Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 121 (2019) 48-58 EISSN 2392-2192

Implementation of Signal Processing Unit for Laser Range Finder

Ran Vijay Singh[1,a], Devendra Chack[2,b], Sushil Kumar[3,c]

[1,2]Department of Electronics, Indian School of Mines, 826004, Dhanbad, India

[3]Instruments Research & Establishment Organization, D.R.D.O. 248008, Dehradun, India

[a-c]E-mail address: 92ranvijaysingh@gmail.com , devendra.chack@gamil.com , sushil@irde.drdo.in

ABSTRACT

Detection of the range of a target using laser range finders requires filtering of incoming data in real-time which can be achieved by a dedicated hardware to meet demanding time requirements. In this paper efficient filter structure which is the combination of constant false alarm rate (CFAR) and pipelined least mean square (LMS) adaptive filtering technique used to create solution for various adaptive filtering problems. Cell averaging (CA) CFAR and automatic censored cell averaging (ACCA) CFAR algorithm are fused separately with the adaptive filter in order to filter the incoming signal so that the detection of the of a target can be achieved through peak detection unit and accordingly range can be calculated. The design with CA-CFAR fused with PLMS filter is synthesized and implemented on a Xilinx Virtex4 FPGA with 32 MHz clock using Xilinx ISE software. Other design with ACCA-CFAR combined with PLMS filter is modeled and simulated in MATLAB simulink.

***Keywords*:** Laser Range Finder, CFAR detector, PLMS Filter

1. INTRODUCTION

Laser range finder utilizes laser beam to determine the distance or displacements without physical contact of an object. Basic mode of operation of laser range finder is based on the principle of time of flight (ToF) concept. Principle of ToF is based on sending a narrow beam

(Received 02 February 2019; Accepted 16 February 2019; Date of Publication 17 February 2019)

of laser pulse towards the object and measuring the time taken by that pulse to be reflected off the target and returned to the sender [1]. As light is an energy source, the relevant parameter involved in range estimation is the speed of light.

According to the phenomena the measured time represents the pulse travelling twice the distance and must, therefore, be reduced by half so as to provide the actual range to the target. If "d" is the distance of target from range finder, "n" is average refractive index of air for laser wavelengths used, light velocity is "c", and the time taken for to- and fro- path is given by the relation.

$$t = 2\,d\,n\,/\,c \tag{1}$$

Range accuracy depends on how precisely time "t" is measured. The advantage of the ToF system arises from the direct nature of its sensing as both the transmitted and returned signals follow essentially the same direct path to an object or target and back to the receiver [2].Due to noisy and uncontrolled environmental conditions deploying a fixed threshold can yield undesirable results. This paper is modeled for the betterment of the signal processing unit of laser range finder. As the signal processing unit is the key component of the LRF it should be accurate, less complex and resource efficient. This false detection can be controlled by using a CFAR technique which provides the threshold adaptability based on local information of total noise power [3].

There are number of CFAR techniques employed according to the environmental conditions that are given in radar literature based on type of environment [4-5].

The authors have developed a model which is versatile in nature i.e. it's not dependent on environmental parameter and robust in every sense. To make the model versatile two CFAR algorithms, CA-CFAR and ACCA-CFAR are separately fused with LMS adaptive filter. In order to analyze the behavior of the aforementioned algorithms on the whole system for ranging purpose are discussed in the following sections.

2. MATERIAL AND METHODS

There are numerous techniques to detect the targets based on the type of environment in which the detection is to be done and one of the most popular among them are the algorithms based on the concept of threshold, commonly known as CFAR algorithms [6]. A false alarm is caused by interference of noise with the signal of interest and the resultant signal exceeding the threshold selected.

If the background against which targets are to be detected is constant with respect to space and time then a fixed threshold level can be chosen that provides a specified probability of false alarm ruled by the probability density function of the noise which is usually expected to be Gaussian. The probability of detection is then a function of the signal-to-noise ratio of the target return. For different situations in radar applications various CFAR algorithms [7, 8] have been developed.

Basic CFAR technique is shown in Fig. 1. These different CFAR algorithms are developed to increase the probability of target detection under numerous environmental conditions, especially to deal with two of them: (i) region of clutter transitions and (ii) multiple target situations.

