Integrated Position & Velocity Measurement for Smart Vehicle Link

D. Mondal, S. Maity,R. Bera, S.Kumar, A. Ghosh M. Mitra

Abstract— This paper addresses the development efforts towards realization of radar based Smart vehicle. Commercial Vehicles with multiple radars has the limitation of more false detection as the detection technology is based on ' Skin' mode of radar[1] operation and the radar receives its transmitted energy after reflection from the body of the target vehicles. The 'Transponder' mode of radar operation will definitely improve the false detection leading to CAWAS system (Collision Avoidance and Warning System)[2][3]. The Vehicles will be the 'friends' to each other by integrating the local radar mounted on each vehicle with Vehicular Communication. Furthermore, IHCS makes use of facilities to carry out traffic control and transmits the information to drivers and concerned departments, and implements traffic management measures, such as vehicle count, vehicle speed, vehicle range, speed control and so on.

Index Terms— Intelligent Highway Control system (IHCS), radar, RADCOM, DAR (Digital Array Radar), STAP (Space Time Adaptive Processing), collision, LFM, OFDM, CFAR .

I. INTRODUCTION

With the tremendous growth of VLSI, vehicles are now commercially available with multiple collision avoidance radars with both Short range (SRR) and Long range (LRR) versions [4]. SRR are used for nearby vehicle and LRR are used for prediction of remote vehicles. Recent research showsthat sensing and communication system can be integrated to develop an Integrated Radar and Communication (RADCOM) system which will involve both detection and communication of the information for IHCS also. The Radio signals of the radar further can be processed to find the velocity of the moving object, its cross sectional area and its range [5]. Therefore the RADCOM model can be used to improve the existing highway control system. It can calculate the velocity with which the vehicle is moving and also its range can be estimated with respect to other vehicles. This information can then be broadcasted to other vehicles so that they can take control actions whether to increase or decrease their speed.

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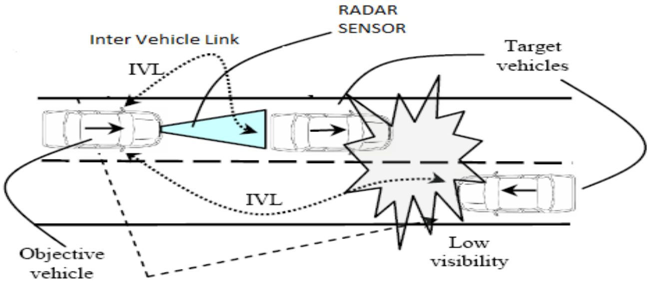

Fig. 1: The CAWAS Model

II. THE DESIGN

A. Choice of frequency for LRR and SRR mode of radar operation

The vehicles should be surrounded by electromagnetic field during SRR mode of radar operation. The antenna pattern should be omni-directional for SRR operation and maximum distance may be 20 meter or so. The authors have chosen 12/11 GHz for such transponder mode of SRR operation. For LRR mode of radar operation, 60 GHz is chosen which exploits the directional beam of 60 GHz by covering a maximum distance of 100 meter. Here authors are interested in SRR only.

B. 12/11 GHz Transmit and Receive Front End for SRR operation

*a) **PIN Modulator at 12/11 GHz***

One PIN modulator at 12/11GHz is used to modulate the TX_IF signal of 20 MHz and up converted to 12/11 GHz using a GUNN oscillator of 0 dBm power. The output of the Modulator is radiated to the space using a Horn antenna having a gain of 20 dB.

*b) **Low Noise Block Converter (LNBC) in receive Chain***

LNBC having the best noise performance of 20 degree Kelvin used for satellite reception is utilized here for best signal to noise ratio. The Horn antenna is also embedded with this LNBC and with the help of embedded DRO; it converts the incoming 12/11 GHZ carrier to 1 GHz RX_IF1.

*c) **Satellite Tuner in receive Chain*** The 1 GHz RX_IF1 is fed to satellite tuner and with proper tuning voltage the IF1 is further down converted to 20 MHz RX_IF2_I and RX_IF2_Q which is fed to SM for further processing.

