Simulation of Radar Architecture in MATLAB

M. Vishwaja[1], Deepti Agrawal[2], Dr. AK Singh[3], Dr.S.P. Singh[4]
[1]*PG Student, Mahatma Gandhi Institute of Technology, Hyderabad*
[2, 3]*Scientist's, Defence Research Electronics Laboratory, Hyderabad*
[4]*Professor, Mahatma Gandhi Institute of Technology, Hyderabad*

Abstract: Radar is used in Defence to map the presence and speed of aircrafts, missiles and other objects, which could prove to be of adverse nature to us. The Radar waveforms incorporate various methodologies to achieve this. Radars use different types of waveforms, each waveform with its own specifications, characteristics that depend on the desired application. In this paper, different types of waveforms used in Radar systems in different scenario were studied using simulation and Modelling of radar, which is simulated using Matlab and Simulink.

Keywords: Radar, Target, LFM, polyphase code, Matlab and Simulink.

I. INTRODUCTION

Today radar is being used for various applications and particularly in defence, it is being used extensively for battle field application. Security of the nation against the rival nations has become the most important requirement in the present day technically competent combat world. The national defence ministry and the military primarily aim at the utmost security of its citizens. Today the radar systems have a key role in the integral part of Electronic Warfare [1]. But the need to secure communications is much more pervasive than one might at first realize, and the threats are much more diverse. Radar is widely used to detect threats and multiple target handling. It uses low power consumption and low transmitting power. Radar provide superior penetration capability through any type of weather conditions, short and fast reaction time between target handling and ready to fire moment. It is easy to operate and hence highly mobile system [2].

II. RADAR WAVEFORM ANALYZER

The Radar Waveform Analyzer app is a tool for exploring the properties of various kinds of signals often used in radar and sonar systems. The following waveforms [3]:app lets us to determine the basic performance characteristics.

2.1 Comparing different waveforms using Radar waveform analyzer.

i) *Sample rate:* Specify the sample rate, in Hertz, as a positive scalar. The ratio of the Sample rate parameter to the Pulse repetition frequency parameter must be an integer. This is equivalent to requiring that the pulse repetition interval be an integer multiple of the sample interval.

ii) *Pulse width (s):* Specify the duration of each pulse, in seconds, as a positive scalar. The product of Pulse width and Pulse repetition frequency must be less than or equal to one.

iii) *Pulse Repetition Frequency (PRF):* Specify pulse repetition frequency (PRF) as a scalar or a row vector. Units for PRF are hertz.

2.1.1. Linear Frequency Modulation(LFM) waveform

A Linear FM waveform is a frequency modulated waveform with carrier frequency varying linearly with time for some specified period or within the pulse width [4].

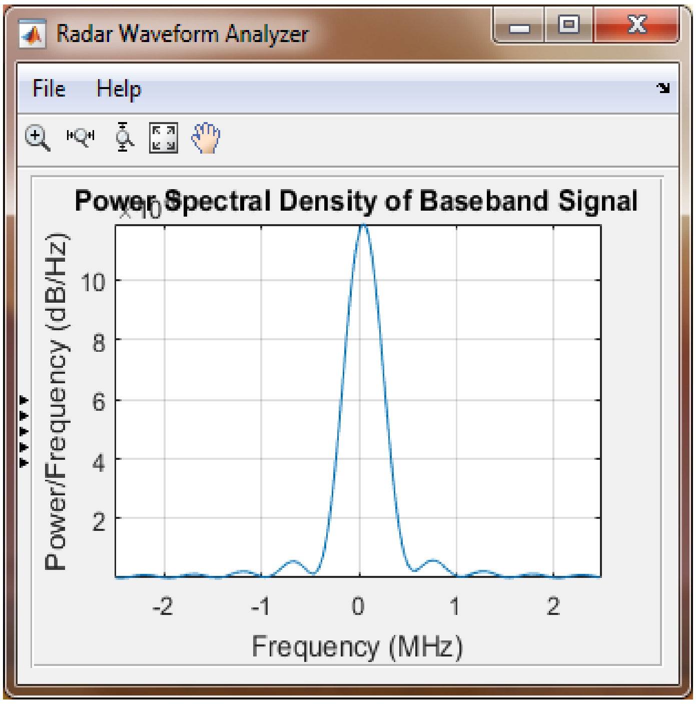

Fig.1 Linear FM Waveform

In Fig. 1 A linear FM waveform has been plotted in power spectral density of baseband signal varies with frequency(MHz) Vs power frequency(dB/Hz)with Range resolution -1.5km, Doppler resolution-25kHz and Duty cycle-10 percent.

