Implementation of Simulated Radar Target at Baseband

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***Abstract*—For performance evaluation of radar system many times real targets are not present to enable users to test the performance of the system. In order to facilitate radar system to test its performance in the situation when real targets are not present target simulation provides the solution. Proposed digital design has been implemented to simulate target at signal level for evaluating the radar receivers in the absence of real scenario target. This design helps to simulate stationary as well as moving target signals. Target is simulated digitally at baseband level for a particular target of known velocity. The information of the target in terms of range, velocity and number of targets is sent by radar controller to exciter/receiver (ER) controller. ER Controller computes the phase change on pulse to pulse basis and this phase change information is passed to the digital logic. According to the phase change information the radar waveform is generated which is shifted with the desired phase corresponding to the doppler. After a particular delay corresponding to the target range, this waveform is generated and fed to receiver section of radar.**

This concept is designed in MATLAB Simulink and is implemented on XILINX Virtex-2 FPGA. Simulated Target waveform is generated at baseband and digitally up converted. After RF up conversion it is looped back at receiver front end where it is RF down converted. Then Digital Down Conversion (DDC) is performed and data is sent to Signal Processor (SP) for the analysis and verification of the results using pulse compression and coherent integration.

This design is useful as it facilitates the radar receiver to be tested and evaluated as a standalone unit in the absence of real target. Using this design complete transmit and receive chain of exciter and receiver unit can be tested in the lab and also in the field as a standalone unit.

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***Keywords*— Target, Doppler, receiver, baseband, IF, RF.**

I. INTRODUCTION

The main idea behind this design is to enable the radar system to test and evaluate its transmitter and receiver performance in the absence of real target. For the radar target simulation two most important parameters those can be simulated are changing range and doppler. This can be implemented in many ways. One concept is RF bite in which variable attenuator controlled by digital control value can be implemented in order to simulate range of target. Other way is to simulate target after digital I, Q data has been generated by receiver, to insert target data at signal processor level. Another way is to simulate target at signal level i.e. waveform generation level. In the present paper this technique is used in order to simulate target. In the pulsed radar a constant velocity target will be resulting into constant pulse to pulse phase shift. This concept is utilized in the present design. In order to simulate the target, pulse to pulse phase shift is calculated based on the target velocity and that is given to the exciter/receiver (ER) controller by the radar controller. Phase shift logic is implemented at waveform generation stage. Modulated waveforms can be generated in digital domain by using sample to sample phase relationship and can be implemented using matlab and other tools like Xilinx. In order to generate radar target waveform first IF up conversion can be done digitally depending upon system clock frequency.

In order to down covert, RF is brought down to a level for digitisation from which baseband signal with phase shift can be recovered.

II. DESIGN METHODOLOGY

The basic design of the simulated target consists of phase shift logic. The logical block diagram of phase shift logic is shown below in Fig 1. The phase is computed by the controller according to the target velocity. To simulate the velocity this phase value needs to be shifted pulse to pulse in the pulsed radar. To simulate the target it will be assumed that radar waveform is transmitted with no phase shift with respect to reference and after getting the echoes from the target there will be some phase shift with respect to the reference. To simulate, phase shift will be introduced in the Idata and Qdata of radar waveform, as given below:

Let,

Θ = Phase of transmitted radar waveform

ϕ = Phase introduced due to target motion in receive waveform

So,

IRAM samples value = $\cos \Theta$

QRAM samples value = $\sin \Theta$

And,

In phase component of target phase = $\cos \Phi$

Quadrature phase component of target phase = $\sin \Phi$

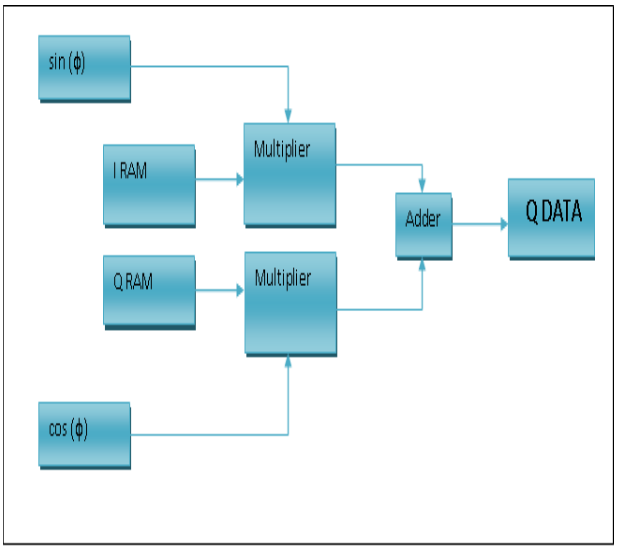
Hence,

$$\text{Final value of QDATA} = \sin \Phi * \cos \Theta + \cos \Phi * \sin \Theta = \sin(\Theta+\Phi)$$

And,

$$\text{Final value of IDATA} = \cos \Phi * \cos \Theta - \sin \Phi * \sin \Theta$$

$= \cos(\Theta+\Phi)$



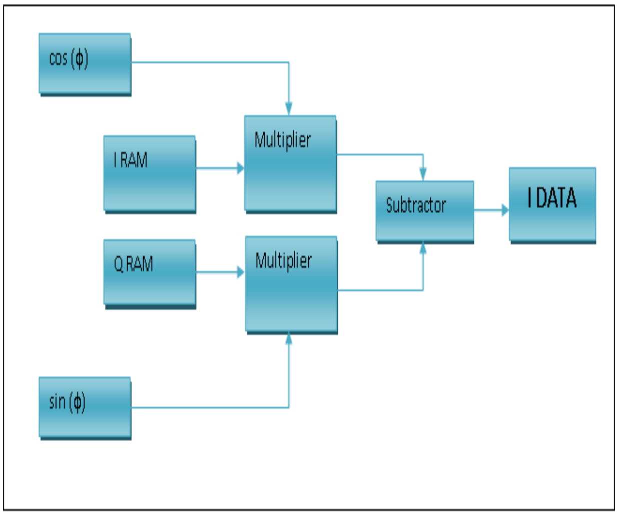


Fig.1 Block Diagram of I data and Q data generation for required phase shift

IDATA and QDATA are used for generating radar signal at required frequency band as if it is returning from target. using above concept radar signal was generated at required intermediate frequency (IF) band using digital up conversion.

The design of the radar simulated target at baseband is performed using above concept with DUC and DDC in Matlab. The above techniques were implemented using Matlab Simulink and Xilinx System Generator Tools and tested on Xilinx Virtex2 FPGAs.

III.IMPLEMENTATION OF RADAR TARGET GENERATION LOGIC

The radar target can be generated at RF level as well as at baseband level. Here the logic is implemented to generate the simulated target at baseband level. As shown in the block diagram for radar waveform I and Q values are calculated offline, this I and Q values are modified as per the phase value given by the controller using phase shift logic as explained in previous section This phase shift value is calculated by radar controller according to the velocity of the target. For a constant velocity moving target pulse to pulse phase shift will be constant. In this implementation technique the transmit pulse is divided into no of sub pulses of same duration. The phase shift is implemented at sub pulse level.