III. DETERMINATION OF TARGET USING MATLAB CODE

To predict the dynamic & Static Characteristics of Moving & static object author have taken LFM signal of short pulse width (10^{-6} sec.) 50 MHz Radar Band Width for very long & short distance communication .From reflected compressed echo signal multi target can be identified and ranging with proper RCS values. The net energy concentration of the incident radiation from the targets will be towards their focus as they are parabolic in nature.A calibration curve is shown in Fig-2 which will be very much useful in quantifying the target classification and also used in finding RCS of multi targets.

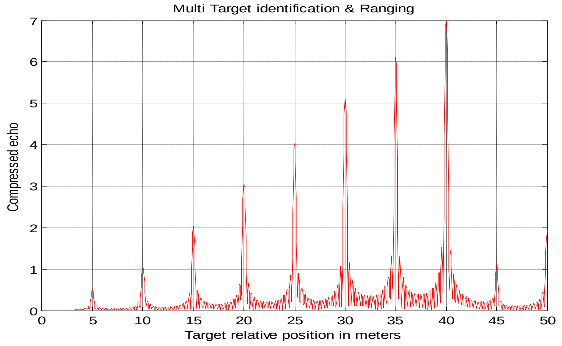

Fig.-2: Multi Target Identification & Ranging

B. Single target detection using VSA based Radar:

The system settings are: Tx Power=25dBm; Baseband Bandwidth=100MHz; Baseband=13-Bit Pulsed Barker Code of 6% Duty; No. of Input Channel Taken=2 (One Reference from Transmitter and another one is Received signal from Target assembly); Target Distance=4.4 meter; RF Frequency=1.45GHz; VSA Resolution Bandwidth=1MHz; VSA Span=110MHz and VSA Source API of SystemVue, CFAR Process for offline processing.

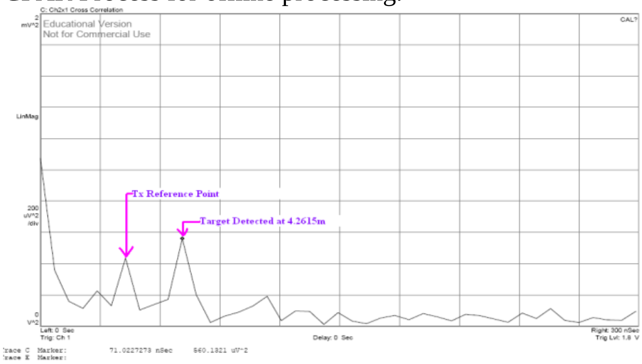

Fig. 3: Single Target detected at 4.2615 m (shown by marker)

The above figure shows detected peaks through the correlation processing in open range at 0 nSec, 42.61 nSec & 71.02 nSec. The Correlation Peak at 0 nSec is due to Antenna Leakage, the 2nd Peak at 7 meter is due to Cable Length plus System Delay and the 3rd Peak at 4.2615meter, representing the Target measured with respect to the reference points.

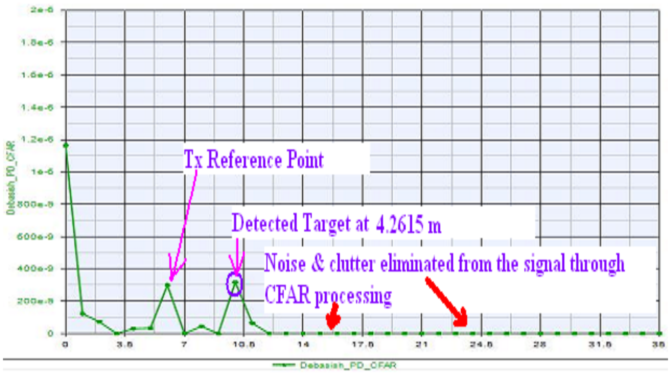

Fig.- 4.: Targets Detected in Open Range at 0, 6 & 10th Sample with CFAR Only

The same Range detection is achieved using CFAR (Fig.-4.) over the samples coming from VSA Based RADAR Receiver. The Antenna Leakage is at 0 sample, the 2nd peak is at 6th Sample which is equivalent to 7 meter (i.e., the Cable Length plus System Delay) and the 3rd Peak is at 7th Sample which is

B. Multiple target detection:

The system settings are: Tx Power=25dBm; Baseband Bandwidth=100MHz; Baseband=13-Bit Pulsed Barker Code of 6% Duty; No. of Input Channel Taken=2 (One Reference from Transmitter and another one is Received signal from Target assembly); 1st Target Distance=2.5 meter; 2nd Target Distance=5.5 meter; RF Frequency=1.45GHz; VSA Resolution Bandwidth=1MHz; VSA Span=110MHz .

