DETECTION IMPROVEMENT OF HIDDEN HUMAN'S RESPIRATORY USING REMOTE MEASUREMENT METHODS WITH UWB RADAR

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Abstract: Sensing vital parameters especially respiration, is important in many application fields, such as military services, medical activities, and rescue missions. Because of high resolution and appropriate penetrating factors, ultra wide band (UWB) radars have got more attention in these applications. In this study, we use UWB radar to detect respiratory signal of hidden human behind a wall. Acquiring the optimal transmitted signal, to obtain the best detection result in receiver's output is the novelty and the aim of our proposed work. For this purpose, we test Gaussian signal and some derivatives of this signal as transmitted signal and compare the receiver output results. To extract the required information about the target from receiving signal and subtract the background noise, the wavelet transforms are the adequate methods and are used in this work. At the signal processing part, different wavelet transforms will be considered, depending on some parameters such as the distance between the radar and the target or the wall's substance. With choosing the appropriate wavelet transform we can detect accurate human breathing signal affected by background noise that will be shown in the obtained results.

1 INTRODUCTION

One of the most important challenges about using UWB signals is to eliminate environmental noises from the desired signal.

In spite of many advantages, UWB signals are always exposure to noise because of operated frequency domain. Also in human respiration detection with UWB radars, background subtraction is always considered, because of the sensitivity of respiration signal and its enormous influence ability by environmental noises.

Different methods have been used for this application. Using matched filters in receiver is one of these methods, which is most often used to obtain human respiration signal in absence of barriers like a wall (Goswami et al., 2012).

The most common application of this method is taking care of patients and elderly exposure to cardiac arrest at hospital and at home.

In second method, averaging and Hilbert's transform are used in signal processing section to obtain respiration signal from received signal (Zhao et al., 2010).

Also other methods like using wavelet transform for extracting respiration signal in signal processing section are appropriate for complex environments with barriers like a wall. In this paper, different wavelets for extracting the optimized detection results from received signal are analyzed and compared.

This method can be applied in different fields like detecting location of criminals hidden inside of the apartments by police forces, or finding wounded people buried under debris of disasters like earthquake or avalanches.

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2 GENERAL FORM OF SYSYEM

Figure 1, shows the signal changing during the scattering state that can be expressed as in (Eq. 1).

$$S_2(t)=\frac{dS_1(t)}{dt},S_3(t)=\frac{dS_1(t+\tau)}{dt},$$
$$S_4(t)=\int\frac{dS_1(t+\tau)}{dt}\times h(t-\tau)dt \tag{1}$$

In this figure $S_1(t)$ is the transmitted signal, τ is the time delay and h is the channel function indicating the reflection model of the target.

The signal released from transmitter antenna changes according to the antenna characteristics. Then it hits different layers of barriers and target with different dielectric constants and signal changes accordingly. At last, after time delay and assembling with channel noise, the signal reaches to receiver.

Choosing an appropriate antenna for better radiation and also choosing a suitable signal in transmitter can improve the results of target detection accuracy. To extract more complete information about the target, an appropriate signal processing method can be used.

In the next section, the appropriate antenna types and the transmitter signal have been discussed. Finally, obtained results have been presented after applying the proposed signal processing method. It is worth noting that in this work, CST microwave studio (computer simulation technology) software is used to simulation the antenna-target model and obtain the received signal

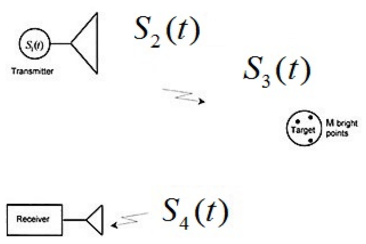

Figure 1: Signal changes during forward and backward path to radar

2.1 Antenna

The most proper antennas used in UWB radars are Horn and Vivaldi antennas which in most of the published papers. These antennas have been used as both the transmitter and the receiver antenna.

Vivaldi antenna gets to use because of its wide bandwidth and high gain and simple shape. Another advantage of this antenna is, easy fabrication for PCB (Printed Circuit Board) products. Horn antenna also has high gain and because of ability of decreasing the operating frequency to pass from barriers with high dielectric constants is more adequate. In this work, the horn antennas result has been discussed

Figure 2 shows a man behind a wall with real dimensions in the presence of horn antenna. Figure 3 shows the used CST human model in simulations which is a complete model of human presence considering all organs to obtain real results.

