Multi-Wavelength Vehicular Radar System

[1]D. Mondal

[1]Associate Professor,
[1]Department of Electronics and Communication Engineering,
[1]Future Institute of Engineering and Management,
Sonarpur, Kolkata-150 Kolkata,India

Abstract: An attempt to implement a single radar technology for the detection of dynamic nature of moving multi target detection in both short as well as long range distance. Conventional vehicular radar system concentrate on the mono tasking.This innovative radar system will perfom based on space sectoring and spectral spreading technique having one at 24.125 GHz as LRR and another at 9.4 GHz as SRR will take joint decision synchronously for multi target detection. Due to minimum interference and low false alarm rate and high resolution, speed of the two targets can be distingushed perfectly.Field trial of this Radar system consequences are also adequate in nonlinear dynamic environment. End to end SystemVue simulations are also going on. With this type of motivating effort, authors are trying to converge in a single Radar system to brand a complete E-Vehicle.

*INDEXTERMS— **LRR (Long Range Radar) , SRR(Short Range Radar), ACC(Automatic Cruise Control), Doppler frequency.***

I. INTRODUCTION

Development of modern ADAS(Advance Driver Assist System) system based on two kinds of radar namely SRR (Short Range Radar) and LRR (Long Range Radar), which are used for the purpose of detection of vehicle, its range and ACC(Automatic Cruise Control) operation. Further SRR is used for searching the vehicle in short range nearly about 50 meters and vehicular parking [1] by using a broad beam width of nearly about $\pm30^0$or more. LRR used a beam width of $\pm10^0$ or less for searching the target vehicle within 150 meters. So intgration of both LRR and SRR called multi-wavelength vehicular radar [2] development. The performance of this innovative radar system is based on spectral spreading techniques and it generates two beams. One is narrow beam for long distance target detection and another is broad beam for detection in short range or car parking assist. Radiation pattern of this radar system is shown in Fig.-1. Field trial of this radar system is also adequate in nonlinear dynamic environment to know about its consequences.

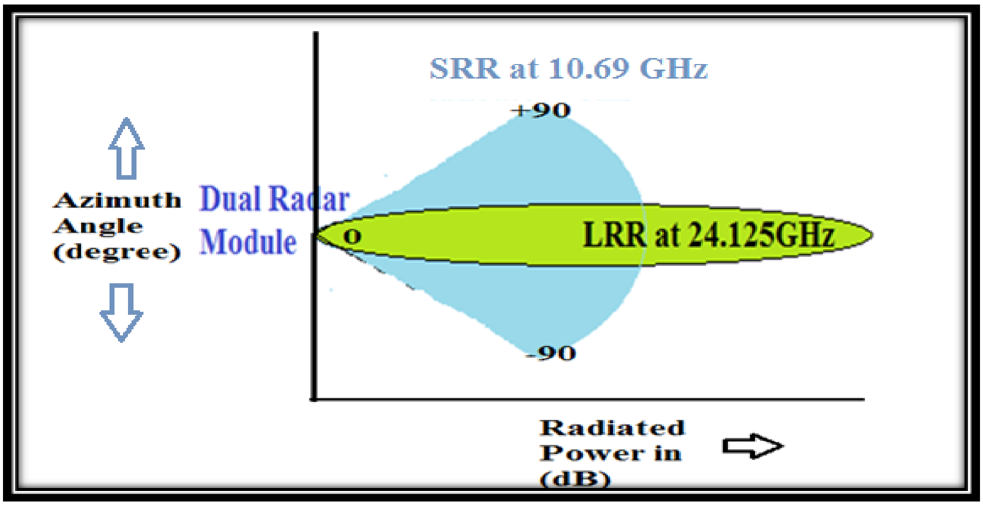

Fig.-1:Radiation pattern of multi-wavelength vehicular radar system

Block diagram of basic multi-wavelength radar system is shown in Fig.-2. Moving object at near distance can measure by SRR at 10.69 GHz but LRR at 24.125 GHz measure at far distance moving object accurately because beam width of LRR is narrower than SRR.