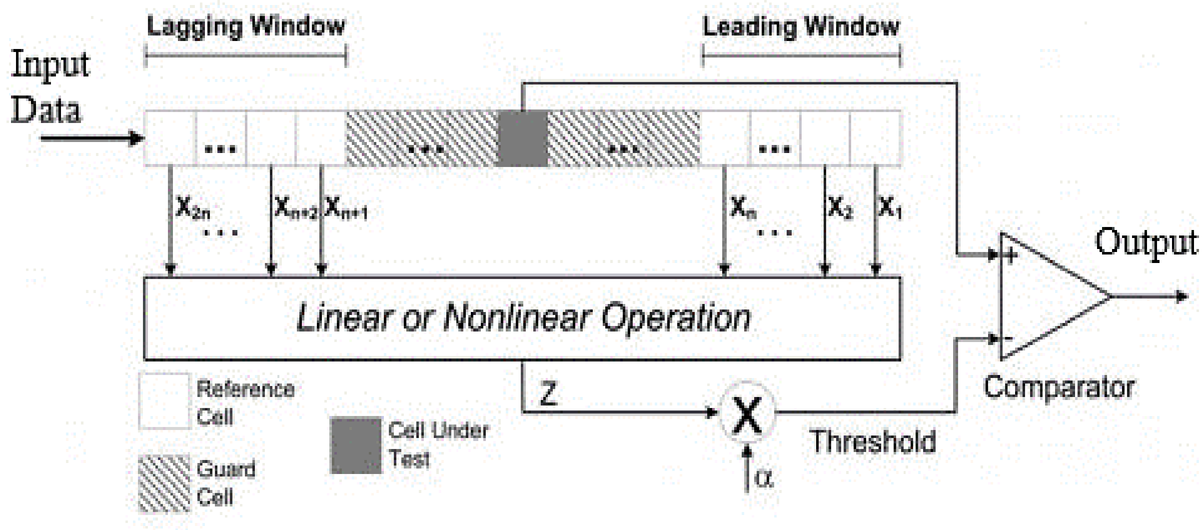


Figure 1. General block diagram of a generic range CFAR processor.

Two types of CFAR techniques that are utilized in this work are as follows:

(A) Cell averaging CFAR (CA- CFAR): Cell averaging technique involves taking the average of all the samples and then combining it with a constant is used to compute a decision threshold whose value is then compared with that of the cell under test (CUT). Hence the presence of target is determined. The cell averaging processor is the optimum CFAR processor in a consistent background when the reference cells contain independent and identically distributed (IID) observation that is dictated by an exponential distribution [9].

(B) Automatic censoring cell averaging CFAR (ACCA-CFAR): This technique ranks the ordered samples and then performs ordered data variability (ODV) based hypothesis in order to determine the decision threshold. In practice the environment is inhomogeneous because of the presence of multiple targets and clutter edges in the reference window which consists of a finite number data samples in the received signal. Hence the OS detectors have found to be useful as long as the non-homogenous and outlying returns are properly discarded. The advantage associated with this detector is that it neither requires any prior information about the clutter parameters nor requires the number of interfering targets [10].

In real time situations the background noise is modeled using various techniques. Some modeling techniques model noise in homogeneous conditions while the other techniques model noise in heterogeneous conditions. The proposed system attempts to overcome the problem of the negative effects of noise on the data samples by employing a couple of variants of constant CFAR algorithm for both homogenous and heterogeneous backgrounds, respectively.

The two techniques that are accounted here are CFAR and adaptive filtering. The former which is generally used in RADAR systems quite extensively is fused with the latter in order to provide the required results. The proposed system is shown in Fig. 2.

Models shown in Figs.3-4 are developed in MATLAB simulink platform.

CA-CFAR simulink model shown in Figure 3 also employs a recursive least squares (RLS) adaptive filter. It is used to compare the performance of both the filters when the output of the CFAR is applied to these filters Fig. 4 shows the ACCA-CFAR model.

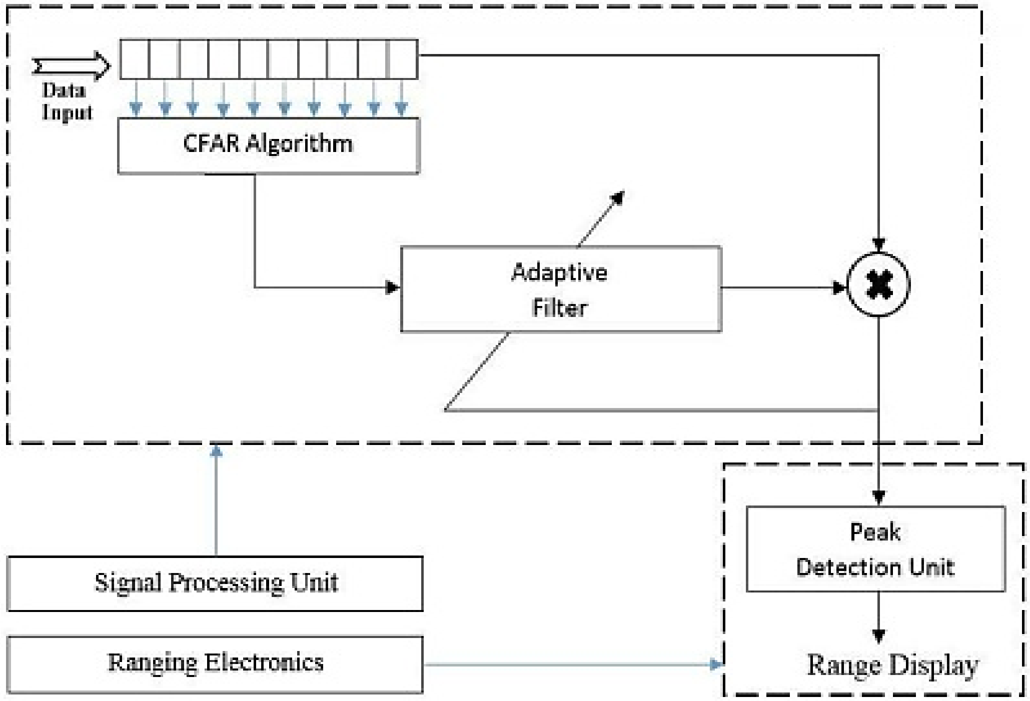


Figure 2. Proposed system showing fused CFAR and adaptive techniques.

