Synthetic Environment for Forward Scattering Radar Software Development

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***Abstract*— There are a lot of measurement and analysis has been done by previous FSR researcher. The data collected from their experimental is very important to other FSR researcher. The needed of the program or software application such as Graphical User Interface (GUI) that can gather all the database of the experimental result for solving their routine problems such as repetition work done. This paper describes the Synthetic Environment for Forward Scattering Radar Software Development. The Design for Software Development is described. The system can estimate the performance and able to predict the signal strength under variety of environmental conditions and kind of targets.**

Keywords—FSR, scatter, radar, vhf, uhf, Syntetic Environment

I. Introduction

Synthetic Environment is a computer simulation that allow visualization and absorption into the environment being simulated during manufacturing process. There are three types of the Synthetic Environment (SE) which are Natural, Human-made and Psychological. The Natural Environment represent of all living species such as the as climate, terrain, rain, forest etc. In contrast, the Human-made environment represent of human made structures like buildings, car, roads, bridges etc. Lastly, the psychological environment represent of human individual or in group based on demography.

Clutter is defined as any objects that may produce unwanted radar returns to receiver of Radar. This will cause the interference in Radar Operations. A lot of study and analysis of the clutter with different parameters such as Operating frequencies, wind speed and baseline length.

Radar is the abbreviation for RAdio Detection And Ranging [1] and can be classified as mentioned in [2].One of the special type of Bistatic radar is the Forward Scattering Radar (FSR) where the distance of the target is very close to both transmitter and receiver baseline. The differences of this special type compare to Bistatic Radar as illustrate in Figure 1(a) and 1(b). Obviously in Figure 1 (b) the bistatic angle, β is equal or near to 180°.

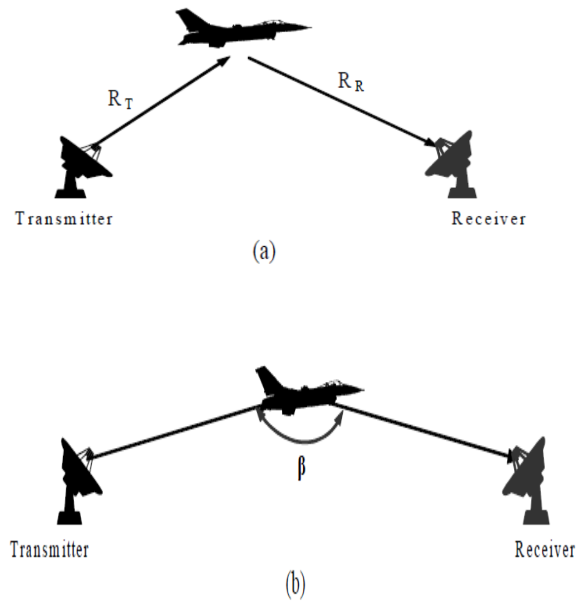

Figure 1: a) Bistatic Radar b) Forward Scattering Radar

The FSR Detection have been developed and discusses since 1999 in [3] and the principle and its architecture of FSR performance model well explain in [4]. This model has been used to predict several parameter such as the operating condition and frequency, the separation of the transmitter and receiver, the size of the target, the number of bits and error in Analogue to Digital Converter. The development of this model has no cost for hardware development. The researcher confirms the ability of the FSR in the detection and tracking of a small jet target in this study.

The analysis of FSR for ground target detection have been study in [10]. The power budget analysis and the cross-range resolution has been briefly by the researcher. It also proof that the distance between transmitter and receiver does not give an impact to split between two targets. In 2006, the study of the FSR current and Future Applications have been discussed in [5]. In this paper, the researcher successfully proof the concept of the vehicle-category classification by doing experiment and collect data of 850 car signatures. The result proof that the FSR system suitable for ground target detection.

