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Analysis of Human Kinetics using Millimeter-wave Micro-Doppler Radar

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Abstract

In this paper, we presented a millimeter wave micro-Doppler radar for human motion detection. The concept of micro-Doppler is used to identify the motion of different body parts. Recently, the human detection using radar has number of application like surveillance, tracking and security. We have analyzed the received radar signals from pendulum and human as targets using spectrogram (time-frequency representation).

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*Keywords:*Micro-Doppler radar; millimeter wave radar; human kinetics; human detection.

1. Introduction

In recent years, several papers related to the detection, classification and tracking of human using Doppler radar for surveillance, security and civil applications have been published[1-8]. The main advantage of using radar that it can efficiently operate in the darkness, at long range and almost all climate situations.

The micro-Doppler signature from human body parts are different for walking, running, jumping and other activities. So it is easy to determine the human activity using micro-Doppler radar[2].

By analyzing the Doppler signature, one can also get information such as velocity of different body parts, stride length, etc. of the target. Also, it is possible to classify the target is either human or animal because the stride length and velocity of animal are unlike to that of human[2, 3].

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The received radar signal can also be used to determine the target is either rigid body or non-rigid body. The rigid body having body with a fixed size, whereas non-rigid body is having a deformable body parts. Thus, Doppler information for both types are different[4, 5].

Rest of paper is structured as follows: Basic concepts of the micro-Doppler radar is given in Section 2. Section 3 describes millimeter micro-Doppler radar. Experiments and micro-Doppler analysis are presented in Section 4. Finally, Section 5 summaries and concludes the work presented in this paper.

2. Basic concepts of micro-Doppler radar

Doppler Effect is the effect due to the motion of either source or observer, which causes change in the frequency. This frequency shift depends on the direction of motion and the relative radial velocity. The transmitted wave may be sound or electromagnetic wave. For example, the frequency of siren on the car gradually increases as moving towards than when the car is moving away from observer. In radar technology, the wave travels 2-way: from the transmitter to the target and then from the target to the receiver that results. Thus, the Doppler Effect occurs twice in case of a radar. The change or shift in frequency due to the relative radial speed is given as Doppler frequency[6]:

$$f_{Doppler} = \frac{2.Ve}{\lambda}.Cos\theta \tag{1}$$

where, $f_{Doppler}$ = Doppler Frequency (Hz)
λ = wavelength (m)
Ve = velocity (m/s)
θ = angle of arrival.

In radar, the Doppler frequency can be used to calculate speed of target (Doppler radar), or to identify moving target (MTI radar).

The micro-Doppler effect is the additional frequency modulation due to the motion or rotation of a target which generates side bands about the main Doppler frequency. The main Doppler frequency corresponds to speed of the core body part. The target characteristics can be identify by the micro-Doppler signatures[7, 8].

Micro-Doppler is sensitive to the carrier frequency of the radar signal and Doppler Effect will be more for higher frequency band. Doppler bandwidth and Doppler resolution is better for millimeter-wave radar, and it is easier to distinguish the micro-Doppler signature from different targets. The kinetics properties of human can determined using Doppler frequency. The simulation results[1] of typical micro-Doppler radar with pendulum and human as target shown in Fig. 1 and Fig. 2.

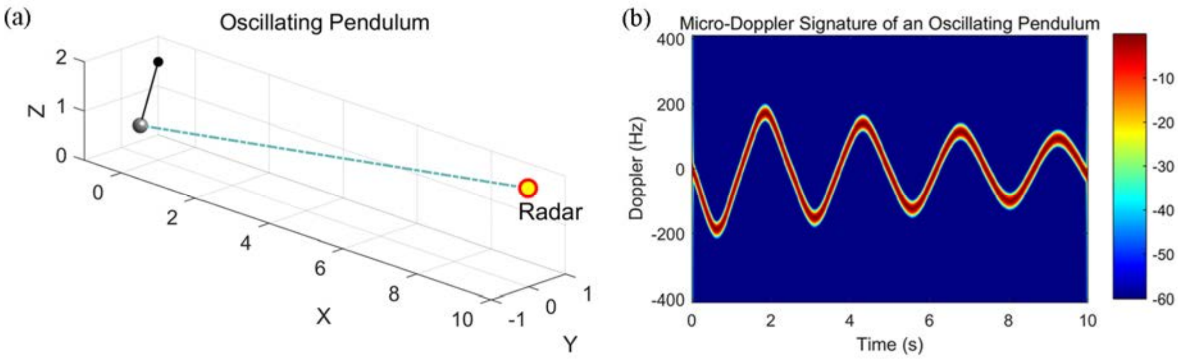

Fig. 1. (a) Pendulum as a target; (b) micro-Doppler signature of an oscillating pendulum.

