Analysis of Performance of Classification of FSR in a Cluttered Environment

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***Abstract* - The effect of clutter to the radar data dispersion has been analysed in this paper. The presence of clutter from the environment may cause errors in the target detection and classification in forward scattering radar (FSR). An experimental approach by comparing the differences between dispersion of the features extraction from the cluttered environment via simulation such as MATLAB can determine the classification of the signal in a database. The outcome from the project should enhance the classification of target classification in a database.**

Keywords – Forward-scattering radar, automatic target classification, clutter, signal-to-clutter ratio.

I. INTRODUCTION

In the past few decades, wireless sensor network has become a vital demand in most technologies that require its services. Their applications have been found in environmental monitoring, tsunami and volcano activities, meteorological and seismic parameters, alarm systems and remote asset monitoring, road traffic control and other commercial operations.

In this era, the capabilities of these sensors in detecting ground targets has triggered the development of a wireless sensor network for defence applications such as force and perimeter protection, situational awareness and border security. One of many branches of this development is the Forward Scattering Radar (FSR), which is designed for situational awareness in ground operations [1]. Few advantages regarding the usage of wireless sensoring network has been spotted such as ease of implementation on new devices at any time, monitoring accessible through a centralized monitor, and low implementation of physical media transmission. However, their weakness need to be considered such as expensive and easily exposed to internal and external interference.

FSR offers some of advantages such as hardware simplicity, robustness to any kind of environmental conditions and landscapes, low maintenance and a long target integration time due to reduction in its radar cross section fluctuations as compared to monostatic radar [2]. Nonetheless, FSR also introduce relatively a number of disadvantages, including the absence of range resolution and operation within narrow angles in proportional to the transmitter-receiver baseline [3].

Despite of having its weaknesses, the primary challenge when dealing with FSR system is to observe and consider the presence of clutter as they are also taken from the overall coverage area. The performance declination of FSR can be affected in many perspectives and one of them is clutter, which has caused a problem in target detection and classification.

The goal of this paper is to investigate the effect of different level of signal-to-clutter ratio (SCR) towards the dispersion level of targeted signals and the accuracy performance of database classification. The accuracy of classification is also affected by different value of tested frequencies. The following sections demonstrate the experimental procedures and results of this project

This technical paper will explain the overall concept involved in this project together with the explanation from researches which have been conducted. The research methodology consists of procedure occurred in order to obtain the result that is presented in few perspectives for better understanding.

II. SYSTEM CONCEPT

A. Forward Scattering Radar Basics

Many researches on FSR have been conducted for many years as the theory behind this network is more sophisticated and far from full achievement [3].

Basically, the concept of FSR can be described as one of the bistatic radar classes that operate when the target is observed passing through the baseline between separated transmitter and receiver within the bistatic angle of 180 degrees (Fig. 1).

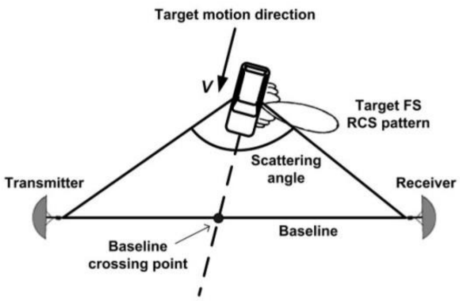


Fig.1 Plane view of the Ground FSR topology

Past research has been conducted on FSR network for situational awareness in ground operations [4]. Its primary objectives are for detection, parameter estimation and automatic target classification (ATC) of various types of ground targets within its coverage area (Fig. 2).

A better detailed explanation and description regarding FSR's system topology and the practical sensor and network realization can be reviewed in [1].