In Fig.2 Linear FM waveform has been plotted in power spectral density of baseband signal varies with frequency(MHz) Vs power frequency(dB/Hz) with Range resolution-500m, Doppler resolution-25kHz and Duty cycle-25 percent.

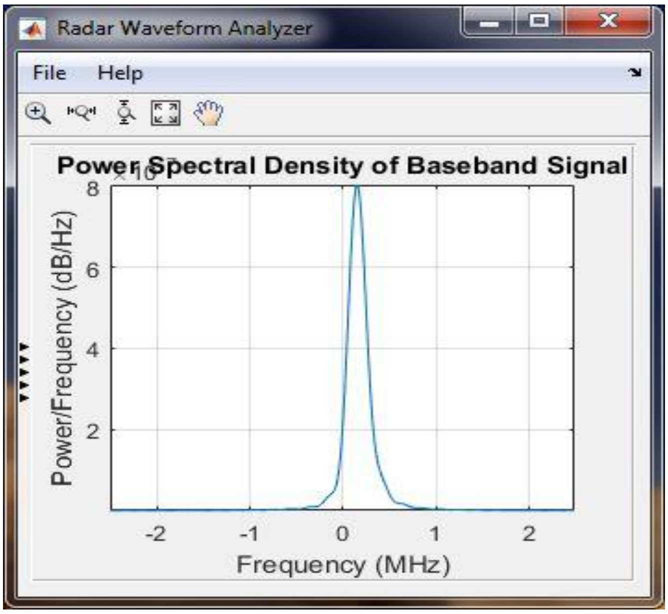

Fig.2 Linear FM Waveform

2.1.2. Phase coded waveform

A phase-coded waveform is a waveform in which the pulse is sub divided into sub pulses of equal duration, each with a specific phase. The phase of each sub pulse is owed to given code sequence [4].

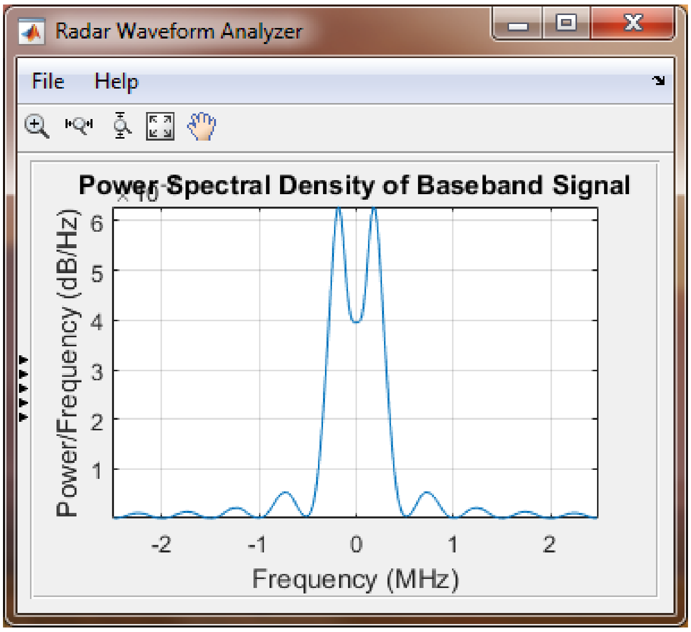

Fig.3 Phase Coded Waveform

In Fig.3 Phase coded waveform has been plotted with frequency (MHz) Vs power frequency(dB/Hz) with Rangeresolution-150m, Doppler resolution-25kHz and Duty cycle-5 percent.