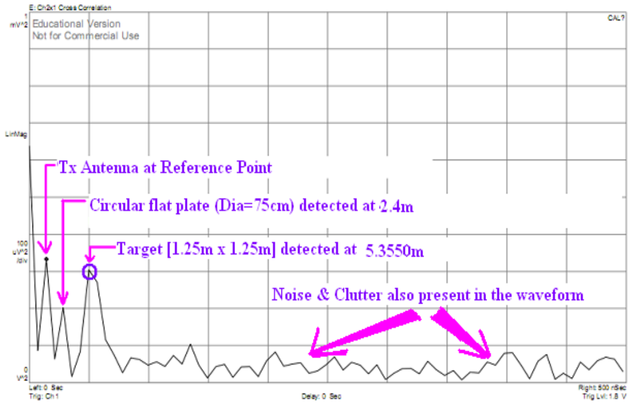

Fig. 5. Multiple Targets detected by Spread Spectrum RADAR.

The Target [1.25m x 1.25m] has been aligned to the Boresight and detected prominently at 5.355m. Another Circular Flat Plate of Diameter=75cm is inserted in between the RADAR Antennas and the Target [1.25m x 1.25m]. The newly inserted circular target is detected at 2.4m. So authors have measured the target range successfully using VSA based Radar .We have designed a test model also to simulate the DBF followed by Linearly Phased Array Antenna where 4 array elements along X-direction and 1 array element along Y-direction have been considered. We have modeled it using Agilent SystemVue. The Simulation schematic has been shown as below:-

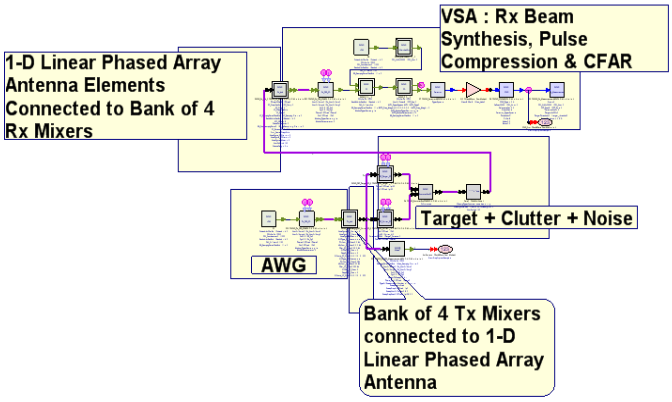

Fig:6 Simulation of DAR

IV. MODELING OF DAR WITH STAP PROCESSING AND TARGET DETECTION USING LFM WAVEFORM

This experiment is carried out for observing the output Target-to-Clutter Ratio w.r.t the different ranges of target but the beam steered orientation is fixed at 36° i.e., the array elements have got such phase shifts that its resultant synthesized beam pattern is looking / directed to an angle of orientation (Azimuthally) 36°.

Case-1: Target at 1 Km; Clutter Vt=75m/sec; No. of DSP ARRAY Ant in X-direction = 4; No. of DSP ARRAY Antenna in Y-direction = 1

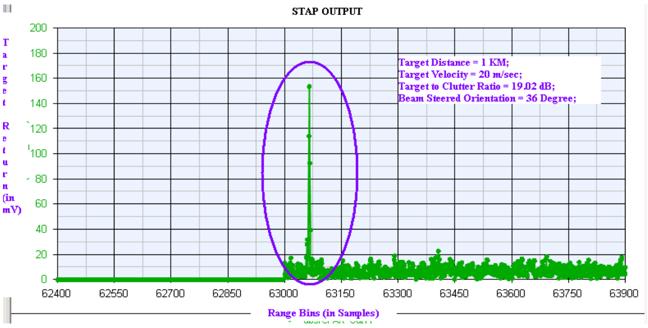

Fig.-7: Target detected after STAP and output Target to Clutter Ratio = 19.02 dB obtained.

