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UWB RADAR IN HIDDEN HUMAN DETECTION

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Abstract- *Hidden human detection and tracing have many civil and police security application. In this study, The UWB radars as the best system for human detection is discussed. For acquire the optimal result, proper antenna as a transmitter and receiver is presented. Gaussian signal as a suitable transmitter signal in UWB is presented. In the signal processing part two methods are debated and appropriate wavelet transforms for background subtraction is chosen.*

Keywords: UWB radar, Gaussian signal, wavelet transforms, background subtraction.

1. INTRODUCTION

Because of high resolution and appropriate penetrating factors, ultra wideband (UWB) radars have got more attention in the hidden human detection. UWB radars in hidden human detection have many civil and police service applications. For instance, the determination of the position of a human behind a barrier in earthquakes is one of them. The other one is the detection of supervising heartbeats and respiration of patients, children and old people at the hospital. In police service, tracking a hidden person inside a building is an application of this system. In this study, we used UWB radar to detect respiratory signal of hidden humans behind a wall. The general system of UWB for detection is discussed. Types of antenna that could be used in UWB systems are discussed. Gaussian signal and some derivatives of Gaussian signal as a transmitter signal is presented. Background subtraction as a big challenge in signal processing is discussed and some wavelet transforms in different environment for obtain the best result are presented [1], [2], [3].

2. UWB SYSTEMS

Ultra wideband (UWB) has advanced and consolidated as a new technology.

The advantages and possibilities of UWB could be summarized by Shannon's famous capacity equation.

$$C = W\log(1+\frac{S}{N}) \quad (1)$$

Where C is the maximum channel capacity (b/s), W is the channel bandwidth (Hz), S is the signal power (watts), and N is the noise power also in watts [4].

According to equation for improving the channel capacity there are three parameters. Decrease the noise, increase the signal power or bandwidth could improve the channel capacity.

There is a linear relation between capacity of channel and bandwidth. Although, the logarithmic correlation can be observed between channel capacity and signal power. Then could be a bandwidth tradeoff for signal power reduction.

UWB systems defined by Federal Communications Commission (FCC) in United States of America (USA) as systems with bandwidth larger than 500MHz or relative bandwidth B/fc (fc is the carrier frequency) larger than 20%. Therefore, UWB systems have a great potential for high-capacity communication systems.

The interference of UWB systems with the other existing systems that working in the same frequency could be ignored because of the low power spectral density of UWB. This property enables the unlicensed operation of UWB devices. High resolution property of UWB systems, because of it's short pulse, could be helpful in sensitive systems like human respiratory detection [5].

In this work, we used the very large bandwidth advantage of UWB systems like, high time resolution, high date rate, obstacle penetration, low power consumption resistance to interference, for human respiratory detection behind a wall.

3. SYSTEM SCHEME

The basic model of detection system shown in figure1. Transmitted signal changes due to transmitter antenna characteristic, passing different layers (air, wall) and hitting the target. Rotating back signal, after crossing the channel again, reaches to the receiver antenna.

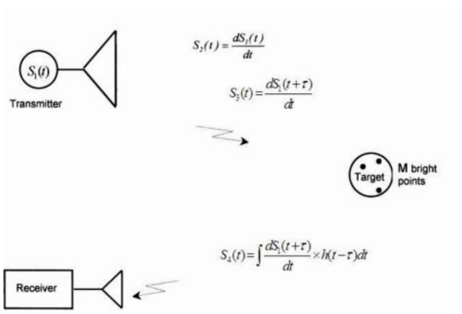

Figure 1. System model, $S_1(t)$ is transmitted signal, h(t) is channel function and is τ time delay.

Transmitted signal is the important challenge in this system. This signal should have some properties as better penetration and ability to analysis in frequency and time domain. Then in the next step this subject will be discussed. Choosing proper antenna is another important parameter. Last but not least, for getting a better information about the target and background subtraction appropriate signal processing methods will be discussed. CST microwave studio (computer simulation technology) software is used to simulate the antenna-target model and getting the received signal. MATLAB software is used to create a transmitted signals and for processing on received signals.

