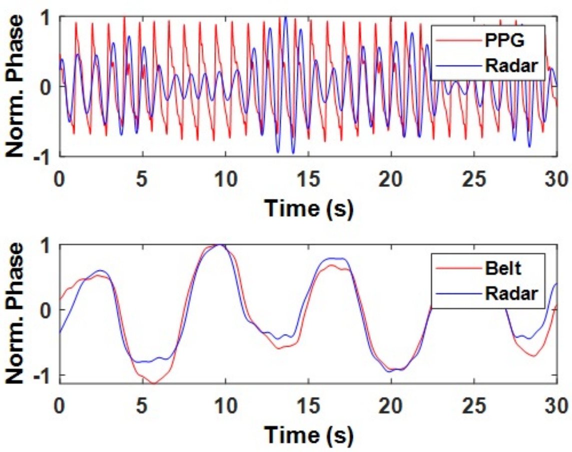

Figure 3. Example of the acquired heartbeat and respiration signals by radar, PPG and belt.

they are transmitted every 3.027 ms. This results in a sampling rate of the Doppler (vital signs) signal of about 326 Hz, which is higher than the typical vital signs range of 0-3 Hz. The 0 dBm transmitted peak power and the chirp configuration satisfy the worldwide Ultra-WideBand (UWB) indoor radio regulations. The FMCW signal is synthesized by the voltage-controlled oscillator (VCO) which is connected to a phase locked loop (PLL). It feeds a branch line coupler from which two copies of it (with smaller amplitudes) are generated. One is connected to the transmitting antenna (TX) thought its connector. The other output serves as a local oscillator for the mixer. The reflected signal is received by the receiving antenna (RX), amplified by a low-noise amplifier (LNA), before feeding the second port of the mixer. After mixing, the baseband radar signal is filtered, amplified, and acquired by an analog to digital converter (ADC). A Temperature Compensated Crystal Oscillator (TCXO) is used to provide the clock reference to the PLL and ADC. This ensures perfect synchronization between chirp generation and acquisition, avoiding phase errors. A Field Programmable Gate Array (FPGA) controls the PLL's synthesizer to generate the chirps, collects and sends the ADC's samples to MATLAB by an Ethernet port.

3 Experimental Results

The experiments have been conducted in a standard size bedroom. The radar was placed on top of the bed at about 2 m. The subject was invited to reproduce a realistic sleeping situation, i.e., moving limbs and changing positions, and also different breathing conditions (i.e., holding breath, spontaneous, and paced breathing). The g.USBamp device (https://www.gtec.at/product/gusbamp-research/) was used to measure heart and respiration activities, through a photoplethysmogram (PPG) finger sensor and a thorax expansion belt, respectively, useful to compare the results. Figure 2 and Figure 3 show two examples of the acquired heartbeat and respiration signals by radar and the comparison of these signals respect to the same signals acquired by PPG and belt, respectively. For each signal, the normalized magnitude and phase have been reported to evaluate and test the efficiency of the system.

4 Conclusions

A remote in-bed monitoring system of the vital signs (respiration rate and heart rate) of a sleeping subject based on a radar sensor and a signal processing algorithm has been proposed. The accurate detection of these parameters represents an important contribution in the OSA events detection and treatment. A radar can detect small abnormalities in vital signs that may not be easy observed during clinical examination. The Doppler signal presents small or imperceptible changes and variations indicating these anomalies supporting physician in their diagnosis and treatment. This system represents a potential novel applications in the domain of ambient assisted living, telemedicine and healthcare to assist individual affecting by OSA. Further works need to be done to confirm the presented finding involving more subjects and including further sleeping conditions and positions.

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