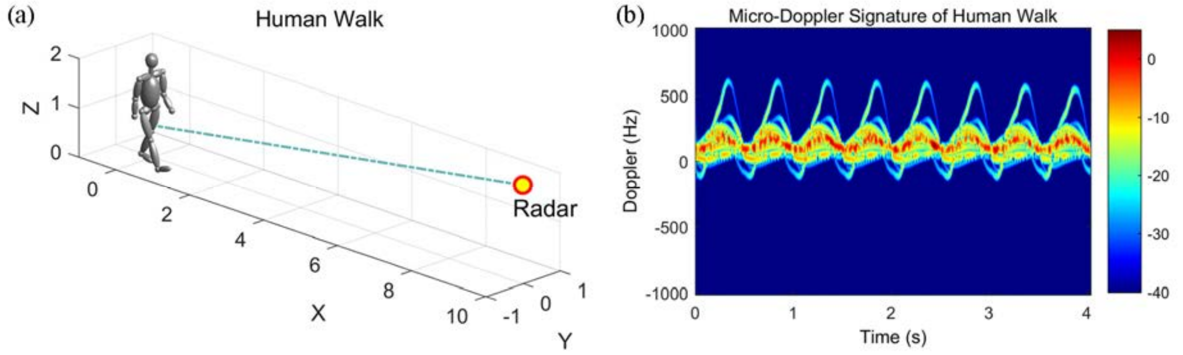

Fig. 2. (a) Human as a target; (b) micro-Doppler signature of human walk.

The target can be either rigid body (pendulum) or non-rigid body (human). The Doppler signal from rigid body shows limited patterns whereas non-rigid body has diverse Doppler signature depends on the type of activity, because speed of flexible moving parts changes correspondingly.

3. Micro-Doppler Radar System

We have used 94 GHz Doppler radar with intermediate frequency of 48 KHz, and received signal is sampled at 192 KHz. Block diagram of radar system is presented in Fig. 3.

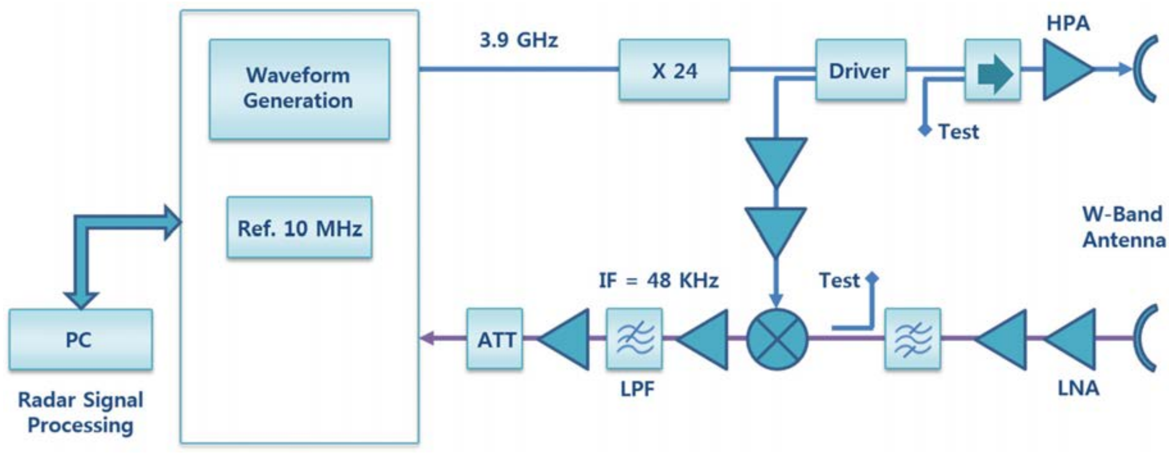

Fig. 3. Block diagram of 94 GHz Doppler radar system.

