International Journal of Soft Computing and Engineering (IJSCE)
ISSN: 2231-2307, Volume-5 Issue-6, January 2016

# Design and Implementation of an Integrated Radar and Communication System for Smart Vehicle

**D. Mondal, R. Bera, M. Mitra**

***Abstract:*** ***This paper addresses the development efforts towards realization of 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 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). The Vehicles will be the 'friends' to each other by integrating the local radar mounted on each vehicle with Vehicular Communication. The authors have developed one such CAWAS model utilizing the VLSI based advanced development platforms. This paper will highlight the achievements and limitations of the developed model.***

***Index Terms:*** ***CAWAS system (Collision Avoidance and Warning System)., Intra Vehicle Link (IVL) Short range ( SRR) and Long range ( LRR), ACC (Adaptive Cruise Control)., VLSI ,Vector Signal Generator (VSG) , Software Defined Radio (SDR), Time Correlation Function(TCF)***

## 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 [1][2]. This is now an established collision avoidance scheme utilizing 'Skin' mode of radar operation where vehicles having such types of radars detect nearby vehicles on the road and invoke ACC (Adaptive Cruise Control).But modern vehicles should also have vehicular communication to avoid collision in better way utilizing 'Transponder' mode of radar operation and leading towards a CAWAS system [3]. With a motivation to realize a CAWAS in modern vehicles, efforts are imparted by the authors to implement concurrent communication and radar based sensing in smart vehicle operation. One Such CAWAS Model is shown in Fig. 1

**Revised Version Manuscript Received on December 11, 2015.**

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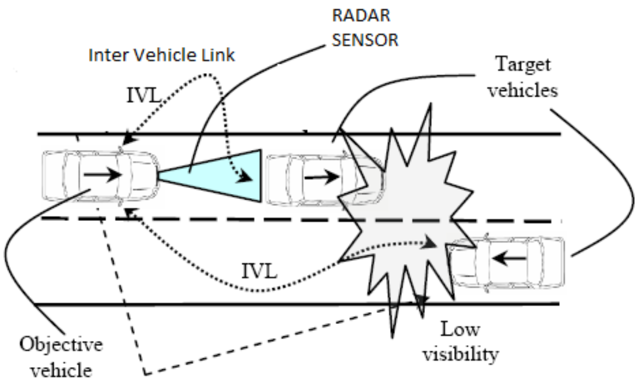


**Fig. 1: The CAWAS Model to be realized.**

The objective vehicle has an obstacle vehicle (target vehicle) in front of it, objective vehicle want to overtake it but second target vehicle is approaching in opposite direction and there are low visibility conditions. The three vehicles have Intra Vehicle Link (IVL) communication systems. Additionally, each vehicle has local radar sensors as in ACC systems.

## 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.

### a. *List of Equipments for the realization*

1. Signal Master Dual ADP (SM) is used for baseband and IF processor in both transmit and receive chain of Objective Vehicle.
2. SFF SDR is used for baseband, IF processor in both transmit and receive chain of target vehicle.
3. Laptop as Remote Host or GPP
4. Vector Signal Generator ( VSG) as I Q Modulator in Transmitter Chain
5. 12/11 GHz Transmit and Receive Front End for SRR operation
6. 60 GHz Transmit and Receive Front End for LRR operation.
7. Horn antennas

### b. *The Architectures of Major Items*

#### *i) Signal Master Dual ADP [ Advanced Development Platform]*


Published By:
Blue Eyes Intelligence Engineering
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Lyrtech make SM Signal Master Dual [4] is an ADP solution including one Virtex 4 FPGAs and two TI C 6416 DSPs in cPCI Chasis. Laptop is used as a Remote HOST or GPP connected to the cPCI chasis through a PCI bridge and its Ethernet port. At the reset or turn on, the GPP is initialized and Signal Master and other drivers are loaded into the memory and application program from Matlab/Simulink /VHDL/others will run. One ADACMASTER III card is used as ADC & DAC card and can be fitted with the SM card through a special LYRIO+ Bus. I Q signals are Input and output from this card.

***ii) Lyrtech Make SFF SDR***

SFF SDR composed of 3 tier boards [4].

Tier 1: Base band processor board having one TI 6446 SOC where both GPP and DSP are integrated in a single IC, one Xilinx Virtex 4 FPGA. Laptop having Matlab /Simulink is connected to the Ethernet port of the SOC and thus Laptop becomes the integral part of the System. The communication between the SOC and the FPGA is established using VPSS bus.