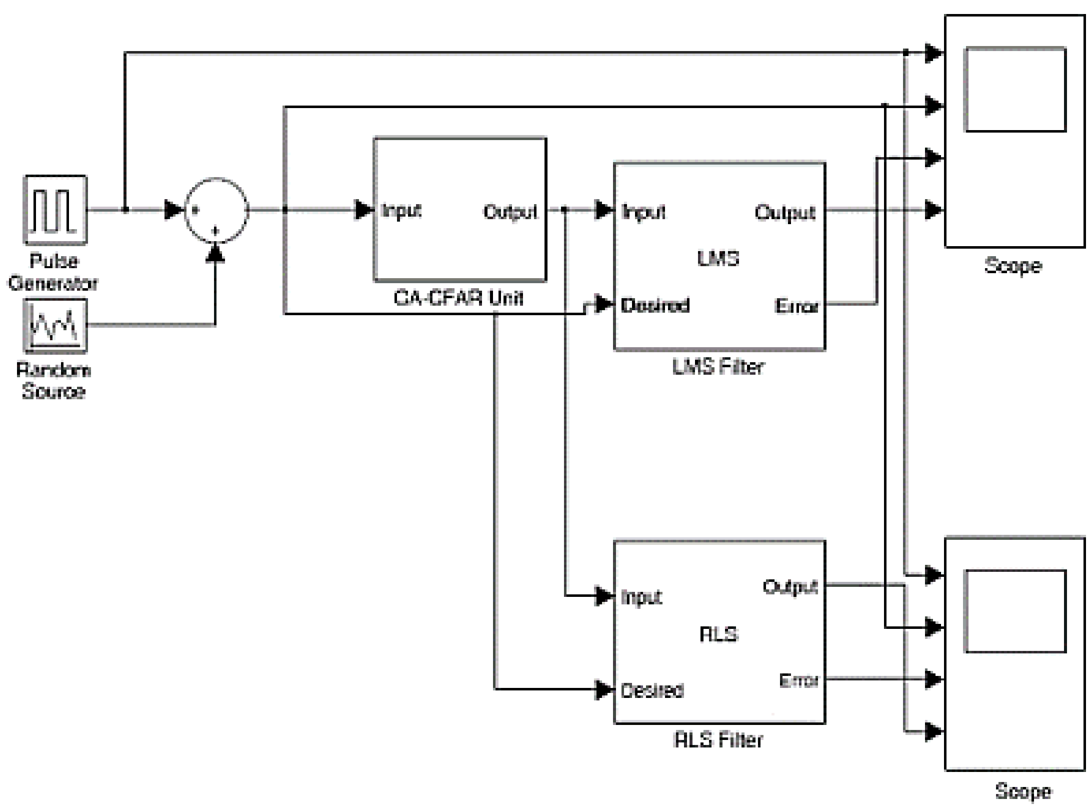


Figure 3. Simulink model of proposed system for the implementation of CA-CFAR fused technique.

The censoring block provides the estimated noise value to the adaptive filter which is achieved by automatic censored cell averaging algorithm. This algorithm can be easily understood by going through the literature [11]. It is also to be noted that the ACCA algorithm in this model has been developed for a specific value of data and P_{fc} both of which are important design parameters.

It is deduced from Figs. 5-6 that the filter accompanying the RLS algorithm does not have as promising results compared to that of the filter using LMS algorithm. That is why the LMS filter is utilized further for better results. The step size of the LMS filter can be decreased but at the cost of slow convergence. LMS filter is taken under the consideration of implementation process due to the less complexity of FIR filter structure than that of IIR filter structure utilized in RLS filter.

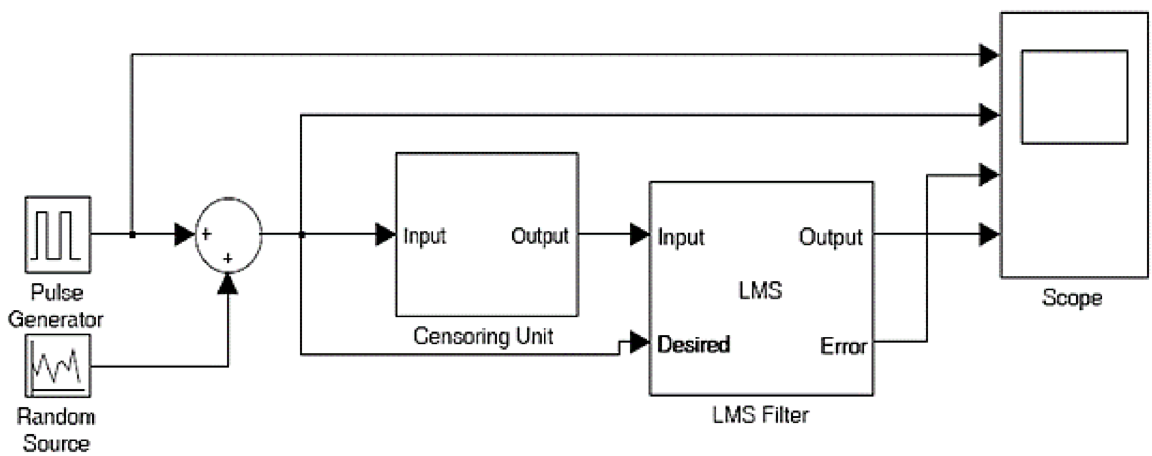


Figure 4. Simulink model of proposed system for the implementation of ACCA- CFAR technique.

