Adaptive CLEAN Algorithm for High Resolution Inverse synthetic aperture radar (ISAR) Imaging For Vehicular Application

Samarendra Nath Sur, Soumyasree Bera, Rabindranath Bera
Department of Electronics and Communication Engineering,
Sikkim Manipal Institute of Technology, Sikkim, Rangpo, East Sikkim-737132.
samar.sur@gmail.com

Abstract— *High resolution RADAR images of contiguous targets like vehicles on road often suffer from side lobe enhancement. This leads to false alarm in target detection and degradation in image quality. In this paper, adaptive CLEAN algorithms are introduced to eliminate side lobe enhancement and significantly improve the target detection with better image quality. The effectiveness of the CLEAN algorithm is demonstrated through the experimental results.*

Keywords*- RADAR, Inverse synthetic aperture radar (ISAR), CLEAN Algorithm, Range, Correlation, Intelligent Transport System (ITS)*

I. INTRODUCTION

ITS [Intelligent Transportation System] means addition of information and communications technology to the transport infrastructure like vehicles in order to improve safety and reduce vehicle wear, transportation times, and fuel consumption etc. To provide potential benefits of ITS [1] applications in a national highway network, a broad range of research and development efforts are being carried over under the umbrella of ITS technology. Remote sensing is one of the ingredients towards achieving the goal of the ITS. This paper deals with the development of high resolution imaging radar for vehicular application. In this paper authors have introduced ISAR [2, 3] processing along with some advanced signal processing tools to develop a system for classifying and recognizing targets. Basically this type of Radar is for roadside use only to identify the types of vehicle.

But the performance of such a system may degrade significantly due to strong side lobe level due to congested vehicles on a busy road. And also in practical scenario high resolution microwave images of adjacent targets also suffer from side lobe enhancement [4] either in range or cross range domain. The net effect is that the dynamic range of the image is reduced. And this leads to severe problem, in the case of radar imaging of contiguous targets, that is the side lobes interact, causing peak misallocation and spurious peaks [5, 6]. Therefore proper classification, location identification of vehicles play an important role to minimize the number of collisions. In order to enhance the radar performance, the authors have introduced a hybrid processing scheme for a polyphase coded spread spectrum system by combing the matched filter and adaptive coherent CLEAN algorithm [7, 8, 9]. Adaptive CLEAN is a CLEAN-like algorithm, as depicted in flowcharts given below, that removes radar returns from the surrounding environment by subtracting signals using a pre-computed delay spread model. Unlike windowing techniques that remove the entire region anything outside the window opening, adaptive CLEAN resolves objects or vehicle in close proximity to each other. The proposed signal processing scheme is intended to remove the direct radar return from the predefined statistic environment and the associated sidelobe clutter while preserving the shape and location of the vehicular target. This algorithm will help to localize and classified the vehicular targets.

II. ADAPTIVE CLEAN ALGORITHM

In this paper, the CLEAN algorithms are introduced to eliminate side lobe enhancement and significantly improve the target detection performance and image quality of polyphase coded spread spectrum ISAR radar. The effectiveness of the CLEAN algorithm is demonstrated through the experimental results. The hardware results show how excellent performance can be attained by combining the creator and the CLEAN Deconvolver. Thus signal processing methods like cross correlation, FFTs, CLEAN on range data and CLEAN algorithm on target images, are incorporated to improve the radar system performance.

