HUMAN DETECTION AND RECOGNITION SYSTEM USING PASSIVE FORWARD SCATTERING RADAR

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ABSTRACT: *Radar detects the presence of any objects that passes through its system. In this study, passive forward scattering radar is used to detect human crossing through the range of forward scatter region and to differentiate human size. Passive radar means that the signal is transmitted from an existent commercial antenna. When human passes between the transmitter and receiver, a signature wave is produced at the passive radar, and this is called human Doppler signature. It is due to the scattering that occurs when the wave collides with the object, or in this case, humans. Example of this situation is when an object is placed in front of a flashlight, that object would produce a shadow. In this case, the object is human, and the silhouette produced is what being detected in the passive radar system. Different individuals have different Doppler signature because of every human does not have the same body build. Therefore, the passive radar system is able to differentiate the individuals in terms of body size. The Doppler data is collected at Malaysia Agro Exposition Park Serdang (MAEPS) where it has a strong signal of mobile network from the transmitter base station. Conclusively, the passive forward scattering radar system is capable to detect and differentiate human size and are useful for border protection security system in detecting and preventing the illegal entry of person into the country.*

Keywords: Passive radar, forward scattering, human detection

1. INTRODUCTION

Undetectable radars is quietly gaining traction in enquiry community exclusively with a new model of small, handy and less power consumption. This concept is introduces by passive radar systems which the systems did not emit any signals and could complement conventional radar coverage for important applications. Accordingly, passive radar systems hard to detect by conventional means, even they cannot be detected by thermal signatures because of no dedicated transmitters generating heat. The most important regarding passive radars is that they are easy to set up and did not require any frequency allocations. The specifications of passive radars are essential for enhanced security and provide effective protection from new threats [1].

Additionally, passive radar system presents a receiver without a co-located transmitter and enhanced compare to a straight radar system, which is an active radar [2].

Previous investigation had proven a multi frequency radar systems could detect humans and categorize their activities at short range through wall and long range foliage penetration using S-Band frequency [3].

When a moving object infiltrates a radar system, there would be some differences in the signal amplitude and frequency. The differences in the signal are caused by scattering of the signal that happens when the signal collides with the object. The factors that affect the signal are the speed and the size of the object, and also the distance between the object with receiver. This phenomenon is called the Doppler's Effect.

This paper focus on human detection using passive forward scattering radar system. Forward scatter radar contribute in border detection defense system [4]. Improvement of the radar cross section could increase the detection range in the forward scatter radar system [5].

From the experimental result, Doppler data of two individuals with different sizes passing through the radar system is collected, with the help of MATLAB software. The scattered Doppler signal is processed for target detection.

Following with signal processing of passive forward scattering radar system, the combination of denoising and transformed time domain filtering has led to the state-of-the-art clustering techniques. Therefore, a principal component analysis (PCA) could be used as spectral signature for target's distance from the passive radar receiver recognition [6].

The main objective of this project is to prove that the human Doppler signature produced by different individuals of various sizes and shapes is unique. This paper is also stressed on detection of human moving target to observe human behavior and performance where it can be applied at the international country border for security system.

2. METHODOLOGY

2.1 Experimental Site

The experiment is done at a parking lot in MAEPS. The red line indicates the distance between transmitter (Tx) and receiver (Rx), which is 465.7 meters. Figure (1) shows the image of the experiment site and figure (2) illustrates how the experiment is carried out.

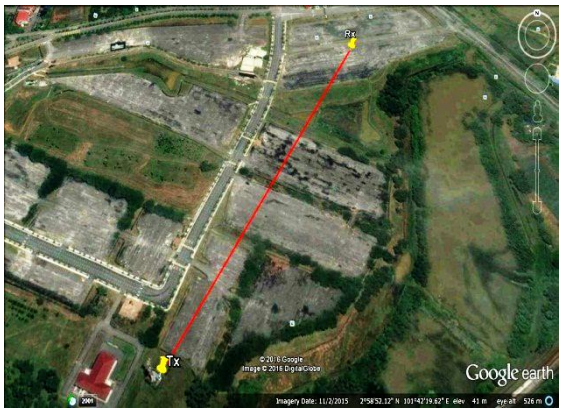

Fig (1) Map of the experimental site.

