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Signal Processing Algorithm for Vital Sign Extraction of Trapped Victims

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Abstract: ***Continuous wave radar plays an important role in search and rescue at disaster relief sites. Various Signal processing approaches are used to identify and to extract human vital signs behind the barrier. For detection of vital sign, experimental setup is developed in laboratory. The life detection algorithms proposed for stepped frequency continuous wave (SFCW) radar, are mainly based on Fast Fourier Transform (FFT) approach to extract human vital sign frequencies, such as heartbeat and respiration frequencies. Breathing signal is successfully detected in the results obtained for proposed methods.***

Keywords: SFCW radar, FFT, Vital sign, Range profile.

1. Introduction

The remote and contactless detection of life signs via radar sensing is an emerging technology which is very useful for detecting and identifying unknown objects behind barriers. It can be used in different applications ranging from survivor detection in rescue, life detection under earthquake rubble [1]-[5], hostage operations, to people localization in anti-terrorist operations [6]-[9] and also in medicine [10]-[12].

Quick detection of trapped victims buried under rubble and their subsequent rescue are big challenges to scientists and technologists. Utilizing the differences between biologic and the static targets, which are micro-doppler activities, the life targets can be detected. The current study focuses on i) radar hardware design and ii) developing the SFCW radar signal processing technique for human vital sign detections in a number of scenarios that might be pertinent to efficiencies and reliability in earthquake disaster victims search and rescues. Ultra-wideband (UWB) radar plays an important role in search and rescue at disaster relief sites. Various types of UWB radar or continuous wave radar used of this purpose but SFCW radar technique offers substantial benefits over other radar systems. SFCW radar possesses several advantages over other radar system like higher dynamic range and resolving power, more flexibility in the antenna, high reliability, stability and relatively easy implementation. The proposed method which is used for stepped-frequency continuous wave radar, utilizes FFT to extract the micro-vibration parameters of the life targets and remove the static objects.

In Section 2, we describe the methodology, experimental setup for data collection and radar specifications. Section 3, deals with signal processing algorithms used for analysis. Results are discussed in section 4. Finally, section 5 provides the conclusion with prospects for future work.

2. Methodology

2.1 Principal of Operation of SFCW Radar

In this Radar system, Horn Antenna is used for transmission and reception purpose. Firstly microwave is sent through the barrier to detect vital signs of life.

SFCW radar transmits a group of N coherent pulses whose frequencies are increased from pulse to pulse by a fixed frequency increment Δf as indicated in Fig. 1. The frequency of the n-th pulse can be written as:

$$fn = f_0 + (n-1)\,\Delta f\,;\; n = 1,2,3,\ldots\ldots,N$$

Where,
f_0 - Initial frequency
Δf - Frequency step size
N - Number of stepped- frequency

Each pulse is τ seconds wide, and the time interval T between the pulses is adjusted for ambiguous or unambiguous range. Each frequency is constant within each pulse. A group of N pulses, also called burst, is transmitted and received before any processing is initiated to realize a high-resolution measurement of the signal being measured. Since the frequency is constant within the individual pulse, its bandwidth is approximately equal to the inverse of the pulse width. These pulses have narrow bandwidths, thus making the instantaneous bandwidth of the radar narrow.

2.2 Experimental Setup and Data Collection

Figure 1 shows experimental setup used for proposed analysis. The frequency of desired range is generated by vector network analyzer (VNA) and is transmitted toward the human object beneath the obstacle with help of horn antenna. Here single horn was used for both transmission and reception of microwave signal. The obstacle was plywood wall of 12 mm thickness. As single horn is used for both transmission and reception purpose, we have measure S_{11} parameter at port-1 of VNA E5071C.

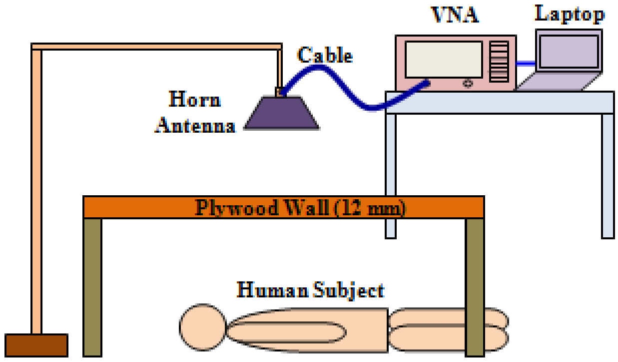

Figure 1: Experimental Setup

To validate the proposed method in practical applications, an experiment is set up in a room as shown in Figure 2. Twenty-four years young health boy lie down beneath the plywood wall. The distance between antenna and wall is maintained at 46 cm while distance between wall and human target is fixed at 58 cm. considering wall thickness (Plywood) of 12 mm, the total distance from antenna to target is approx. 105 cm.

Figure 2: setup of practical experimentation

The other radar parameters set for experimentation are shown in Table 1 given below.