3. RESULTS AND DISCUSSION

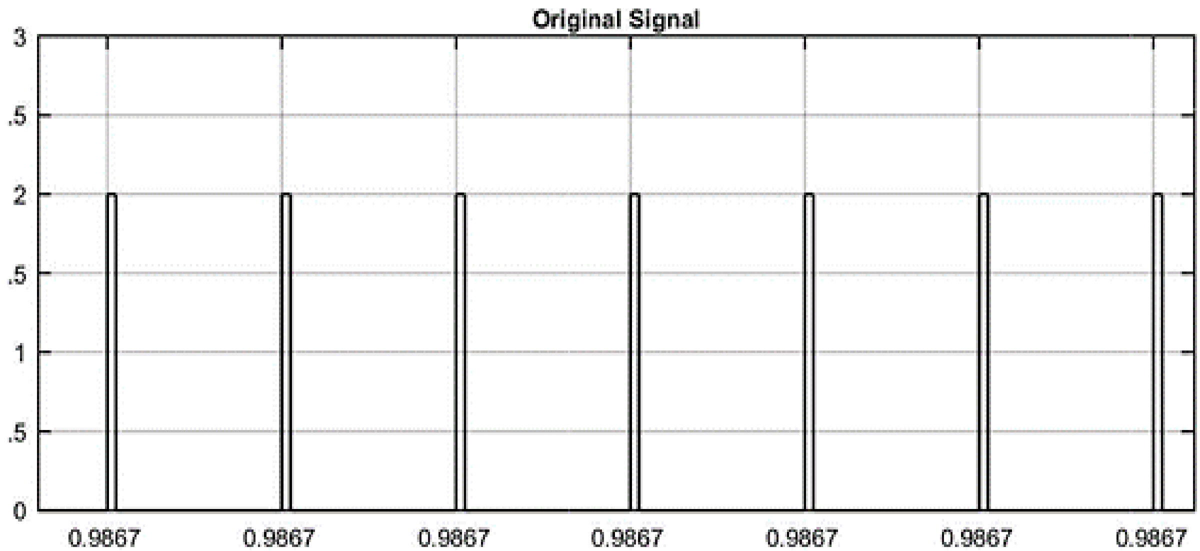
According to the proposed system models have been realized in MATLAB using the simulink toolbox. The results of CA-CFAR with RLS adaptive filter model in which pulse from pulse generator is mixed with not repeatable zero mean and unit variance Gaussian noise are shown in Fig. 5.From the results it is clear that the filter accompanying the RLS algorithm has not given any promising results.

In fact some of the pulses are not even recovered after the application of the proposed system. Even though some pulses that are recovered have values less than the surrounding noise pulses and this may result in the false detection which in turn leads to false ranging. This false detection affects the system accuracy and it is to be avoided.

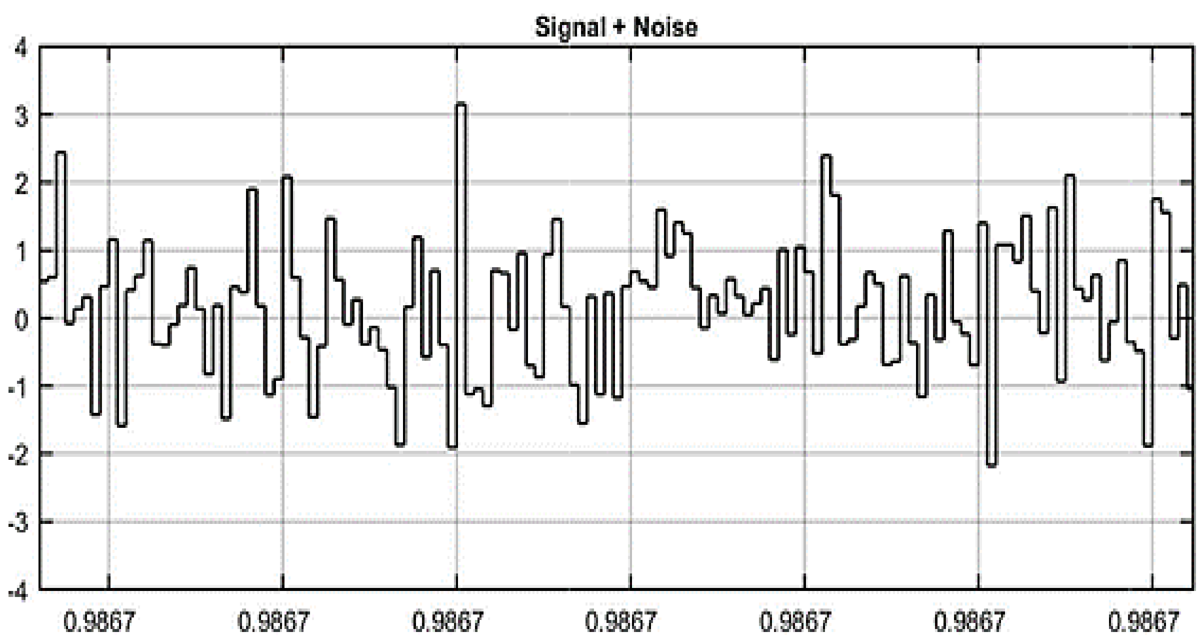
If the result of CA-CFAR combined with LMS algorithm as shown in Fig.6 is compared with RLS model, it is seen that for each segment the desired pulse is higher than that of the noise peaks surrounding that pulse. Now by applying the peak detection unit the desired results are obtained without any error.