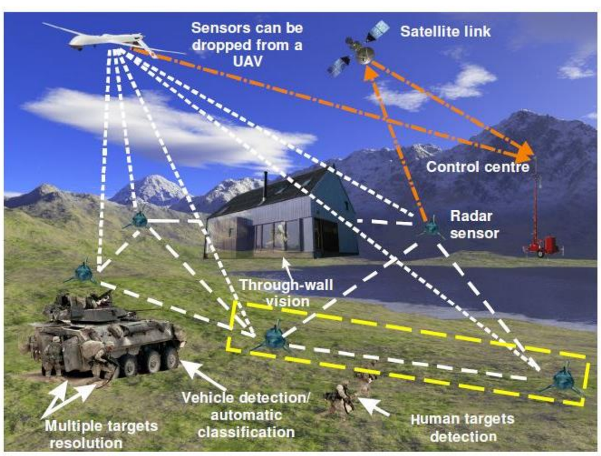


Fig. 2 The concept of the FSR micro - sensors rdar network (Sensors enlarged for visibility)

B. Automatic Target Classification System

Few researches have been done in creating an automatic target classification system which extracts data information from the receiver. Different types of frequencies from VHF and UHF is tested in order so that the targets can be classified accurately [4].

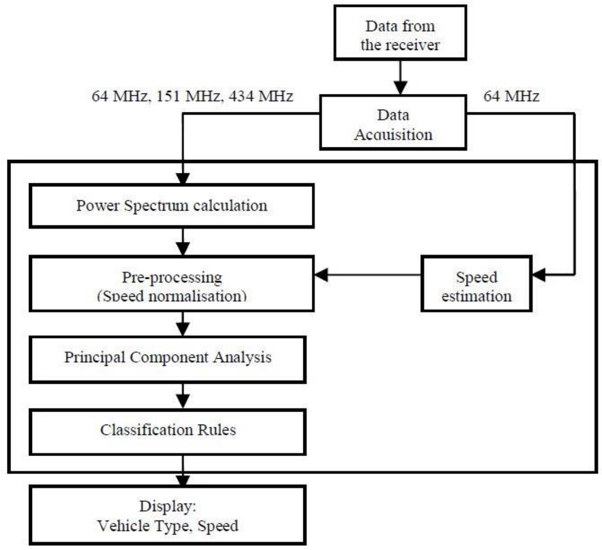


Fig. 3 Automatic Target Classification Block Diagram

In ATC system, the time-domain signatures are transformed into frequency-domain by using power spectrum estimation technique. The frequency-domain is then normalized in pre-processing stage [3]. Due to the fact that the received signal spectrum is considered as feature vector and cannot be used directly for further processing because its shape is affected by the speed of vehicle that appears either compressed or expands. Principal Component Analysis (PCA) is executed in order to reduce the dimensionality of the spectral feature vector and to describe it in more effective manners and visuals [2].

C. Clutter Generation

In general, clutter is similar to noise in communication terminology which can be defined as any unwanted signals that cause the quality degradation of its information [5]. The presence of clutter will cause the FSR's system to be more complicated to identify the target detection process especially when the returning information is mixed with clutter.

A research has been done which describe the effect of clutter on ATC accuracy in FSR in which a general self-generated random noise is used which form a simulated clutter signal. The simulated clutter signal is then added to the target signal in the time-domain at various SCR. The reader is prompted at [2] for more technical information regarding this clutter generation.

However, as far as this project is concerned, the simulated clutter is generated based on the real clutter modeling database. Different test sites with terrain profiles varying from a concrete runaway to dense woodland were chosen in order to record a large number of clutter signals so that the results of modeled clutter characteristics can be validated. Technical description and equipment set-up in order to obtain the results is well explained in [6]. By doing this, a good quality of non-stationary clutter generation can be obtained and used to produce a FSR detection performance with any parameters such as speed and crossing angle [6].