The received data is digitally demodulated and the micro-Doppler frequency of I and Q signals are analysed using spectrogram.

4. Experiments and micro-Doppler analysis

In this section, we have present the experimental scenario and the results are analyzed. Firstly, we used a simple pendulum as rigid body target for testing and verifying our 94 GHz radar system.

The pendulum length is 1.5 m and the radar signal is analyzed with micro-Doppler, presented in Fig. 4. It is clear from spectrogram that pendulum is swinging and the time period is about 2.5 sec. Also, it confirms our 94 GHz Doppler radar is operating well.

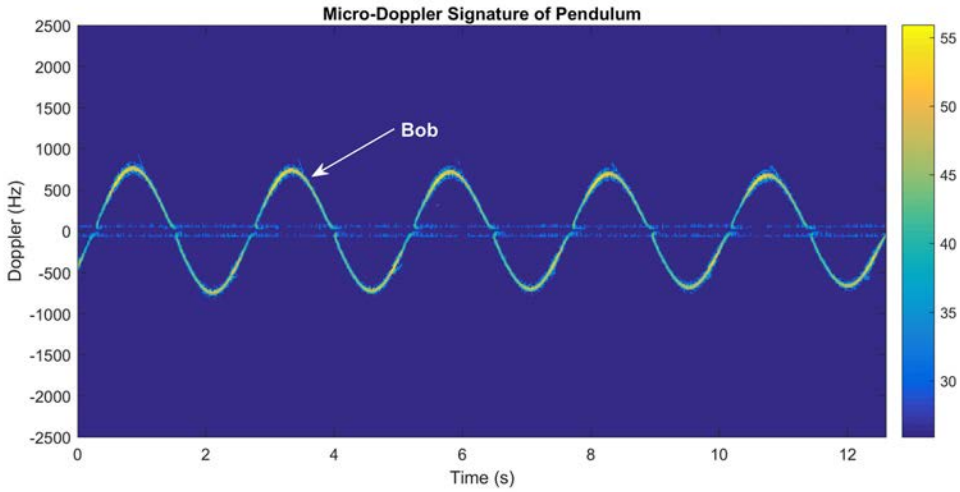

Fig. 4. Experimental result shows micro-Doppler signature of an oscillating pendulum.

Human target is analyzed for two different cases: moving away from radar and moving sideways at 2 m distance. The spectrogram shows micro-Doppler signature, we can get information regarding arm movement in case of walking human away from radar system. In the case of sideway human walk, we have some evidence of human movement. The result of experiments are given in Fig. 5 and Fig. 6.

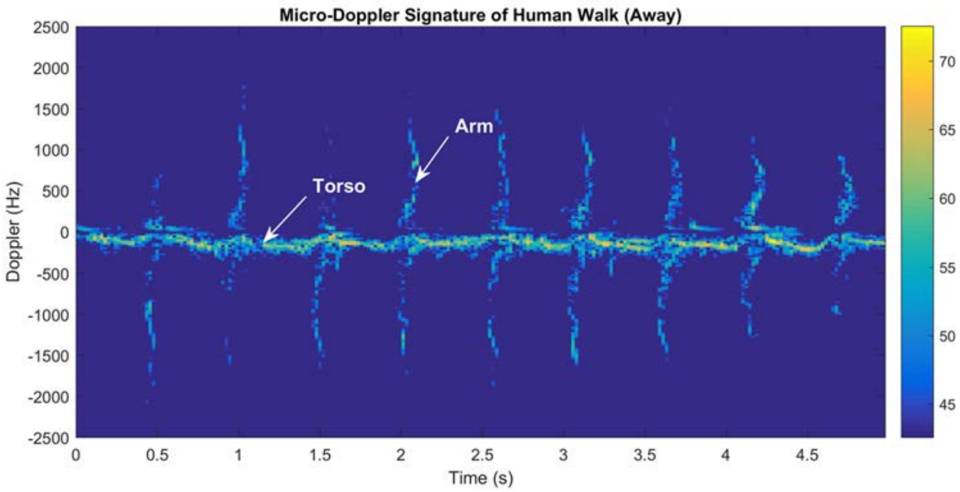

Fig. 5. Experimental result shows micro-Doppler signature of human walk (away).

