

Target Classification in Forward Scattering Radar in Noisy Environment

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ABSTRACT

Forward scattering radar (FSR) is a special case of bistatic radar that can be used for automatic ground target detection and classification, the interest in FSR is rises after its capability in target classification is validated. The recent development of the FSR system for ground target classifications did not consider a rough environment analysis. This paper introduces and analyze and study to the automatic ground target classification using Neural network under different noisy conditions this include the overall classification system and the extraction of features from the radar measurements provided results have shown the effectiveness of neural network as potential classifier for ground targets even in sever noisy environment

Keywords: Forward Scattering Radar, Neural network, Signal to noise ratio

1.INTRODUCTION

Forward scattering radar (FSR) is a special configuration of bistatic radar that occurs when the angle is 180 degree in Bistatic radar. Currently there has been increase of interest of researches in this area .This is due to FSR has many features include relatively simple hardware; an enhanced target radar cross-section (RCS) [1-4] .The Principles and basics of FSR can be found in the works of Willis [1]. The forward scattering RCS mainly depends on the target's physical cross section and the wavelength, and is independent of the target's surface shape. Most of the recent studies and results of FSR reported in the stated literatures have only been carried out in a small number of scenarios specialty for the ground targets. Recent study focusing on ground target classification [3][5] did not consider the operating rough environment which may include high noise contributing to the received signal .this contributing noise may significantly affects the classification process

2.FORWARD SCATTERING RADAR BASICS AND THEORY

Bistatic radars have been used extensively in World War I and II for airborne targets [1]. However, their geometry was similar to the forward scatter configuration, where targets fly near the transmitter-receiver baseline. Since the coverage area is very narrow, only targets that penetrated a single given fence could be detected. Therefore they found to be of very limited use for air target detection.[2]. Consequently, most of the early forward scatter fences were eventually replaced by monostatic radars which have better spatial coverage area and location accuracy [3][5] the theory behind FSR is rather more complicated and far from full development. This section summarizes the basic technical of FSR in terms of signal scattered. More detail about this subject can be found in [1-10] The basic FSR system is shown in Fig.(1) which comprises of transmitter, T_x with f_c central frequency with an appropriate wavelength, λ and a receiver, R_x separated by a distance, b from the transmitter. The target, T_a is assumed to be moving along a trajectory that crosses the baseline with speed, V has zero elevation and the system operates in a ground plane. For a moving target, the shadow signal experiences Doppler shift, f_{dbr} and can be evaluated as: [6]

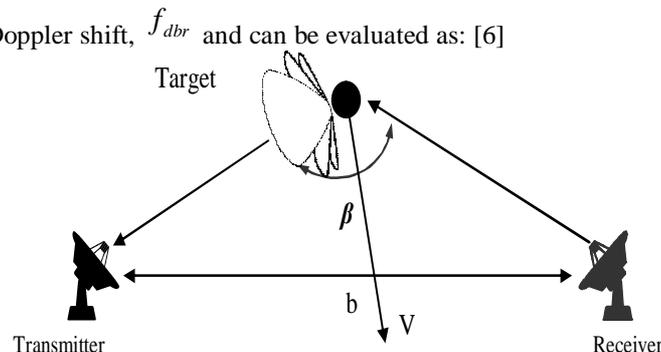


Figure 1: FSR general layout

$$f_{dbr} = 2v \frac{1}{\lambda} \cos \delta \cos(\beta / 2) \tag{1}$$

Where V is Target speed, λ is wavelength and β is the bistatic angle, the information from the scattered Doppler frequency is used in the processing of target classification from the assumption that a unique target possesses a unique Doppler signature in frequency domain[6]. From (1) the Doppler shift depends mainly on the target velocity vector components and the carrier frequency. The general equation that describes the received waveform, that is, target signature from the moving sample target with a rectangular shape is described in [6]. At the time when the bistatic angle β approaches to 180° , the target blocks part of the transmitted signal, which leads to a reduction of the received signal power. In this case, the target acts as an aperture antenna with a maximum gain of: [4][6]:

$$G = \frac{4 \pi A}{\lambda^2} \tag{2}$$

The target can be characterized by a forward scattering cross-section (FSCS), σ_B , which also depends upon the target area A [6] more details on FSR theories, modeling can be found in [1-10]:

$$\sigma_B (180^\circ) = \sigma_F = \frac{4 \pi}{\lambda^2} (A)^2 \tag{3}$$

3.DATA COLLECTION

In this section, the experimental set-up and the method of data collection are described briefly .However more details can be found in [2-3][6]

