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Heartbeat rate and heart rate variability Extraction using ultrasonic transducer

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Abstract : This paper presents a Doppler radar system used to detect the heartbeat signal from a distance of one meter. The proposed system is based on using a ultrasonic transceiver and two antennas. Measurements are performed at 2 GHz for different power levels between 0 and -25 dBm. Both heartbeat rate and heart rate variability are extracted and compared to a simultaneous ECG signal.

Keywords: microwave systems • Doppler effect • noncontact detection • cardiopulmonary activity • heartbeat rate

I. INTRODUCTION

The use of microwave Doppler radar has been increased for many applications such as home health care and various hospital needs. The monitoring of heart rate using the affixed electrodes become anxious for long term monitoring ,and as well as for patients with conditions such as burn victims or newly born infants. henceforth a touch-less technique is very much necessary to detect the vital life signs for patients who are seriously injured.

II.LITERATURE SURVEY

The touch less technique based on Doppler principle a target with seemingly periodic movement reflects the transmitted signal were the target position varies according to its phase modulation.[1] the target now is the person's chest then the reflected signal contains the details about the movements of chest due to the simultaneous heartbeat and respiration . However, on holding the breath, the reflected signal depends on the chest displacement due to heartbeat alone. At rest, the variation of the chest displacement, caused by respiration, is between 4 and 12 mm [2], and the chest displacement due to heartbeat alone ranges between 0.2 and 0.5 mm [3].

The respiration rate corresponds to a frequency that varies between 0.1 and 0.3 Hz, while the heartbeat rate(HR) corresponds to a frequency that varies between 1 and 3 Hz [4]. Previous works tend to detect life signs [5, 6], respiration rates and heartbeat rates, using fixed frequency and fixed power of the transmitted signal. *Direct-conversion Doppler* radars, operating at 1.6 GHz and 2.4 GHz, have been integrated in 0.25 _m CMOS and BiCMOS technologies [7]. Heart and respiration activities were detected using a modified Wireless Local Area Network PCMCIA card, and a module combining the transmitted and reflected signals [8]. Other systems operating in the Ka-Band were described in [9, 10] using a low power double-sideband transmission signal. Recently, a new study shows the possibility of detecting the presence of a person through a wall using Ultra-Wideband (UWB) radar [11]. Some experiments are performed for the detection of life signs using the 4 –7 GHz band with 1 mW power and around 7 dB antenna gain [12]. Another system operating at 10 GHz showed the ability to detect the heart and the respiration activity of a person behind a wall [13].

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III.PROPOSED METHOD

In this paper, the system for the detection of heartbeat is proposed and declared legally with the use of an electrocardiogram(ECG)signal. Where the proposed system has the ability to tune both the frequency and power to make the patients safer on using minimum power. the optimal frequency can be determined with the minimum transmitted power using the proposed system.the extraction of both Heartbeat and heart rate variability is made and compared to the values found by the ECG signal. .The rest of the paper is organized as follows. Section II presents the proposed system and shows the heartbeat signal detected vs the ECG signal. Section III shows the heartbeat signals detected

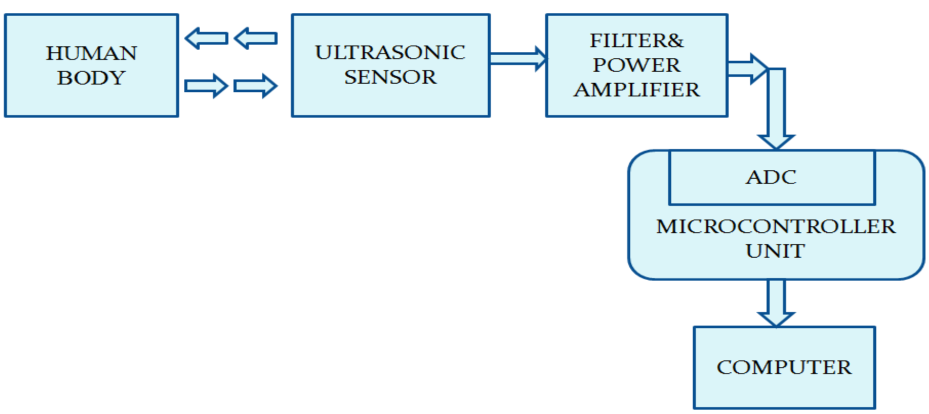
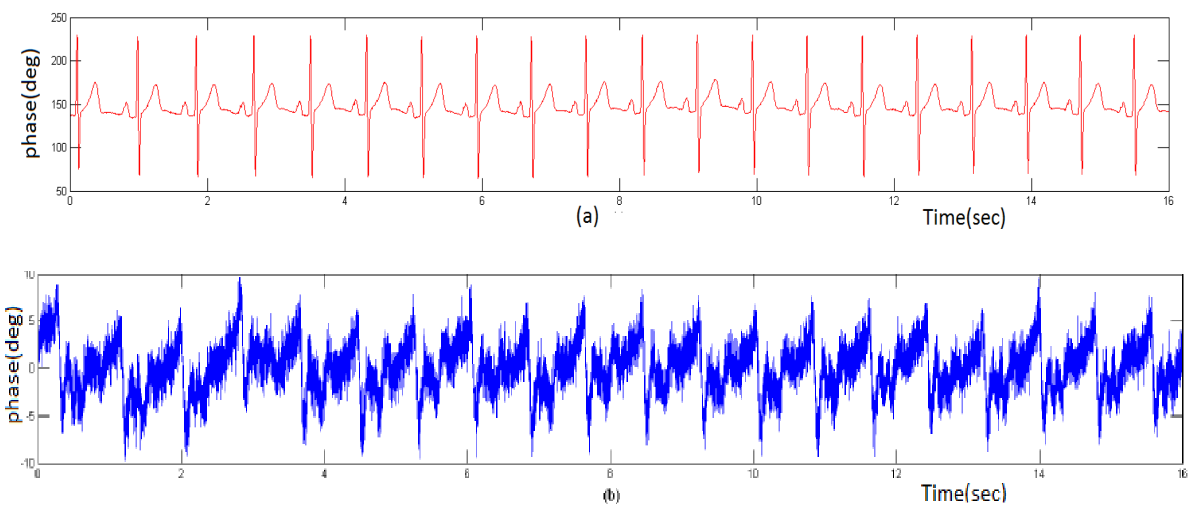