Table 1: Radar Parameters

Parameter	*Specification*
Operating frequency range	1 GHz to 3GHz
Radiated Power	0 dBm
No. stepped point per trace	201
Number of traces	1024
Frequency step size	10 MHz
Swept time	0.024881 sec

A stepped-frequency continuous-wave, with frequency range of 1GHz to 3GHz, for 201 linearly stepped points with step size of 10 MHz is transmitted and received by horn antenna. For data set, 1024 numbers of traces are collected to ensure the accumulated signal-to-noise ratio and frequency resolution. Data is collected for 1024 traces by using VBA Macro program and transfer to PC for further processing. Matlab (R2008b) software is used for signal processing purpose.

3. Signal Processing Algorithm

Utilizing the differences between biologic and the static targets, which are micro-doppler activities, the life targets can be detected. This Life detection Algorithm utilizes Fast Fourier Transform (FFT) to detect the biologic objects. This method can detect and estimate the range of the biologic targets, and get rid of the static objects. Most biologic targets have the micro-vibration activities, such as human respiration and heartbeat, which can be detected to distinguish the biologic and non-life targets. They usually have the stable frequency and the amplitudes, thus, can be described as double-harmonic phase modified model. The biologic and stillness targets have much difference in the same range gate, we can design the algorithm to extract the micro-vibration information and leach the static objects. Microwave is having the property to penetrate through barriers and would reflect back from some objects. These objects include humans. When the beam hits the body, the signal reflected with an additional modulation created by movement of heart and lungs. So, the reception of modulated signals shows the presence of alive human beneath the barrier. If we detect the heartbeat frequency (1.2-1.7 Hz) and respiration frequency (0.2-0.5 Hz) from received signal, we can say that vital sign is present at that location.

a) Life Sign Detection Algorithm

The detection algorithm of micro-vibration life targets for SFCW radar can be processed as follows:

i. According to the maximum detection range and the minimum range resolution, select proper range for transmitted frequency and number of traces (N) over which we are collecting the data.
ii. Transmit SFCW signal for N number of traces, and obtain range profile for each trace by IFFT compressing.
iii. Search peaks in range profile of each trace and observe the variation for all N number of traces.
iv. Find the peak location at which we get amplitude variation.
v. Extract signal from location where we are getting amplitude variation for all N number of traces.
vi. Change to the frequency domain by applying FFT on extracted signal.
vii. In frequency spectrum if we get, the frequency in range of 0.2 to 2 Hz, we can say that a biologic target is detected. At the same time, the range information is also obtained.

According to the above analysis, the life detection algorithm processing flow is showed in Figure 3.

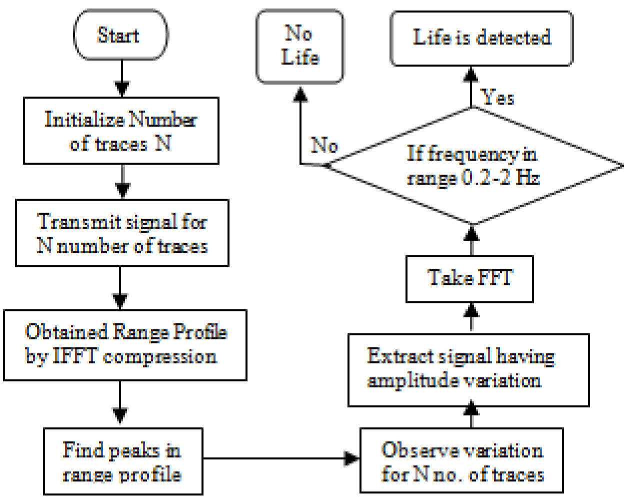

Figure 3: Life Detection Flow for FFT method

4. Results

For one data set, we have collected 1024 traces. Applying the Inverse Fast Fourier Transform (IFFT) to the received signal in discrete domain, the range profile is generated. The range profile plots for single trace and for 1024 traces are shown in Figure 4 (a) and (b) respectively.

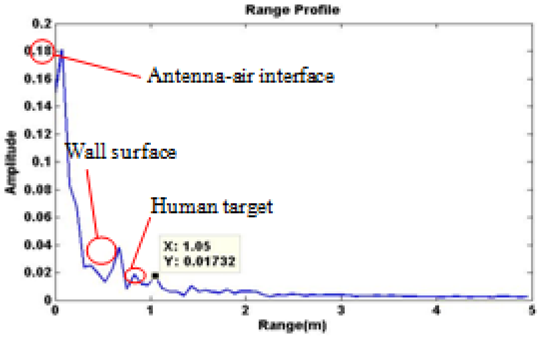

Figure 4 (a): Range profile plot for one trace

In range profile plot, the first peak is for antenna-air interface, while second highest peak is for plywood wall and at distance of 105 cm, we observe one peak for human target. In range profile plot for 1024 traces, we can clearly observer the amplitude variation at human target location as shown in Figure 4 (b).