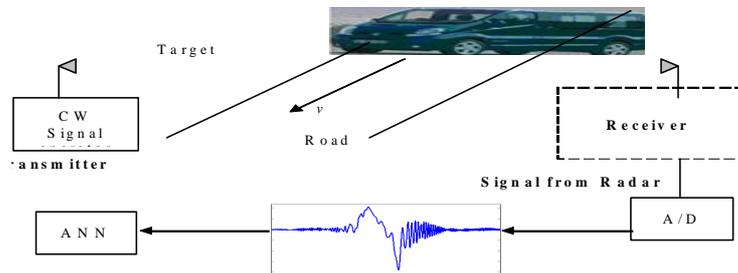
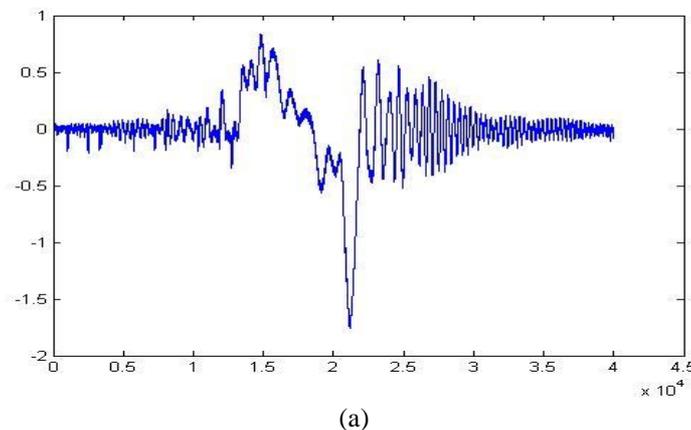


Figure 2: FSR system block diagram

Fig (2) illustrate the overall FSR system block diagram and. The transmitter generates CW (continuous wave) signal at an 900 MHz with two directional flat antennas have been used as the transmitting and receiving antenna. At the receiver, the vehicle signature is detected whereby the arriving signal, which contains both the direct signal and the signal with the Doppler components, is processed by the amplitude detector [2-4]. The low-pass filter allows only this Doppler component to pass through [3].Fig (3) shows sample FSR signal with 100 dbm for different car samples Astra,combi and traffic respectively



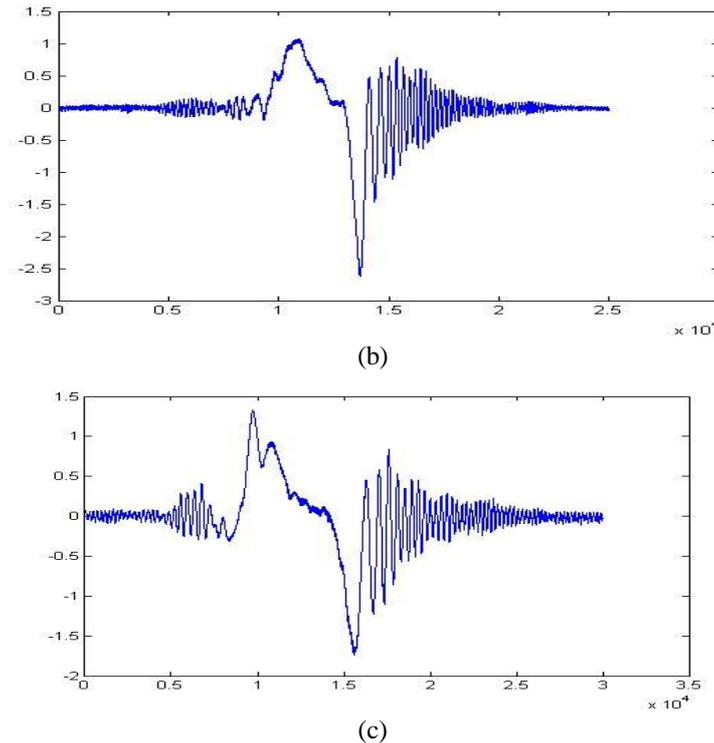


Figure 3: Time domain Received FSR signals with SNR 100dbm (a) Astra (b) Combi (c) Traffic