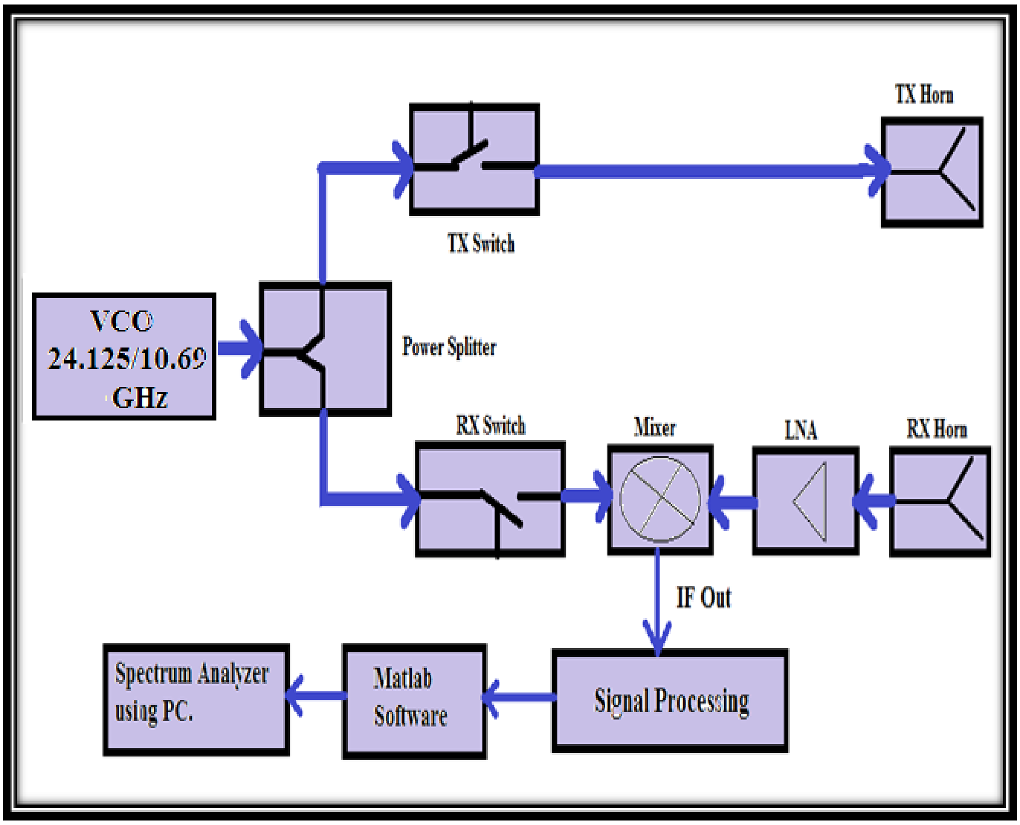

Fig.-2: Multi-wavelength vehicular radar at 24.125/10.69 GHz

II. Development and Experimental arrangement of Multi-Wavelength Vehicular Radar

This section deals with the experimental as well as simulation results based on the relevant working equation. Also a flow chart for the purpose of interfacing between the multi-wavelength radar system and the Matlab software is developed. Two different radars development are initiated (one at X band and other at K band) to invoke multi wavelength mode. Radar one is driven by a Gunn diode having biasing voltage of 7v and current of 200mA at X band and the second one with a Gunn diode having biasing voltage of 5v and a current of 170mA at K band. Due to narrow beam width LRR could not detect the moving target at its blind zone beyond its illuminated beam width but due to wide beam width SRR radar can detect more targets within its broad angular range. Doppler frequencies are received followed by carrier demodulation at the output of the Doppler modules. After filtering by a low pass filter and amplifying the weak Doppler signals are fed to Matlab window for speed measurement. Another way the Doppler signal is verified by connecting with DSO. For both the case same results are obtained. The system was found successful in measuring instant velocity of any moving object which is either in near field or at far field. However the system was very portable, cost effective and of low power consumptions. So it is best suited for vehicular radar and can fit at the front and back of the vehicle for the detection of other vehicles, searching and tracking [3][4]. With this innovative radar system author has initially measured the speed of a dummy vehicle in laboratory and the result was successful.

