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A Passive Forward Scattering Radar for Detecting Humans and Characterizing Human Behaviours

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ABSTRACT

Background: The capability to detect human and identify their movement is progressively important in military and security applications. Usually, most of the radar systems are active systems which it is easily to be detected by the opponent. In consequence, passive radar is set to become alternative to conventional active radar which it offers a decisive operational advantage, it could not be located. Passive radar does not emit any signals of its own which it could not be jammed. Therefore, passive radar use many different transmission sources that are sent out from various location to detect ground moving target especially human**. Objective:** The integrating of passive forward scattering radar that provide a lot of benefits and capable to detect human and characterize human behaviors which the radar system analysis and signal processing are using MATLAB software. **Results:** The radar system able to detect human and characterize the behaviors which divided into two movements, walking and running. **Conclusion:** This is the evolving area of research provide a more useful outcomes in detecting and characterizing the human movements specifically used the passive forward scattering radar concept of unseen by others**.**

INTRODUCTION

A new perception of small, portable, virtually undetectable radars is quietly gaining traction in the ground scrutiny community. Passive radar 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 easily to set up and did not require any frequency allocations. The specifications of passive radars is essential for enhance security and provide effective protection from new threats (Westra, 2009). This paper is emphasis on detection of human moving target using passive forward scattering radar to observe human behavior and determine whether it is a threat or not.

Passive Forward Scattering Radar:

Passive radar also introduces a receiver without a co-located transmitter and enhanced compare to conventional radar system (Salah *et al*., 2014). Previous research had proven a multi frequency radar systems

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could detect humans and classify their activities at short range through wall and long range foliage penetration using S-Band frequency (Narayanan *et al*., 2014).

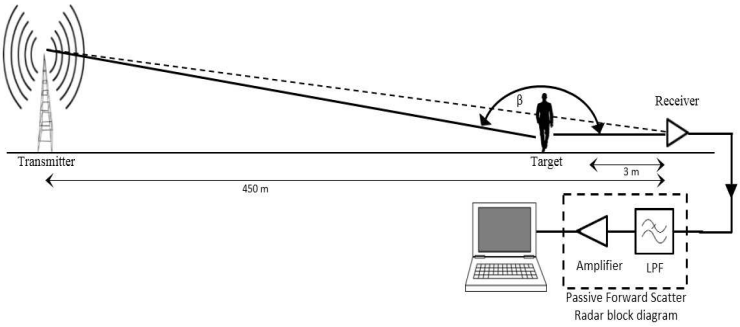


Fig. 1: Architecture of passive forward scattering radar system.

Figure 1 shows the architecture of the passive forward scattering radar systems where a transmitter is needed as an illuminator of opportunity and then setup a receiver as a passive radar. The receiver is directly fronting to the transmitter, in which any ground of moving target (human) crossing the area between the transmitter-receiver, the target could be detected. Subsequently, the target signal is send to the passive forward scatter radar block diagram which have a low pass filter, an amplifier, a detector and analog to digital converter for signal processing.

In signal processing, 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 (Abdul Aziz *et al*., 2015).

Human Detection:

Radar systems provides a special benefits thru the sensors for the human detection. In this paper, the experimental results took in tropical environment climate zone which experiences hot and humid weather. Nevertheless, humans are challenging targets to detect because they have a small radar cross section (RCS) and they move with a low speed. Consequently, human detection frequently fall below the Ground Moving Target Indication (GMTI) radars minimum detectable velocity (MDV) and is simply camouflaged by a clutter. The human body is divided into twelve basic body parts which are the head, upper arms, lower arms, torso, thighs, lower legs and feet as illustrates in Figure 2 which each point is taken to lie at the center of the body part (Gürbüz *et al*., 2007).