In 2008, a simple model of vegetation clutter have been develop by the researcher in [8]. This vegetation clutter is come from the Natural SE. The researcher develop a model of tree by using pendulums. This oscillating pendulums has been proposed to predict the clutter properties. The clutter measurement were calculate with various Operating Frequency, VHF/UHF which are 69, 151, 433 and 869 MHz. The concept of a Forward Scattering Micro-Sensors Radar Network for Situational Awareness have been explain in [6]. The node network of the FSR sensor can detect the ground target. As for example a vehicles entering the network coverage area. The maximum baseline is around 150-200m for human targets. There are 4 items that the researcher represent to execute the experiment, which are the Signal Compression, Parameter estimation Resolution and also Through-wall vision.

Further investigation in [8] has been continued in [9]. This experimental used different operating frequency which are 64,135,173 and 434 MHz while the baseline is around 50-200m. The researcher successfully verify the measurement of the modeled the clutter signals and target Doppler and also the windblown vegetation clutter to enable detection of the performance analysis. The characteristic of simulated clutter envelopes, Power Spectral Density (PSD) and also Probability Density Function (PDF) has been simulated to measured clutter.

Recently, there are study on the Empirical Clutter Analysis for Forward Scatter Micro-Sensors in [11]. This analysis specifically focused on the operating frequencies, wind speed and also the different baseline length towards clutter. During experimental, the researcher still used same frequencies as in [9] but this time they used Forward Scatter Micros-sensors radar network system with the Omni-Directional antennas. No changes for the baseline distance compared in [9].

In this paper, the researcher maintained to capture the Doppler Signal for the respective frequencies and also the output signal, envelope, PSD, PDF and Weibull distribution. The researcher added another three more relationship between Clutter Power with Frequencies, Wind Speed and also Baseline Distances. Accurate results were reported where the Amplitude of the Doppler signals increasing when there are increasing of Frequencies and wind speed.

II. METHODOLOGY

The research will be conducted in three phases which are (i) Design Phase, (ii) Implementation Phase, and (iii) Evaluation Phase as shown in Figure 2.

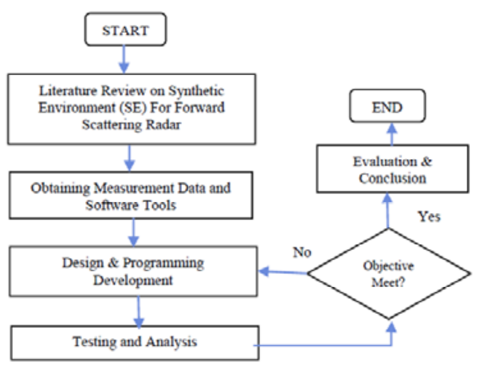

Figure 2 Flowchart Project

There are a few parameters limited to certain value such as Operating Frequency is limited to VHF and UHF Frequency which are 64,135,173 and 434 MHz. The baseline distance of the data measurement is vary from 50m to 200m.

The data measurement has been collected by previous researcher. All the measurement is subject to the availability of the parameter needed. MATLAB GUI act as the Software tools. The researcher will be using the collected data from previous researcher. This measurement data has been collected in a few places in United Kingdom (UK). The detail location and Synthetic Environment as per Table 1.

No.	Location	Environment
1	Horton Grange	Mix Vegetation
2	Malvern Hills	Hills
3	Airfield	Flat Terrain
4	Lickey Hills	Dense Wood

Table 1: Location of the Experiment

There are four categories for wind conditions which are low, medium, strong and very strong which indicated in Table 2.

Wind Category	Average Wind Speed (Km/h)
Low	<10
Medium	10-20
Strong	20-30
Very Strong	>30

Table 2: Wind Speed condition during Experiment.

III. SOFTWARE DESIGN DEVELOPMENT

The objective of this Software development is to develop a GUI program that can estimate the performance of the FSR using data collected and can predict the signal strength under variety of environmental condition and any kind of targets.

