COMPARISON STUDY OF TWO APPROACHES FOR BIORADAR DATA PROCESSING

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Abstract

In this paper, we present a feasibility study for life signs detection using a continuous wave radar working in the band around 4 GHz. The data processing is carried out by using two different data processing approaches, which are compared about the possibility to characterize the frequency behaviour of the breathing and heartbeat activity. The two approaches are used with the main aim to show the possibility to monitor the vital signs activity in an accurate and reliable way.

Keywords: Bioradar, multi-frequency radar, remote monitoring, two processing methods comparison.

1 Introduction

The remote and contact-less detection and monitoring of life movements and signs as breathing and heartbeat activity is a topic of increasing attention in many fields such as: the homeland defence and homeland security systems [1, 2]; the rescue of persons buried under rubble or under snow [3-5]; the medical field for a contact less monitoring of the conditions of patients [6]. A very recent application of non-contact microwave based transceivers have been recently proposed as diagnostic tools in the biomedical field [4, 7, 8].

In this work, we propose a feasibility study of a life signs detection and characterization system using a multi-frequency radar; the measurement are processed by using two different data processing approaches and their performance are compared in terms of frequency characterization of breathing and heartbeat activity.
The multi-frequency bioradar with a quadrature receiver has been designed at the Remote Sensing Laboratory, Bauman Moscow State Technical University with the aim to carry out remote monitoring of movement activity, breathing and pulse of human being [9].

2 Apparatus and Methods

Two different processing approaches have been deployed to make the data processing. The first one has been presented in [10] and aims to provide frequency analysis of the life signs activity by the maximizing of the scalar product of the Fourier transform of the measured signal, accounting for the researched for displacement, and the one given a theoretical electromagnetic model. The second data processing approach is designed with the aim to gain information not only about the frequency behavior of the life signs but even about the range of the investigated subject [9, 11]. The procedure can be summarized according to the step below. The first step allows to build the range-frequency matrix [9]; this matrix contains all possible signal reflection including ones from the motionless objects (MO), located in different range cells. These objects are the cause of static clutter. The suppression of signals from MO is carried out by rejection of the matrix components for the approach zero frequencies. The range-frequency matrix resulting from the suppression of the zero or nearly zero frequencies is given in the upper panel of Figure 1. The separation between the breathing and heartbeat signals is carried out next by using rejection of the frequency components corresponding to breathing in the range-frequency matrix and the result is shown in the lower panel of Figure 1.

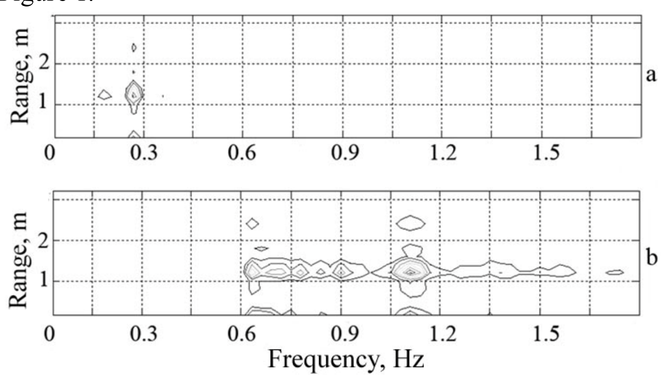

Fig.1. Range-frequency matrix for the examinee at 1.5 m range: a) (upper panel): before breathing harmonics rejection; b) (lower panel) after breathing harmonics rejection.

Reconstruction of breathing and heartbeat signals is carried out by applying inverse Fourier transform to the matrix row corresponding to the distance to the examinee (1.5 m) and evaluating it phase. Thus obtained signals corresponding to range-frequency matrixes from Figure 1 are shown in Figure 2.

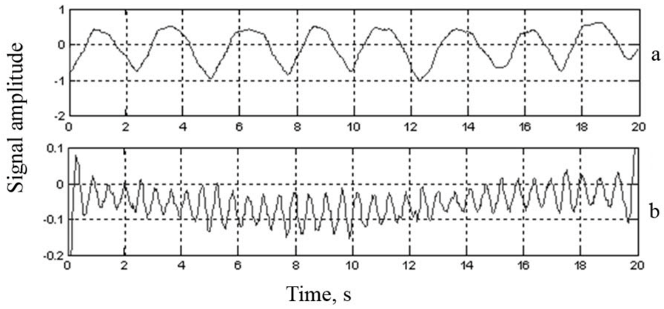

Fig.2. Reconstructed breathing and heart beat signals of the examinee corresponding to range-frequency matrices from Fig.1.

Figure 2 points out in a clear way the good performances of the approach in separating breathing and heartbeat signals.
The second approach aims at providing information not only about the frequency of the life signs but also at gaining information about the range of the investigated target by getting range-frequency matrix. Separation of respiration and heart beat signals was made by application of rejection filtration to corresponded line of range-frequency matrix [9, 11].

A multi-frequency radar designed at the Remote Sensing Laboratory (Bauman Moscow State Technical University) was used in the experiment [9, 11]. The radar has the main technical parameters reported in Table 1.