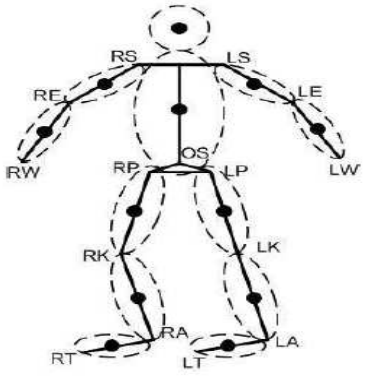


Fig. 2: Twelve points of human model (Gürbüz *et al*., 2007).

Detection of human beings is based on movement detection which causes changes in frequency, phase, amplitude, and arrival time of reflected signal from a human being. In case of through wall human target detection, these changes can be very small, especially for a brick or concrete walls. According to research using ultra-wideband (UWB) active radar, reflected signal is highly sensitive to human posture and thus makes detection development challenging such as the human breathing changes the received waveform shape. An effective human detection method requires a model of human body in radar waveform propagation and scattering. A target such as human body has complex shape and three-dimensional point which is larger than the

transmitted radar signal pulse width, the multipath components of returned radar signal, the scattered incident pulse with different times and different amplitudes (Liang, 2009; Stephen *et al*., 2008; and Yarovoy, 2006).

Methodology:

Figure 3 illustrates a block diagram of signal pre-processing in detecting and characterizing human behavior using passive forward scattering radar system. The experimental result were obtained from passive forward scattering radar receiver that had been setup at Serdang, Malaysia. The passive radar system is directly fronting the transmitter base station which have several networks from different provider. Next, the human target crossing the line-of-sight signal propagation of the transmitter-receiver where the human could be detected. In this circumstance, the moving of human target is 3 meter away from the passive radar receiver.

After received the target signal from the passive radar receiver, a selection and segmentation should be prepared before the following stage which is denoising using wavelet transform. Subsequently, Fast Fourier Transform (FFT) is performed to define the frequency domain and plot the unique frequencies. Following with power spectral density estimation to obtain the average power in the target signal over the frequency band (Gaoping and Songli, 2002). After accumulating all the power spectral density data, principal component analysis is used for spectral signature to characterize the behavior of human moving target.

Table 1 describes the human behaviors for this passive forward scattering radar system which is separated in two categories, walking and running. Commonly for walking the target's speed is around 4.5 km/h and for running is 11.0 km/h. Even from the silhouette of human, it's uncomplicated to distinguish the human's behavior.

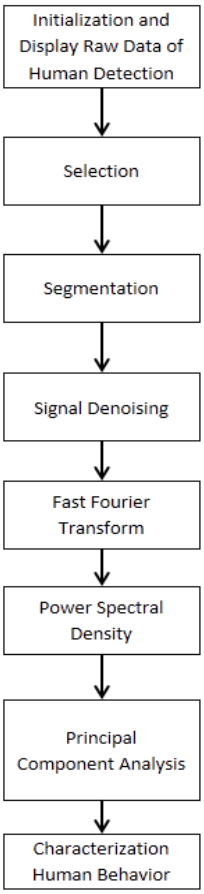


Fig. 3: Signal pre-processing block diagram of characterization human behavior in passive forward scattering radar system.

RESULT AND DISCUSSION

After examining the data received from the passive forward scattering radar, the results show the coherent integration time in the conceptual of forward scatter is depends on the spend time of the target is visible within the coverage of forward scatter. Figure 4 shows the time domain of human while walking which he took around

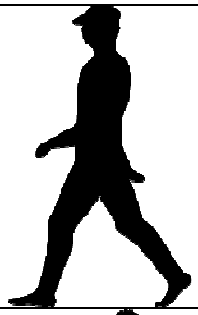
2 seconds to be detectable within the forward scatter range. Figure 5 shows the time domain of human while running in which he only took around 1 second to pass thru the region of forward scatter receiver.

Figure 6 and Figure 7 show the power spectrum density of human detection using passive radar while walking and running, respectively. The first lobe of walking behavior shows 5 Hertz for frequency domain with -18 dB of normalize power. The third lobe of walking shows until 11.5 Hertz which the normalize power is -46 dB. However, the first lobe for running behavior is 4 Hz with -7 dB of normalize power and the third lobe shows until 12.5 Hz with -34 dB of normalize power.