A. SE FSR Main Menu

The SE FSR Main Menu is for user to start the program. To run the Sefsr GUI, the user has to Start MATLAB and set path of the directory to where Sefsr code is stored. Typing Sefsr at the command window will execute GUI as shown in Figure 3.1

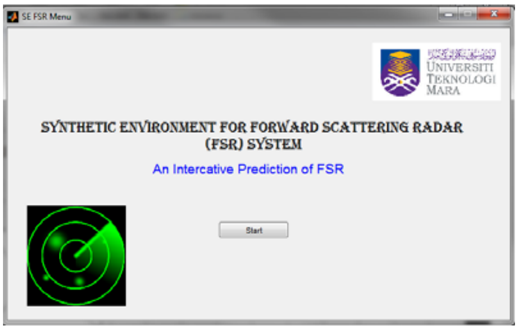

Figure 3.1 Sefsr Main Menu GUI

B. *Define Parameter & Output Menu*

This module is designed to collect the system parameters, target information and environmental data. It functions as a central database for the program, and converts each parameter to a suitable unit for subsequent computations. The drop down features will be dedicated to Operating Frequency, Wind Condition and also Environment Type. So the user can choose which parameter that they want to predict. Figure 3.2 shows the GUI layout designed for the module.

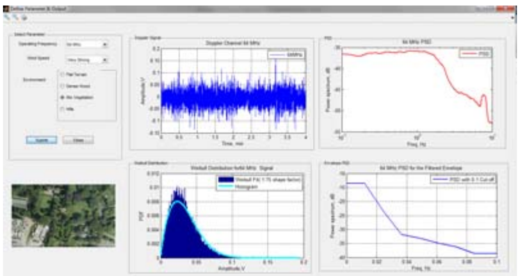

Figure 3.2 Define Parameter and Output GUI

C. *Close Confirmation Diaglog Menu*

This module is for the user to close the program confirmation. By clicking the Close button displays the modal dialog box as per shown in Figure 3.3.

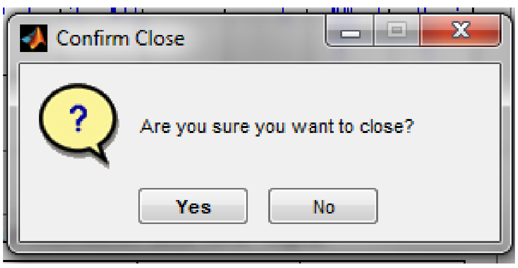

Figure 3.3 Close Confirmation GUI

IV. Clutter Simulation and Signal Processing

For the clutter simulation and Signal processing. It will discuss on Horton Grange due to the complex vegetation in surrounding therefore it has the strongest clutter. Other than that, the database for Mix Vegetation almost complete compare to other environment. In this section we will discuss on the generated Doppler signal, PSD, PDF and envelope for the lowest Frequency 64MHz and the highest frequency 434 MHz with different wind speed conditions. These two types of frequencies used in Communication equipment. The generated result shown in section A, B, C and D below.

A. *Frequency 64 MHz vs 434 MHz (Low Speed)*

Figure 4.1 and 4.2 present generated Doppler Signal, PSD, PDF and Envelope for Low Speed wind Condition taken from Mix Vegetation environment. It can be seen that, when the wind speed low, the highest amplitude for 434 MHz is 0.2 V while for 64 MHz is 0.13 V. As the frequency increased, the clutter amplitude will increase.

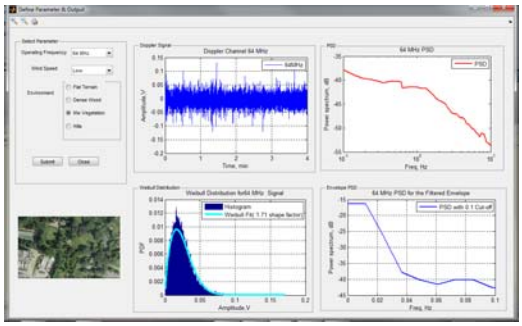

Figure 4.1 Generated Doppler Signal, PSD, PDF and Envelope, 64 MHz (Low)