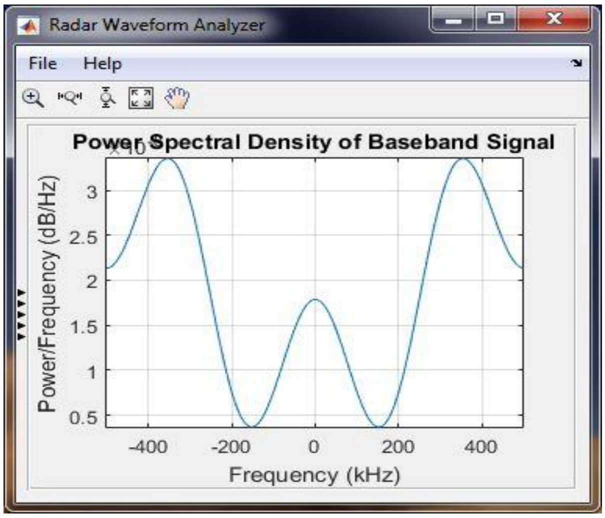

Fig.4 Phase Coded Waveform

In Fig.4 Phase coded waveform has been plotted with frequency (MHz) Vs power frequency(dB/Hz) with Range resolution-150m, Doppler resolution-5kHz and Duty cycle-1 percent.

2.1.3. FMCW waveform

A radar transmitting a continuous carrier modulated by a periodic function such as sinusoid or sawtooth wave to provide range data [4].

In Fig.5 FMCW waveform plotted in power spectral density varies with frequency (MHz) Vs power frequency (dB/Hz)with Range resolution-1.5km and Doppler resolution-5kHz.

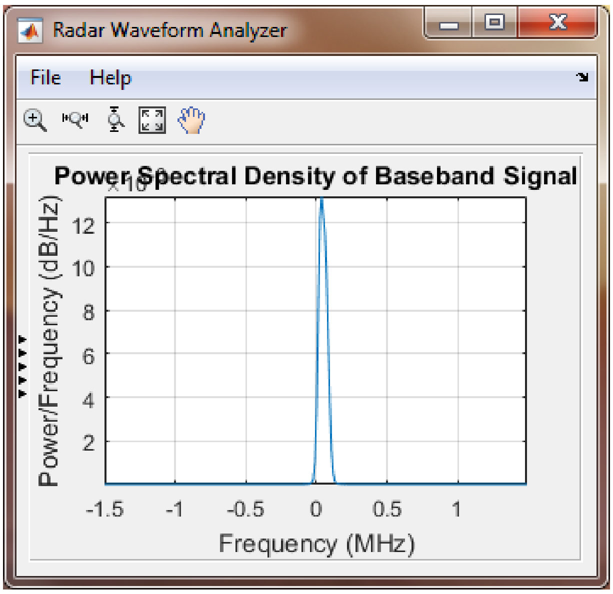

Fig.5 FMCW Waveform

In Fig.6 FMCW waveform has been plotted in power spectral density varies with frequency(MHz) Vs power frequency (dB/Hz) with Range resolution-1.5km and Doppler resolution-5KHz.

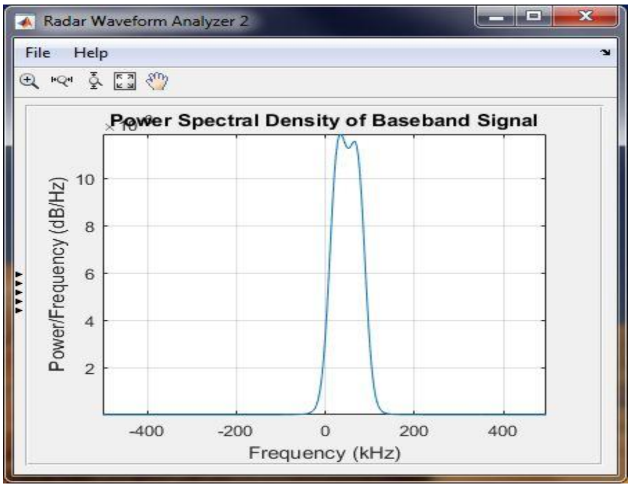

Fig.6 FMCW Waveform

Comparing different types of waveforms, we came to know that Linear FM waveform has high resolution and Duty cycle. So, we can consider Linear FM waveform for waveform generation in the design of high resolution Radar.

III. RADAR WITH TARGETS

The below Fig. 7 shows the Radar system model which is divided into three parts: the transmitter subsystem, the receiver subsystem, and the targets and their propagation channels. The model shows the signal flowing from the transmitter, through the channels to the targets and reflected back to the receiver. Range-Doppler modelling is then performed at the receiver to generate the Range-Doppler map of the received echoes [5].