III. WORKING EQUATION OF THE SYSTEM

For experimental purpose authors have taken two moving objects as small cooler fan with of same radius r. Using X and K band radar system author has able to measure the speed of moving fans successfully for different ranges. Now from general equation v, the velocity of any vehicle measured in bi-static mode Doppler radar can be written as

$$v = c\frac{f_d}{f_o} \qquad (1)$$

where c is the velocity of the light, f_d= Doppler frequency, f_o = carrier frequency; where $v = r.\omega$; where $r$is the radius of the table fan andω is angular velocity of the cooler fan which can be written as

$$\omega = c\frac{f_d}{rf_o}\ rad/sec = \left[\frac{30cf_d}{\pi r f_o}\right] \text{ in r.p.m.} \qquad (2)$$

Again author has converted this R.P.M in to linear velocity and have simulated in SystemVue software. The results were better in LRR than SRR radar which are depicted in fig.6.8 and fig.6.9.For experimental purpose technical specification of both radar module is tabulated in Table-1.

Table-1: Technical Specifications of Radar Module at X and K band

Technical Specifications of Doppler Radar Module at X band		**Technical Specifications of Doppler Radar Module at K band**	
Supply Voltage	+ 7.0 V(DC) ±.1V	Supply Voltage	+4.5 to +6 V
Supply Current to Gunn Device	(130 -165) mA	Supply Current to Gunn Device	150 -250 mA
Power Output at 7V	10mW	Power Output at 5V	5dBm
Operating Temperature Range	0^o C to $+40^o$ C	Operating Temperature Rang	-40^o C t0 + 80^o C
Center Frequency	10.69 GHz	Center Frequency	24.125GHz

In this work we have converted this R.P.M to linear velocity and have simulated in SystemVue software using same data. The results were better in LRR radar than SRR radar[5] which are discussed in section IV.

IV. Interfacing methodolodgy

For extraction of Doppler frequency author has used interfacing methodology using Matlab software, which is shown in a flow chart of Fig.-3.Analog input data from radar receiver antenna is interfaced to the sound port of the PC installed with audio recorder and Matlab software. This analog data is first sampled with a sampling rate of 8000 sample/sec and each sample size was set to 8 bit length. Using Matlab command two channels were created for the data processing of X-band and K-band radar[6] receiver simultaneously. A "recobj" variable is created using the function of audio recorder as mentioned in flow chart. Object recorder will collect the analog signal in 1 second. Now with the help of Matlab software command this signal has done FFT (First Fourier Transform) operation and the signal is converted to sample domain. All the sample data is stored in this variable and allow to pass information between data acquisition engine and the hardware driver. After initializing all parameters, author has plotted the stored absolute value of sampled data on Matlab window. Using control loop author has checked the largest amplitude value of the sample for both channel. The frequency corresponding the largest power level is the

