TTW Life Sign Detection by means of CW X-band Radar, Homeland security and rescue Applications

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***Abstract*—The aim of this research works is to developed a very simple and efficient strategy to detect vital life signs in Through the wall (TTW) scenarios, by taking advantage of a simple detection scheme and by exploiting a properly designed measurement set-up working in X-band regime. In the proposed method of a light weight microwave system based on continuous wave X-Band rescue radar, implementation has been done through proper experimental set-up and a new model of detection schema has been performed. The information of life signal has been extracted from the backscattered electromagnetic field employing independent component analysis (ICA) algorithm which works as an effective blind source separation technique to separate vital sign through complex noise, interference and clutter removing. Comparing among different algorithm like ICA, ACMA, EFFICA, the most efficient one gives the expected outcome was ICA.**

Keywords— X-band radar; I/Q detector; Life sign; ICA; TTW; FFT

I. INTRODUCTION

Detection of heartbeat, respiration activity and the body movement has shown promise toward using of microwave radar with the evidence of concept demonstrated in various applications [2,7,8]. Comparing to other methods, an additional benefit of microwave Doppler radar includes the versatile ability to work at a significant distance through clothing, walls, or debris. This permits the system to work in different applications like medical health care scenarios, the search and rescue operations when victims trapped under the rubble of collapsed building during an earthquake or other disasters [3,10]. This kind of operations can also be implemented with through the wall surveillance technique applied [6,7]. In this context, until now the research works that has been done for this purpose was simply detection of life signs through the Doppler radar with heartbeat variability (HRV) [4,9]. Recently, the idea of microwave life-detection systems concept has been developed to remotely identify the vital life signals for rescue missions [1, 5]. A signal processing technique was adopted successfully to analyze mixed signals, brain signals and electroencephalographic (EEG) data [11]. Unfortunately, due to the lack of separating interferences and noises that have been added to the reflected signal coming back to the receiver antenna of the radar systems, this principle has not been developed to the practical level of applications.

In this work, an advanced method has been developed for the detection of life signal by using a new detection scheme with synthetically generated model that gives precise outcome. There has been considering different small reflections, through-wall, movement of chest of the victims during trapped, heart rate variability and breathe rate variation. The probable noise and interferences have also been considered and method of expected signal extractions were developed to get the required output. Various measured experimental data has been analyzed for different range of distances for the human and no-human target.

II. MATHEMATICAL FORMULATION

Let us consider the signal received by the receiving antenna can be expressed through following mathematical formulation [3]-

$$E_{rx}(t) = A_x \cos(\omega_0 (t - \frac{2R_s(t)}{v})) + \sum_{j=1}^{j} A_j \cos(\omega_0 (t - \frac{2R_j(t)}{v})) \quad (1)$$

where, ω_0 represents the angular frequency and v is the propagation velocity of the electromagnetic waves, A_x, A_j, are the amplitudes associated with life signals and rubble respectively, $R_s(t)$ and R_j are the round-trip distance of the survivor and rubble from the radar system. The received backscattered field is weak and is a mixture of vital signals, noise and clutter contribute. The detector that can generate two signal mixtures as E_I and E_Q can be expressed as.

$$E_I(t) = a_{11}\varphi_x(t) + a_{12}N(t)$$
$$E_Q(t) = a_{21}\varphi_x(t) + a_{22}N(t) \quad (2)$$

Here, in phase and the quadratic component of the field, can be described as-

$$E_I(t) = A_I \cos(\varphi_x(t)) + N(t)$$
$$E_Q(t) = A_Q \cos(\varphi_x(t)) + N(t) \quad (3)$$

where, $N(t)$, represents the noise contribution due to the clutter and other interfering sources. The terms a_{11} a_{12}, a_{21} and a_{22} are parameters that depends on the phase shift. The two original signals $N(t)$, and $\varphi_x(t)$ are assumed to be statistically independent at each time instant. For this reason, it is possible to estimate the original signals processing the mixed signals $E_I(t)$ and $E_Q(t)$ observed at the orthogonal detector. Now, considering the metrical representation and estimating the coefficients matrix [A] and its inverse $[A]^{-1}$, it is possible to obtain the original signals as shown in the following equations –

$$\begin{bmatrix} \varphi_x(t) \\ N(t) \end{bmatrix} = [A]^{-1} \begin{bmatrix} E_I(t) \\ E_Q(t) \end{bmatrix} \qquad (4)$$