Results of ACCA-CFAR combined with LMS model is given in Fig.7. From the results it is clear that even pulses that are completely suppressed by the noise are restored back with the help of this model. Implementation work is carried out for the CA-CFAR with LMS filter model only. The received pulse is converted to digital form with the help of the on-board ADC unit of Virtex 4 FPGA kit and the converted waveform is stored in the block Ram of the kit.

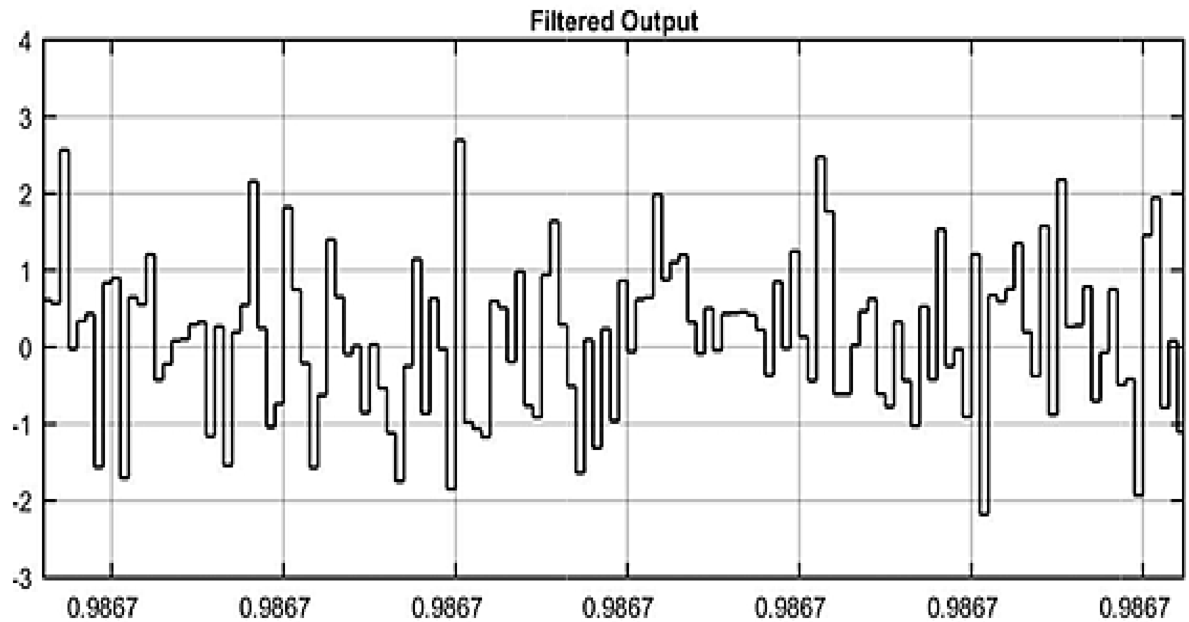
The sampled data is then sent to the CA-CFAR unit and to the LMS unit for estimation of the background noise. After the background noise has been filtered out, the peak detection and ranging unit is then utilized for range determination of the target.



(a)

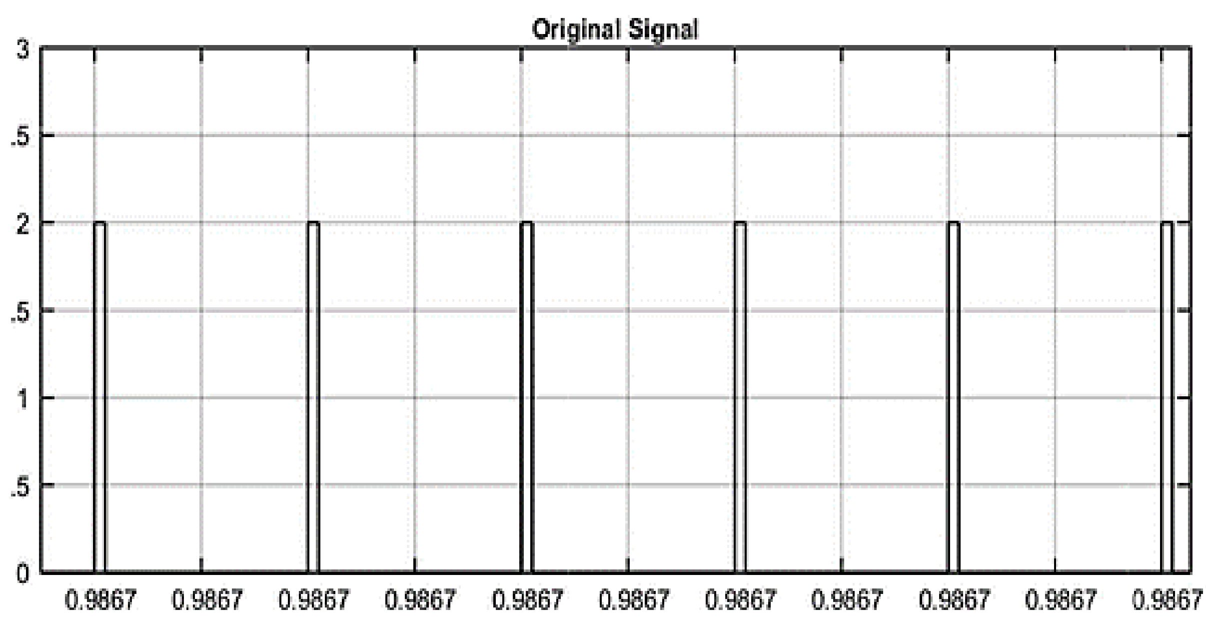


(b)