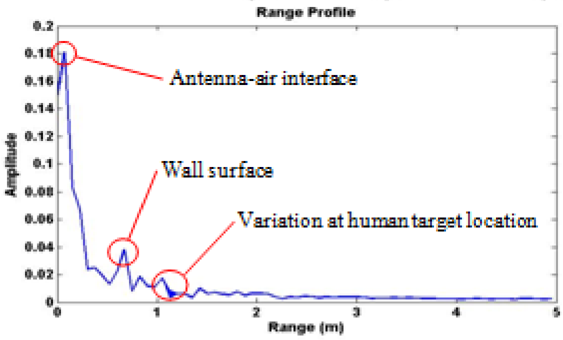

Figure 4 (b): Range profile plot for 1024 trace

For better observation, we can plot the amplitude variation only for detected peaks *i.e.* peak due to antenna-air interface, due to wall surface and due to human target for all 1024 traces as shown in Figure 5.

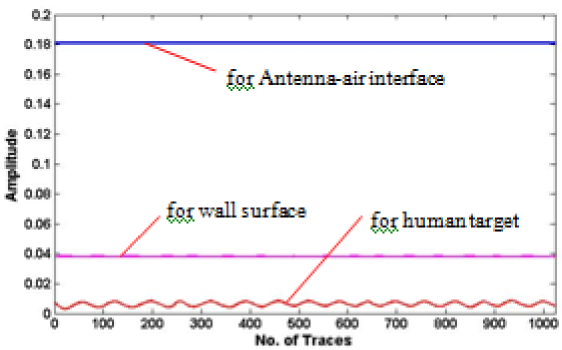

Figure 5: Amplitude variation plot for detected peaks

In Figure 5, it is clearly observed that for the first two peaks i.e. peak due to antenna-air interface and peak due to wall surface, there was no variation in amplitude for all 1024 traces. While, there is amplitude variation at human target location. So in next stage we are only extracting the signal at which we got the amplitude variation. The amplitude variation plot at target location is shown in Figure 6 below.

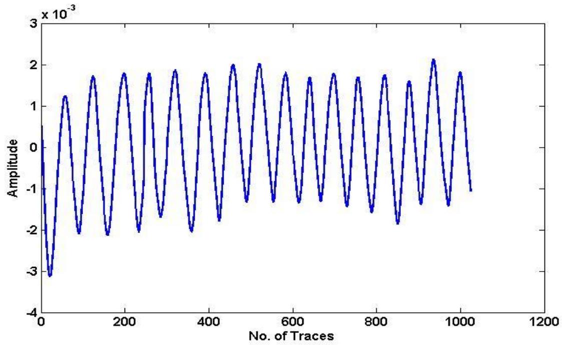

Figure 6: Amplitude variation at target location

But the plot shown in Fig. 4.6 is in time domain; from that we cannot make any predication. We need to change to frequency domain. Applying the FFT to above amplitude variation, the result obtained is shown in Figure 7.

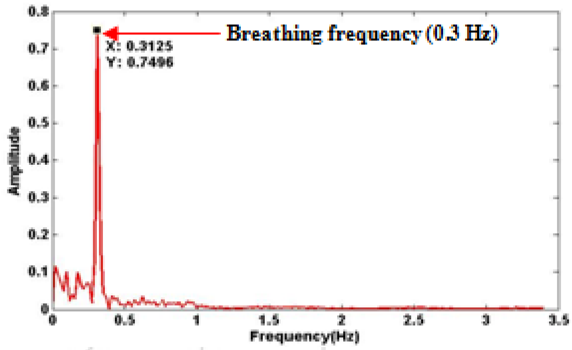

Figure 7: Frequency spectrum after applying FFT

In frequency spectrum, peak is detected at 0.3125 Hz which is nothing but the breathing frequency (0.2-0.5 Hz) for human. In this heartbeat frequency (1.2-1.7 Hz) was not detected because of small amplitude variation and due to presence of clutter.

5. Conclusion

In this, we have proposed signal processing algorithms which are used for vital sign extraction of trapped victims beneath plywood wall. Vital sign is successfully extracted by using FFT methods. In the this method, the life detection algorithm is proposed for stepped-frequency continuous wave radar, which utilizes FFT to extract the micro-vibration parameters of the life targets and remove the static objects. The experimental results shows that proposed methods have successfully detect the breathing frequency of human.

In future, need to work for complex environment or real life scenario. We have successfully detected breathing frequency, but heartbeat signal is not detected. Some clutter reduction technique can be used to improve the performance of analysis to detect heartbeat signal.

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Utkarsh S. Verulkar received the B.E. degree in Electronics and Tele-communication from Sant Gadge Baba Amravati University, Amravati, in 2013 and currently he is pursuing M.E. degree in Digital Electronics from same university. His research interests include wireless communication, digital signal and image processing, VLSI circuits and embedded system design.

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