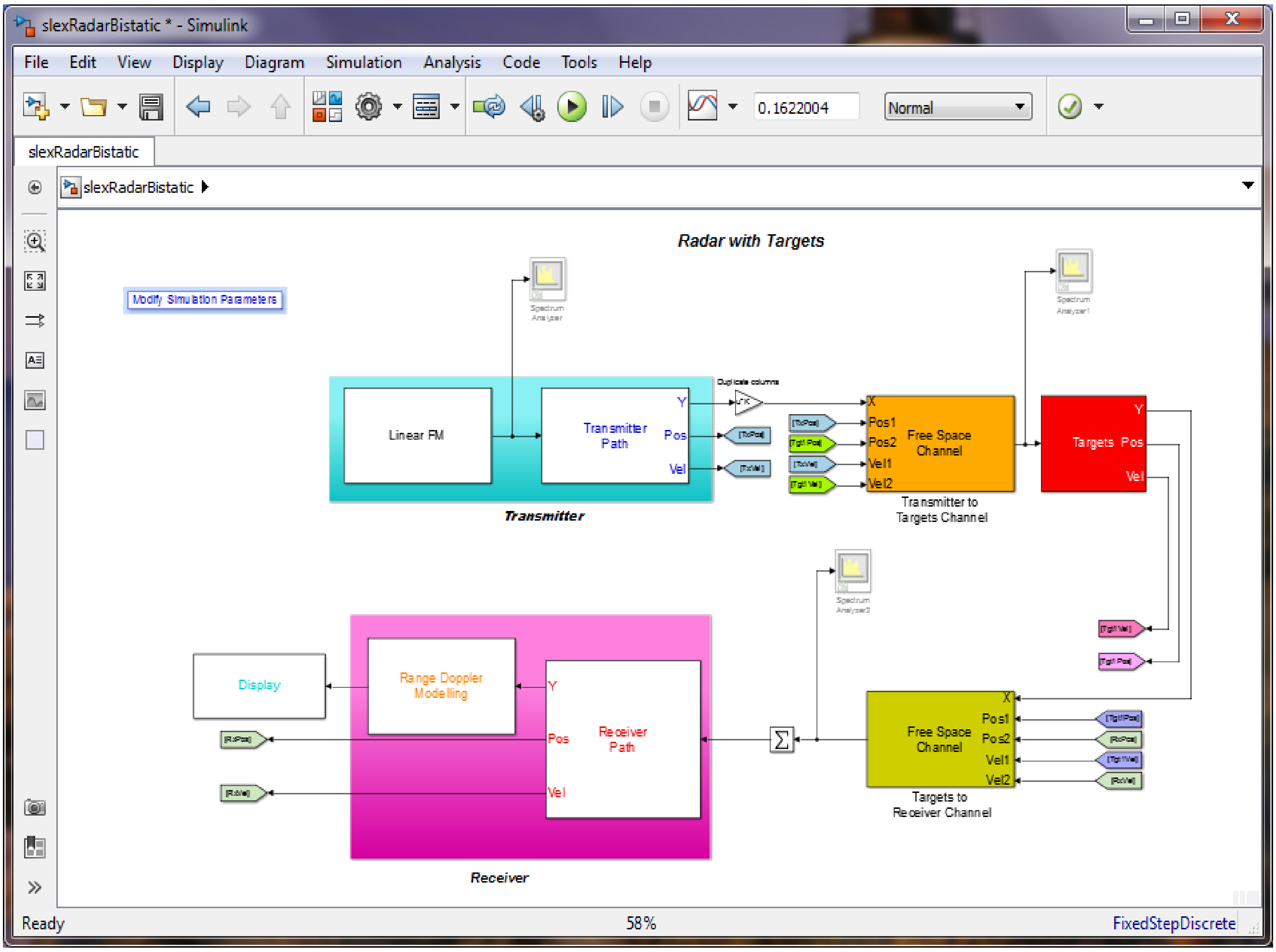

Fig.7 Radar model with Targets

3.1.Transmitter Path:

i)Linear FM - Creates linear FM pulse as the transmitter waveform. The signal sweeps a 3 MHz bandwidth, corresponding to a 50-meter range resolution.

ii)Radar Transmitter - Amplifies the pulse and simulates the transmitter motion. In this case, the transmitter is mounted on a stationary platform located at the origin. The operating frequency of the transmitter is 300 MHz as shown in Fig. 8.

