Advances in Intelligent Transportation Systems (AITS)
Vol. 1, No. 2, 2012, ISSN 2167-6399

www.worldsciencepublisher.org

Integrated Radar and Communication as Collision Avoidance and Warning System

[1]Arun Kumar Singh, [2]Samarendranath Sur,[3] Soumyasree Bera, [4]Rabindranath Bera

[1]M.tech ,Department of Electronics and communication engineering
[2]Assistant Professor, Department of Electronics and communication engineering
[3]Scientist-B, Department of Electronics and communication engineering
[4]Head of the Department, Department of Electronics and communication engineering
[1,2,3,4]Sikkim Manipal Institute of Technology, Majhitar
Sikkim,India

{arunsingh.smit, samar.sur, soumyasree.bera, rbera50}@gmail.com

Abstract: The concept of “smart” cars or intelligent vehicles is presented as one of the most promising solutions to reduce the high mortality rate that occurs on the world’s roads nowadays. Besides, the recent publication of standards as the European Standard for Intelligent Transportation System (ITS) or the international standard IEEE 802.11p confirm the importance of the future vehicle-to-vehicle or vehicle to-infrastructure networks, which can aid the driver with information about the road status like traffic conditions etc. The main aim of this paper is to propose such a system which is a integration of radar and communication modules which can be collectively called as Collision Avoidance and Warning System.

Keywords: Intelligent Transportation System (ITS); dedicated short range communications (DSRC); ultra wide band (UWB); Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA).

1. Introduction

Every year there are many road accidents which takes thousands of lives. Is there any way to save those valuable lives? The answer is yes. This problem can be solved by the using the technology of Integrated Radar and Communication.

This technology is standardized as Intelligent transport system (ITS). ITS involves a broad range of wireless and wire-line communications-based information, control and electronics technologies. Short-range communications (less than 500 yards) can be accomplished using IEEE 802.11 protocols, specifically WAVE or the dedicated short range communications (DSRC) standard being promoted by the intelligent transportation society of America and the United States department of transportation. The US FCC has allocated 75 MHz of spectrum in the 5.9 GHz band (5.8 GHz for Europe and Japan) for DSRC to enhance the safety and productivity of the nation’s transportation system. To provide potential benefits of ITS applications in a national highway network, a broad range of research and development efforts are being carried over under the umbrella of ITS Technology.

This is made possible with the rapid progress in electronics and communication technology, such as radar, DSP etc.. We know that radar system and communication system are similar in principle. They are all processes of electromagnetic wave transmitting and receiving. Therefore we can say that radar system and communication system have many similar modules, for example, antenna, transmitter, receiver and signal processor, etc.

The block diagram shown below will make the scenario much clear.

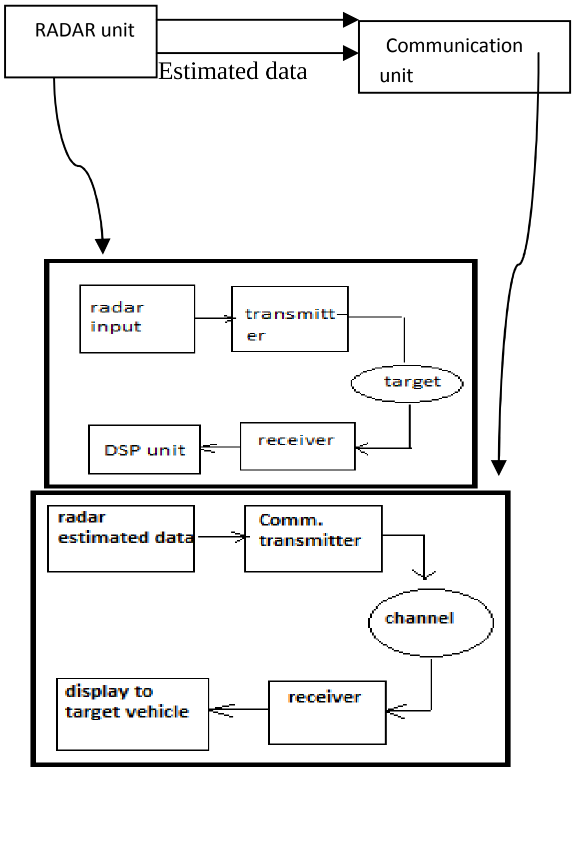


Fig.1 Basic block diagram showing the joint Radar and communication Operation.