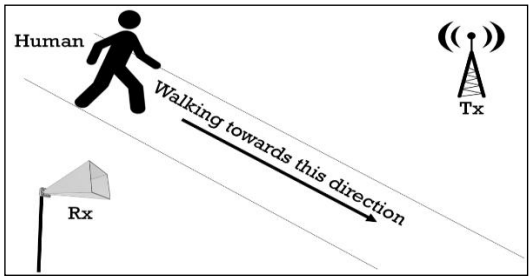

Fig (2) Illustration of human detection using passive forward scattering radar system.

2.2 Human Detection

Three persons of different heights have participated in the Doppler data collection at the experimental site. The individuals pass between the transmitter (Tx) and receiver (Rx) at the distance of 5 meters from the receiver, with the average speed of 5 km/h. Table 1 is a description of the individuals.

Table 1: Description of the Individuals

Person	Silhouette	Height (m)
1		1.7
2		1.5
3		1.6

2.3 Signal Processing

Figure (3) below shows the data processing process that is done with the aid of MATLAB software.

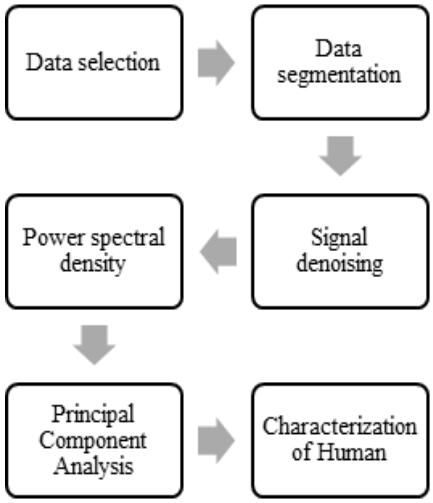

Fig (3) Flowchart of the experiment.

The collected Doppler data is recorded for 20 seconds, but later it is segmented into 4 seconds only. The 4 second data is the human Doppler signature.

After segmenting the data, the noise in the data is removed via denoising process using Matlab coding. Images of the denoised data signal is also saved in the process.

Power spectral density (PSD) exhibits the strength of an energy in terms of frequency. In simpler terms, it shows the variation of energy at which it may be strong or weak [7]. PSD prepares the data for the next step in processing, which is the principle component analysis.

The major idea of the principal component analysis (PCA) is to reduce dimensionality of a data set that comprises of a large set of related variables [8]. It is basically a mathematical procedure that is used to convert a set of recorded data into a graph as shows in figure (4).

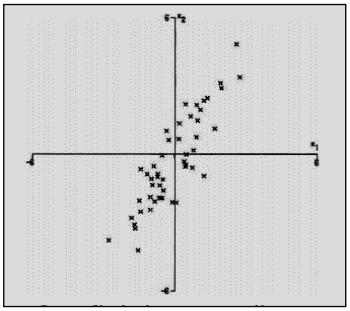

Fig (4) Example of a PCA graph [8].

2.4 Variance

Variance is a measure of how distributed a series of data is, or in other words, it measures the spread between the data in a set [9].

A variance is never negative; it is calculated by the formula shown below. Higher variance means that the data is more spread between each other, and vice versa. Variance also could be calculated automatically in Matlab. Equation (1) shows the formula of variance.

$$\sigma^2 = \frac{\Sigma(X-\mu)^2}{N} \quad (1)$$

2.5 Spectrogram

Spectrogram is usually used to show the frequencies of waves. It is also used to represent the signal strength over a specific time [10]. Spectrogram is quite similar with the concept of the spectrum. Low amplitudes are represented in dark colours, and bright colours like red corresponds to stronger amplitudes [11]. Figure (5) shows an example of a spectrogram.

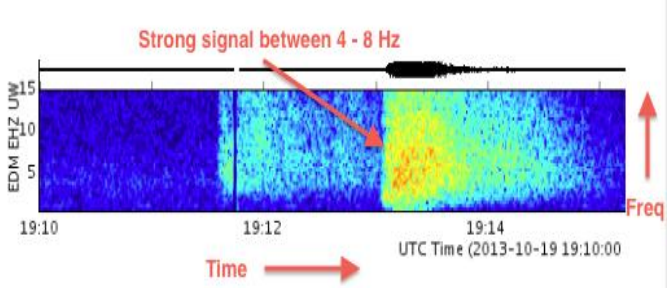

Fig (5) Example of a spectrogram [10].