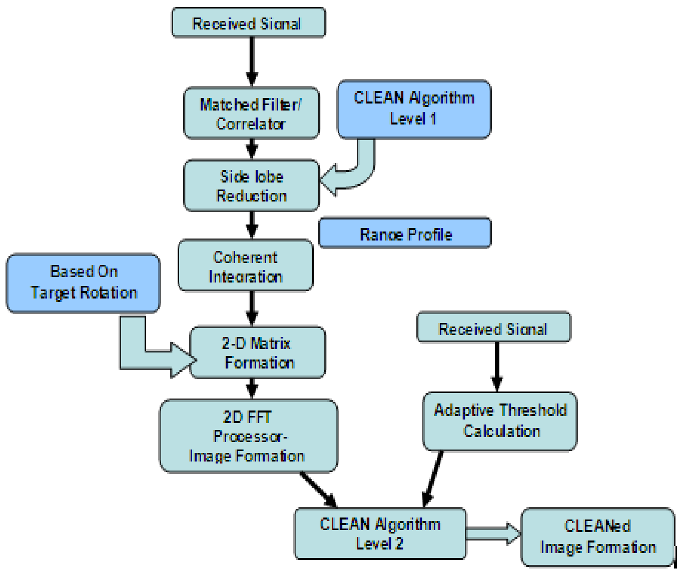

Fig 1: Adaptive CLEAN Algorithm based ISAR Image processing

As in above figure, the CLEAN algorithms [9] are used twice with the purpose as given below

Level 1- as a side lobe reduction technique during range profile estimation figure 2a. This level produces high range resolution profiles (HRRP) for high range resolution ISAR radar.

Level 2- to improve the image quality of a polyphase coded spread spectrum ISAR system using flow chart as in figure 2b.

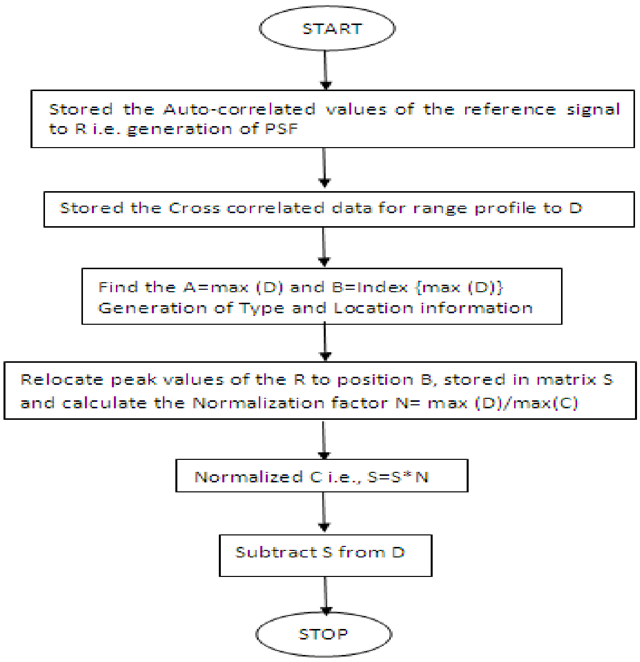

Fig. 2a: CLEAN algorithm for Side lobe reduction.

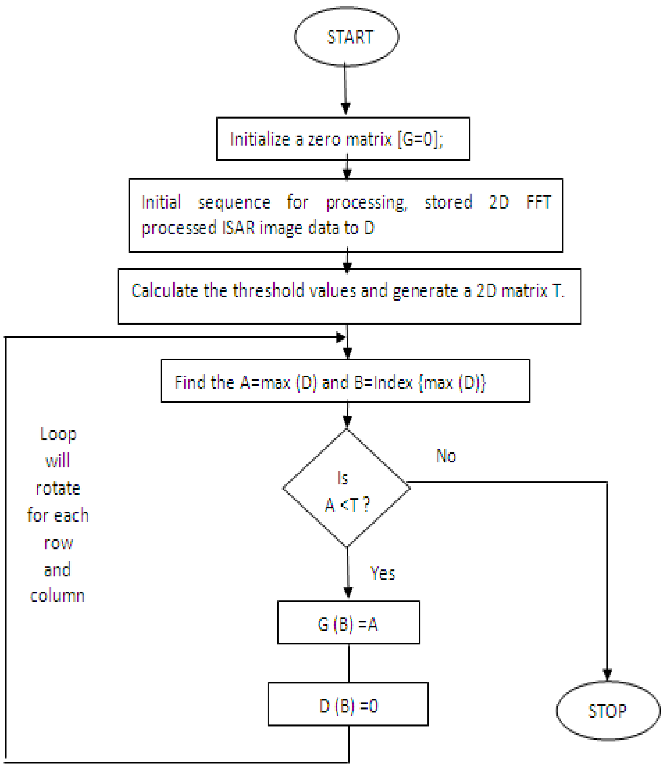

Fig. 2b: CLEAN algorithm for Image cleaning.