Radar only focused on the upper body of human, thus micro-Doppler of arm and torso are captured. The micro-Doppler signature of arm movement is weaker than the main Doppler frequency of torso, see Fig. 5. Whereas, speed of arm swinging is much more than overall body movement. The result of sideway human walk is very weak because the smaller radial speed of human.

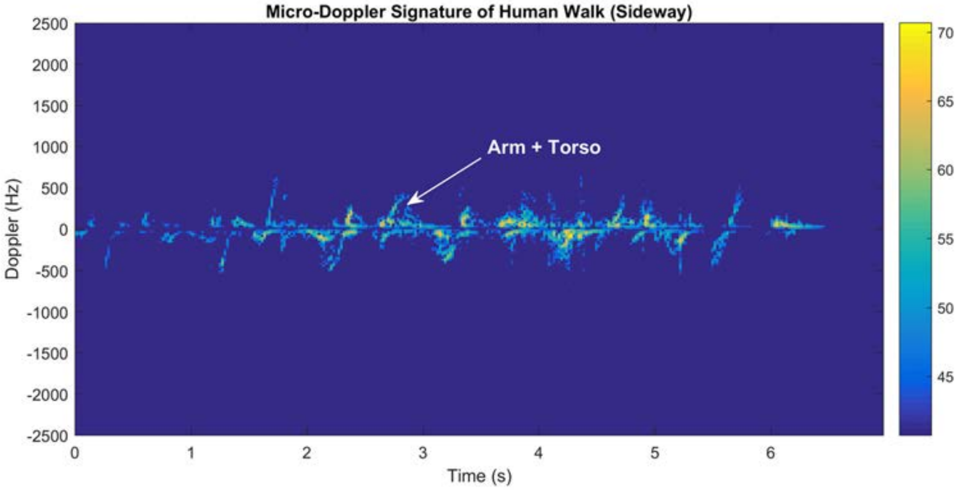

Fig. 6. Experimental result shows micro-Doppler signature of human walk (sideway).

5. Conclusions

In this paper, the micro-Doppler signature of pendulum and human as target are analyzed using spectrogram. The time-frequency representation gives information regarding the motion of target, which clearly shows the micro-Doppler signature. Doppler bandwidth and Doppler strength can be used to classify the type, size or shape of the target. The results show that we can identify pendulum motion. Also the Doppler signal of human target are shown for two cases. In future, we will improve the results for human walk and also include other activities like jumping and running.

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References

1. Chen VC, *The Micro-Doppler Effect in Radar.* Artech House; 2011.
2. Kim Y, Ha S, Kwon J, Human detection using Doppler radar based on physical characteristics of targets. *IEEE Geo. & Remote Sens. Letters* Feb. 2015;12(2):289-293.
3. Chen VC, Li F, Ho SS, Wechsler H, Analysis of micro-Doppler signatures. *IEEE Proc. Radar, Sonar and Navig* 2003;150(4); 271-6.
4. Thayaparan T, Abrol S, Riseborough E, Stankovic L, Lamothe D, Duff G, Analysis of radar micro-Doppler signatures from experimental helicopter and human data. *IET Radar, Sonar & Navig*;2007;1(4):289-299.
5. Erol B, Gurbuz SZ, A kinect-based human micro-doppler simulator. *IEEE Aero & Elect Systems Magazine* 2015;30(5):6-17.
6. Mahafza BR, *Radar Systems Analysis and Design using MATLAB.* 2nd ed. Chapman & Hall/CRC; 2005.
7. Qiu ZK, Li DZ, Jiang WD, Study of continuous wave radar for human motion characteristics measurement. *IEEE Inter. Conf. on Signal Proc* 2010; 1078-1081.
8. Chen VC, Fayin L, Ho SS, Wechsler H, Micro-Doppler effect in radar: phenomenon, model, and simulation study. *IEEE Trans on Aero & Elect Systems*; 2006;42(1):2-21.