Case-2: Target at 2 Km; Clutter Vt=75m/sec; No. of DSP ARRAY Ant in X-direction = 4; No. of DSP ARRAY Antenna in Y-direction = 1

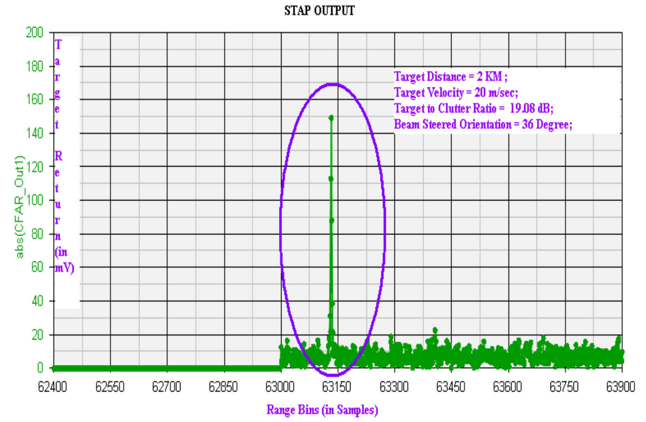

Fig.-8: Target detected after STAP and output Target to Clutter Ratio = 19.08 dB obtained.

V.DESIGN AND SIMULATION OF OFDM RADAR

The following schematic is showing the designing of an OFDM Radar where 64 subcarriers have been generated among which only 11 Cyclic Prefix have been used for simulation of radar .

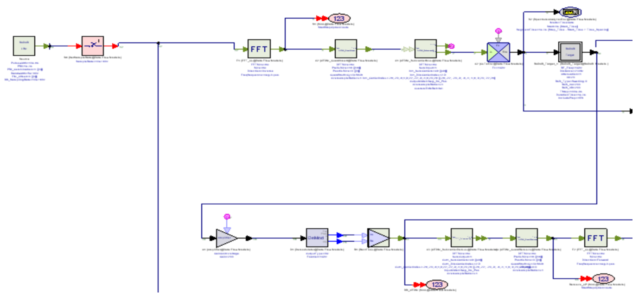

Fig 9: Simulation Schematic of the OFDM Radar utilizing Digital Beam Forming (at Tx and Rx).