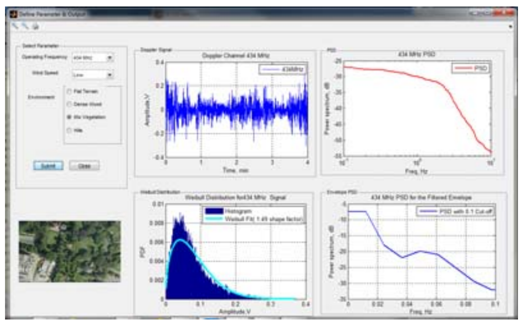

Figure 4.2 Generated Doppler Signal, PSD, PDF and Envelope, 434 MHz (Low)

For the power spectrum, it will be increased with the increases of the frequency. As shown in Envelope PSD, it has approximately 40 dB per decade slops. The total clutter power increased about 10 dB between 64 MHz and 434 MHz channels. It proof that the theory the clutter power increased as the frequency increase.

For the Histogram and Weibull PDF fits, for 64 MHz, the shape factor 1.71 while for 434 MHz, the shape factor 1.49. Thus with increases of the frequency, the degree of similarity to Weibull PDF decreased.

B. Frequency 64 MHz vs 434 MHz (Medium Speed)

Same as discussed before in section A, Figure 4.3 and 4.4 present generated Doppler Signal, PSD, PDF and Envelope for Medium Speed wind Condition taken from Mix Vegetation environment. It can be seen that, when the wind speed Medium, the average of the amplitude for 434 MHz is 0.6 to 0.9 V while for 64 MHz is 0.04 to 0.08 V.

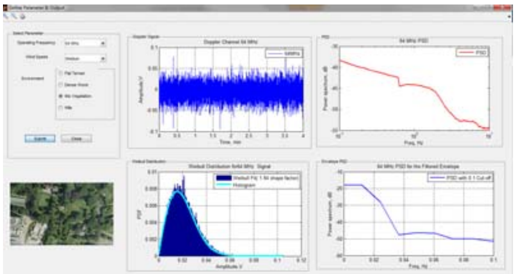

Figure 4.3 Generated Doppler Signal, PSD, PDF and Envelope, 64 MHz (Medium)

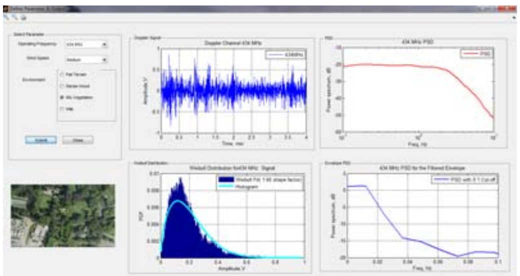

Figure 4.4 Generated Doppler Signal, PSD, PDF and Envelope, 434 MHz (Medium)

The Envelope PSD, it has approximately 40 dB per decade slops. The total clutter power increased about 15 dB between 64 MHz and 434 MHz channels in Medium wind condition. For the Histogram and Weibull PDF fits, for 64 MHz, the shape factor 1.94 while for 434 MHz, the shape factor 1.60.

C. Frequency 64 MHz vs 434 MHz (Strong Speed)

Figure 4.5 and 4.6 represent generated Doppler Signal, PSD, PDF and Envelope for Strong Speed wind Condition taken from Mix Vegetation environment. It can be seen that, when the wind speed Strong, the highest amplitude for 434 MHz is 2.0 V while for 64 MHz is 0.14 V. As the frequency increased, the clutter amplitude will increased.