The system shown in fig.1 can be called as intelligent transport system (ITS).

The proposed Radar system in this paper is an Ultra-Wide Band(UWB) Radar. It has attracted much interest for fine resolution radar and high rate communication over the past decades. According to Shannon channel capacity equation

$$C=B\ log_2(1+S/BN_0) \qquad (i)$$

which means ultra-wide band has huge channel capacity and potentially carries ultra high information. Additionally more bandwidth means Range resolution will be more as it depends on

$$Range= C/2B \qquad (ii)$$

UWB system can utilize spread spectrum techniques for low probability of interception, high immunity against electromagnetic interference (EMI) and anti jamming. And because of transmitting short pulses without a carrying frequency, the time-domain system is relatively simple, cheap and robust.

That's why UWB in automotive radar is now very common. There are two types of automotive radar; "long-range radar at 77GHz with a range capability up to 200m"for automatic cruise control (ACC) and "short-range radar at 24/26 and 79GHz up to 30m"for anti-collision. Long radar with narrow radiation beam enables a automobile to maintain a cruising distance, while short-range radar has recently attracted attention because of many applications such as pre-crush warning, stop-and-go operation and lane change assist. The short-range radar with a very broad lateral coverage has a few significant problems to be overcome such as target detection and clutter suppression. This is because the widely radiated radar echo contains not only automobile echo, but also unwanted echoes called clutter. It is actually not easy to detect a target echo in increased clutter. Ultra-wideband impulse-radio (UWB-IR) radar with high range-resolution (refer eq.ii) has recently attracted much attention for automotive use, because it offers many applications such as pre-crush warning and lane change assist.

As said above the radar system and communication system have many similar modules, for example, antenna, Transmitter, receiver and signal processor, etc. That is to say, if we can multifunctionalize RF subsystems, we can reduce cost, minimize the radar cross and probability of intercept, and allow systems to work simultaneously with tolerable co-site interference in the time domain.

In order to have an integrated Radar and Communication system, the major thing that is to be noticed is to avoid interference between Radar and Communication signal.

For this both the signals should be mutually orthogonal. Let $S_{ITr}(t)$ denotes the signal of the integration transmitting, it can expressed as

$$S_{ITr}(t)=S_r(t)+S_c(t) \qquad (iii)$$

where $S_r(t)$ and $S_c(t)$ and are the radar and communication signals respectively.

Assuming an ideal condition we can express the signal received by the integration as

$$S_{Ire\ c}(t)=K_1S_r(t)+K_2S_c{}'(t) \qquad (iv)$$

where k1 and k_2 are coefficients that account for the radar and communication signals propagation and reflection losses, and $S_c{}'(t)$ is the communication signal transmitted by the integration which communicates the data to the receiver. According to the matched-filter theory and assuming perfect synchronization, we get the detection statistic $S_{ID}(t)$ as follow:

$$S_{ID}(t)=\int_{-\infty}^{\infty} S^*_{ITr}(t)\ S_{I\ rec}(t)\ dt \qquad (v)$$

$$= k_1\int_{-\infty}^{\infty} |S_R(t)|^2\,dt + k_2\int_{-\infty}^{\infty} S_c^*(t)\,S_c{}'(t)\,dt + k_2\int_{-\infty}^{\infty} S_c^*(t)\,S_R(t)\,dt + k_2\int_{-\infty}^{\infty} S_R^*(t)\,S_c{}'(t)\,dt \qquad (vi)$$

According to (4), to avoid degradation by the radar and communication data interfering each other, $k_1\int_{-\infty}^{\infty} |S_R(t)|^2dt$ and $k_2\int_{-\infty}^{\infty} S_c^*(t)\,S_c{}'(t)\,dt$ must be extracted independently. Additionally $k_2\int_{-\infty}^{\infty} S_c^*(t)\,S_R(t)\,dt$ and $k_2\int_{-\infty}^{\infty} S_R^*(t)\,S_c{}'(t)\,dt$ should be zero. This means different signals should be mutually orthogonal. We can accomplish the function through spatial orthogonality or temporal orthogonality respectively. Conventional methods to prevent self jamming are spatial orthogonality, which capitalizes on the independence between signals from different transmitters and receivers. It can be said as MIMO (Multiple-Input Multiple-Output) method. Spread spectrum technique is another approach to orthogonalize the different signals.