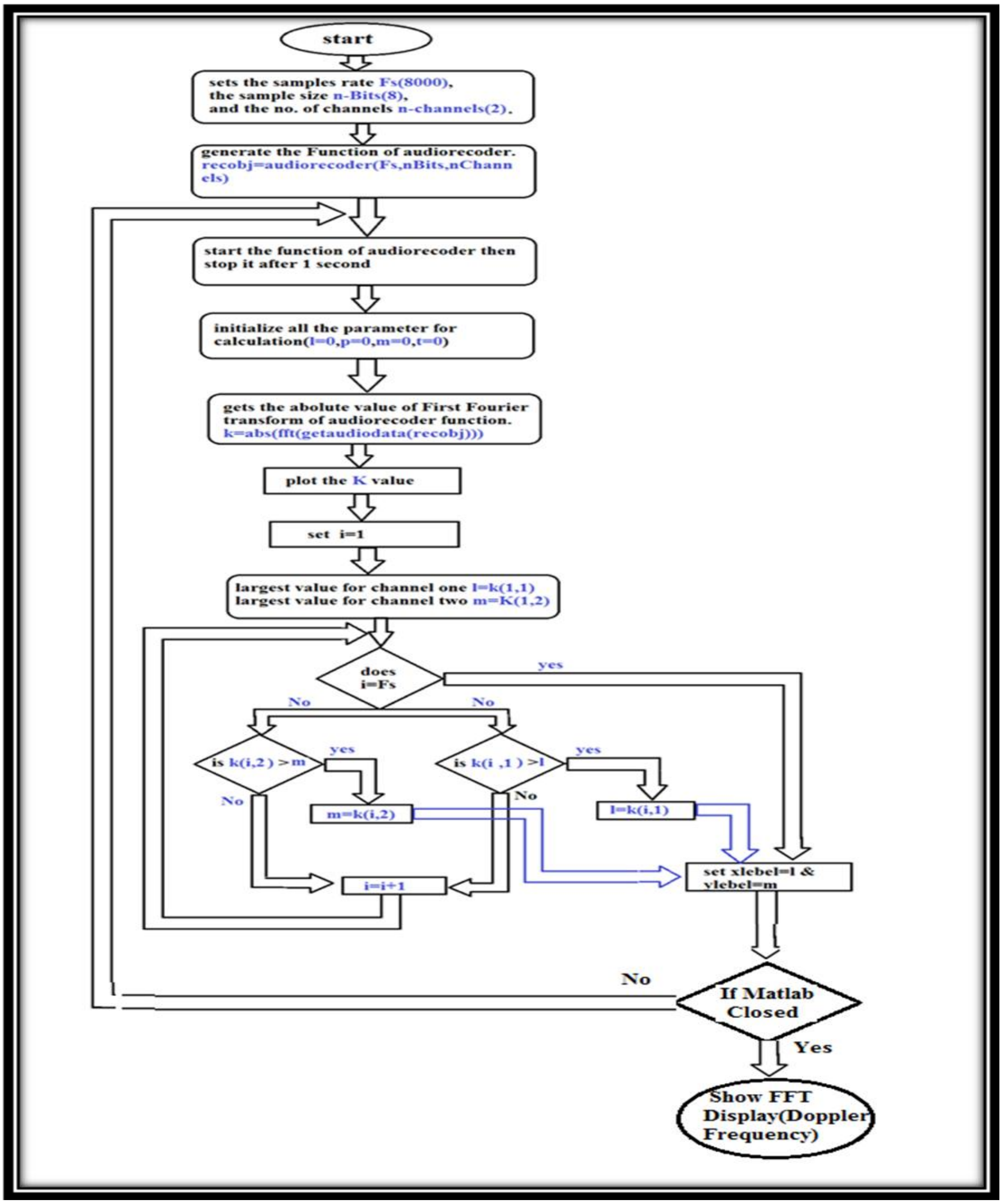

Fig.-3: Flow chart of multi target detection based on Matlab interfacing

Doppler frequency of both channel. Both channel's data are plotted in single Matlab window which is mentioned in Fig.4 and Fig.5 respectively in different moving situations. Fig.-4 and Fig.-5shows that FFT(First Fourier Transform) plot of two moving object which is mentioned in the graph. Green colour line shows the FFT plot of SRR for nearest target to the multi-wavelength radar and blue colour line shows the FFT plot of LRR for another target located in far field. Both peaks are almost same at doppler frequency but their power level is different due to diffeent location in range. For 24.125 GHz LRR radar system[7], Doppler frequency was 211.575 Hz and for 10.69 GHz SRR radar system measure doppler frequency at 208.65 Hz.Fig.-6.6shows that FFT(First Fourier Transform) plot of two moving objects which are seperated in different Doppler frequency.