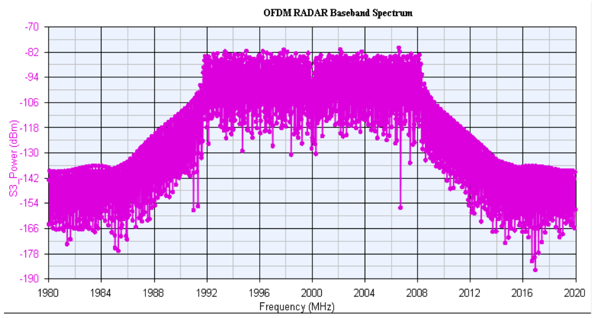

Fig.10: OFDM Subcarrier spectrum Frame

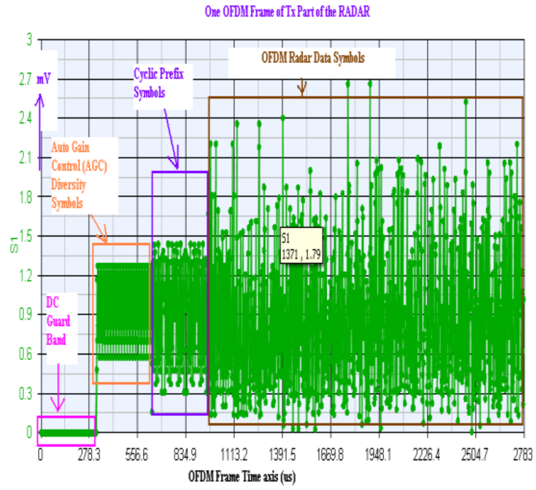

Fig.- 11 : Time diagram of a Complete OFDM Frame

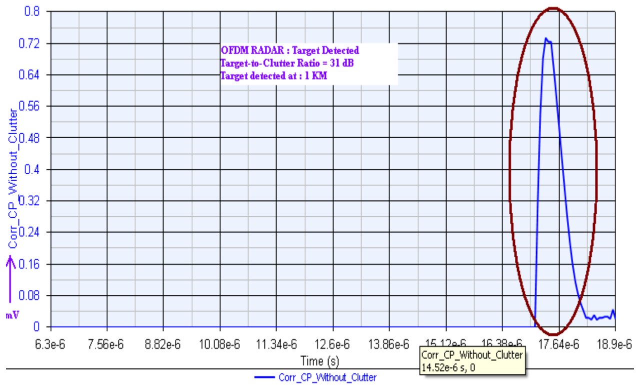

Fig.-12: The Target detected at 1 KM by the OFDM Radar and it is almost free from clutter

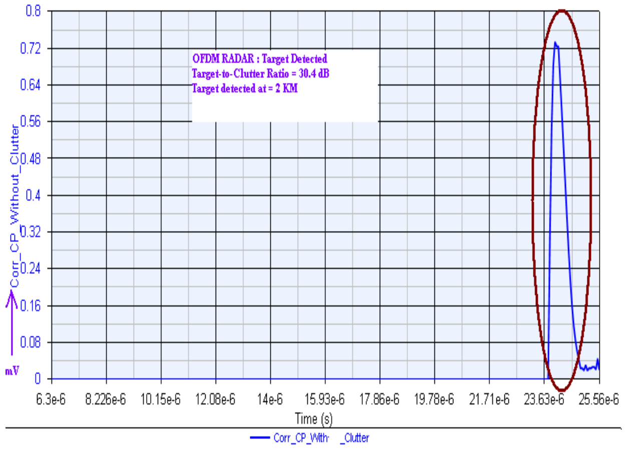

Fig.13: The Clutter Free Target is detected at 2 KM by the OFDM radar

Table: Comparison of LFM and OFDM Radar

Comparison Table	Target-to-Clutter Ratio (dB) for Target Distance = 1 KM	Target-to-Clutter Ratio (dB) for Target Distance = 2 KM
Pulsed LFM RADAR	19.02 dB	19.08 dB
64-Multicarrier OFDM RADAR	31dB	30.4 dB

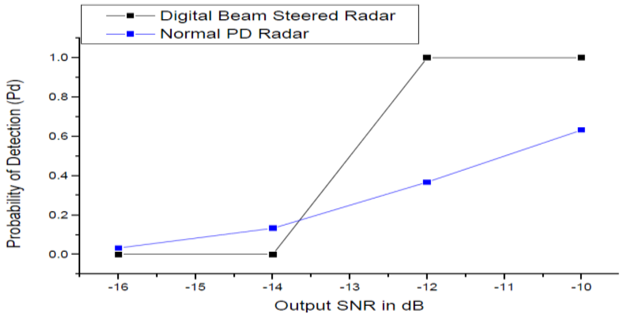

Fig.14: The Probability of Target Detection is 100% ambiguity free in case of a Digital Beam Former Radar w.r.t a normal Radar within the negative SNR zone of -12dB to -10dB.

So after a lot of experimental work author has concluded that the implementation of OFDM Signal has enhanced the Target Detectability as we observed from the simulation of the Digital Array Radar. The LFM waveform has been replaced by this OFDM signal to attain the betterment in Target-to-Clutter Ratio at the Radar output. Here we have taken 13 bit Barker code is generated at the baseband level which is pulsed to 6% duty cycle using a pulse generator. The baseband signal is then up converted to 20 MHz Tx_IF and then to 10 GHz RF and transmitted through the transmit antenna. The target echo signal is received at the radar receiver and auto correlated to extract the different target [6][7] information like range , velocity, target RCS etc. So, here the essentiality of Waveform Design & Diversity (WDD) in concern with better detection of target can be perceived through our experiments. The Digital Array Radar with 4x1 Linearly Phased Array Antennas have been employed in the design because we can achieve a very lightweight solution for the Antennas. The Digital Beam Forming technology is adopted for beam sharpening so that point scatterer of interest can be illuminated very deterministically. It ultimately improves the clarity of Radar image. The possibility of on-line imaging is induced in our design by a rotating target so that dynamic RCS measurements could be made visually eventful. ***Thus, an attempt has been made to explore the SYSTEMVUE, AWG, VSA towards a digital array radar for achieving 'ultimate' performance in radar operation and thereby, target RCS estimation.***