Parameters of the radar system	
Number of frequencies	16
Sampling frequency	62.5 Hz (time spacing 0.016 sec)
Operating frequency band	3.6 – 4.0 GHz
Distance space resolution	0.5 m
Dynamic range of the recording signal	60 dB
Recording signals band	0.03 – 5 Hz
Dimensions of antennas block	150×370×370mm

Table 1 Parameters of the radar system.

Figure 3 is a photo of the experiment where the subject is located in front of the radar system. In particular, the experiment was carried out with a male, 20 years old, no bad habits, professional skier; the distance between antennas and subject was 1 m. The experiment was divided into two stages. During first stage monitoring of breathing and pulse parameters at steady state was carried out and it took about 5 minutes. At the second stage a breath holding test was carried out. It gives a rough index of cardiopulmonary reserve, measured by the length of time a person can hold breath. The test is widely known in medicine, and is used for estimating fitness of the human body while training of pilots, submariners and divers. Each stage of the experiment was carried out for several times for slightly different displacement of examinee and bioradar in order to confirm the possibility of multi-frequency bioradar to estimate the range by using the second data processing approach.

Figure 3 Sketch of the experimental set up.

3 Reconstruction results

This Section presents the processing results for the datasets collected at the two stages of the experiment for the probing frequency equal to 3.6 GHz.
For the first stage of the experiment a time window of 304 sec was used. For this overall time-window 19 time intervals of 1024 time samples (for a time interval equal to 16,3 sec) have been considered and for each of these intervals the two data processing approaches described in the sections above were applied.
Figure 4 depicts the modulus of the signal and also the 19 time intervals analyzed in the monitoring are also pointed out.

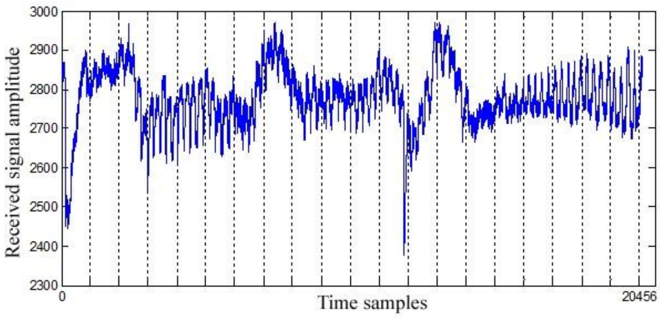

Figure 4 Amplitude of the life signal.

The results of the breathing activity monitoring for the two approaches are depicted in Figure 5. A good agreement is observed between the results for the two data processing approaches; in particular, an almost uniform breathing behaviour is observed with a frequency of 18 acts/min apart few time intervals. Figure 6 depicts the heartbeat analysis. It can be seen that the average frequency is at about 80 beats per minute. In addition, it can be noted a correlation between the time-behaviour of the breathing and the one of the heart-beat; in fact when the breathing frequency decreases also the heartbeat frequency has the same behaviour and that for the tens of the time-window a similar behaviour can be seen for the two patterns.

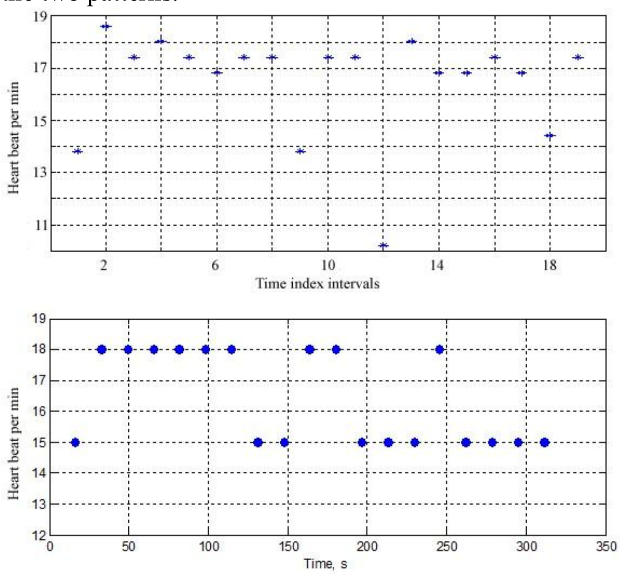

Figure 5 Comparison between the data processing approaches for the breathing activity monitoring. Upper panel: first data processing approach; lower panel: second data processing approach