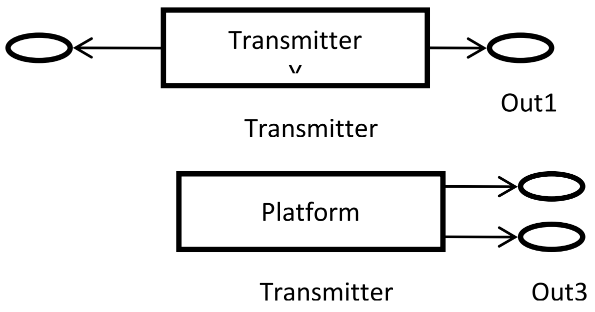

Fig. 8 Transmitter path

3.2.Targets:

This example includes two targets with similar configurations. The targets are mounted on the moving platforms as shown in Fig. 9.

iii)Transmitter to Targets Channel - Propagates signal from the transmitter to the targets. The signal inputs and outputs of the channel block have two columns, one column for the propagation path to each target.

iv)Targets to Receiver Channel - Propagates signal from the targets to the receiver. The signal inputs and outputs of the channel block have two columns, one column for the propagation path from each target.

v)Targets - Reflects the incident signal and simulates both targets motion. This first target with an RCS of 2.5 square meters is approximately 15 km from the transmitter and is moving at a speed of 141 m/s. The second target with an RCS of 4 square meters is approximately 35 km from the transmitter and is moving at a speed of 168 m/s. The RCS of both targets are specified as a vector of two elements in the Mean radar cross section parameter of the underlying Target block.

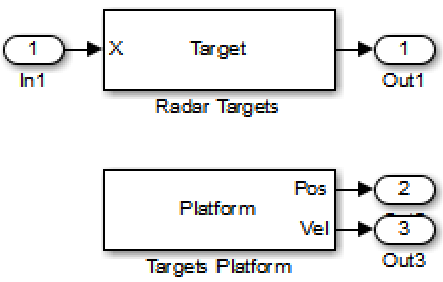

Fig. 9 Targets

3.3 *Receiver Path:*

vi)Radar Receiver - Receives the target echo, adds receiver noise, and simulates the receiver motion. The distance between the transmitter and the receiver is 20 km, and the receiver is moving at a speed of 20 m/s. The distance between the receiver and the two targets are approximately 5 km and 15 km, respectively as shown in Fig. 10.

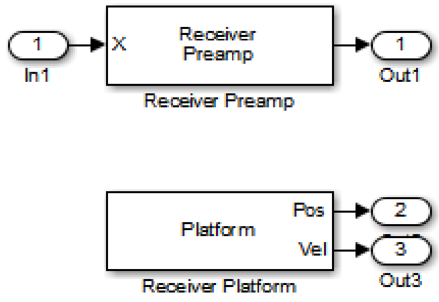

Fig. 10 Receiver path

3.4 Range-Doppler Modeling:

vii) Range-Doppler Modeling - Computes the Range-Doppler map of the received signal. The received signal is buffered to form a 64-pulse burst, which is then passed to a Range-Doppler processor. The processor performs a matched filter operation along the range dimension and an FFT along the Doppler dimension as shown in Fig.11.

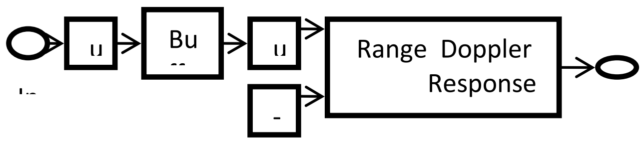

Fig.11 Range Doppler Modeling

3.5 Exploring the Model:

Several dialog parameters of the model are calculated by the helper function . To open the function from the model, click on Modify Simulation Parameters block. This function is executed once when the model is loaded. It exports to the workspace a structure whose fields are referenced by the dialogs. To modify any parameters, either changes the values in the structure at the command prompt or edits the helper function and rerun it to update the parameter structure.