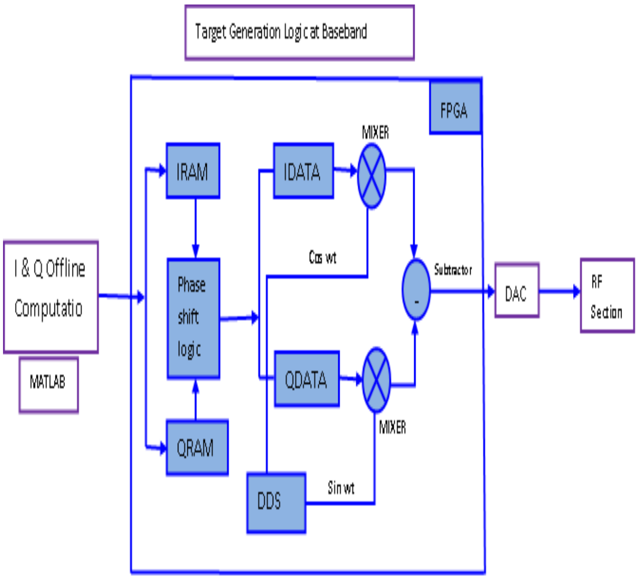


Fig 2: Target generation logic at baseband

The I & Q values are computed offline, phase shift logic is applied according to target properties i.e. velocity, and DDS is tuned to generate waveform (discrete signal of single tone) in order to provide first level up conversion i.e. digital. Controller determines the pulse and sub pulse duration and phase shift value and these can be programmed online. DDS parameters are chosen in order to generate waveform in digital domain which is used to get first stage frequency up conversion digitally. After DAC the RF section is used to up convert the generated waveform at required band in order to generate final radar waveform with required phase shift in analogue to the echo returned from moving target.

All the logic bocks highlighted in blue in Fig 2 are implemented in Matlab Simulink model using Xilinx System Generator block sets.

The Simulink model implemented is shown in Fig 3.All the blocks in blue in the model are the logics which are programmed into the FPGA. Using phase shift logic, required phase shift value is introduced at baseband level after that digital up conversion is performed in order to generate radar waveform which is up converted to required frequency band.

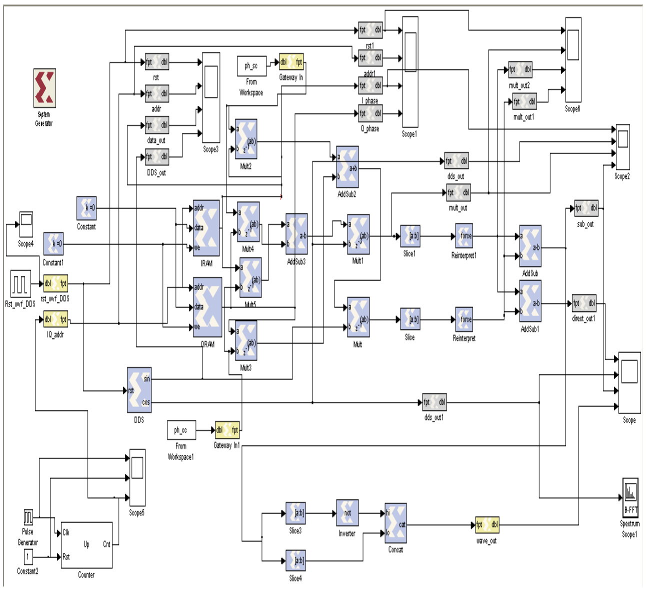


Fig.3 Implementation of Simulated Target Generation Logic in Matlab Simulink

In receive chain the returning echo is received at RF band. Two stages down conversion is applied to bring the frequency to IF level followed by Digital Down Conversion. After Digital Down Conversion data is sent to Signal processor unit to analyse and verify the results.

IV. RESULTS

The above design has been verified with different velocity of target. Different velocities correspond to different phase shift values of echo signal. The functionality of above design was tested using a test setup shown in Fig.9. The Controller receives burst parameters from the Radar Controller. The Controller in the Exciter/Receiver unit configures all the digital cards through the VME bus using DMA transfer of data from burst to burst. Based on the radar target velocity, the phase shift value is calculated by radar controller and is given to the phase shift logic. The waveform generator module generates the phase shifted radar waveform. This waveform was up converted to required band and looped back to RF receiver for RF down conversion.

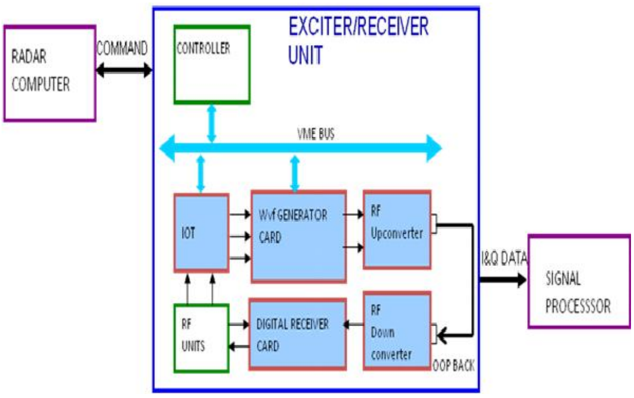


Fig.4Test setup for testing phase shift logic

After this digital receiver performs digital down conversion. The data is then packed and sent to the Signal processor. Different coherent integration plots are shown below for different phase shift values. According to the phase value the response can be seen in different filters in coherent integration plot as shown in figure 5 and 6.