III. RESEARCH METHODOLODY

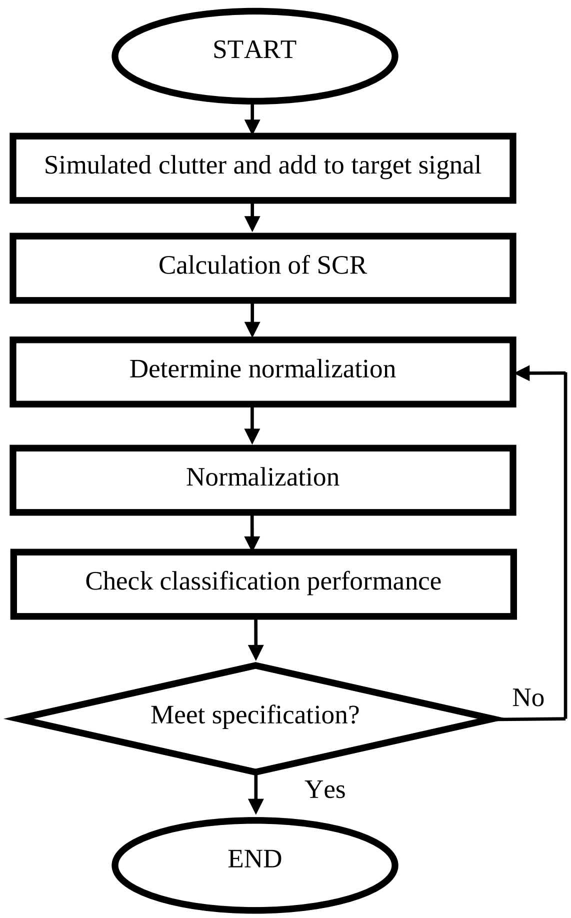


Fig. 4 Block Diagram

Fig. 4 shows the visual procedure of this project which will show the results on next section.

A. Experimental Set-up

The project starts by implementing simulated clutter signals. Three different frequencies (64MHz, 151MHz, and 434MHz) are used in order to measure the spreading of variance of the PCA components for four different types of tested vehicles. Clutter level is set to level 1 for all tested frequencies which indicate a weak clutter signal.

Once the SCR has been added into the clutter signal, the signal is generated by mixing the targeted signal with the generated clutter signal in order to observe the dispersion of spreading on 2-D PCA plot.

A set of cleared database is used in order to determine the performance of classification of the tested vehicles. The Power Spectrum Density (PSD) for each type of vehicle is loaded and the frequency-region of the PSD is set. This will be used for PCA calculation that will determine the spreading of PCA components.

The result obtain shall be discussed later as the level of SCR will determine the accuracy of the classification on cleared database.

B. Implementation of SCR

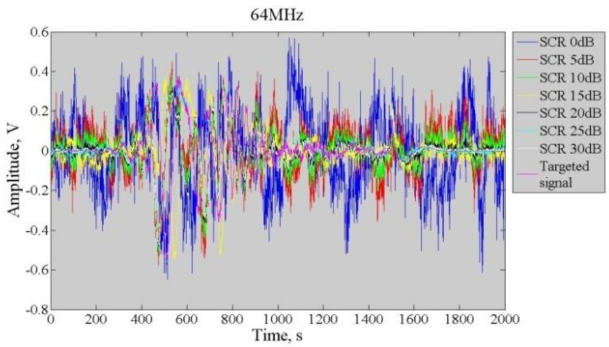
The SCR was calculated by using formula below:

$$SCR = 10 \ \log \ (P_s/P_c)$$

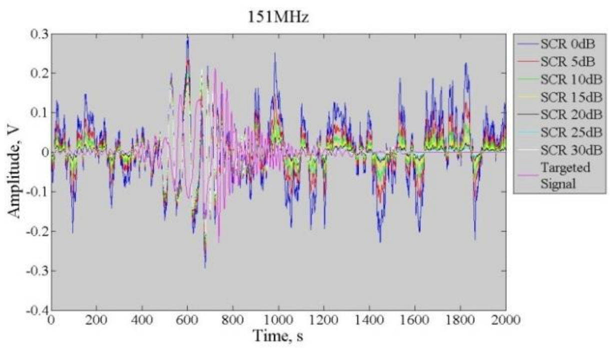
where P_s and P_c are total power of real targeted signal and total power of generated clutter respectively. These SCR indicates the level of clutter dispersion and will show the effect to the targeted signal. In this experiment, the clutter was generated from 0dB to 30dB, with 5dB intervals.

IV. RESULTS AND DISCUSSIONS

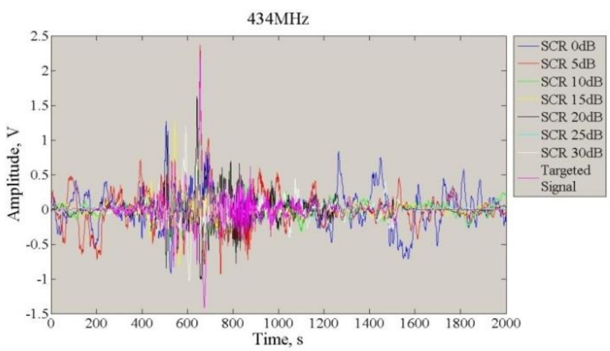
The result obtained is presented in different types of figure as a better presentation of the effect of clutter to the targeted signals.