Fig (1):proposed method



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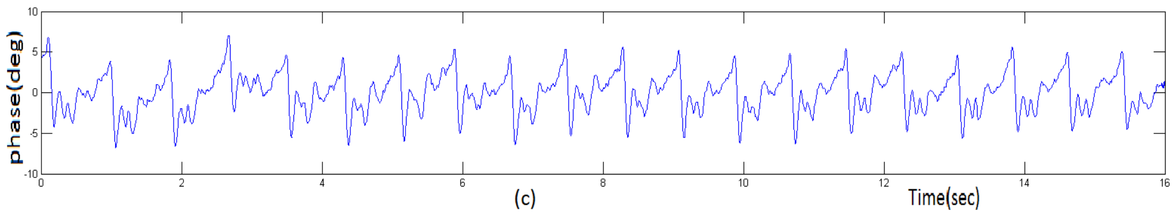

Fig. 2. ECG signal (a) and the phase variations due to heartbeats detected at 2 GHz and -5 dBm: original signal (b), smoothed signal (c)

Fig.2.(a) shows the normal heartbeat detection using the ECG signal
Fig.2.(b) shows the detection of Heartbeat detection using the ultrasonic transducer at an operational frequency of 2GHz
Fig.2.(c) shows the Heartbeat signal after applying the smoothing technique.
The goal of our system is to measure the Heartbeat rate by calculating the average of R-R interval

IV.DETECTION OF HEARTBEAT AT DIFFERENT POWER LEVELS

The main aspect of this method is to minimize the transmitted power which would be safer for both patient and the medical staff. The SNR ratio is improved by the smoothing technique. The SNR ratio is given by the newton relation

$$(a+b)^n = \sum_{k=0}^{n} (c_n^k) a^{n-k} b^k$$

where $n+1$ ($n = 2m$ where m is an positive integer number) is the length of the smoothing window. In this case, the phase $p(i)$ is replaced by the weighted mean of the values: $p(i-m)\ldots p(i+m)$. The weighting coefficients are given by the Newton binomial Fig. shows the heartbeat signal detected by our contactless ultrasonic transducer at 2 GHz and for several transmitted powers: 0 dBm (a), -5 dBm (b), -10 dBm (c), -15 dBm (d), - 20 dBm (e), and -25 dBm (f). it is evident from the figure that the signal to noise ratio decreases as the power decreases.Phase variations due to heartbeat signals detected at 2 GHz for different transmitted powers after applying the smoothing technique