This CLEAN algorithm, works by subtracting the normalized complex point spreading function (PSF) of target response (S) from the cross correlated value of the range domain map (D). In this approach, the authors have considered only the range domain response of the target after the coherent detection. The PSF has been generated based on the autocorrelation of the reference signal [4, 9].

After the side lobe reduction, the range domain matrix is stored in a one dimensional map. Then through the angular rotation of the target, a 2D matrix has been generated involving the range and angular domain (cross range) information. This matrix or the image map (D) represents the full range and cross range information about the target.

The second stage of the CLEAN algorithm works by identifying the brightest spot in the image map (D). The location and intensity information for the brightest spot are retained in a clean map (G). Once the brightest spot is removed from the image map (D), the procedure is repeated with the next brightest source in the image map until some predetermined adaptive condition has been reached. In this paper the adaptivity in the CLEAN algorithm has been introduced based on the statistical behavior of the background information. Then after the pixel to pixel comparison the amplitude and position of each source are noted and represent the "cleaned" image.

The adaptivity in CLEAN algorithm is basically based on the statistical behavior of the target returned signal and previously stored background information. In the adaptation cycle the number of iterations has been decided based on the ratio (R) and the value of R will be determined based on the statistical distribution function of the background information. Here the statistic of the background information plays an important role. For highly scattering environment the ratio R to be chosen small to impinge the Cleaning effect. With each iteration the value R to be calculated and to be compared with the predefined R value. After reaching the desired R value, the cycle will stop its iteration. The adaptive cycle is presented below. The detail algorithm is given below.

```
% Initial Calculation for initial parameter
        1. Estimation of Statistical Distribution of the
Background Information.
        2. Lookup for Ratio R based on Statistical
Distribution.
        3.Var_dirty=sum(var(Dirty Map));
        4. Peak Detection in Dirty Map
        5. Initial 2-D Matrix Clean Map Generation
        6.Var_Clean =sum(var(Clean Map));
  Ratio, R= Var_Clean / Var_dirty;
  cc=1;
  while Ratio < Predefined Ratio value based on
          statistical distribution of background information
        1. 2nd Stage Peak Detection
        2. 2nd Stage Clean Map Generation
        3. Var_Clean =sum(var(Clean Map));
        4. Ratio, R= Var_Clean / Var_dirty;
              cc=cc+1;
  end
```

III. EXPERIMENTAL RESULTS

In our experiment we have used P4 coded spread spectrum baseband signal of 100 MHz bandwidth. Arbitrary Wave Generator (AWG) is used to generate IF signal over 70 MHz. The IF signal then up-converted to RF level (sweep range 1-2 GHz) using RF mixer and transmitted in the direction of target using a transmitter side antenna.

Targets are placed on a 2-axis positioner. For range cross range 2D imaging we have rotated the target in the azimuth direction. As a target authors have placed one toy car on the positioned with the dimension 0.6m (cross range) x 0.9 (range).

The target reflected signal is collected at the receiver side using receiver side Horn antenna. Then the received signal is down-converted to baseband level for further signal processing, using a vector signal analyzer (VSA), to extract the target information. The Radar signal processing (RSP) algorithm includes a correlation process for ranging information followed by 2D FFT for cross range information. The adaptive CLEAN algorithm has been applied to improve the image quality.

Figure 3a-3b represent image of the target without background cancellation, whereas 4a-4b represent image of the target after background cancellation. Effectiveness of the CLEAN algorithm is depicted in figures 5a-7b.