4.CLASSIFICATION USING NEURAL NETWORK

Artificial Neural Network (ANN) has been considered a reliable classification tool especially in the image and signal processing. These processing is adopted for many applications such as medical, machining, power, control and many more [5]. But, only few radar application is utilizing ANN for classification as well as for other purposes as in [11][12].recent studies such as in [3] and [10] were based on Principal Component Analysis (PCA) and K-Nearest Neighbor (KNN) classifier .Most recent studies on target classification in FSR based on ANN can be found in [5] in this study ANN architecture is proposed , and compared to the K Nearest Neighbor. It was found that the proposed ANN provides a higher percentage of successful classification than the KNN classifier. All previous works have been carried out in frequency domain and did not consider the noise factor that may degrade the classification process. In this paper the classification process is performed in time domain and under different noise level masking the received signal. The main aim of the neural network is to transform the inputs into meaningful outputs. The ANN is trained with the available data samples to investigate the relation between inputs and outputs. In this study, backpropagation based Multilayer Perceptron (MLP) network was used. Because of its ability to generalize well on variety of problems.[5] the first layer of the network accepts input signals from the outside and passes these signals to all neurons in the second layer. Neurons in the hidden layer detect the features, associated the weights of the neurons in the input patterns.[5] These features then used by the output layer in determining the output pattern

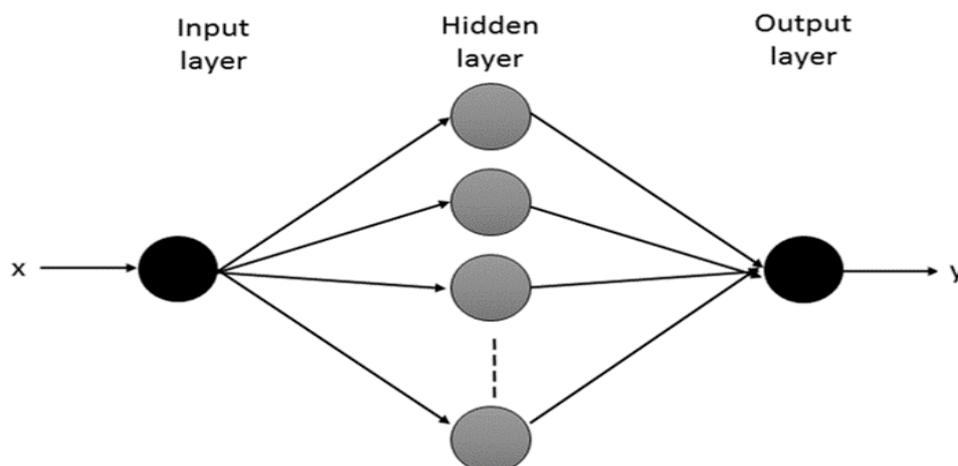


Figure 4: Neural network Model

Fig (4) show the proposed neural network model which consists of three layers, the first one is the input layer consisted of 1 neuron that accept the target signature detected by FSR in time domain. The hidden layer is represented by 20 neurons. The activation function used the hidden layer is log-sigmoid transfer function. Simulated noise is added to the FSR signal. White Gaussian noise have been selected in this study because it has been a common technique that experimented in many researches [5], several experiments have been carried out with different noise level, the SNR level range was from 100dbm to -39dbm