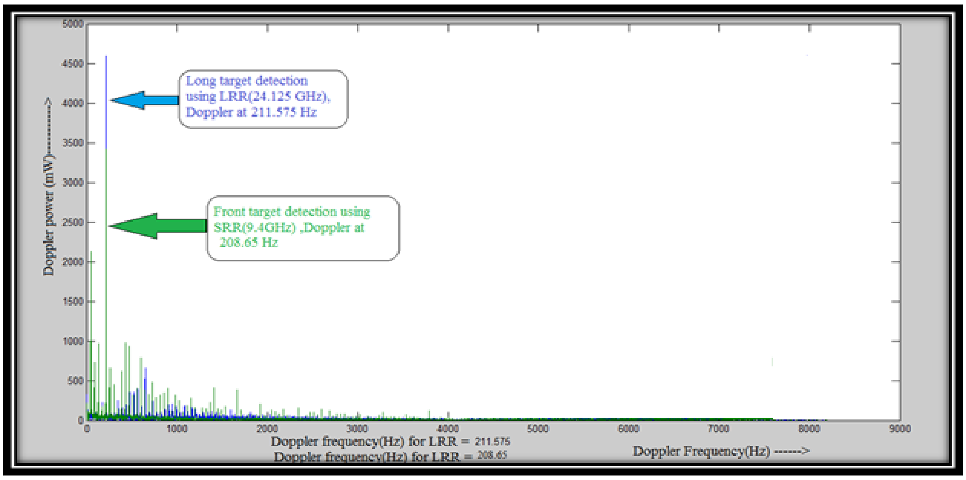

Fig.4: Spectrum of two moving objects in different speed

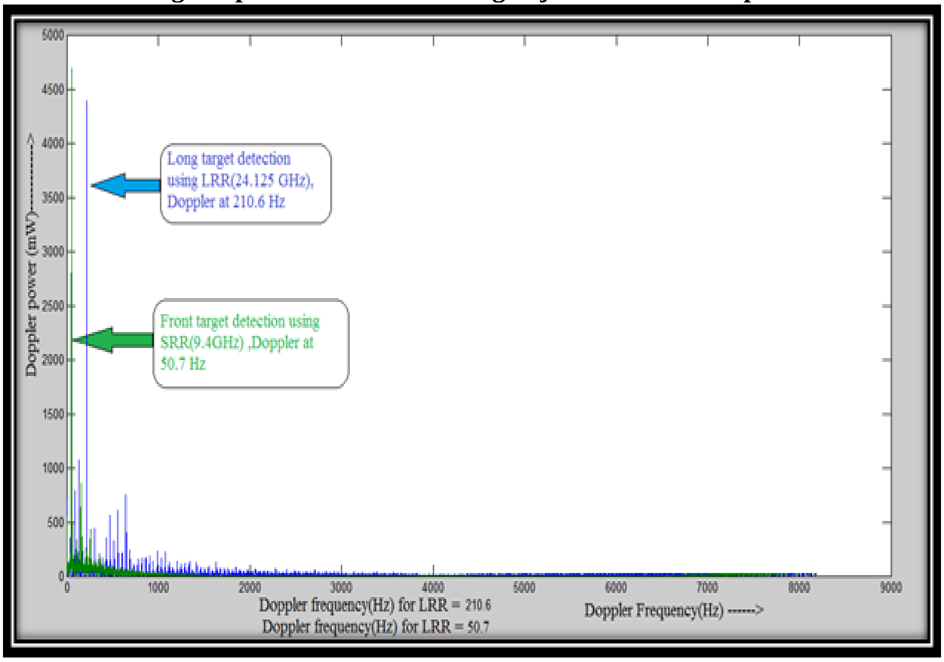

Fig.-5: Spectrum of two moving objects in different speed

Here SRR(X-band) radar system[8] detects the moving target at doppler frequency of 50.7Hz with corresponding angular velocity nearly equal to 630 rotation per minutes as mentioned in green colour line.Simultaneously LRR(K-band) radar system detects the moving target at doppler frequency of 210.6Hz which is mentioned by blue colour line. Angular velocity corresponding to that doppler frequency can be written nearly about 230 rotation per minutes.

V. EXPERIMENTAL AND SIMULATION RESULTS

Now using this linear velocity parameter in SystemVue software a comparitive study of simulation and hardware results are being done.Evaluted SystemVue and hardware results are tabulated in Table-2 for X band.

Table-2: Table for velocity measurement using SRR(X-band) radar system

SRR Radar at 10.69GHz Center Frequency								
Electrical voltage (Volt)	R.P.M.	Assigned Linear Velocity corresponding RPM(m/s)	Using System Vue Doppler (Hz)	Velocity using SystemVue(m/s)	Doppler using Matlb(Hz)	Evaluated Velocity (using Matlab)(m/s)	Doppler using DSO(Hz)	Velocity using DSO(m/s)
40	170	1.068144	66.937	1.06814	75	1.196805	70.5	1.124997
50	255	1.602216	100.406	1.60222	126	2.0106324	100	1.59574
60	375	2.358713	147.813	2.35871	193.05	3.08057607	150	2.39361
80	630	3.96149	248.253	3.96147	324	5.1701976	270	4.308498
100	914	5.7428448	359.885	5.74283	474	7.5638076	395	6.303173
120	1260	7.916832	496.121	7.9168	642	10.2446508	530	8.457422
150	2086	13.106552	821.342	13.1065	1050	16.75527	875	13.96273
170	2230	14.011536	878.056	14.0115	1080	17.233992	925	14.7606
190	2413	15.161362	950.112	15.1613	1140	18.191436	950	15.15953
210	2501	15.714284	984.762	15.7142	1170	18.670158	950	15.15953
220	2505	15.739416	986.337	15.7394	1170	18.670158	950	15.15953