In the rich scattering environment, as shown in figure 5b, choice of R in important. The higher value of R tends to no cleaning effect whereas the lower value of leads to a Cleaned image as in figure 7b. And also, by comparing figure 4a and 7b one can easily figure out the impact of the CLEAN algorithm

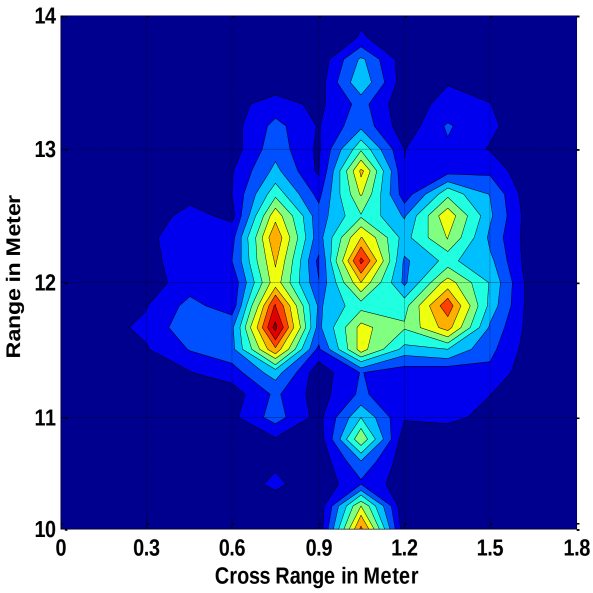

Fig 3a : Target (Car) image before background cancellation

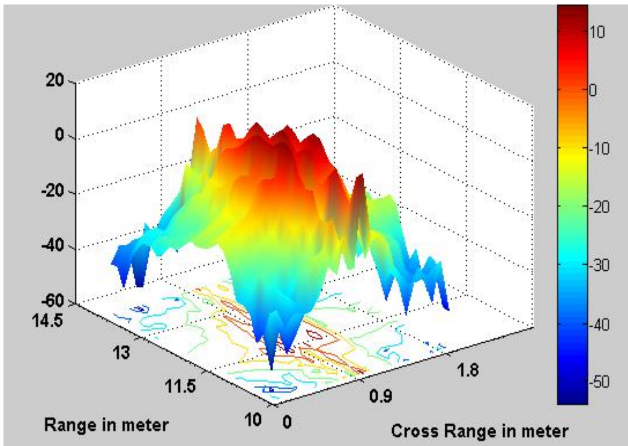

Fig 3b: Target (Car) image before background cancellation (surfc plot)