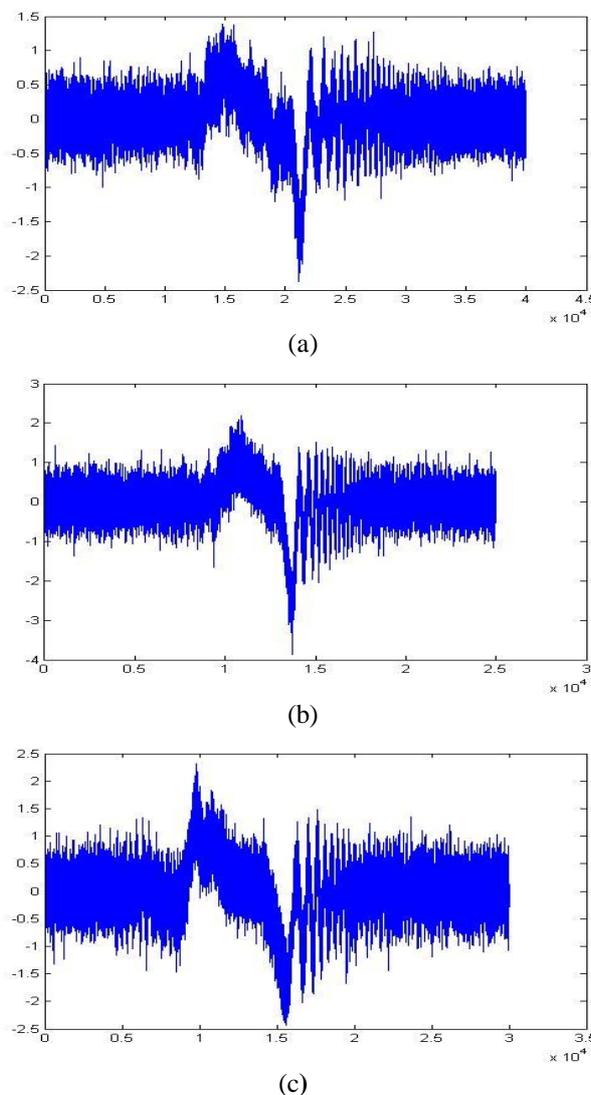


Figure 5: Time domain received FSR signals with SNR 2dbm (a) Astra (b) Combi (c) Traffic

4.1 Training and testing data

The data recorded during experimentation has been used as inputs to the ANN. ANN have to be trained and tested in order to be used for classification purpose. The training data is fed into the input layer to extract the input features these features are propagated to the hidden layer and then to the output layer. This is called the forward pass of the back-propagation algorithm. [5] The output values of the output layer are compared with the target outputs value. If the value is different, error is calculated and then propagated back toward hidden layer [5]. This error is used to update the connection strengths between neuron. In our research 70% of the input data has been used for the training phase, 15% for testing to test the trained network and 15% for validation these figures have been selected carefully taking into consideration processing speed and classification effectiveness

5. RESULTS AND DISCUSSION

After training and testing phase of the received FSR signal, ANN model is used for the classification process, provided that, the sample signals used for cars are almost with similar size and shapes. About 10 samples from each type have been tested .The evaluation and performance criteria for the classification effectiveness was the regression. Signals were processed in their original form as they were collected from the experiments with high SNR .Fig (6) shows the

classification results, from the figure the trained ANN successfully classify the input signals. The figure shows the successful classified targets represented in regression percentage combined all in one figure for all cars, the blue, orange and green colors represent the Astra, Combi and Traffic respectively. All the 10 samples per category have been classified successfully. Obviously the highest value of the regression occurs at high SNR and it degrades gradually to 0 as the SNR value approaches to 10dbm. At this point the high noise level mask the features of the time domain signals and hence complicate the classification process of the ANN model to recognize the input signals regardless of the training and testing samples as in Fig (5). However there are a marginal variance between the regression values between the different cars in the range between 5 to -16 dbm. As result in general the ANN classification performance degrades significantly as the signals goes below 0 dbm.

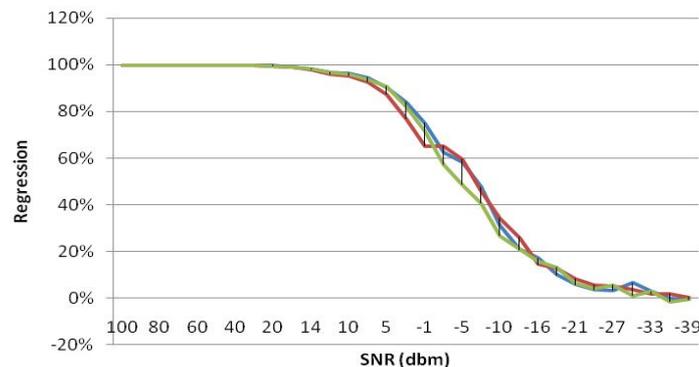


Figure 6: Classification results

6. CONCLUSION

In this paper the FSR ground target signals under the influence of simulated environment noise were successfully classified using the proposed method. It was found that classification using an ANN is robust against noise. This paper introduced FSR classification in time domain rather than frequency domain. The proposed technique can also be applied as part of the automatic classification algorithm for FSR. However, to realize FSR application, future work needs to investigate real environmental noise under different experimental scenarios techniques that can be used to enhance the classification process

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