VI. HARDWARE REALIZATION

The above items are cascaded to form the total embedded system. In the Laboratory, systems are tested for all the modes using 12/11 GHz front end and interesting results are obtained. Efforts are put to implement CAWAS system with local LRR and SRR combined system. Such total system will be tested at the field where both the front ends to be operational

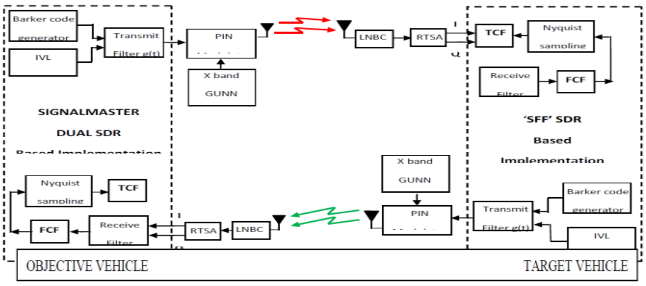

Fig.15. Realization of CAWAS model having one signal master dual in objective vehicle and SFF SDR in target vehicle along with the IVL communication between vehicles.

VII. REAL TIME IMPLEMENTATION.

The real time implementation of RADCOM was done using two cars, two laptops and a radar. The entire survey was done in NH-31A from Majhitar to Rangpo. The main aim of the survey was to demonstrate the application of RADCOM for the IHCS. The entire processing of the received signal from the Radar was processed in Matlab to extract the velocity using Doppler RADAR module. The two laptops were connected with the AdHoc network for the transmission and reception of the velocity of the vehicles and the number of vehicles crossing the radar.

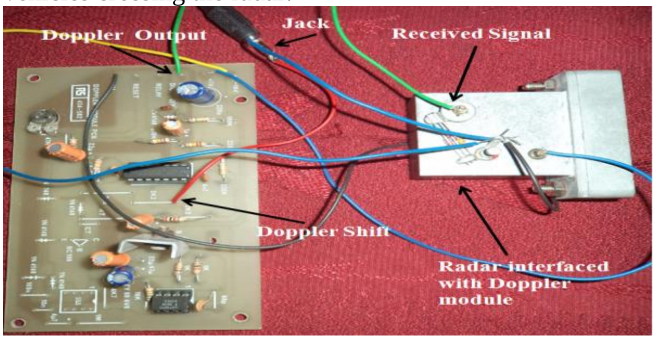

Fig.16: Doppler radar Module

1) Static condition implementation: In this case the vehicle containing the radar was kept in a static position and the radar was placed near the glass window and the velocity of the vehicles passing by along with the vehicle count was obtained and was successfully broadcasted to the other vehicle containing the client laptop. When there was no vehicle on the highway the radar did not sense anything and thus the resultant velocity was zero. But when there was a moving vehicle passing by radar, it sensed the vehicle and velocity of the vehicle was estimated and was transmitted to the client laptop in the other vehicle along with the vehicle count and the time at which the vehicle crossed the radar. The valid reception of the vehicles speed and the vehicle count is shown in the Fig. 12 and 13.