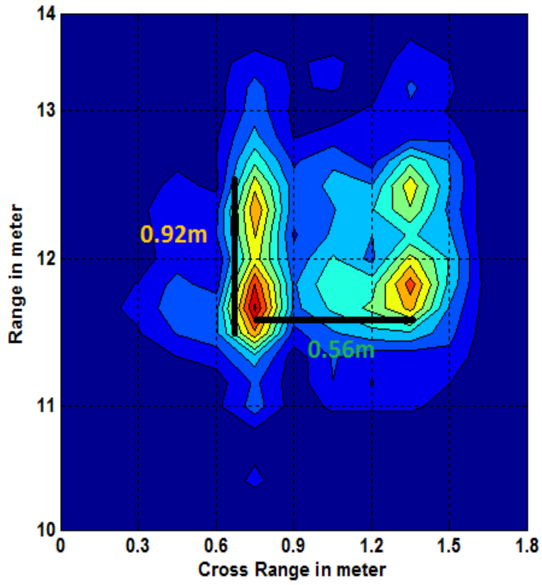

Fig 4a: Target (Car) image after background cancellation

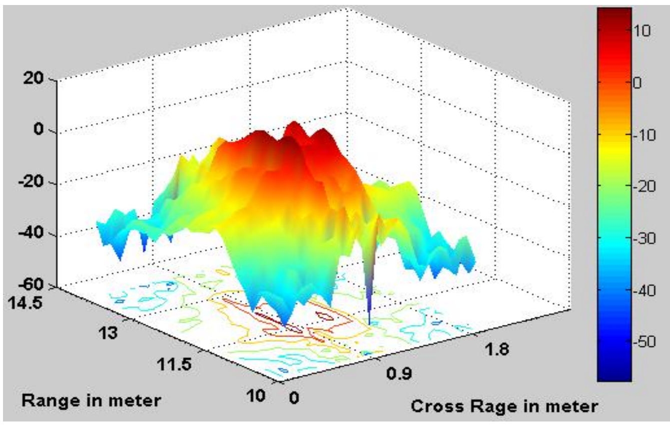

Fig 4b: Target (Car) image after background cancellation (surfc plot)

CONCLUSION

Inverse synthetic aperture radar is widely used all over the world for classifying and recognizing targets and that can be used for vehicular application also. But as a road side channel can be considered as severe channel condition, the system performance can be greatly affected by the side lobe enhancement. In this situation efficient use of Adaptive CLEAN algorithms provides significant performance enhancement as represented in above experimental results.

REFERENCES

[1] EU. eSafety, "Final Report of the eSafety Working Group on Road Safety", November, pp.7-39, 2002

[2] T. Cooke, M. Martorella, B. Haywood, and D. Gibbins, "Use of 3D ship scatterer models from ISAR image sequences for target recognition," Digital Signal Processing, vol. 16, no. 5, pp.523–532, 2006.

[3] K.-T. Kim, D.-K. Seo, and H.-T. Kim, "Efficient classification of ISAR images," IEEE Transactions on Antennas and Propagation, vol. 53, no. 5, pp. 1611–1621, 2005.

[4] Ranjan Bose, "Lean CLEAN: Deconvolution Algorithm for Radar Imaging of Contiguous Targets" IEEE TRANSACTIONS ON AEROSPACE AND ELECTRONIC SYSTEMS VOL. 47, NO. 3 JULY 2011, pp-2190-2199.

[5] J. Tsao, and B. D. Steinberg, "Reduction of sidelobe and speckle artifacts in microwave imaging: the CLEAN technique," IEEE Trans. Antennas Prop., vol.36, pp.543-556, April 1988

[6] Ghaemi, Hirad and Börner, Thomas and Galletti, Michele and Viberg, Mats and Gekat, Frank "CLEAN technique in strip-map SAR for high-quality imaging", IEEE Aerospace Conference, 2009-03-07 - 2009-03-14, Big Sky, MT, USA.

[7] Terry L. Foreman, "Application of the CLEAN Detector to Low Signal to Noise Ratio Targets", 2010 IEEE International Radar Conference (9th), Arlington, Virginia, 10-14 May 2010.

[8] J. A. Hogbom, "Aperture synthesis with non-regular distribution of interferometer baselines," Astron. Astrophys. Suppl., vol. 15, 1974, pp.417–426.

[9] "Improvement in Target Detection and Image. Formation for ISAR System Using CLEAN Algorithm" S.N.Sur S.Bera, A.K Singh, R. Bera. CODIS, 2012, pp-429-432, DOI: 10.1109/CODIS.2012.6422230

Bio data of Authors

Mr. Samarendra Nath Sur: Born in 1984 at Hooghly , West Bengal, INDIA He received his M.Sc. (Electronics Science) from Jadavpur University in the year 2007 and M.Tech from Sikkim Manipal University in 2012. Currently working as an Assistant Professor in Electronics & Communication Engineering Department of Sikkim Manipal Institute of Technology, India. Broadband Wireless Communication Advanced Digital Signal Processing and Remote Sensing are the area of specializations.

Ms. Soumyasree Bera: Born in 1988 at Kolaghat , West Bengal, INDIA. She received her B. Tech from Sikkim Manipal Institute of Technology, Sikkim Manipal University, in the year 2011. Currently she is working as Faculty in the Department of Electronics & Communication Engineering, in same college. Her area of Interest includes Remote Sensing, Mobile Communication, Advanced Digital Signal Processing.