(a)



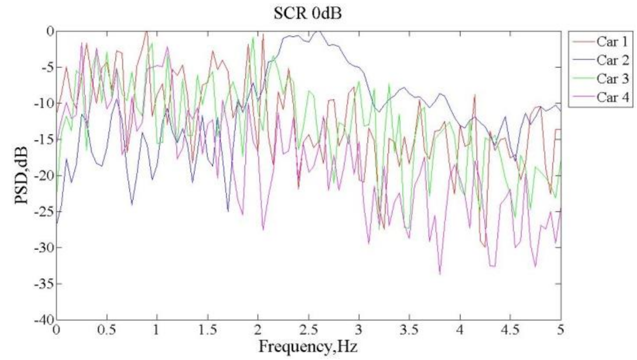
(b)



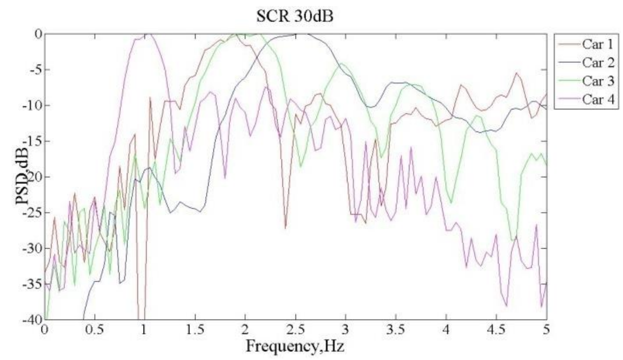
(c)

Fig. 4 Time-Domain Signals for targeted signal that is affected by clutter based on different SCR levels at (a) 64MHz, (b) 151MHz, (c) 434MHz

Fig. 4(a) - Fig. 4(c) shows three different time-domain signals which have been generated from three different frequencies at 64MHz, 151MHz and 434MHz. In the figure, the same targeted signal is corrupted by the different level of SCR. This shows that the distortion of the signal increases with the decreasing of SCR levels. The area of focus is to observe the spreading of targeted signal located between 400 to 900s while any signals outside those range is the clutter signal.



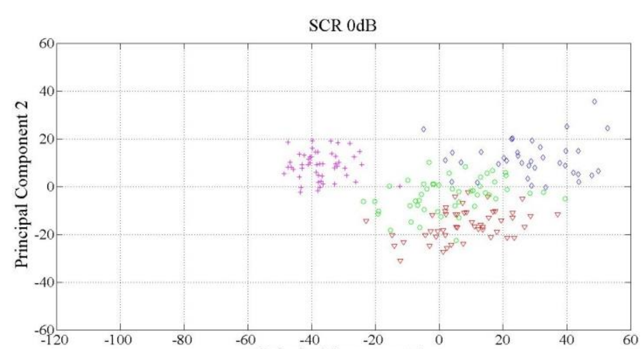
(a)



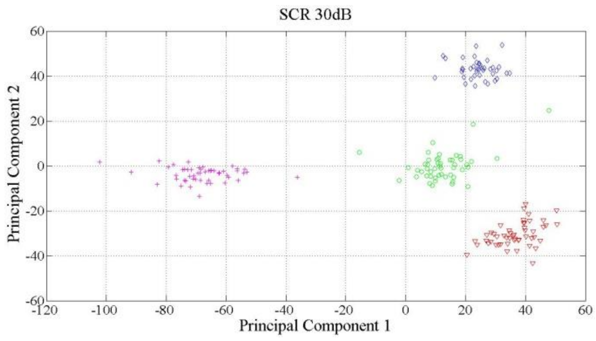
(b)

Fig. 5 PSD signals for two sampled SCR levels at (a) 0dB, (b) 30dB

Fig. 5(a) and 5(b) shows two samples of PSD signals after being transformed from time-domain signatures. The results from Fig. 5(a) and 5(b) display an example of generated PSD signals at SRC level of 0dB and 30dB both at 151MHz respectively. The signal from 30dB shows a smoother variation as compared to 0dB since the clutter has cause interference to the signals at 0dB SCR.