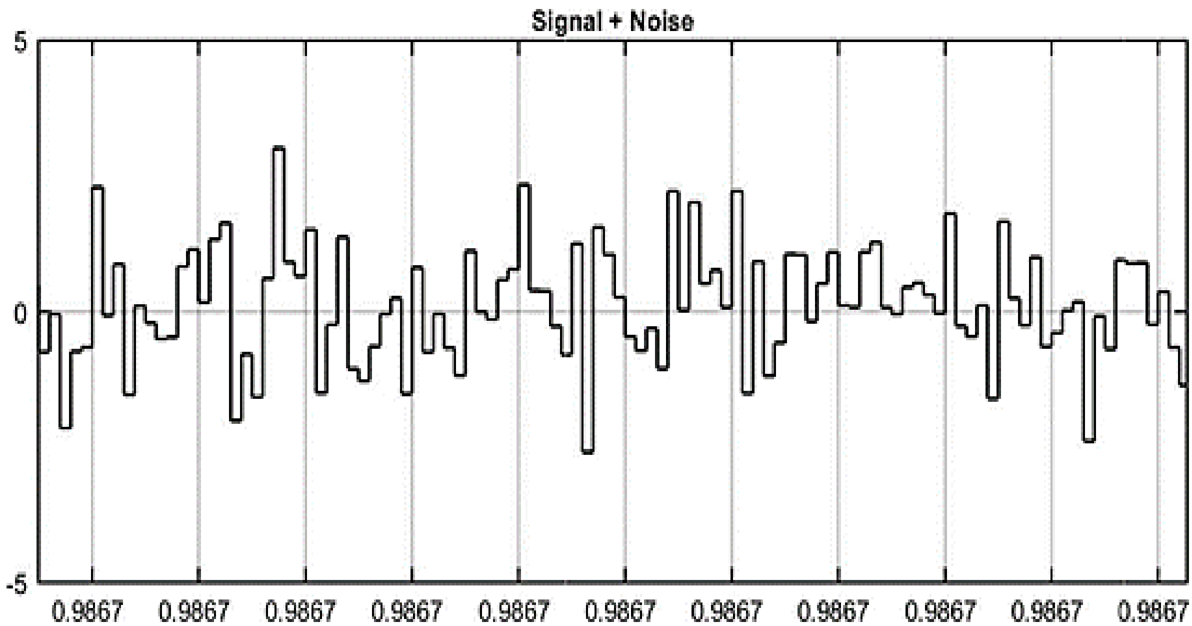


(c)

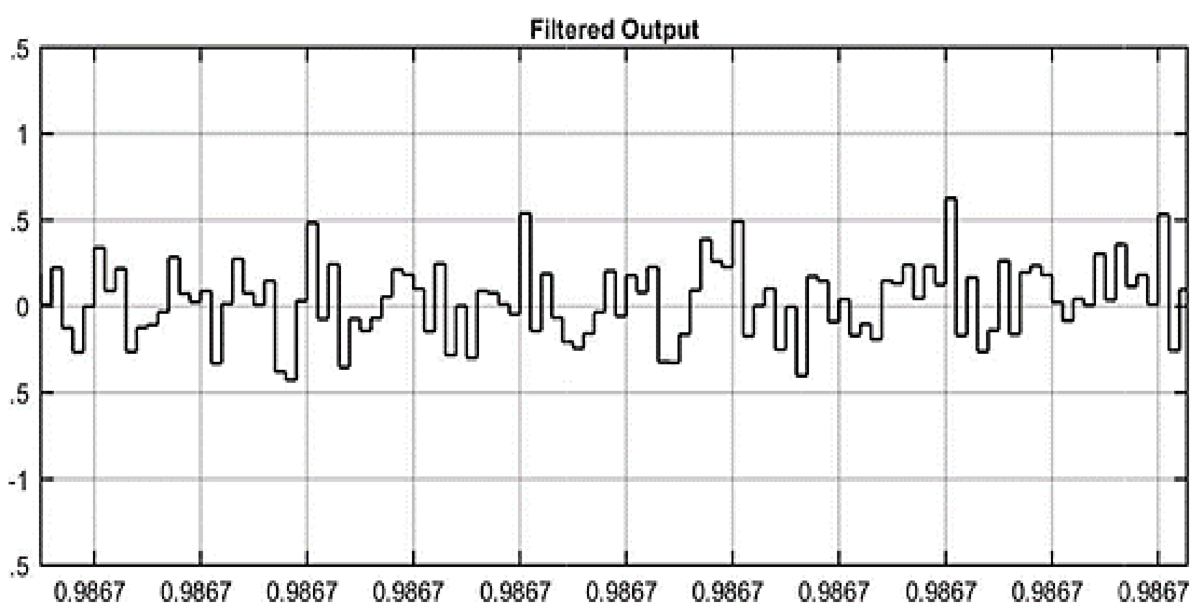
Figure 5. Simulation results of CA-CFAR with RLS filter **(a)** Transmitted signal, **(b)** Received signal corrupted by noise and **(c)** Output of proposed system.