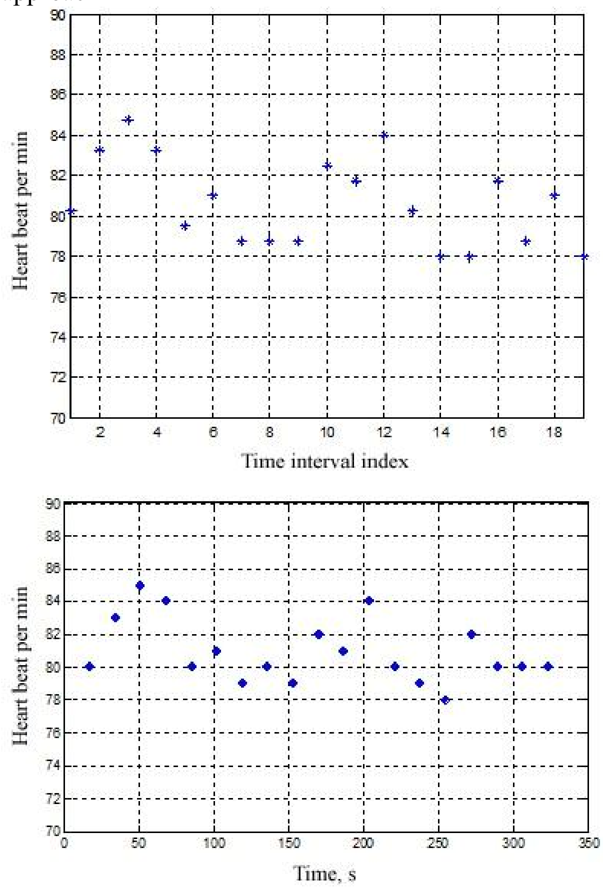

Figure 6 Comparison between the data processing approaches for the heart beat. Upper panel: first data processing approach; lower panel: second data processing approach

The second stage of the experiment is concerned with the status of apnea so that only the heartbeat was characterised. In this case, it was considered an overall observation time of 56 sec divided in 7 time intervals made of 500 time samples (8 sec). Figure 7 depicts the modulus of the measured signal in the 7 time intervals (time window ranging from 800 to 4300 samples).

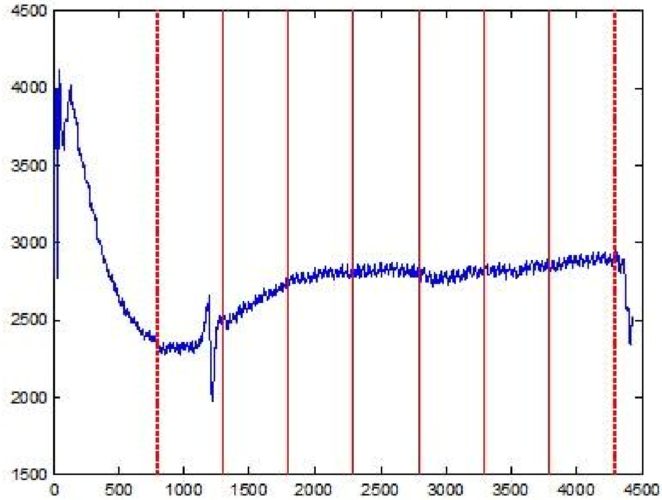

Figure 7 Amplitude of the heartbeat signal. The time intervals used in the monitoring are also pointed out.

The heartbeat frequency behaviour is shown in Figure 8 for the two data processing approaches and a very good agreement is observed for the two approaches. It can be noted that the frequency is almost uniform apart the first two intervals; in particular for the first interval the lower detected frequency is due to the clearly depicted oscillation, almost at the end of the first time interval, which cannot be associated to heart-beat activity.

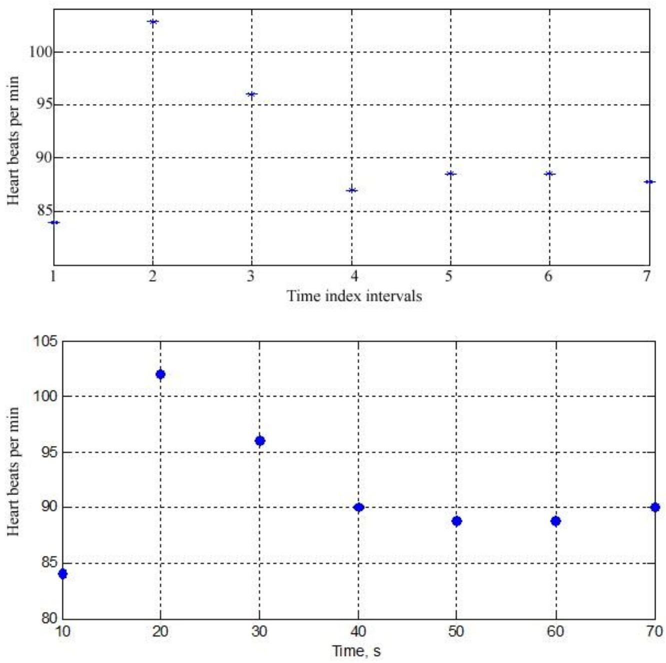

Figure 8 Comparison between the data processing approaches for the heartbeat activity. Upper panel: first data processing approach; lower panel: second data processing approach

4 Conclusion

The paper has presented the study of two different bioradar data processing approaches, which have been exploited with similar performances. It has been shown the effectiveness of the overall system (hardware plus software) as a reliable tool for a long term monitoring of breathing and heartbeat activity. The future activities will address different topics toward the use of the system in full operative conditions as: to account for the obstacle between the radar system and the target; to characterise target movements different from the life signs; to analyse the radar signal so to characterize stress level estimation.

Acknowledgements

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