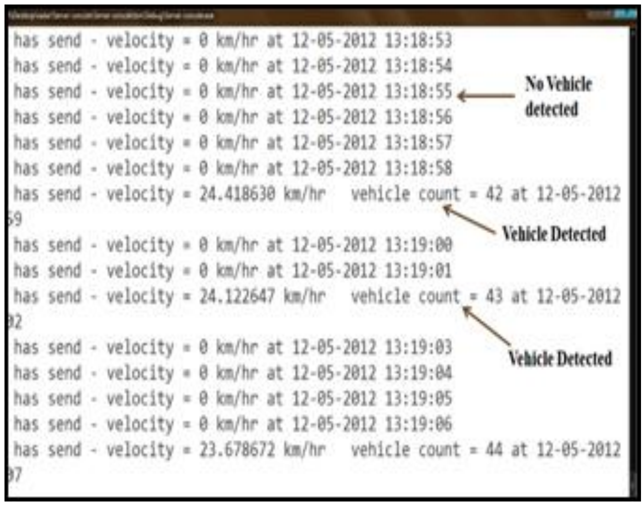

Figure 17: Valid reception of the vehicle velocity crossing the radar

For the static condition successful results were obtained as it sensed all the vehicles which crossed the radar having velocity greater than 15km/hr. The false alarm in this case was nearly zero and satisfactory results were obtained for this case.

2) Moving condition implementation: In this case the vehicle containing the radar was in motion as shown in the Fig. 14 and the velocity of the vehicles passing by along with the vehicle count was obtained and was broadcasted to the other vehicle containing the client laptop.Since the vehicle was in motion, the static objects in the surrounding like lamppost, trees, etc. had relative motion with respect to the vehicle. This relative motion sometime affected the sensing of the radar causing many false alarms as shown in the Fig. 13. These lamppost and trees are also known as clutters which get added with the received signal.

```
Client has send - velocity = 0 km/hr at 12-05-2012 13:31:55
Client has send - velocity = 0 km/hr at 12-05-2012 13:31:56
Client has send - velocity = 0 km/hr at 12-05-2012 13:31:57
Client has send - velocity = 0 km/hr at 12-05-2012 13:31:58
Client has send - velocity = 0 km/hr at 12-05-2012 13:31:59
Client has send - velocity = 0 km/hr at 12-05-2012 13:32:00
Client has send - velocity = 0 km/hr at 12-05-2012 13:32:01
Client has send - velocity = 35.222024 km/hr   vehicle count = 50 at 12-05-2012
13:32:02
Client has send - velocity = 0 km/hr at 12-05-2012 13:32:03
Client has send - velocity = 0 km/hr at 12-05-2012 13:32:04
Client has send - velocity = 0 km/hr at 12-05-2012 13:32:05
Client has send - velocity = 0 km/hr at 12-05-2012 13:32:06
Client has send - velocity = 0 km/hr at 12-05-2012 13:32:07
Client has send - velocity = 32.854157 km/hr   vehicle count = 51 at 12-05-2012
13:32:08
Client has send - velocity = 0 km/hr at 12-05-2012 13:32:09
Client has send - velocity = 0 km/hr at 12-05-2012 13:32:10
```


Figure 18: Detection of vehicle with false alarm

If the cluttering problem can be estimated and resolved, RADCOM can be used effectively in the implementation of IHVS. The estimated velocity and the vehicle count will give an idea to the driver of the number of vehicles on the highway along with their speed and can take certain actions to avoid collision.

Figure 19: Real-time implementation of RADCOM

V. CONCLUSION

Overall conclusion is that the real time experiment of RadCom and implementation of LFM and OFDM Radar and Doppler module was a successful one. It can be used in the IHVS to provide safety and to avoid collision with other vehicles. It can also be concluded that the collisions from three sides i.e. right-side, left-side and back-side can be prevented using the above technique. Three such radars can be placed on three sides of the vehicles and detection of any vehicle from these three sides can be sensed with the radar and the information can be displayed on the screen for the assistance of the driver. The driver can take preventive measures to avoid collision from the three sides and the number of collisions can be reduced to a great extent. For the detection of front vehicle a 77GHz has to be used.

The implementation of the above model can also be used to avoid collision on highway intersections by placing the radar on the roads as shown in the Fig.11 which was the main aim of the project. These radars in this case will be in static condition and will detect all the vehicles passing by without any false alarm as shown earlier. The processing unit will calculate the velocity of the vehicle and in turn will be able to calculate the amount of time required by each vehicle to reach the junction. Further work is going on to solve the cluttering problem and implement the setup described in Fig. 14 in real time environment.

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