The Effect Of Movement Inconsistency To The Performance Of Forward Scatter Micro-Sensors Radar

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***Abstract*—This studies will be covering the effect on inconsistence movement target forward scatter micro-sensors radar (FSR). The performance analysis of FSR will be proposed to obtain high detection accuracy for all condition which includes speed inconsistency and various trajectory angles and movement compared to idealized condition for FSR system. All simulation will carry out using MATLAB software. The expected designated simulation results obtained will be recognized and classified by the system then will graphically compare. From the results, a database and estimation of system performance can be drawn as a guideline for future works.**

***Keywords*—forward scattering radar, ground target, and inconsistence movement**

I. INTRODUCTION

Forward scatter radar (FSR) is a subclass of bistatic radar (BR). Forward scatter occurs when the target is close to the transmitter-receiver baseline in other word when the angle of the target called bi-static angle, β is close to 180^{O}.

FSR commonly used in target detection, coordinate estimation and automatic target classification [2]. Due to unique advantages of FSR such as robustness to stealth targets and enhanced targets cross-sections, FSR provide better result compared to traditional radar. Although FSR offers a promising advantages, but it also have a number of known drawbacks, such as the absence of range resolution, narrow operational area, etc.

Most of research on forward scatter radar demonstrates air target classification on target detection, recognition and coordinate estimation. Some elementary study was conducted on ground target detection and recognition demonstrating FSR promising result [4, 8, and 10]. For ground target (humans and vehicles) detection research, different types of cars are presented as public road transport vehicle that were used as the target of interest. FSR is widely used on road vehicle classification but also provide other useful applications for example in security and medical application.

FSR technologies in vehicles classification are demonstrate widely due to promising advantages, however, there is some parameters could be investigated to expand FSR potential for further improvement. After a survey of literature review on FSR reveals, there is a lack of research and analysis of the factor that influence the accuracy especially on target speed and movement inconsistency.

In [12] shows that classification performance are depends on speed estimation accuracy. Previously, speed estimation accuracy was estimated by playing back a recorded video (time consumed process was done manually). To improve the process, an intelligent method to improving the classification accuracy and estimating speed accuracy should be further explored.

Speed inconsistency also introduced speed percentage error in experimental results analysis. By using different speed, proposed speed estimation accuracy algorithm will be affected. The error will be increased in speed estimation, as decreasing the classification accuracy proportionally. More future work should be conducted for further improve of the latter.

'Idealized condition' was a situation for target (humans and vehicles) trajectory to the FSR system is 90^{o}. Un-consistence movement or arbitrary unknown trajectory angles do occurs when the trajectories angles are less than 90^{O} or approaching 0^{O} ($90^{O} > \psi > 0^{O}$). Research for arbitrary unknown trajectory angles in [9] states that classification accuracy performances decreased significantly when the trajectory target angles becomes low. This statement does prove FSR unknown trajectory scenarios improvement may improve better classification performances. In [9] also, multiple-sensor system suggested to be incorporate with multiple information streams within classification system as proposed strategies to overcome this problem. A number of sensors were placed in number of positions within the area of interest as the unknown vehicle passes through the area. As the target passed through, each sensor provides object illuminated information at different angle.

Hence to further improve the accuracy in FSR, all important parameters such as speed values and trajectory angles should be varies then analyze graphically. Other suitable installation method and configuration is highly considered.