Prof. (Dr.) Rabindranath Bera: Born in 1958 at Kolaghat , West Bengal, INDIA. Received his B. Tech, M. Tech & Ph.D degree from the Institute of Radiophysics & Electronics, The University of Calcutta, in the year 1982,1985 & 1997 respectively. Currently working as Professor and Head of the Department, Electronics & Communication Engineering. Sikkim Manipal University, Sikkim. . His major research Interests in the area of Digital Radar, RCS Imaging, Wireless 4G Communication, Radiometric remote sensing. He has published large number of papers in different national and international Conference and journals.

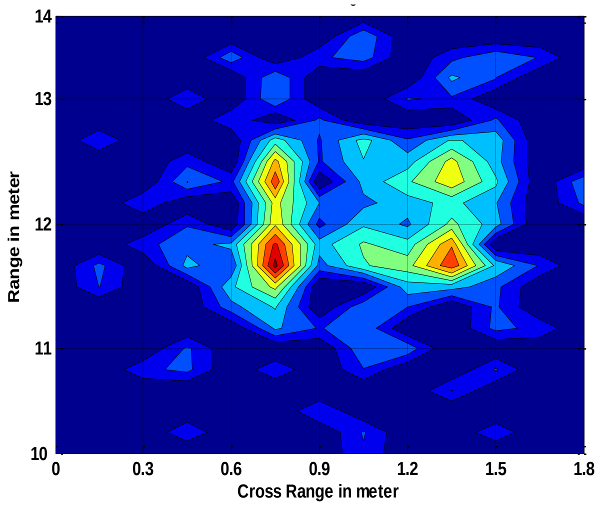

Fig 5a: Cleaned Car Image with ratio (R) 0.8 (Contour Plot)

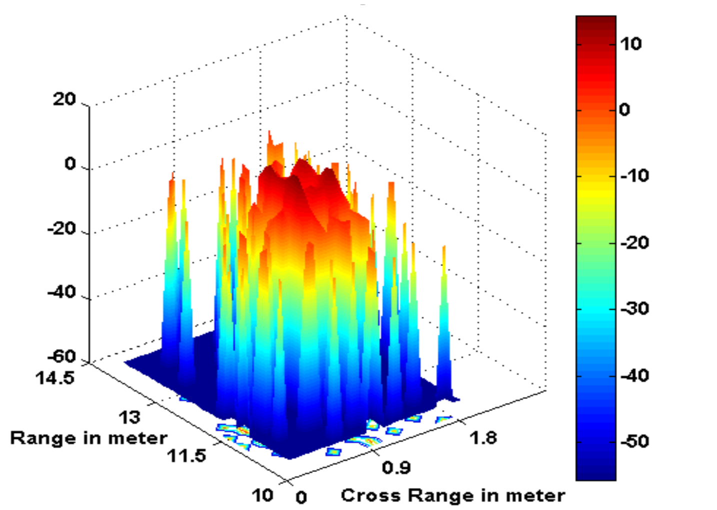

Fig 5b: Cleaned Car Image with ratio (R) 0.8 (Surfc Plot)

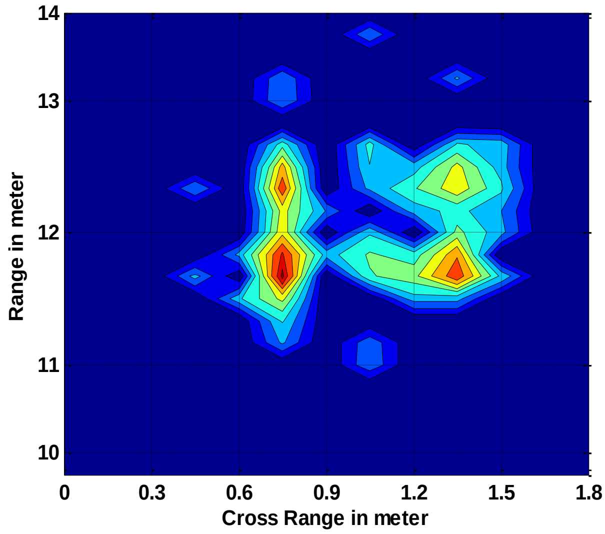

Fig 6a: Cleaned Car Image with ratio (R) 0.6 (Contour Plot)