3. RESULTS AND DISCUSSION

3.1 Time Domain

Figure (6) and figure (7) below show the time domain data collected when the individuals of height 1.7m, 1.5m, and 1.6m walk between the transmitter and receiver consecutively. The individuals are observed from the start to the end to ensure that their speed and walking styles stay consistent. Every individual is given a speedometer as a guide for them to maintain their speed. When the individuals walk, their hands are allowed to move to simulate their real walking style.

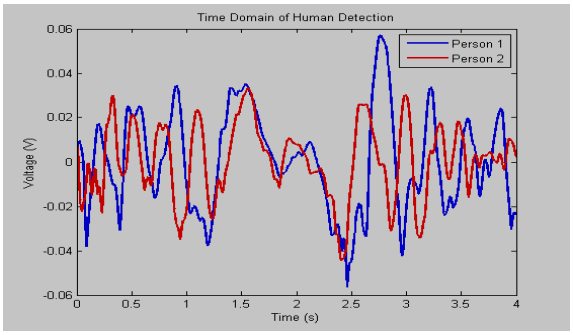

Fig (6) Time domain of human detection of person1 and person2

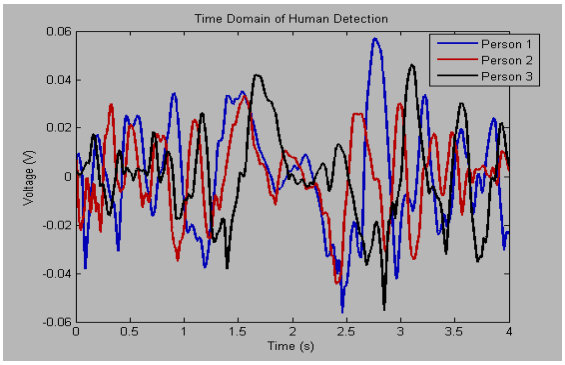

Fig (7) Time domain of human detection of person 1, person 2 and person 3.

In the time domain graph, it could be clearly observed that Human Doppler signature produced by the 3 individuals are different. This is due to the nature of their body shape which give impact on the scattering of the signal. The 3 individuals have different body structure and shape, therefore each of them would produce a unique Human Doppler signature.

3.2 Power Spectral Density of Human Detection

PSD of individuals of different heights would be different because the size of the individual affects the scattering of the signal.

In figure (8), Person 1 is represented by the blue line, and Person 2 is represented by red line. Difference in the PSD of Person 1 (1.7m) and Person 2 (1.5m) can be easily seen between the frequency of 20 Hz and 30 Hz, where the first lobe of the 2 signals are located. First lobe of Person 1 is narrower than Person 2. It shows that the PSD of Person 2 is larger than Person 1, although Person 2 is smaller than Person 1.

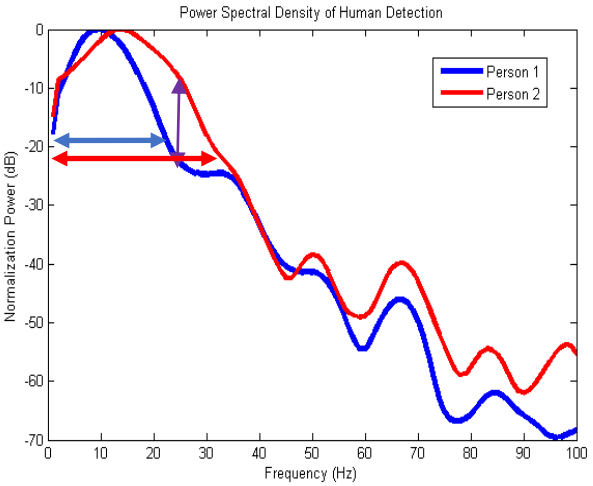

Fig (8) Power spectral density of 2 individuals.

Smaller individual yields bigger power because it causes smaller blockage on the signal compared to larger individuals who would create bigger blockage. An analogy suitable for this situation is when a ball is placed in front of a flashlight. A golf ball would produce a smaller shadow compared to a tennis ball. The shadow in this situation is the PSD of the individuals.