II. EXPERIMENTAL SET-UP DESCRIPTION

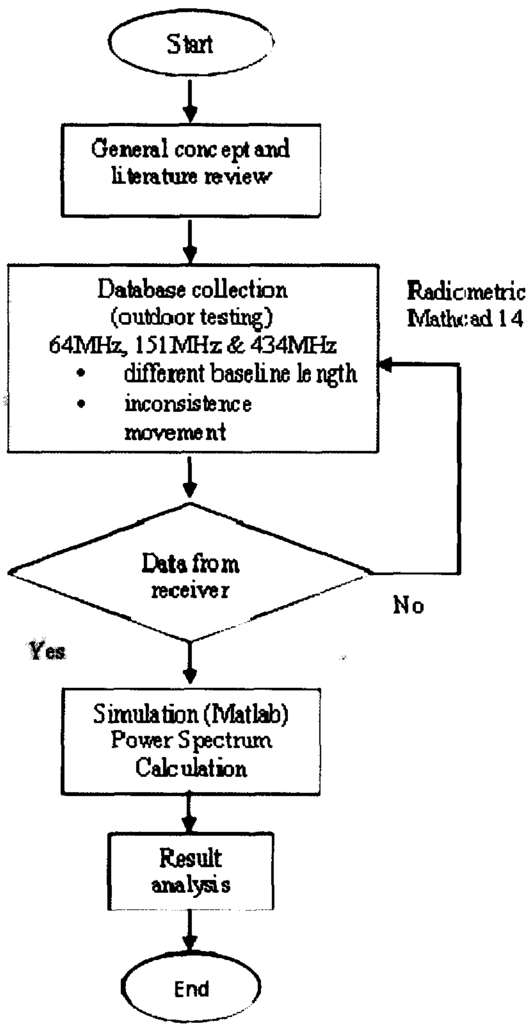


Fig.1: Project flowchart

The experiment site was an empty hall. The project flowchart is shown on Fig.1 and the experimental system topology is shown in Fig.2. Signals of all three transmitter (T) frequencies are transmitted in continuous wave (CW) simultaneously. Then the receiver (R) aims is to record the Doppler signatures of target for inconsistence movement with approximately constant speeds. The transmitting and receiving antennas were placed on the ground.

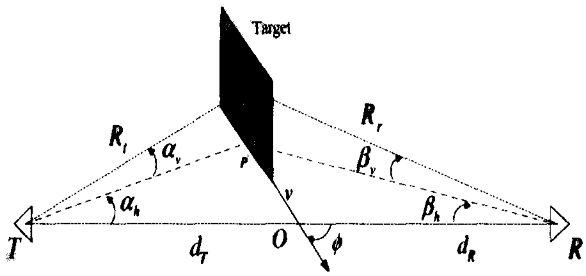


Fig. 2: Experiment Scenario with baseline and the target crossing at the midpoint

At the input of the receiver, the direct and reflected signals were separated using three different Doppler frequencies (64MHz, 151MHz and 434 MHz). For each movement, measurements were repeated for multiple times with same human target.

As the target travel through the FSR coverage, it will partly block the direct waves from the transmitter. The received electromagnetic (EM) wave is actually the forward scattering component of the moving target and it also contains an appropriate Doppler frequency component due to the motion of the target relative to the baseline.

At the receiver, the Doppler signature moving targets extracted by means of nonlinear conversion and low pass filtering of the mixture of the leakage and the scattered

The extracted target signatures can be presented as:

$$S_r(t) = U_{tg}(t)\sin[\varphi(t)] \quad \ldots\ldots (1)$$

where $U_{tg}(t)$ is the envelope of the received signal (equal to the received signal strength) and $\varphi(t)$ is the phase signature of the moving target. The target signature $U_{tg}(t)$ depends on the target forward scattering cross section $-\sigma(t)$, which itself entirely specified by the targets geometrical cross section (silhouette) and the signal wavelength, λ.

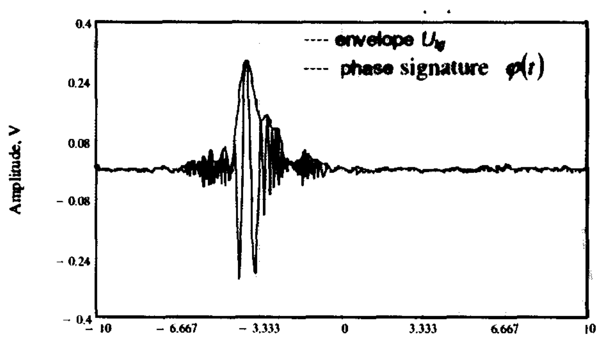


Fig. 3: Example of target signature resembles a two sided chip signal

The phase signature $\varphi(t)$ is given by:

$$\varphi(t) = \frac{2\pi}{\lambda}[R_t(t) + R_r(t)] \quad \ldots\ldots (2)$$

The extracted Doppler signal contains information about target silhouette and velocity. It becomes the input to the classification system.