(a)



(b)

Fig. 6 2D - PCA plots for different SCR levels at 151MH

Fig. 6(a) and 6(b) shows the effect of clutter on data dispersion in 2D - PCA plot. Frequency of 151MHz is chosen for two sampled SCR of 0dB and 30dB respectively. It can be observed that as the level of SCR decreases the dispersion of PCA components' spreading increases for each type of tested vehicles.

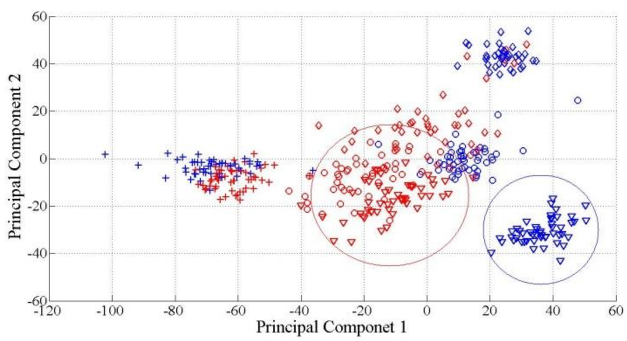


Fig. 7 Comparison of 2D - PCA plot at 151MHz Notation: 0dB (red), 30dB (blue)

Fig. 7 presents the difference of 2D – PCA plot at 151MHz between 0dB and 30dB. The SCR at 30dB is assumed as the targeted signal and is affected with zero clutter. From the results obtained, the clutter has caused the PCA plot to shift from the original position. Nonetheless, the presence of clutter also contributes to the variance of the spreading. It is demonstrated that at 0dB, the clutter have overshadowed the targeted signal with the increasing of spreading as compared to the targeted signal.

TABLE I. TABLE OF TARGET CLASSIFICATION ACCURACY FOR 64MHZ, 151MHZ, AND 434MHZ

Frequency SCR, dB	64MHz	151MHz	434MHz
0	46.25	58.50	42
5	77.75	94.75	54.75
10	89	100	80.25
15	96	100	87.25
20	98	100	90
25	98	100	90.50
30	98.5	100	90.50

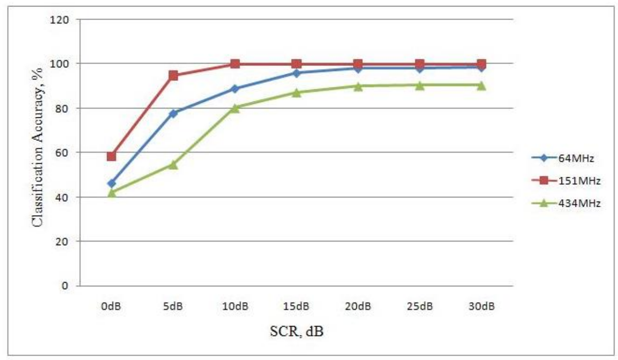


Fig. 8 Graph of target classification accuracy for 64MHz, 151MHz and 434MHz

The presence of clutter will also affect the accuracy of target classification on database. Fig. 8 reveals the accuracy of classification for all tested frequencies with the presence of clutter. From the graph, as the SCRs approaches 30dB, where the targeted signal is assumed has no clutter, the database classification increases towards 100% accuracy.

V. CONCLUSIONS & RECOMMENDATION

This paper presents the effect of clutter to the accuracy of radar data dispersion. The method of comparing the difference of dispersion in database has been conducted via simulation. The improvement shall reduce the response time on target classification in the database.

It is shown that the spreading of variance of PCA plot changes when the clutter level and frequencies varies. Based on the result obtained, the variance of clutter spreading increases as the SCR level decreases. It also tends to shift from its original position. Clutter have also affected the accuracy of database classification in which the accuracy is decreasing when the SCR tend to decrease as well.

Variance calculation for PCA spreading is very important as it is a fundamental base for designing the database. In the future, this project may be continued by finding a method on how to shift back the PCA plots which have been affected by clutter to return to its original position.

Apart from that, reducing the dispersion of PCA with the presence of clutter should be considered in order to overcome the clutter from overshadowing the original clutter and to enhance the accuracy of database classification. These suggestions serve as future improvement for this project.

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