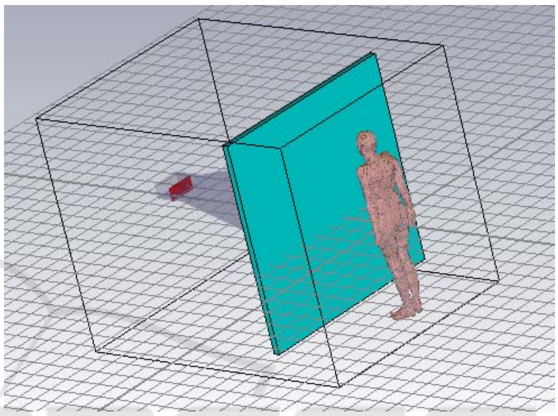

Figure.2: Using horn antenna for human detection

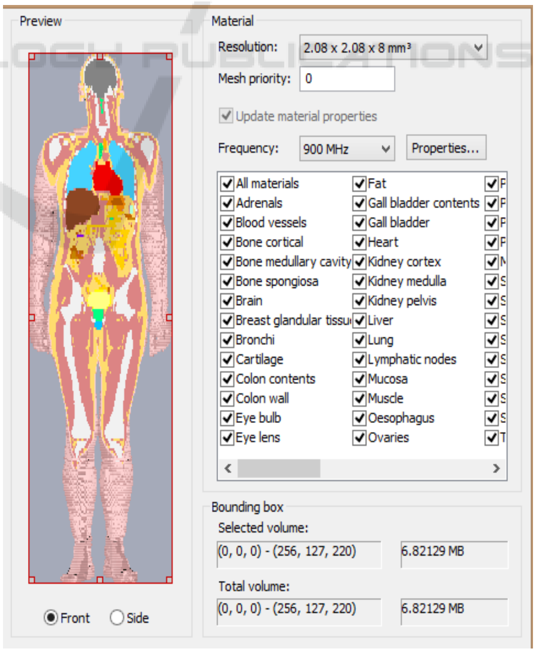

Figure 3: The model of human body that used in simulation

2.2 Signals

The most commonly used signal in UWBs is Gaussian signal and some of its derivatives. The most important advantage of this signal is its localization in both time and frequency domains.

In this paper, Gaussian signal, sinusoidal Gaussian and seven derivative of Gaussian signal is used as transmitted signal from antenna (transmitter) and the obtained results from these signals are analyzed individually in the receiver.

Figure 4 shows Gaussian signal and some of its derivatives used in this work.

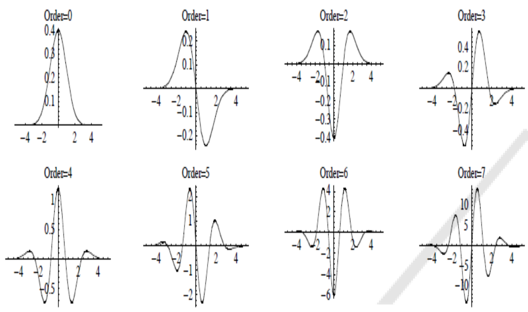

Figure 4: Gaussian signal and some of its derivatives

2.3 Wavelet transform

Wavelet transform can work with non-stationary signals. And therefore in this paper it is preferred to the others like Fourier transform.

Wavelet transform also provides multi resolution analysis with dilated windows which makes it possible to check different resolutions in various frequencies. So, wavelet transform would be a good choice for processing the received signals that change during passing different layers like air and wall.

In this paper, different wavelets transforms for extracting the optimized results from received signal are used. Some of them are: Daubechies, Symlets, Coiflets, Meyer, Gaussian, Mexican hat and Morlet wavelet. For the received signal f(t), its wavelet transform is given by,

$$W_f(a,\tau) = \frac{1}{\sqrt{a}} \int f(t) h^*(\frac{t-\tau}{a}) dt \qquad (2)$$

(h is the mother wavelet)

3 RESULTS AND DISCUSSION

In this study, 9 different types of signals containing Gaussian and sinusoidal Gaussian and seven derivatives of Gaussian signal are used as transmitted signal. Figure 5 shows the sample of these signals. The returned signal from target is received by the receiver antenna and to extract target information, proposed signal processing method is used to analyze. Figure 6 shows some examples of received signals. (In all figures the horizontal axis is time and the vertical axis is amplitude)

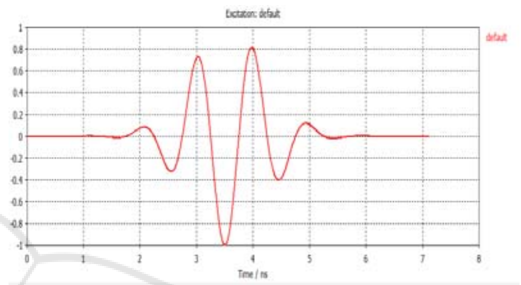

Figure 5a: Gaussian signal using as transmitted signal.

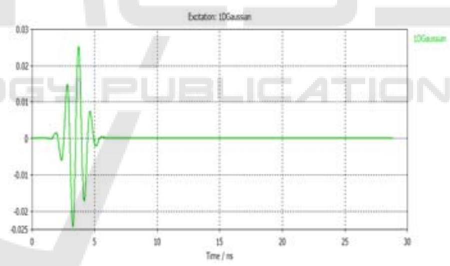

Figure 5b: First derivatives of Gaussian signal using as transmitted signal

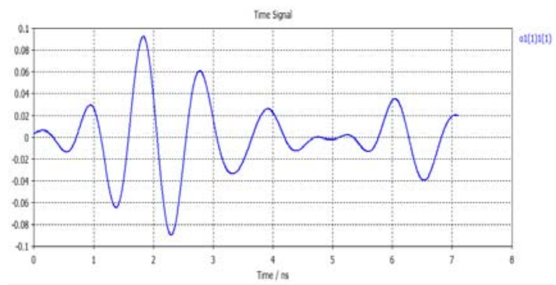

Figure 6a: The received signal when Gaussian signal used as transmitted signal

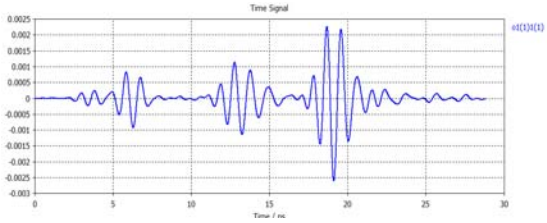

Figure 6b: The received signal when first derivatives of Gaussian signal used as transmitted signal