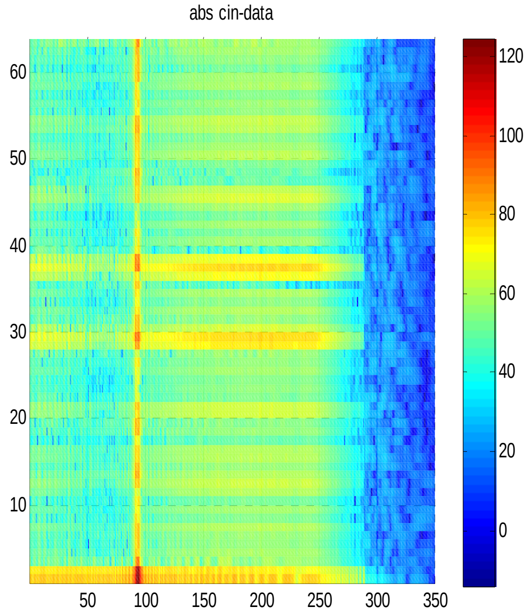


Fig.5 Coherent Integration plot for stationary target (phase shift is 0 degree)

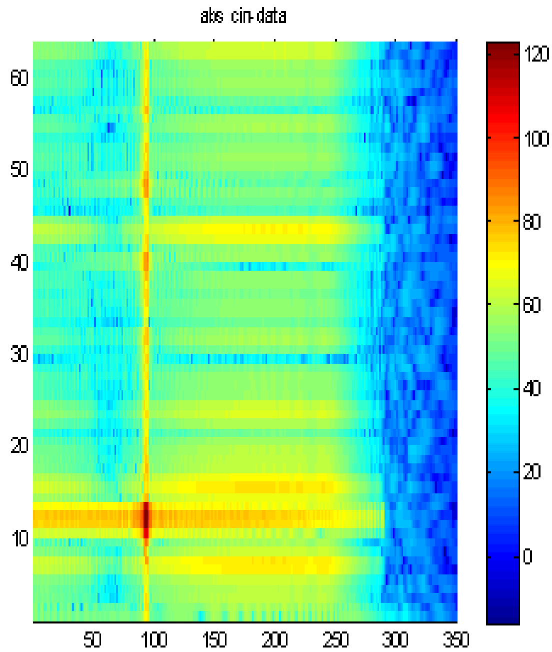


Fig 6 Coherent Integration plot for moving target (phase shift is 60 degree)

For the verification of the injected target coherent integration is performed on the digital samples of simulated target. By checking the filter response in coherent integration plot phase shift values can be verified. This phase shift value for pulse to pulse phase is given by,

Filter No. = Phase shift value of target / (360°/ Total no. of Pulses) + 1

Two cases are taken in above test. In first case, phase shift value is 0 degree i.e. target is stationary.

So according to above formula CI response will be appearing in the filter no. = 0/(360°/60)+1 =1
In second case, phase shift value is 60 degrees i.e. target is moving.

So according to above formula CI response will be appearing in the filter no. =60/(360°/60)+1 =11
From above coherent Integration plots it is clear that results are as per expectations.

CONCLUSION

This radar target simulation technique can be used for standalone testing of the radar system when real target is not available. Further, digital technique can be implemented for target cross section simulation using variable digitally controlled attenuator at baseband or IF level.

REFERENCES

[1] M. I. Skolnik, *Radar Handbook*, 3rd Edition, New York: McGraw-Hill, 2008.
[2] Phillip E. Pace, *Advanced Technique for digital receivers*, Artech House, 2000.

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