CONCLUSIONS

In present scenario 24 GHz radar system is the key enabling technology. This radar system may be the substitute of ultrasonic sensor. So radar system is more robust and the microwave modules can be mounted invisible behind plastic bumpers and this will be the major customer benefits. From this Hybrid Radar system it was not able to measure the range of the target easily because of CW mode. The only solution on the basis of experimental view is to develop Pulse Doppler Radar. So using SystemVue simulation I am compensating the lack of range detection. Lot of simulation is going on using Matlab and SystemVue software for prediction of single target as well as multiple target range using Digital Beam Forming (DBF) hybrid Radar system at 24 GHz and 77/79 GHz also. However hardware of this system was not bulky and power requirement is very much less, to operate the entire Multi-Wavelength Radar system. Secondly it will take very less space that is in size and it can fit in front bumper of the vehicles.

VI. ACKNOWLEDGMENTS.

I am very much thankful to ECE department of SMIT, Sikkim Manipal University, Sikkim, Future Institute of Engineering and Management and IIEST, Shibpur, W.B for the support of entire infrastructure and valuable suggestions.

VII. REFERENCES

1. ETSI EN 302 264-1 v1.1.1 (2009-06) European Standard (Telecommunications series) Short Range Radar
   a. equipment operating in the 77 GHz to 81 GHz band, Part-1: Technical requirements and methods of measurement,
2. CEPT Report 37 , Report from CEPT to the European Commission in response to Part 2 of the Mandate on
   a. " Automotive Short-Range Radar Systems(SRR), Electronic Communication Committee(ECC) within the
   b. European Conference of Postal and Telecommunications Administrations (CEPT)
3. 24 GHz short-range microwave sensors for industrial and vehicular applications P. Heide , M. Vossiek , M. Nalezinski ,
   a. L. Oréans , R. Schubert , M. Kunert , SIEMENS AG, Corporate Technology, D-81730 Munich / Germany ,
   b. SIEMENS AG, Automation and Drives, D-76181 Karlsruhe / Germany 3 SIEMENS AG, Transportation Systems,
   c. D-12424 Berlin / Germany, SIEMENS AG, Automotive Systems, D-93055 Regensburg / Germany Workshop
   d. "Short Range Radar", TU Ilmenau, July 15-16, 1999.page 1.
4. Report on the use of the 24 GHz frequency range by automotive short-range radars as of June 2010 by
5. Strategic Automotive Radar frequency Allocation group 30 June 2010.

   T. v. Kerssenbrock, P. Heide: "Novel 77 GHz Flip-Chip Sensor Modules for Automotive Radar Applications",
6. E MTT-S Int. Microwave Symposium, Anaheim, USA, pp. 289-292.

   ITS Forum 2009, Tyko Feb.26th, 2009.
7. Vehicular Communication and Safety in Realization of Intelligent Transport System" Rabindranath Bera[1],
   a. Dipak Mondal[2], SanjibSil[3], SouravDhar[1] , Samarendranath Sur [1], DebasishBhaskar
8. [1]Subir Kumar Sarkar[4]&DebdattaKandar[1] Published in IEEE CODEC 2009, December 14-16,2009.

   A. H. S. Lai and N. Yung, "Vehicle-type identification through automated virtual loop assignment and block-
   a. based direction-biased motion estimation," IEEE Trans. In tell. Transp. Syst., vol. 1, no. 2, pp. 86–97, Jun. 2000.
9. I. Bekkerman and J. Tabrikian, "Target detection and localization using MIMO radars and sonars," IEEE Trans.

   on Sig. Proc., vol. 54, pp. 3873- 3883, (Oct. 2006).