3.1 Signal processing

As explained in the first section, the shape and bandwidth of transmitted signal changes during passing the wall, hitting the target and returning to the receiver antenna. Wall thickness and its substance and distance between the human and antenna also affect the received signal.

By using appropriate signal in transmitter, the received signal can be predicted. As derivative of transmitted signal, the bandwidth of the signal changes and appears in receiver. Using wavelet transform, because of predicting the occurred changes like waveform and received signal bandwidth, is helpful in background subtraction and results appropriate output signal. Figure 7 shows diagrams of final data resulted from signal processing part which is human respiration periodic signal.

The obtained results show that, Mayer and Morlet wavelets give the best results by sending first derivative of Gaussian signal in transmitter. Also between these two wavelets, Mayer is closer to received signal and has better results. In these results, the background noise is completely omitted and respiration signal with acceptable amplitude can be observed (Figure 7a).

By sending the second derivative of Gaussian signal, Mexican hat wavelet gives better and acceptable output. By the way, Mayer wavelet would be more suitable as the transmitted signal in sending the second derivative of Gaussian signal (Figure 7.b).

During simulation process, it could be understood that the forth derivative of Gaussian signal in transmitter would have the best results using Morlet. For other derivatives (5, 6, 7), using Coiflets, Symlets and Daubechies wavelets would have better results which among them. Symlets would be more appropriate for fifth derivative and Daubechies would be more appropriate for sixth derivative of Gaussian signal.

It can be concluded from the results that the transmitted signal is formed by the transmitting antenna and then it can be interpreted as the second derivative of the transmitted signal at the receiver. Considering this, the best results for the target can be obtained by choosing appropriate wavelet.

In forward, after different simulations, it could be observed that second derivative of Gaussian signal would be the best choice for similar environments. Also, if the distance between human and antenna increase, using Daubechies wavelet would be a better choice for extracting desired target specifications. About walls with higher dielectric constant, using second derivative of Gaussian signal with Morlet wavelet would give the best results for target specifications.

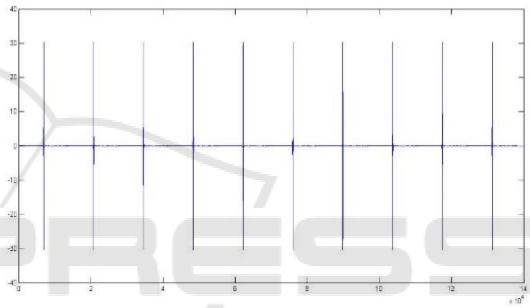

Figure 7a: the result of Meyer wavelet when first derivatives of Gaussian signal used as transmitted signal

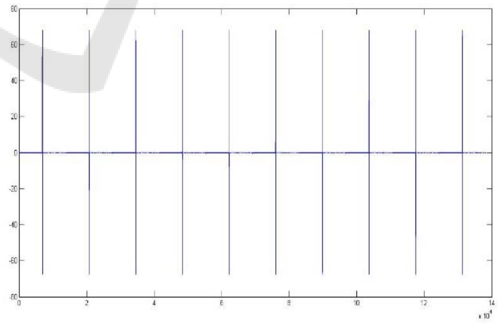

Figure 7b: the result of Mexican hat wavelet when second derivatives of Gaussian signal used as transmitted signal

(Vertical axis show the amplitude of breathing signal and the horizontal axis show the repeat of this signal)

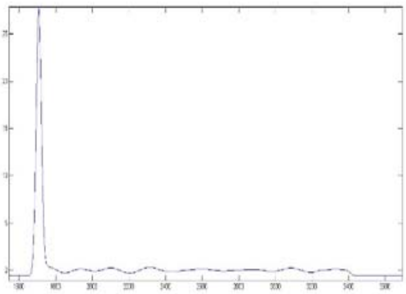

Figure 7c: one pulse of received signal after using wavelet methods

4 CONCLUSION

In this paper, human respiration detecting is considered. At first, the general UWB system used in detection is discussed. Then the choice of the antennas used in this work is presented. According to the importance of the transmitted signal form, appropriate transmitting signal for improving detection and obtaining better results are introduced. Finally, the wavelet transform method as the best method for background subtraction is used and simulation results are presented. It is concluded that for different system geometries, appropriate derivative of the transmitted signal and the mother wavelet selection give the best result. Additionally the respiratory signal of more than one hidden humans and moving humans could be consider in next work.

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