CDMA technique provide a multiple access way for many users to share the available bandwidth, and they can also provide some immunity to interference from existing users, as well as mitigation of interference caused to these users. So we use DSSS technique to orthogonalize the radar and communication data. It avoids interference by configuring the spreading function in the receiver to concentrate the desired signal but spread out and dilutes any other signals.This paper proposes the integration of Radar and Communication model so as to have a complete collision avoidance system.

2. System Architecture description and Results

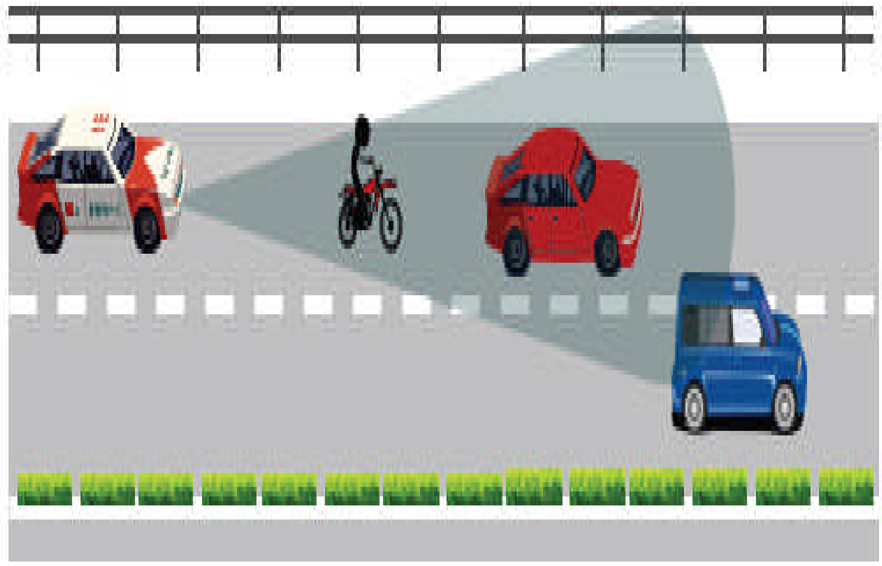
2.1.1 UWB RADAR

As discussed in eq.(i) and (ii), larger the bandwidth greater the channel capacity and the resolution . Radar based on this technology is said to be UWB radar. In particular to this paper a 77GHz automotive Radar has been simulated . The basic principle of UWB radar detection is illustrated in Fig.2 where the received signal includes many echoes scattered from desired and undesired objects. The one-dimensional signal, which is referred to as range profile, is generally presented by multiple impulses with gains { β_K } and propagation delays { τ_K }, where *k* is the impulse index. Suppose a nanosecond pulse of *s*(*t*), the range profile, *y*(τ ,*t*),is the time convolution of *s*(*t*) and the impulse echo response $\Sigma\beta_K\delta(t-\tau k)$ as follows;

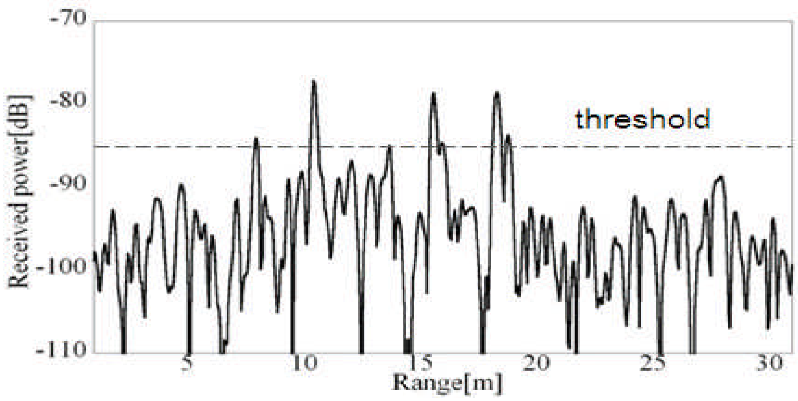
$$y(\tau, t) = \Sigma\beta_K s(t-\tau k)$$

Fig.2 (b) shows an example of received power range profile for a bandwidth of 1GHz (proposed BW of the RADAR, corresponding to 1 nanosecond pulse) on a roadway.