IV. RESULTS AND DISPLAY

The Fig. 12 below shows the two targets in the Range-Doppler map. Because this is a radar, the Range-Doppler map above actually shows the target range as the geometric mean of the distances from the transmitter to the target and from the target to the receiver. Therefore, in Fig. 8 the expected range of the first target is approximately 3.7 km, ($\sqrt{15 \times 5}$) and for second target approximately 13 km, ($\sqrt{35 \times 15}$). The Range-Doppler map shows these two values as the measured values. Similarly, the Doppler shift of a target in a radar configuration is the sum of the target's Doppler shifts relative to the transmitter and the receiver. The relative speeds to the transmitter are -106.4 m/s for the first target and 161.3 m/s for the second target while the relative speeds to the receiver are

99.7 m/s for the first target and 158.6 m/s for second target. Thus, the Range-Doppler map shows the overall relative speeds as -6.7 m/s (-24 km/h) and 319.9 m/s (1152 km/h) for the first target and the second target, respectively, which agree with the expected sum values[5].

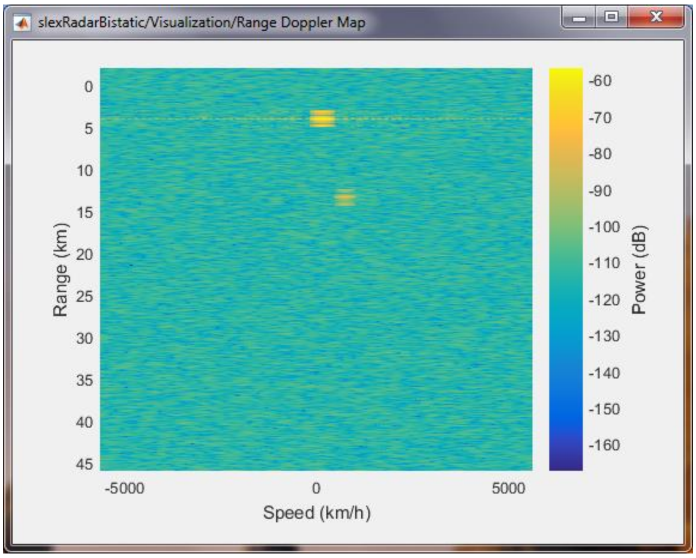

Fig. 12 Range Doppler Map

In Simulation of Radar with Targets we use spectrum analyzers at Transmitter path, Transmitter to targets channel, and Targets to receiver channel to know how the waveform is generated and effected with noise from transmitter to free space channel and free from noise from targets to receiver channel.

In Fig. 13 shows A Linear FM waveform generation varying with frequency and time.

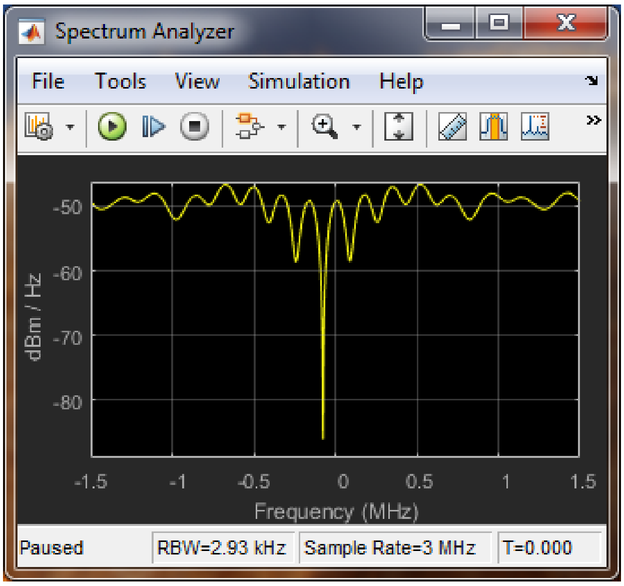

Fig: 13 Linear FM Waveform

A Linear FM waveform when transmitted through a transmitter to free space channel it is affected with noise during channel modulation as shown in Fig. 14.