Principal Component Analysis (PCA) is simple but effective approach for gait recognition. Binarized silhouettes of a motion object are represented by 1-D signals, which are the basic image features are then performed in the lower-dimensional Eigen space for human identification (Ekinci, 2006).

Hence, the compilation of power spectrum density data of several human behaviors is competent to classify the human target behaviors using spectral signature of frequency domain in Principal Component Analysis (PCA).

Table 1: Description of human behaviors.

Behavior	Silhouette	Target's Speed (km/h)
Walking		*4.5*
Running		*11.0*

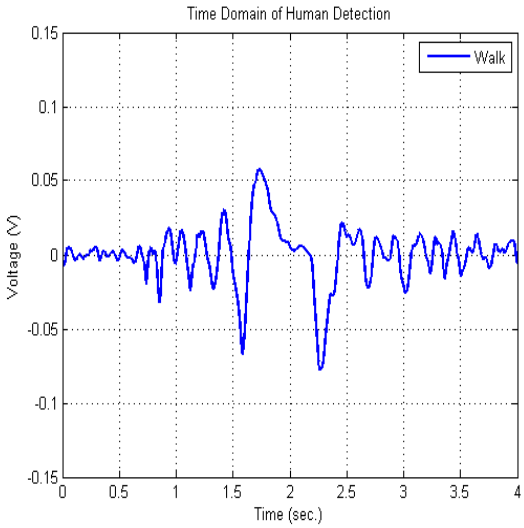


Fig. 4: Time domain of human detection while walking.

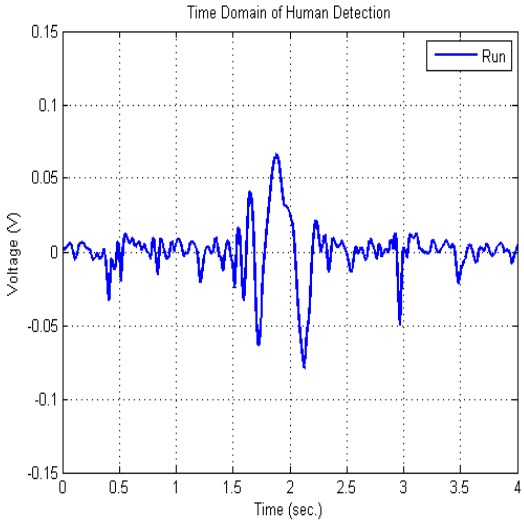


Fig. 5: Time domain of human detection while running.

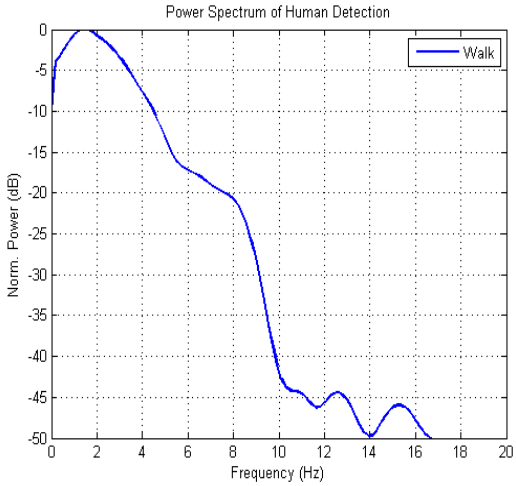


Fig. 6: Power spectrum density of human detection while walking.

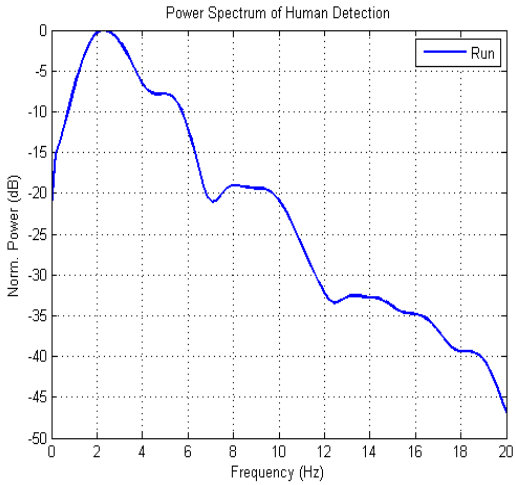


Fig. 7: Power spectrum density of human detection while running.