When a target echo exceeds a given threshold, it can be recognized. However if a clutter echo exceeds the threshold, it is mistaken as a target. This is called a missed detection. Consider the target detection in increased clutter as shown in Fig.2, it is not easy to recognize the automobile target since the echoes over a threshold can't be classified usually as target or clutter.



(a) Automobile radar image



(b) Power range profile

Fig. 2. Principle of radar detection

2.1.2 Simulation description

The most vital part of any system is the characteristics of the input. Input signal decides that what type of system will be. In this particular model we have used spread spectrum technique to generate the input of our desired type. A pulse is being treated with a 13-bit barker code. The other advantage of using the spread spectrum technique is to make the system resistible to noise. The figure below will show he spreading operation.

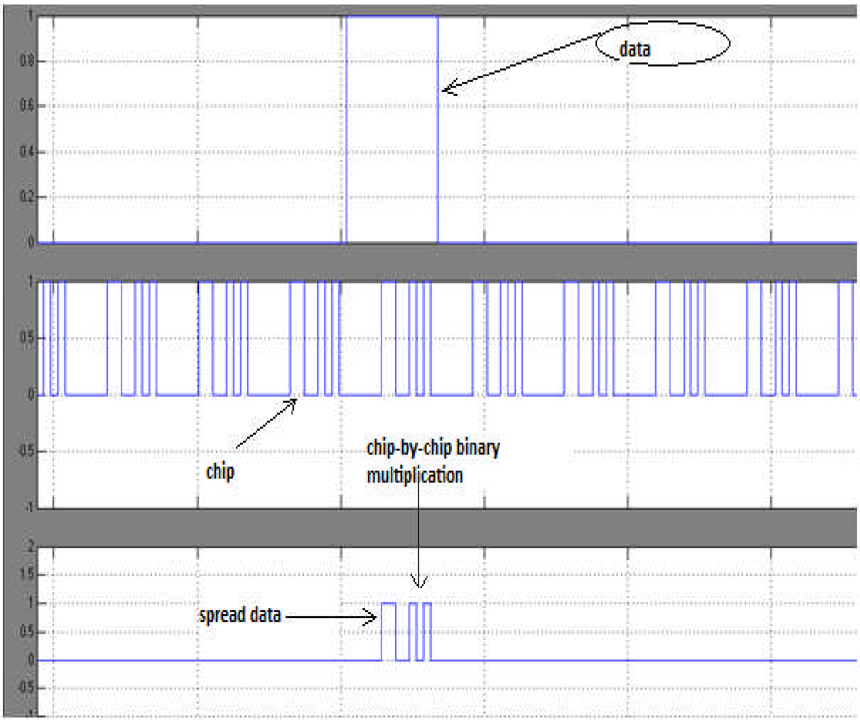


Fig. 3 spreading of signal.

The resultant waveform is the UWB waveforms. The potential advantage of UWB waveforms for radar include better spatial resolution, detectable materials penetration, easier target information recovery from reflected signals, and lower probability of intercept signals than with narrowband signals. Most narrowband systems carry information also called the baseband signal, as a modulation of much higher carrier frequency signal. The important distinction is that the UWB waveform combines the carrier and baseband signal. Baseband or impulse radar are other names for UWB radar and radio signals. The UWB signals generally occur as either short duration impulse signals and as non- sinusoidal (e.g. square, triangular, chirped, pulsed) waveforms.