Tier 2: This board is named as 'The ADACMASTER III' board where two 500 MSPS DAC, two 125 MSPS ADC and one Virtex4 FPGA are involved. The communication between the Tier 1 and Tier 2 is established using LYRIO fast communication Bus supporting a data rate of 5 GBPS.

Tier 3: This RF board is analog RF board having the SPI based tuning from the base band board.

***iii) Vector Signal Generator ( VSG)***

The modulated I Q signals coming out of the SM or SFF SDR are summed together in VSG to form a complex composite signal . It is then up converted to an TX_IF signal at 20 MHz which will come out of the VSG. One R&S VSG is used for this purpose.

***iv) 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.

***v) 60 GHz Transmit and Receive Front End for LRR operation***

***1. Description of Transmitter Section***

The SM or SFF SDR are programmed to generate the TX_IF signal of 20 MHz sub carrier on which both the IVL data and and Barkar code for radar operation are multiplexed. It is then up converted to 60 GHz modulator whose another input uses a varactor tuned Gunn oscillator, which is supplied with 4.7-volt dc voltage obtained from a combination of regulated power supply and precision regulator. The Gunn oscillator is followed by 60 GHz attenuator and frequency meter for the control and frequency measurement of 60 GHz transmitted signal respectively. One horn antenna is connected at the output for radiation of 60 GHz signal.

***2. Description of 60 GHz Receiver***

The receiver of the 60 GHz consists of a front end, which receives signal through another horn antenna. There is another Gunn oscillator generating 61GHz frequency. These two frequencies are fed to a mixer and produces Rx_IF1 1GHz signal at the output. This signal is further amplified by two IF amplifiers and is fed to input of the satellite receiver tuner. The I-Q signals from the satellite tuner form RX_IF2 signals which are connected to either SM or SDR for further processing and information and data retrieval.

## III. SIMULATION OF RADAR AT 60GHZ

### *A. END to END Simulation*

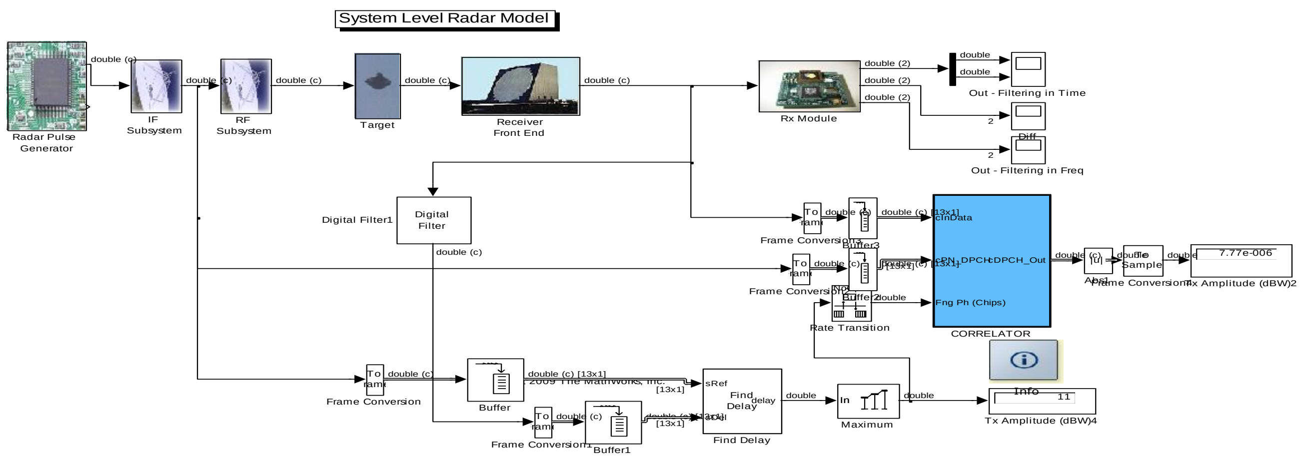


**Fig. 2: The end to end LRR simulation at 60 GHz with transmitter, receiver for the radar and the target vehicle.**

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 60 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 information like range, velocity, target RCS etc.