A MATLAB simulation environment had been developed by other researcher for the testing of spectrogram-based detection and identification of human and non-human targets. The simulations show that spectrograms have some ability to detect and identify human targets in low noise (Gürbüz *et al*., 2007). Consequently, spectrogram-based is an alternative detection and identification method for human behavior using passive forward scattering radar.

Figure 8 illustrates spectrogram of human detection while walking. In terms of time the human target moving from 1.5 second until 2.5 second which the target took 1 second to pass thru the forward scatter region. Subsequently, Figure 9 shows the spectrogram of human detection while running where half of the walking time about 0.5 second for the target to pass thru the forward scatter region. This results verify the spectrogram-based is reliable for human detection and characterize the human behaviors.

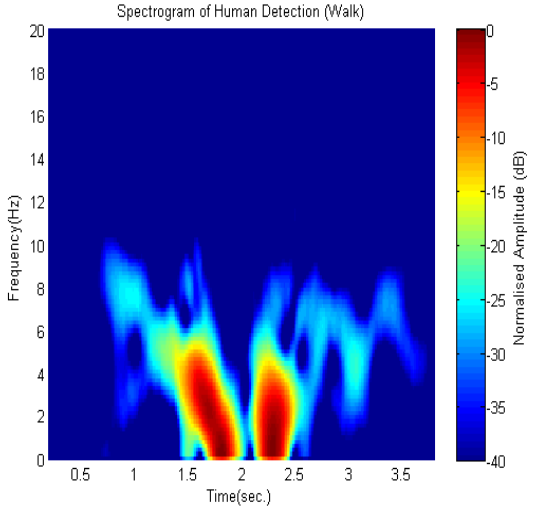


Fig. 8: Spectrogram of human detection while walking.

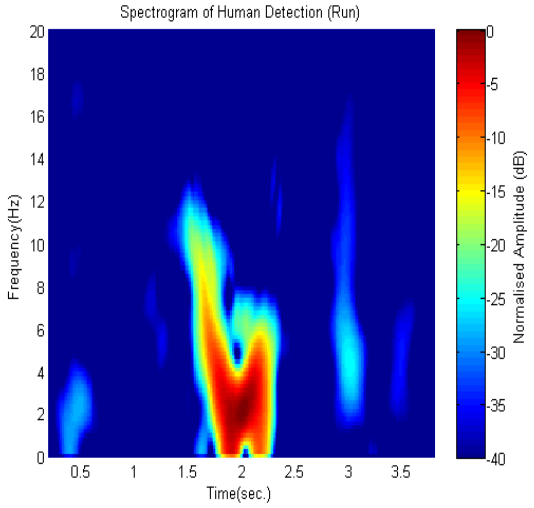


Fig. 9: Spectrogram of human detection while running.

Conclusion:

A new edge in passive forward scattering radar can be used for many applications especially in enhancement security and provide protection from new threats. The capability to detect human and identify their movement is progressively important in military and security applications.

Passive radar is set to become alternative to conventional active radar which it offers a decisive operational advantage, it could not be located. The integration of passive radar with forward scatter technique provide a lot of benefits. The uncostly is an advantage which passive radar just used many different transmission sources that are sent out from various location to detect ground moving target such as human, animal, vehicle, etc.

The experiment from the field of passive forward scattering radar to detect human and characterize human behaviors is successfully accomplish using a simple of signal processing. The passive forward scattering radar system able to detect human and characterize the behaviors while walking and running. This is the evolving area of radar research provide a useful outcomes in detecting and characterizing the human movements specifically used the concept of passive radar to detect without being seen.

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