The PSD of the third individual is as expected, lies in between PSD of Person 1 and Person 2, because the height of Person 3 is 1.6m. From figure (9), it is imposed that the height of the individual is inversely proportional the PSD. The size of the first lobes of the individuals is also according to their heights, where Person 1 being the tallest has the narrowest first lobe, followed by Person 2 with medium sized first lobe, and Person 3 with the largest first lobe. The PSD of Person 3 is represented with black line.

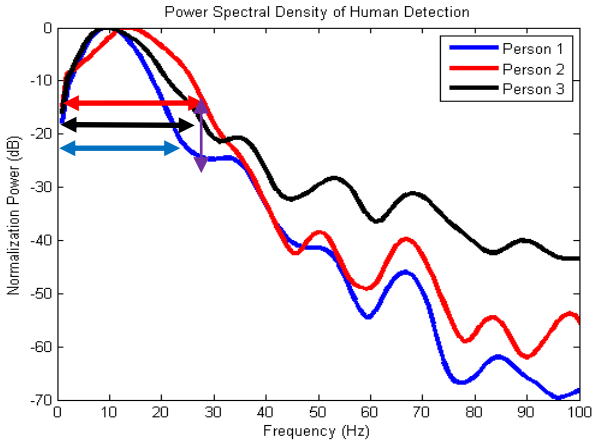

Fig (9) Power spectral density of 3 individuals.

3.3 Principal Component Analysis

In figure (10) and figure (11), Person 1, Person 2, and Person 3 are represented by blue diamonds, red dots, and black triangles respectively.

In Principle Component Analysis (PCA) of 2 Individuals as shown in figure (10), it shows that the points are converged at one center, but the points of both individuals do not mix. The blue diamonds of Person 1 are clustered at the left side of the graph, while red dots of Person 2 is on the right side.

PCA of 3 Individuals in figure (11) also shows the same situation, the points are separated according to their respective group. It can be seen every each of the persons are located in different parts of the PCA space with no-overlap each other. Person 1 (blue diamond) is located at the top center in the range -20 until 20 of PC1 and 0 to 30 of PC2. For Person 2 (red dot), is situated at the left side of PCA graph in the range -70 until -20 of PC1 and -8 until 15 of PC2. Finally, the Person 3 (black triangle) is located at the below center of the PCA graph in the range -10 until 30 of PC1 and -20 until 0 of PC2.

This event states that the data of 3 individuals are unique compared to each other and supports the statement that the radar is able to differentiate the Human Doppler signatures.

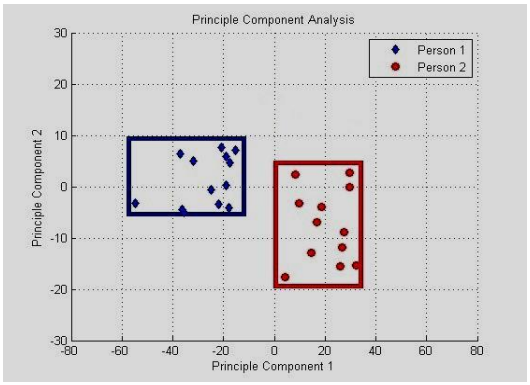

Fig (10) Principal component analysis of 2 individuals.

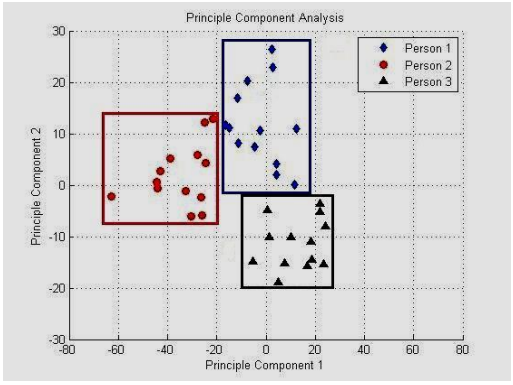

Fig (11) Principal component analysis of 3 individuals.

3.4 Variance

In the PCA variance of 2 Individuals, it is found that the variance explained for the first Principal Component (PC) is nearly 80%. The total variance of 99% is given by three principal components in figure (12).