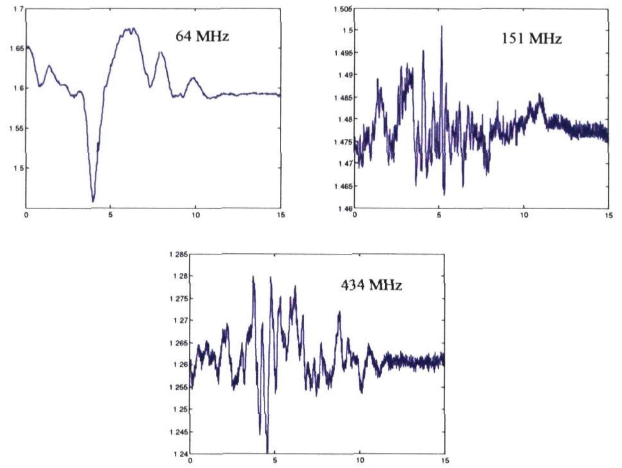


Fig.4: Measured time domain signatures for different frequency channels

III SIMULATION SETUP

Simulation was carried out using MATLAB software. At first, the baseline is set to certain values between transmitter and receiver (40m, 45m and 50m). Then, various types of movement are used in this analysis as in Table 1 at fixed 50m baseline. A target was set to be moving with constant speed 2m/s.

Table 1: Inconsistence movement

No	Types of inconsistence movement
1	45^0 cross trajectory
2	90^0 cross trajectory
3	Cross for 5 sec and stop for 5 sec
4	Zigzag crossing

The target signals are simulated according to the two-ray path propagation model for the period of 30 seconds. The heights, of antenna from ground are varied from 0.2m up to 0.3m depends on the frequency use. The target is simulated based on ideal case scenario where the target is crossing perpendicularly in the middle of the baseline (Fig.5).

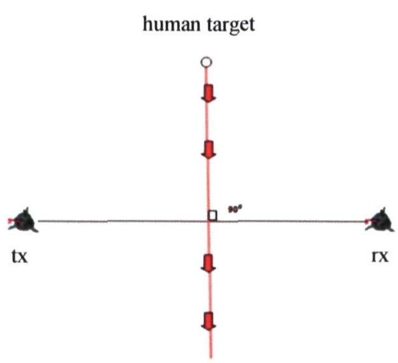


Fig.5: FSR configuration

IV SIMULATION EVALUATION

By using three different dimensions of targets, the received signals for 64MHz, 151 MHz and 434 MHz are plotted. Due to the target motion the signal Doppler frequency shift occurs and can be approximated as a two sides chirp signal, with zero Doppler when the target crosses the baseline. For better signal analysis, the time domain signatures are converted into the frequency domain using power spectrum estimation technique.

A. Effect of different baseline lengths

Fig.6 illustrates the topology of different baseline lengths. The transmitter and receiver locations are denoted by *TX* and *RX*, respectively. The point *O* is the origin of the co-ordinate system and denotes the point where the target crosses the baseline. The distance between *O* and the transmitter is d_T and d_R is the distance between *O* and the receiver. The target moves with velocity, and its motion direction is specified by the angle, φ. In this case, the target moves in a direction normal to the baseline, $\varphi = 90^0$.

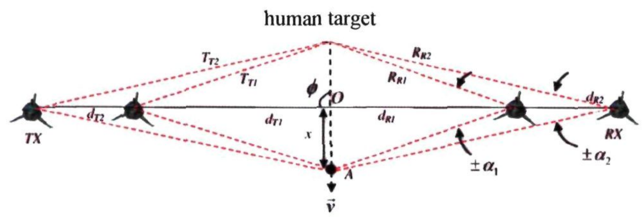
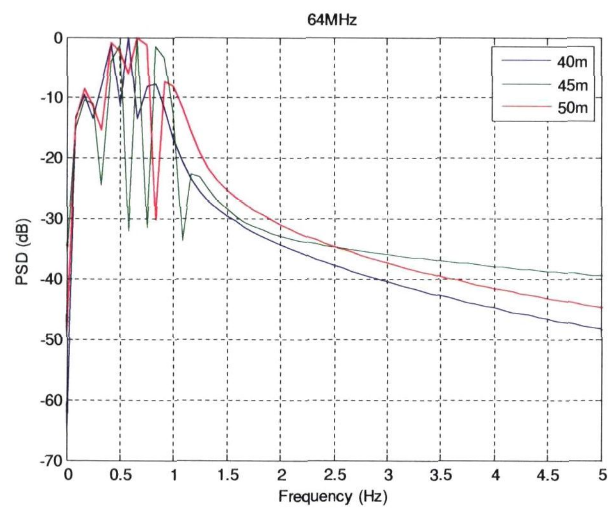


Fig.6: Topology for different baseline length

The effect of different baseline crossing is presented as target's signature. Fig.8 shows the target's signatures process at various frequencies.