### B. Details of Baseband code generation for Radar

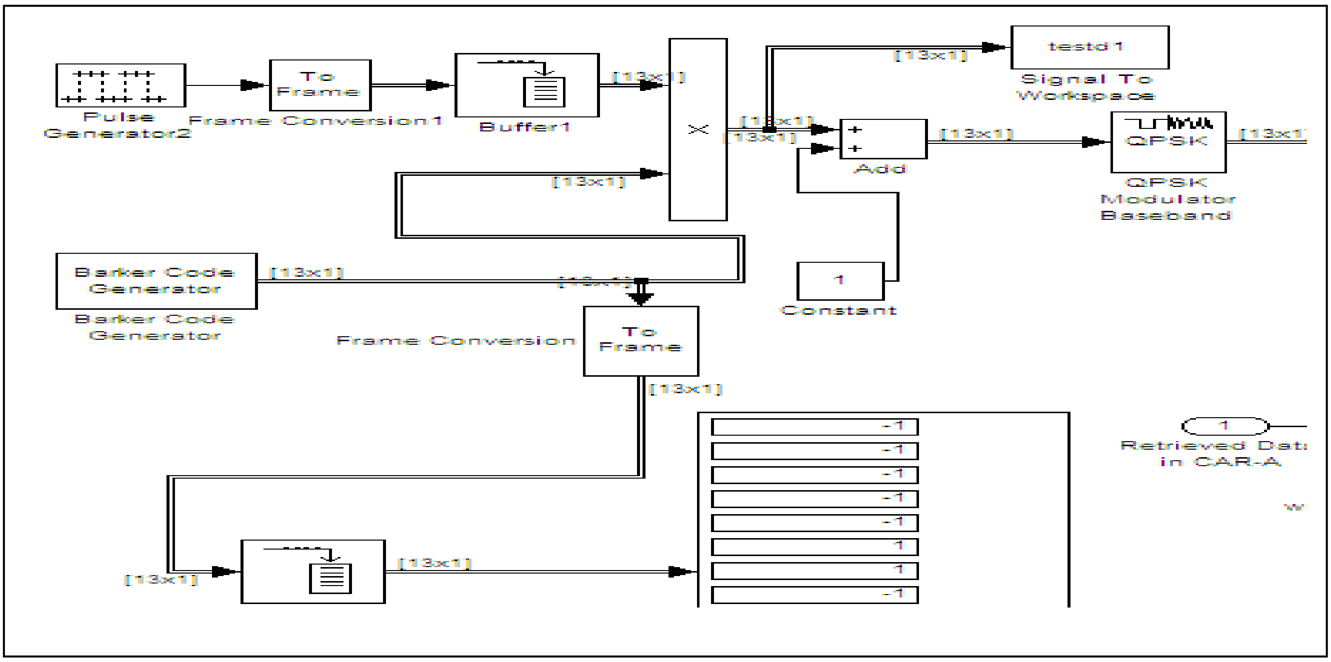


**Fig. 3: baseband pulsed barker code generation for 60 GHz radar transmitter.**

The Baseband pulse of 6% Duty Cycle is used and a 13-Bit Barker Code generates the Spread Spectrum signal which is finally RF Modulated with 60 GHz carrier and sent through the radar Transmitter.

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 simultaneously.

## IV. HARDWARE REALIZATION

### A. The Experimental set up

The above items are cascaded to form the total embedded system which is shown in Fig. 4. In the Laboratory, systems are tested for all the modes using either 60 GHz or 12/11