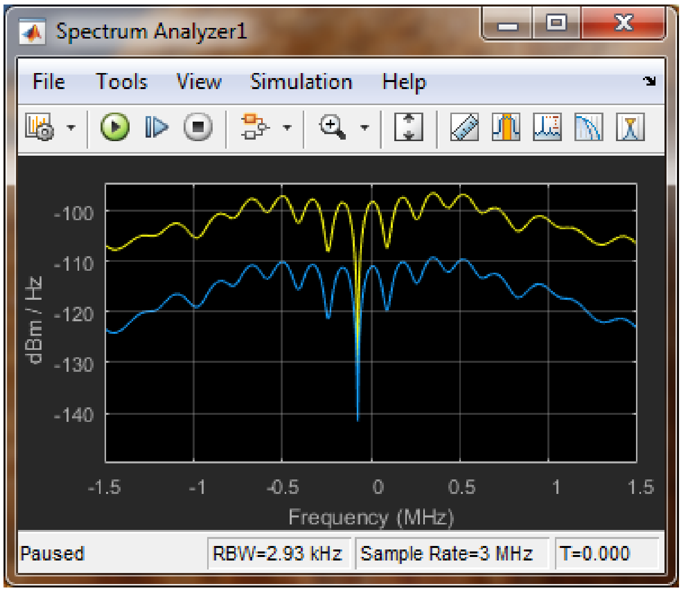

Fig. 14 Linear FM Waveform Affected with Noise Signal.

As shown in Fig. 15 A Linear FM waveform from targets to receiver channel is free from noise during receiver modulation.

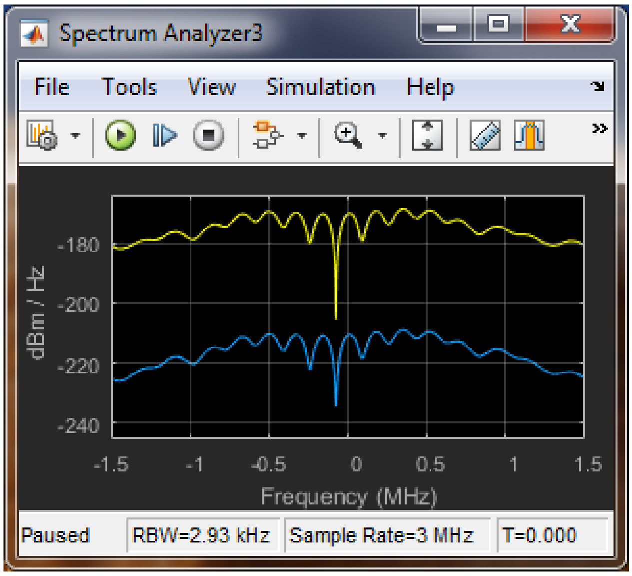

Fig. 15 Waveform Free from Noise Signal.

V. Conclusion

Modelling and Simulation of Radar Architecture in Simulink and Matlab is more easy than Radar to be implemented in hardware. The simulation of radar will facilitate to understand radar and its uses in various conditions. The radar simulator will have option to change its parameters like modulation technique, power, resolution, etc. and enhance its performance.

VI. REFERENCES

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Author Information:

Ms. M .Vishwaja obtained her B.Tech degree in ECE Department from M.C.E.T Hyderabad. Presently, she is a PG student in ECE Department, MGIT, Hyderabad, India.

Dr. A.K. Singh was born in 1969 at Ranchi (Dist) of Jharkhand State, India. He Graduated in Electronics and Communication (ECE) from Institution of Engineers (India), Calcutta in 1993 and M. E. in Digital System (ECE) from Osmania University in 2003. Subsequently he has completed his PhD in signal processing from Osmania University, Hyderabad in 2014 under guidance of prof K. Subba Rao. He joined Defence Electronics Research Laboratory (DLRL) in 1996 after completing his Electronics Fellowship Course at Institute of Armament Technology (IAT), Pune. He has worked on Frequency Receivers for radar EW systems. Currently he is Scientist-'F' and Group Director of Digital Signal Processing. He is leading a team working on design & development of real time Digital Receiver, which is being used for tri-services including UAVs and satellite. He is fellow member of IETE, Member of IEEE, member of Institution of Engineer India (IEI), Member of Association of old Crow (AOC). He has published 25 papers in National & International conferences and 5 papers in National Journal. He has received various DRDO awards for his scientific work.

Dr. S P Singh was born in Ghaziabad (U.P), India. He received Master's and Ph.D degree from Osmania University. He worked for 18 years in the field of radar maintenance. Presently he is working as Professor and Head, Dept of ECE Mahatma Gandhi Institute of Technology, Hyderabad. He has published 75 research papers in journals/ conferences. He is member of IEEE, Life member of ISTE (I), IE (I), and Fellow life member of IETE (I). His current interests are radar signal design and digital signal processing.

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