As for the PCA variance of 3 Individuals, the variance explained for the first PC is 65%, which is lower than the earlier PCA Variance explained. The total variance is given by four principal components as seen in figure (13) to reach 99%.

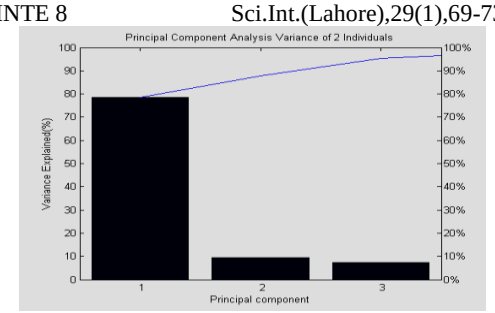

Fig (12) Variance explained of 2 individuals.

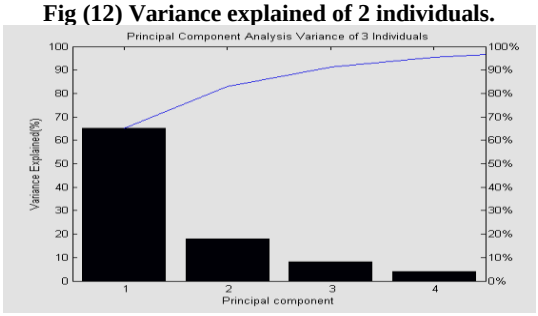

Fig (13) Variance explained of 3 individuals.

3.5 Spectrogram

Spectrogram has a similar concept with PSD. Figure (14a), figure (14a), and figure (14c) show the Spectrogram of Person 1, Person 2, and Person 3 respectively. It is found that the spectrogram readings are different for all individuals due to the fact that their body size are different.

Person 1 being the tallest has the smallest area of high amplitude. This is because of the large blockage area of the signal that happens when Person 1 passes thru between the transmitter and receiver. High amplitudes are denoted by bright colours such as yellow and red in the spectrogram.

On the other hand, Person 3 who happens to be the individual of medium height produces a slightly larger area of high amplitude. Blockage area of Person 3 is smaller than that of Person 1, therefore, the larger red areas.Person 2 who is the smallest, produces the largest area of high amplitude which could be seen in figure (14b). In the spectrogram, red and yellow areas are the most prominent compared to figure (14a) and figure (14c).

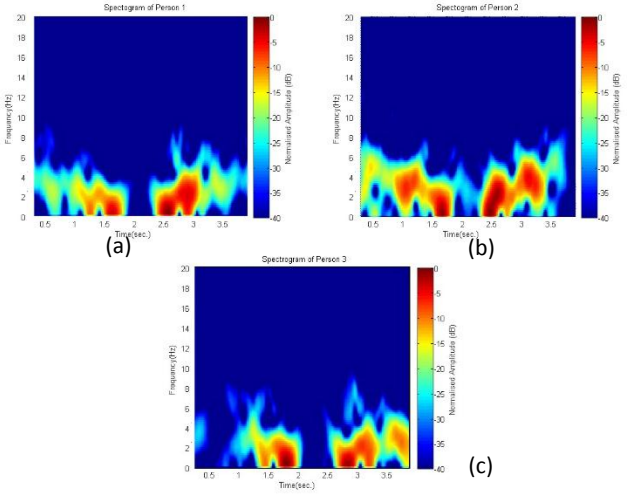

Fig (14) Spectrogram of (a) person 1 (b) person 2 and (c) person 3.

4. CONCLUSIONS

Radar has the ability to detect the presence of any object that passes through its system. In this case, passive forward scatter radar is used to detect and differentiate humans of different sizes when they passed through the radar region.

Passive radar, which uses signal from a commercial antenna is used in this study to detect humans. Every human body does not have the same shape, therefore the blockage area of the signal is different. When the signal interacts with the human body, the signal will be scattered and this produces the Human Doppler signature. Forward scatter radar has the detecting angle of near 180 degrees.

It is discovered that the PSD of the individuals are inversely proportional to their heights, which could be seen in the results. In PCA, data of the individuals show a good convergence in terms of their respective groups.

This topic has the potential to be developed further into a security system, where it could be applied to international border security. Because this radar system is able to differentiate the individuals in terms of size, it can be used to prevent illegal entry of human at the border.

5. ACKNOWLEDGMENT

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