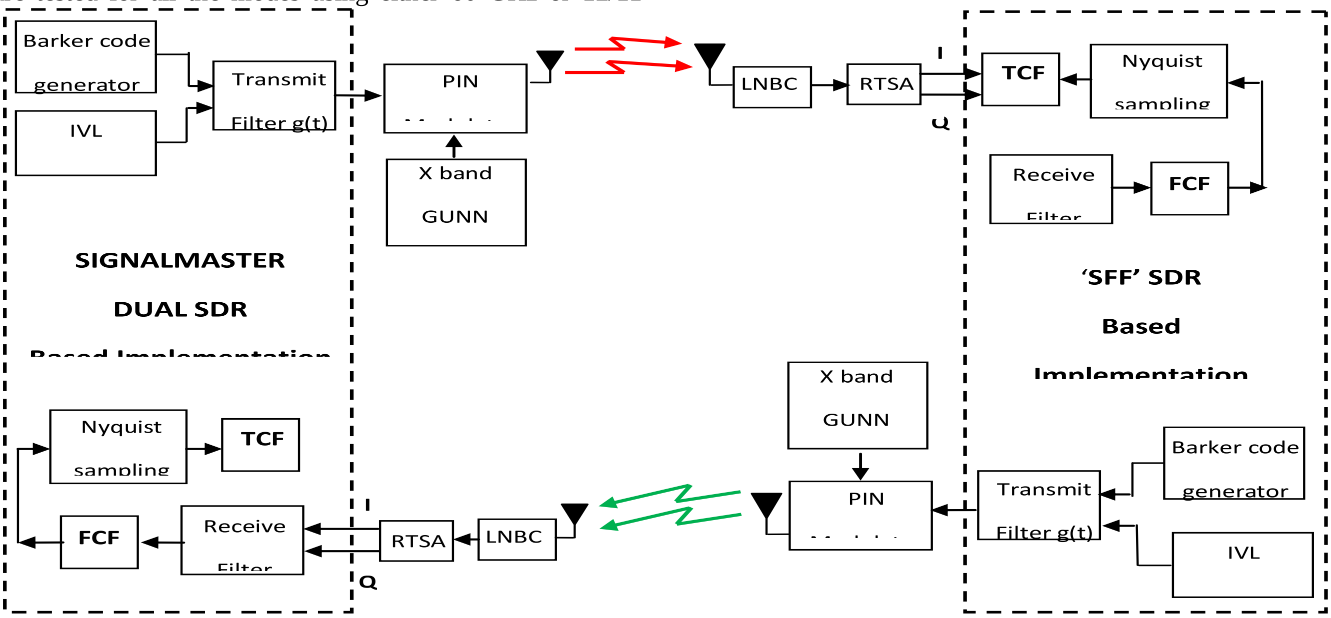


**Fig. 4. Realization of CAWAS model having one signal master dual in objective vehicle and SFF SDR in target vehicle along with the IVL communication between vehicles.**

### B. Model Based software development

Following the Simulink Model based software development approach, we have realized the Spread Spectrum radar transmitter and receiver section with the help of SFF SDR kit. In base band part, first the basic information data is spread by using 13 bit barker code. After spreading, it is then passed through the VPSS bus, which is basically a communicating bus between DSP section and FPGA section.