(a)

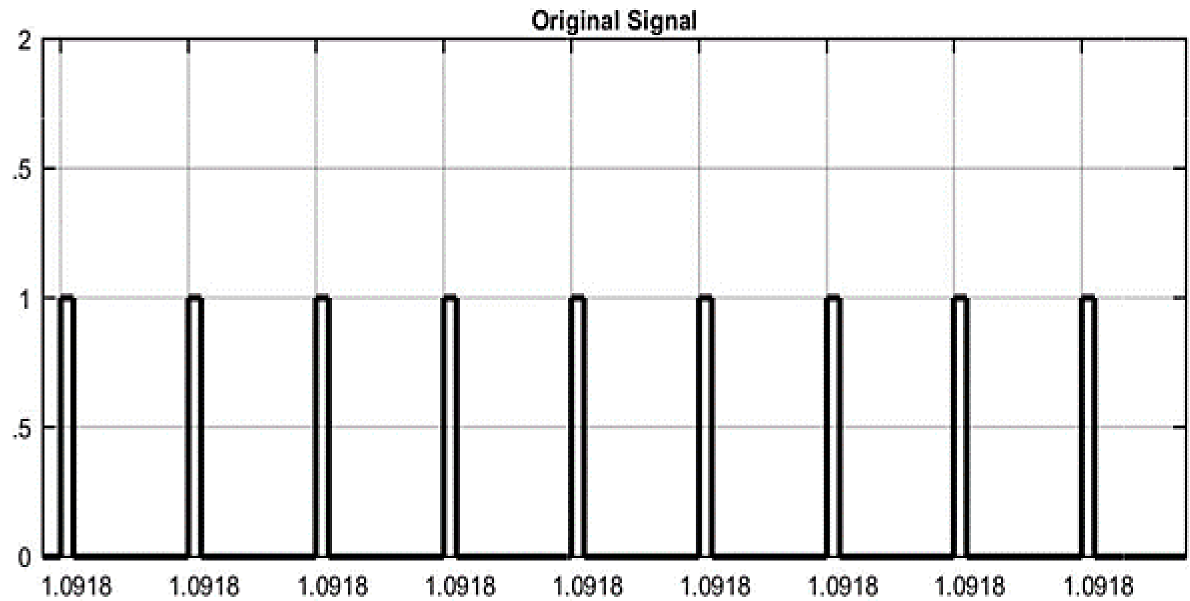


(b)

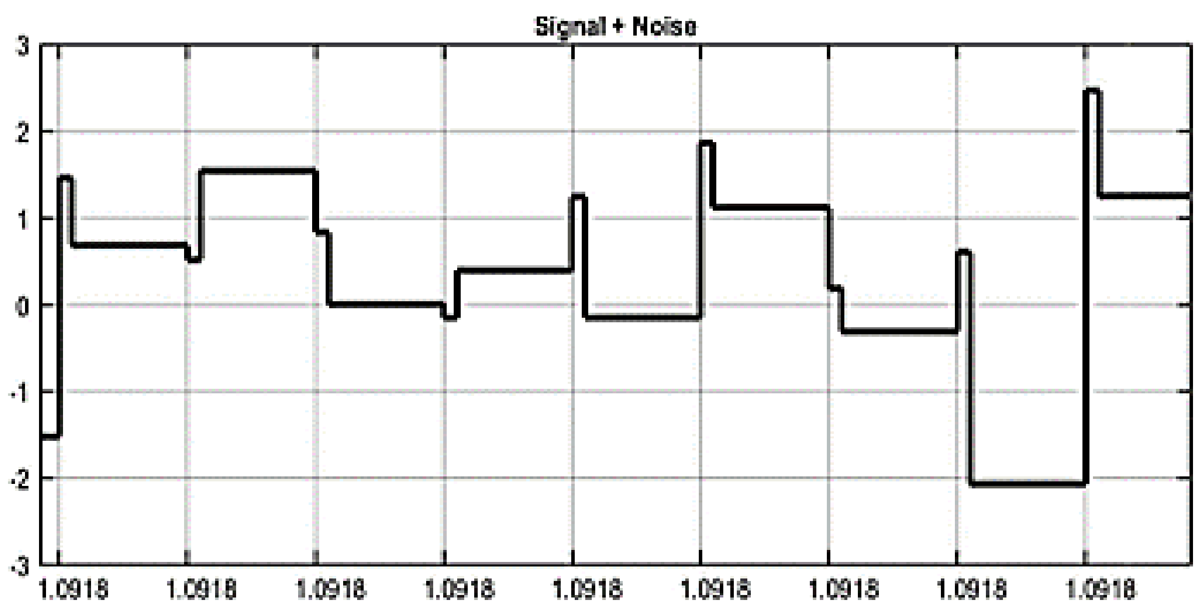


(c)