4. ANTENNA

Due to literature, the most popular antennas are Vivaldi and Horn antennas in the UWB radar applications. Both antennas have important advantages like, high gain, simple shape, wide band and easy fabricate [6].

In present of a wall, we have to decrease the antenna working frequency for passing the signal through the obstacle, because of this rationale, the horn antenna could be a better choice.

In this work the horn antenna is used as transmitter/receiver antenna. Figure2 shows a horn antenna that used for human respiratory detection behind a wall. Figure3, show a pattern of this antenna in 1 GHz frequency.

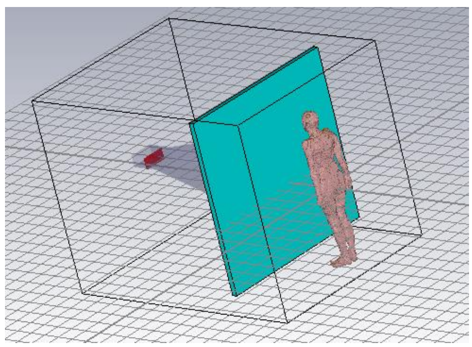

Figure2. A horn antenna in present of a human behind a wall

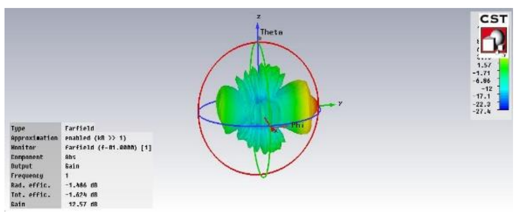

Figure3. The pattern of horn antenna

5. TRANSMITTED SIGNAL

Another important parameter in the detection is the proper transmitted signal. In this study, a signal with the property of localization in both time and frequency domain is needed. The Gaussian signal and some derivatives of this signal are the best candidate. Figure4 shows the Gaussian signal and seven derivatives of this signal that used as a transmitted signal in this work. The equation of Gaussian signal and four derivatives of it is presented as below [7].

$$\left\{\frac{e^{-\frac{x^2}{2\sigma^2}}}{\sqrt{2\pi}\sigma},\frac{e^{-\frac{x^2}{2\sigma^2}}x}{\sqrt{2\pi}\sigma^3},\frac{e^{-\frac{x^2}{2\sigma^2}}(x-\sigma)(x+\sigma)}{\sqrt{2\pi}\sigma^5},\frac{e^{-\frac{x^2}{2\sigma^2}}x(x^2-3\sigma^2)}{\sqrt{2\pi}\sigma^7},\frac{e^{-\frac{x^2}{2\sigma^2}}(x^4-6x^2\sigma^2+3\sigma^4)}{\sqrt{2\pi}\sigma^9}\right\} \quad (2)$$

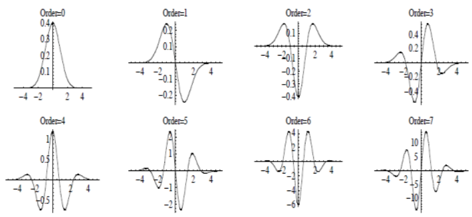

Figure4. The Gaussian signal and seven derivatives of this signal.

6. SIGNAL PROCESSING METHODS

Transmitted signal's waveform and bandwidth will be changed after crossing the channel and hitting the target. In the receiver part, after catching the received signal by antenna, appropriate signal processing method will be applied for obtain the desired information about target.