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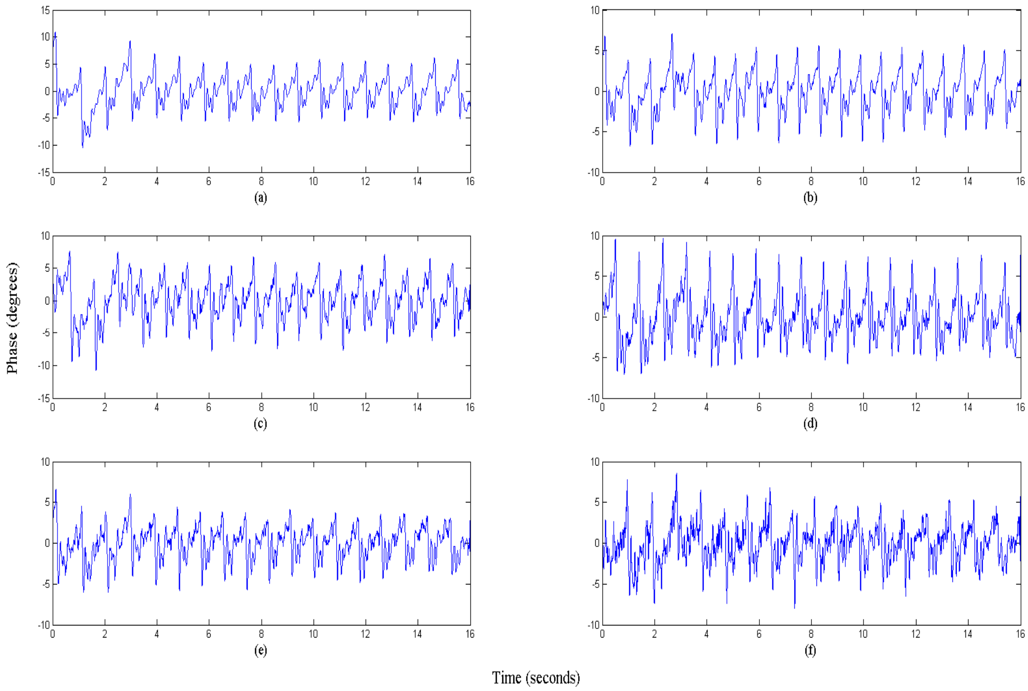

Fig. 3. Phase variations due to heartbeat signals detected at 2GITz for different transmitted powers after applying the smoothig technique

V. RESULTS: HEARTBEAT RATE AND HEART RATE VARIABILITY

Related works tend to extract the average heartbeat rate for a specific window. This does not provide information about the variation of the HR in time, *i.e.* the HRV. Thus, a peak detection technique is required to track the peaks of the signal. In this work, both the heartbeat rate and the HRV of the signals detected at 2 GHz for different power levels are extracted. These values, for both original and smoothed signals, are compared to HR and the HRV obtained from the ECG reference signals.

Fig. 5 presents the relative errors of the heartbeat rate for both original and smoothed signals compared to the reference ECG signal.

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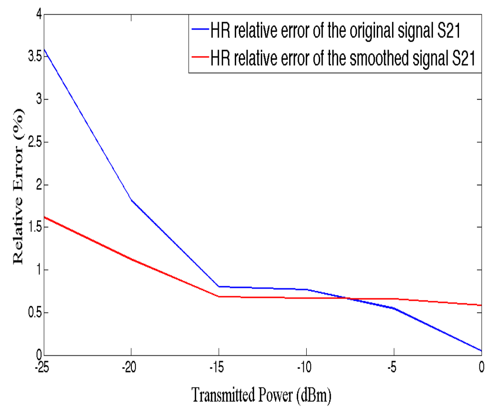

Fig. 4.a. Relative error of the HR: original and smoothed signals vs ECG

For different transmitted power values between 0 and -25 dBm (with a down step of 5 dB), the proposed system shows the possibility of detecting the heartbeat signal with a relative HR error between 0 and 3.5%. Smoothing the signals gives a relative error less than 1.5% for low power levels less than -15 dBm).

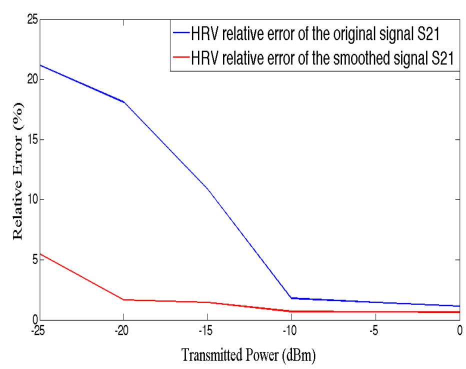

Fig.4.b. Relative error of the HRV: original and smoothed signals vs ECG Signal

VI. CONCLUSION AND PROSPECTIVES

The proposed system shows the possibility to detect the heartbeat activity at 2 GHz for different power levels. This system is tested and compared to simultaneous electrocardiogram. The heartbeat activity is detected for transmitted power between 0 and -25 dBm and for a distance of 1 m between the person and the antennas. Both heartbeat rate and heart rate variability are extracted from the proposed system and compared to the reference signal. A high accuracy is observed for the average HR: its relative error varies between 0 and 3.5%, while it varies between 2% and 21% for HRV. A smoothing technique is applied as well to the orignal signals in order to improve the detection accuracy. The relative errors decrease to 0.5 – 1.5% for the HR, and to 1 – 6% fot the HRV.

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