Through the application of ICA, the cleaned signals $N(t)$ and $\varphi_x(t)$ are separated from each other. Out of these two signals, only $\varphi_x(t)$ contains information related to the weak life signal while $N(t)$ is negligible. After that, $\varphi_x(t)$ has been taken for the further processed with the powerful FFT algorithm to estimate the heartbeat and the breath rate.

III. Numerical Results

The experimental data has been measured and collected as I/Q data format in the frequency range of 10GHz transmitted signal with the target at 170 cm distance. The data has been measured in both with target and without target situation and the reflected backscattered signal has shown in figure 1. It seems that without applying ICA algorithm it is almost impossible to differentiate the human target or non-human target and the simulated outcomes of the reflected signal shows a very complex signal.

The powerful algorithm ICA, known as Blind Source Separation (BSS), is applied to separate heart and breath signal from the noise and the clutter, which works like filtering techniques [11]. Two original sources have been separated, one is the noise sources due to clutter and other interferences and another is the signal that contains weak life signals, where both are assumed to be statistically independent. A strong method of Fourier transform, FFT have applied to detect heart signal and breath signal clearly in frequency domain when there are life signals exist shown in figure 2. Two band pass filter has been applied in the range of 0.9-2 Hz and 0.08-0.5 Hz on our mixing signal so that it can be recognized as Heart and Breath signal separately. Finally, a synthetically generated heart & breathe signal has been used with Doppler co-relation technique to see the exact heart and breath rate. Expected life sign of heart and breath signals for a specific experimental data of 10 GHz, 170 cm, has shown in figure 3.

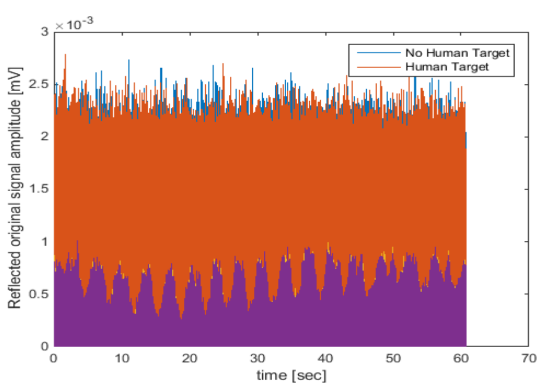

Fig. 1. Reflected Electromagnetic backscattered signal without modifying.

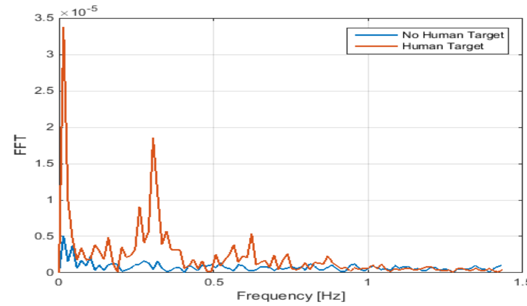

Fig.2. FFT after filtering of the human target and non-human target data

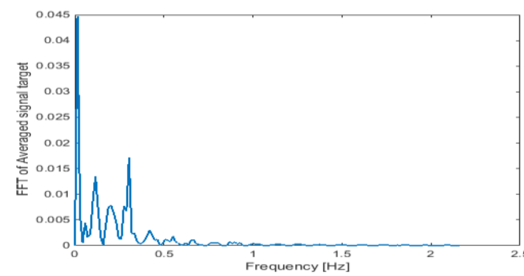

Fig.3. FFT on the output of the ICA algorithm for human target.

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