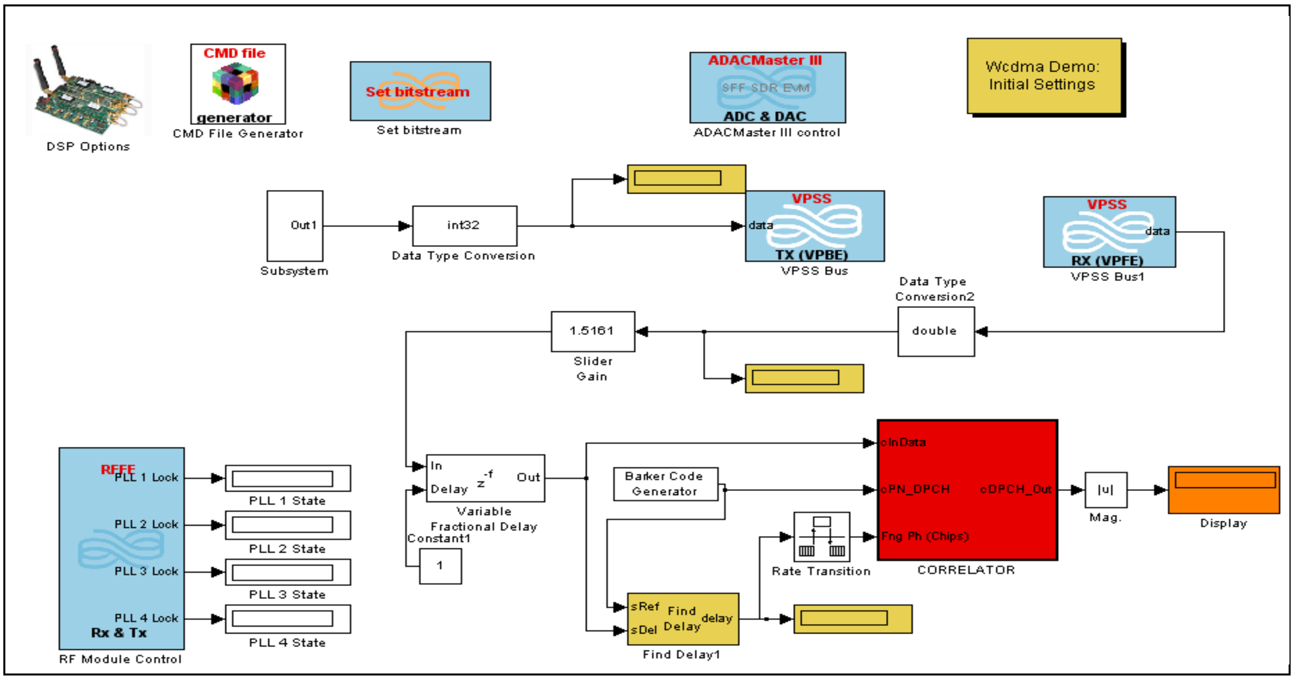


**Fig. 5: Sample DSP model for base band transmitter and receiver processing**

### C. Experimental Results

#### i)Measurement of range and range resolution

In the Laboratory, instead of vehicles, standard metal surfaces like two Flat Plates of dimension (0.68m x 0.91m) and (1m x 1m) are placed in front of the radar to measure the range between the two. The range and range resolution are tested and is shown in Fig.6.

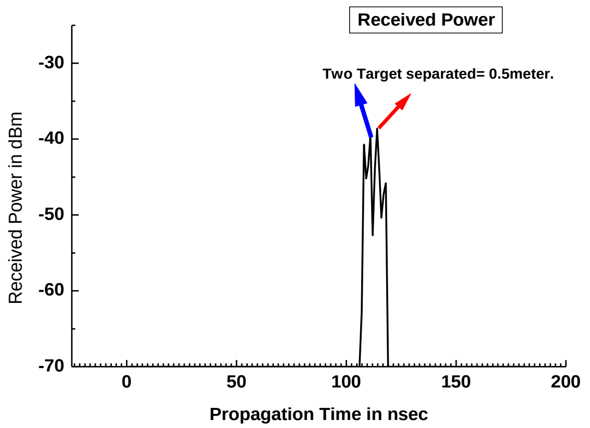


**Fig. 6: Range estimation for double targets ($R_1$= 16.55m, $R_2$= 17.1m).**

#### *ii) Clutter Rejection Through Time Correlation Function*

If we observe the following plot, it is clearly visible that around the Target Zone, the unwanted peaks are vanished. This implicates that the Ground clutters are rejected significantly over the Target Zone. [5]

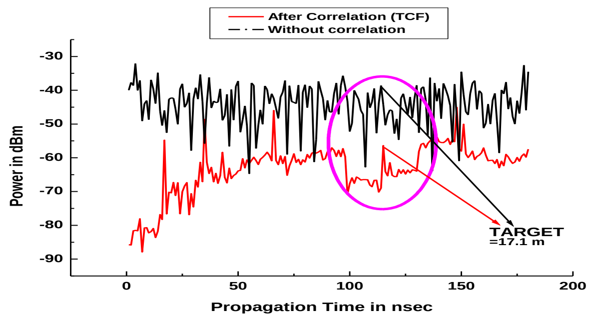


**Fig. 7: Clutter Rejection by Implementing TCF**

#### *iii) RANGE and CROSS RANGE RESOLUTION*

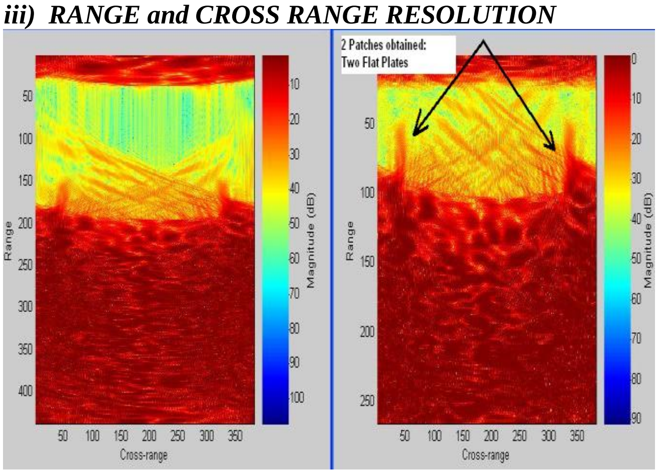


**Fig. 8: Two Flat plates are resolved in cross range.**

The flat plates are placed in cross range dimension and 2 patches are obtained as shown in Fig. 8. Lots of others interesting results are obtained and analyzed.

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