Spectrum for all frequencies clearly shifted in the lobe between each target signature compare to others baseline lengths.

Therefore, 50m baseline length characteristic are selected for one of inconsistence movement experiment parameter. This promised an accuracy signal target for different trajectory and movement data records.



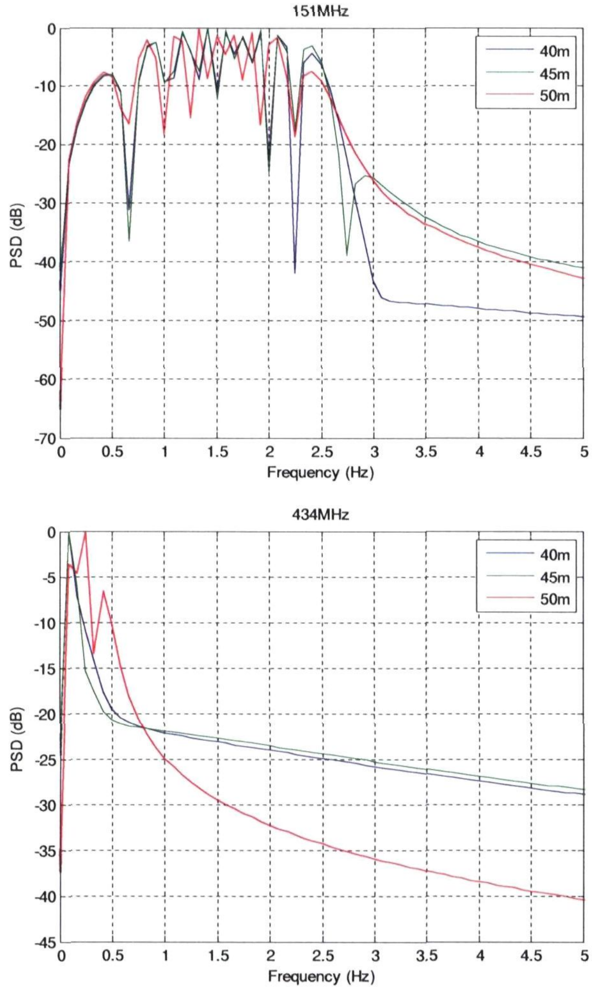


Fig.7: Target signature for different baseline length characteristic at 64MHz, 151MHz and 434Hz

B. Effect of different trajectory angles and movements

As mentioned earlier, in forward scatter the shadow field occurs when the target partly blocks the signal wave front from the transmitter. The pattern of the shadow depends on the target silhouette and not on the target surface shape. Different target silhouette areas give different target signature. This suggests that target signature fluctuates are also dependent on the angular properties of the target and the direction in which the target is viewed.

It is essential to investigate the effect of small changes in target crossing angles to the target with a baseline of 50m. Then three different trajectory angles to the transmitter-receiver baseline (45^0, crossing for 5 seconds with delay 5 seconds and zigzag crossing) compared with 90^0 crossing trajectory as a reference signal (due to ideal case scenario).

The effect of different trajectory angles and movements is presented as target's signature at various frequencies using 50m baseline length parameters.