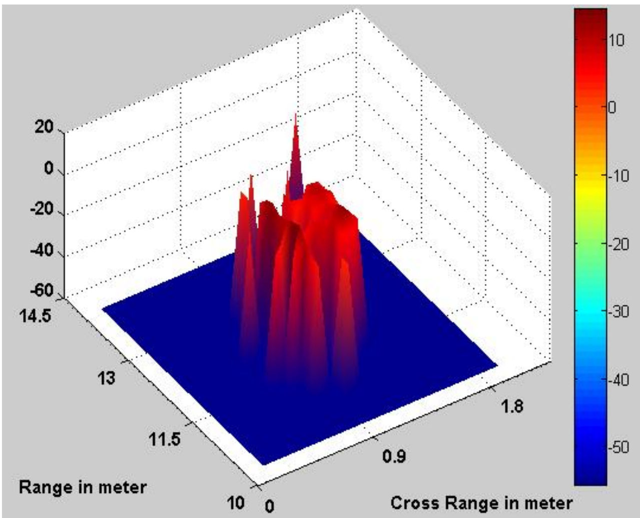

Fig 6b: Cleaned Car Image with ratio (R) 0.6 (Surfc Plot)

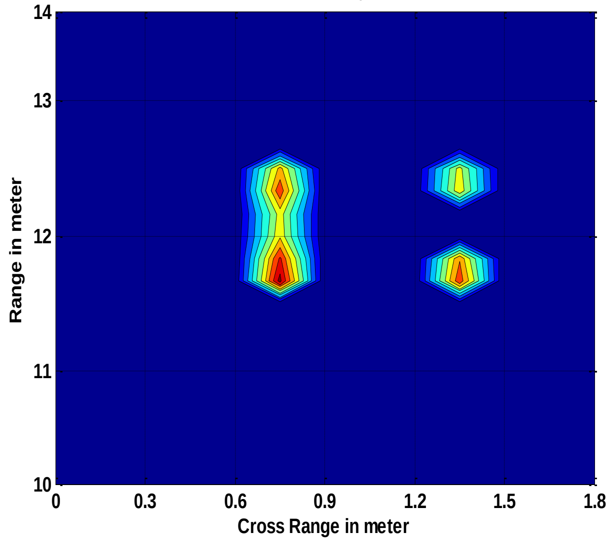

Fig 7a: Cleaned Car Image with ratio (R) 0.3 (Contour Plot)

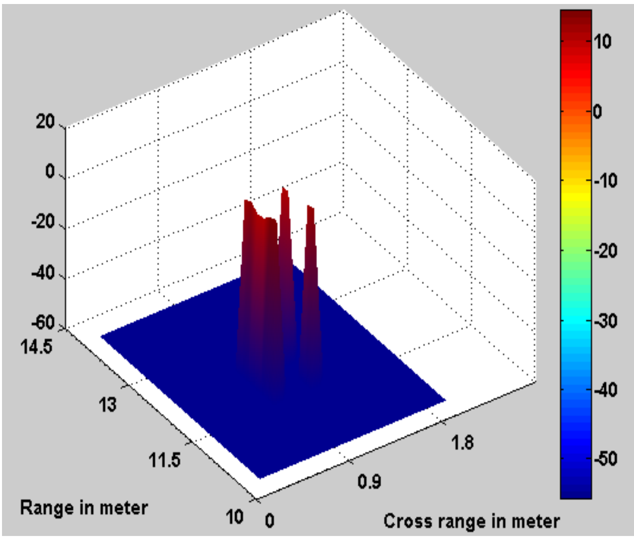

Fig 7b: Cleaned Car Image with ratio (R) 0.3 (Surfc Plot)