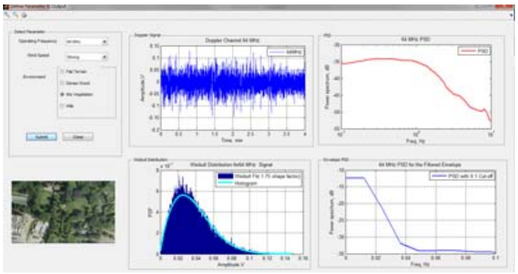

Figure 4.5 Generated Doppler Signal, PSD, PDF and Envelope, 64 MHz (Strong)

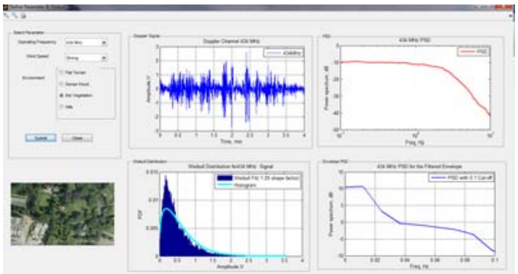

Figure 4.6 Generated Doppler Signal, PSD, PDF and Envelope, 434 MHz (Strong)

As shown in Figure 4.5 and 4.6 Envelope PSD, it has approximately 40 dB per decade slops. The total clutter power increased about 15 dB between 64 MHz and 434 MHz channels in Strong wind condition. For the Histogram and Weibull PDF fits, for 64 MHz, the shape factor 1.75 while for 434 MHz, the shape factor 1.29. Thus with increases of the frequency, the degree of similarity to Weibull PDF decrease.

D. Frequency 64 MHz vs 434 MHz (Very Strong Speed)

Same as discussed before in A, B and C section, Figure 4.7 and 4.8 present generated Doppler Signal, PSD, PDF and Envelope for Very Strong Speed wind Condition taken from Mix Vegetation environment. It can be seen that, when the wind speed Strong, the highest amplitude for 434 MHz is 4.0 V while for 64 MHz is 0.16 V. As the frequency increased, the clutter amplitude will increased.

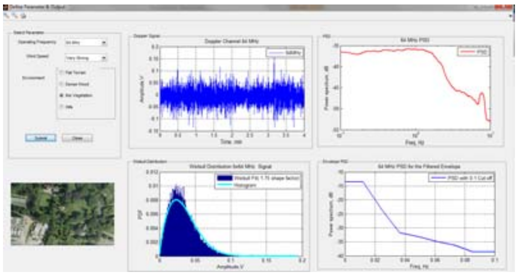

Figure 4.7 Generated Doppler Signal, PSD, PDF and Envelope, 64 MHz (Very Strong)

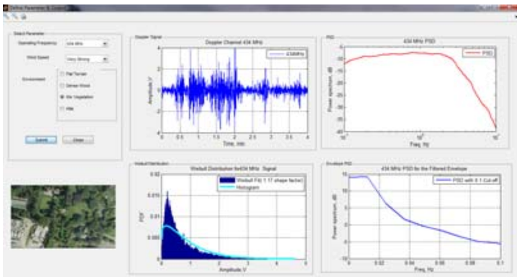

Figure 4.8 Generated Doppler Signal, PSD, PDF and Envelope, 434 MHz (Very Strong)

As shown in Figure 4.5 and 4.6 Envelope PSD, it has approximately 40 dB per decade slops. The total clutter power increased about 20 dB between 64 MHz and 434 MHz channels in Strong wind condition. For the Histogram and Weibull PDF fits, for 64 MHz, the shape factor 1.75 while for 434 MHz, the shape factor 1.17. Thus with increases of the frequency, the degree of similarity to Weibull PDF decrease.

V. Conclusions and Further Work

Compare the result from low wind speed with the strong wind speed for both frequency, it proof that the wind speed increased the clutter amplitude will also increase. The spectrum increased with the increased of wind speed. Once again, it proof that the wind speed gives the most influence to clutter which will affect the performance of the target detection.

We have shown that accurate results were reported where the Amplitude of the Doppler signals increasing when there are increasing of Frequencies or wind speed. Future research should improve the data collection in other environment such as flat terrain, dense wood and hills to update in the database of the sefsr system.

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