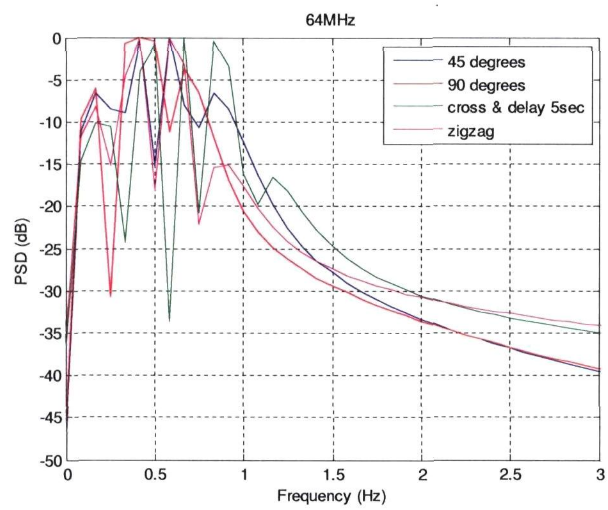


Fig.8: Target signature of inconsistences movement characteristic at 64MHz

From Fig.8, Fig.9 and Fig.10 we can clearly see that for each movement, different signal target signature produced. This plotting proves the earlier statements that different target silhouette areas give different target signature and spectra. For each movement trajectory crossing, clear spectra differences between crossing target movement become visible as target crossing the baseline at varies frequencies. Wide different signal pattern are recorded. The shadow of forward scatter radar recorded as a signature signals according to each crossing target surface shape.

A larger database of target signature with different types of target might be needed in order to accommodate all different movement signals (especially for inconsistence movement) from experimental and simulated results, or the classification accuracy will decreased.

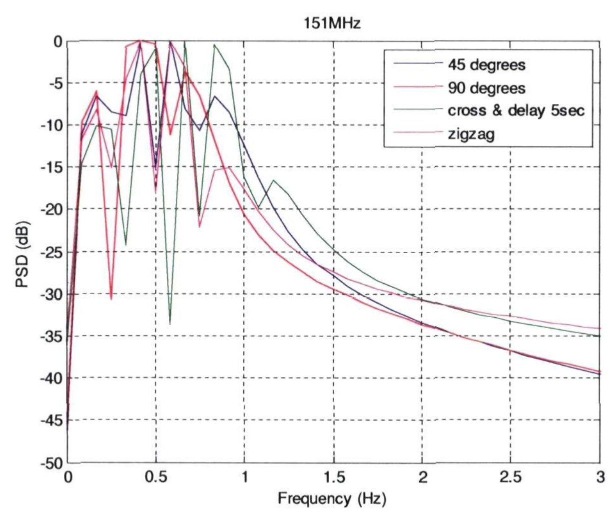


Fig.9: Target signature of inconsistences movement characteristic at 151MHz

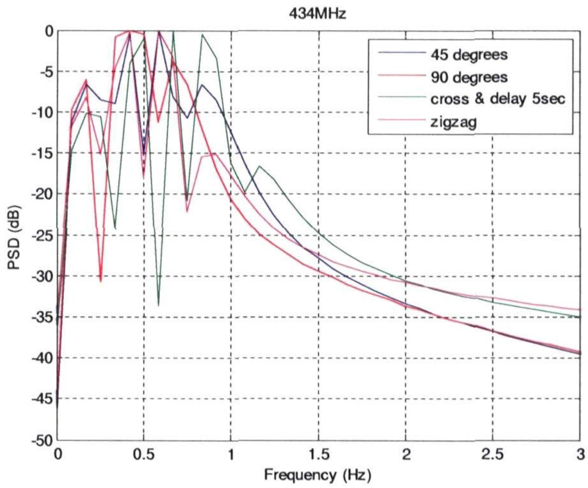


Fig.10: Target signature of inconsistences movement characteristic at 434MHz

IV CONCLUSION

In this paper, the effect of inconsistence movement and speed was analyzed. Studying on the similarity and stability of signal signature with different baseline lengths, length parameter for inconsistence parameter are set. After applying a baseline fixing value process, the system can precede to next level which is movement analysis to various frequencies. As the target approaches optical approximation, the differences in the target's spectra for different baselines become more evident.

In case of different movement target signature, it can be seen that for all signal can be separated quite well from each other varies to the frequencies. Each target that provide same special pattern through repeated experiment, suggest that large database might be needed in order to accommodate all different signal, in order to promote high accuracy of ATC (automatic target classification).

Without doubt the results themselves could be improved and should be the subject of further study. In this test experiment, we are assuming no other signal interference such as clutter is possible factors that can affect the signature signal. Further studies regarding this factor are needed. Apart from that, other factors (such as different crossing points) that have a possibility to influence the changes in target signature should be investigated.

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