There are two main methods for background subtraction and acquiring the information related to the chest and respiration of human in literature. In the shorter distance, using Matched filter is one of the most common methods [8]. When there is no barrier between the human and the antenna, this method could be helpful for getting the better result. Another method is wavelet transforms. This method is suitable in more complicated environments [7]. In this work, because of obstacle (wall) and different dielectric constant wavelet transform is chosen. Wavelet transform can work with non- stationary signals and this is so important property in this type of works. Wavelet transforms also provide multi resolution analysis with dilated windows which makes it possible to check different resolutions in various frequencies [9]. Some of wavelet transforms that used as a proper signal processing method for background subtraction is presented in figure5.

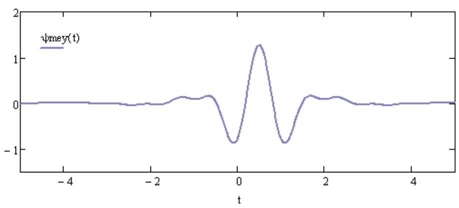

Figure5.a Meyer wavelet

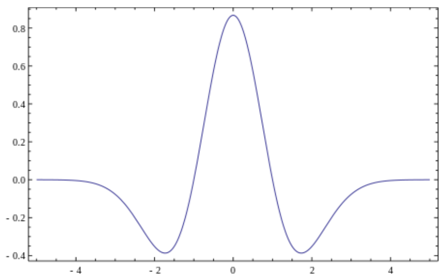

Figure5.b Mexican hat wavelet

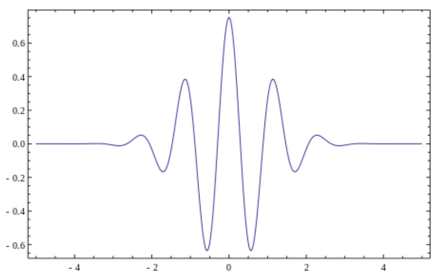

Figure7.c Morlet wavelet

6. RESULT AND DISCUSSION

In this work, Gaussian signal and some derivatives of Gaussian signal are used as transmitter signal. For background subtraction and obtaining the desired signal some wavelet transforms are operated. The result is presented for different environment presented as below. Figure6 show the received signal in the receiver antenna. By sending the first order Gaussian signal, Mayer and Morlet wavelet is the best wavelet for extract the target's information from received signal. The Mexican wavelet gives better result in present of second derivative of Gaussian signal as a transmitter signal. During simulation process with CST and MATLAB software, could be observed that in the longer distance and in present of an obstacle with high dielectric constant the Morlet wavelet transform would give the best results for extract the target specifications [10]. Figure7 shows the sample result of simulation and figure8 shows the incorrect result with using the wrong signal processing method.

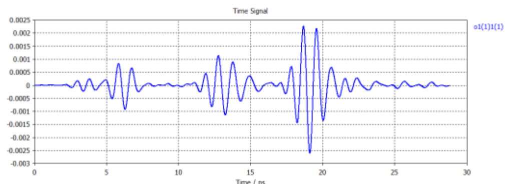

Figure6. One sample of received signal by receiver antenna.

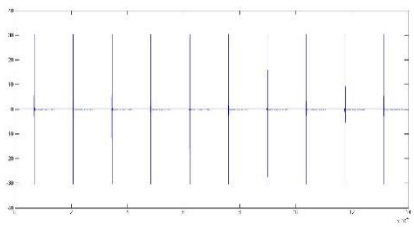

Figure7. The result signal

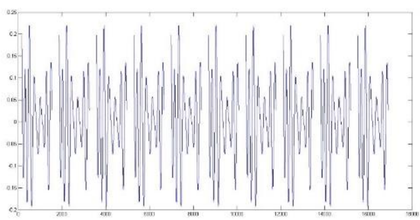

Figure8. Incorrect result with using wrong wavelet transforms.

6. CONCLUSION

In this paper, hidden human respiration detection is considered. First of all, UWB systems and properties of systems is discussed. The general form of detection systems was in the next step. Proper antenna, transmitted signal and signal processing methods is discussed separately. The wavelet transforms selected as the best background subtraction method and the results of simulation are presented.

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