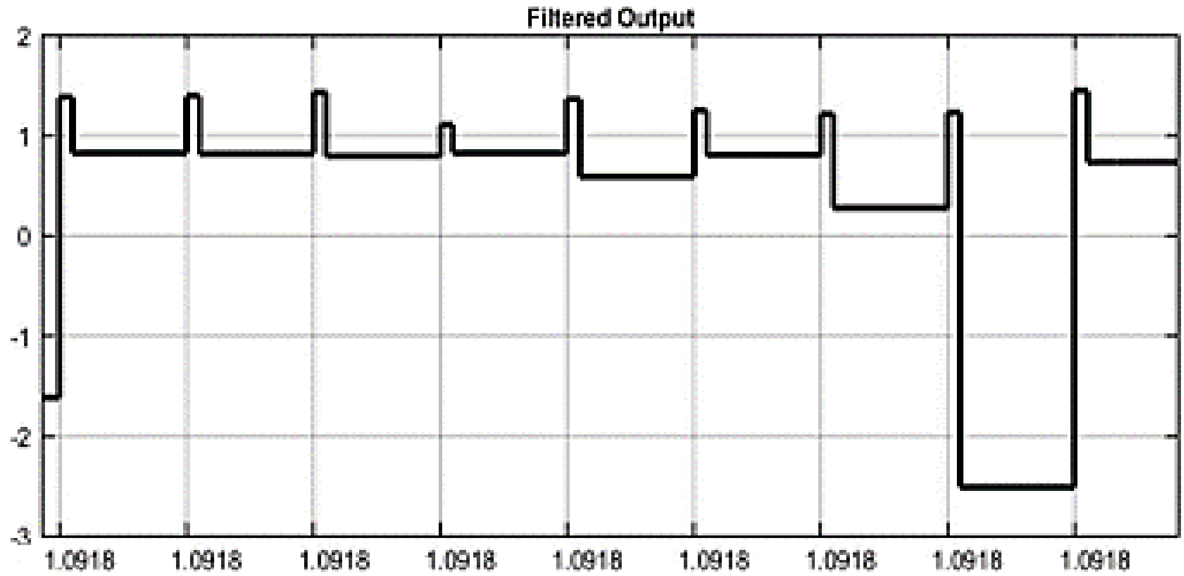
Figure 6. Simulation results of CA-CFAR with LMS filter **(a)** Transmitted signal, **(b)** Received signal corrupted by noise and **(c)** Output of proposed system.


Original Signal
2
.5
1
.5
0
1.0918
1.0918
1.0918
1.0918
1.0918
1.0918
1.0918
1.0918
1.0918

(a)


Signal + Noise
3
2
1
0
-1
-2
-3
1.0918
1.0918
1.0918
1.0918
1.0918
1.0918
1.0918
1.0918
1.0918

(b)



(c)

Figure 7. Simulink simulation of ACCA-CFAR algorithm with LMS filter **(a)** Transmitted Signal, **(b)** Received signal corrupted by noise and **(c)** Output of proposed system

Table 1. Design utilization summary

Logic Utilization	Used	Available	Utilization
Number of Slices	937	15360	6%
Number of Slice Flip Flops	1586	30720	5%
Number of 4 input LUTs	1608	30720	5%
Number of bonded IOBs	58	448	12%

After testing each module these modules are combined together to form the whole system and Table 1 shows the device utilization summary i.e. the number of resources used on the Virtex 4 xc4vsx35-10ff668 kit.

4. CONCLUSIONS

The aim of this paper is to generate a signal processing unit for laser range finder that is robust and versatile in every sense. In this work a novel system is developed which is the combination of a CFAR detector and pipelined LMS adaptive filter. CFAR algorithm utilized provides noise estimation for the incoming noisy signal which is fed to the adaptive filter working on noise cancellation application with LMS algorithm to provide a filtered output so that the ranging can be done accurately. The proposed system is first modeled and simulated in MATLAB simulink in order to define the selection of the adaptive filter. Then the entire system program is developed in the Xilinx ISE platform while the process is implemented on Virtex 4 xc4vsx35-10ff668 system. As a future work the proposed system with ACCA algorithm which is also simulated in MATLAB smulink will be implemented on FPGA kit as the simulated results of this proposed system are very promising.

References

[1] Douglas, S.C. Introduction to Adaptive Filters, Digital Signal Processing Handbook Ed. Vijay K. Madisetti and Douglas B. Williams Boca Raton: CRC Press LLC, 1999.

[2] Farrouki A and Barkat M., Automatic censoring CFAR detector based on ordered data variability for non-homogeneous environments, *IEE Proc. Radar Sonar Navig.* (2005) 152(1), 43–51

[3] Finn H. M. & Johnson R.S., Adaptive detection mode with threshold control as a function of spatially sampled clutter estimates, *RCA Rev.* 29(3), (1968) 414-464.

[4] Ghandhi P. P. and Kassam S. A., Analysis of CFAR processors in nonhomogeneous background, *IEEE Trans. Aerospace. Electron Syst.* 24(4) (1988) 427–445.

[5] Rohling H., Radar CFAR thresholding in clutter and multiple target situations, *IEEE Trans. Aerosp. Electron. Syst.* 19(4) (1983) 608–621.

[6] Schmid K., Waters K., et al, LIDAR 101: an introduction to LIDAR technology, data and applications, *NOAA Coastal Services Center*, Charleston, SC (2008).

[7] M. Kronauge and H. Rohling,Fast two-dimensional CFAR procedure. *IEEE Transactions on Aerospace and Electronic Systems*, vol. 6, no. 9, (2013) pp. 1817-1823.

[8] JunweiYan; Xiang Li, Zhenhai Shao, Intelligent and fast two-dimensional CFAR procedure. *IEEE International Conference on Communication Problem-Solving* (ICCP), (2015) 461-463.

[9] Tsakalides P. &Nikias C. L., Performance Assessment of CFAR Processors in Pearson Distributed Clutter, *IEEE Transactions on Aerospace and Electronics Systems*, 36(4) (2000) 1377-1386.

[10] Uwe Meyer-Baese, Digital Signal Processing with Field Programmable Gate Arrays, Third Edition, Springer Series on Signals and Communication Technology. Springer-Verlag Berlin Heidelberg 2007. ISBN 978-3-540-72612-8