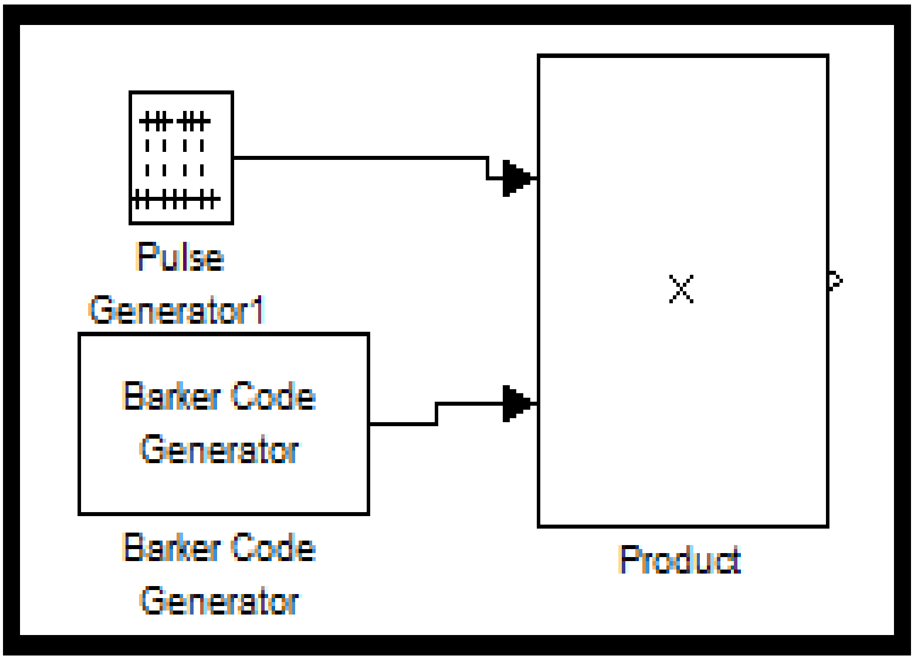


Fig.4 Radar input signal generation.

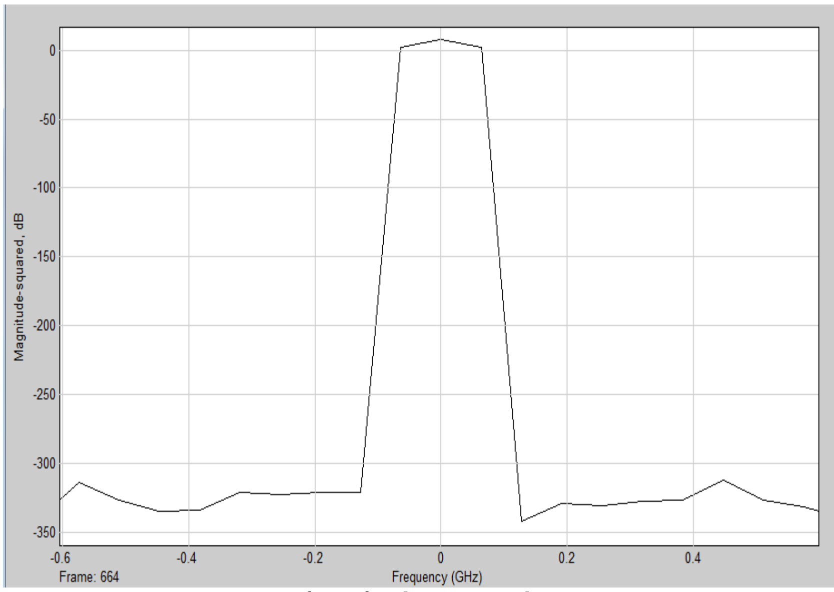


Fig.5 waveform of Radar input signal generation.

2.1.3 Receiver Correlation:

Correlation is basically the relation between two variables. In context of this paper correlation is done between two signals so as calculate the target distance. It is calculated from the time taken by the reflected wave to reach to the receiving antennas. It is given as:

R = C. Td /2 ……………….(vii)

where R is the distance, C is the speed of light[4] and Td is the travelling time to the target and back and is calculated by the correlation between the received barker code and the reference barker code. Autocorrelation is given as:

$$R_{aa}(\tau)=\frac{1}{T}\int_{-T/2}^{T/2} a(t)a(t-\tau)dt=\{1 \quad \text{for } t=0$$

$$\{\ 1-(n+1)/n(\tau)/\Delta \qquad \text{for } -\Delta\leq t\leq\Delta$$

$$\{-1 \qquad \text{otherwise}$$

Autocorrelation figure for Barker code is given as:

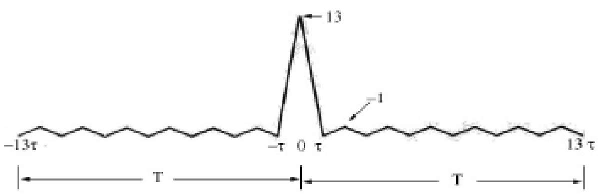


Fig 6. Autocorrelation figure for 13 bit Barker Code

2.1.4Target Detection

From the simulation model of the made 77 GHz millimetre wave UWB Radar, target detection , range and velocity estimation has been done. Detection of targets is shown as below.

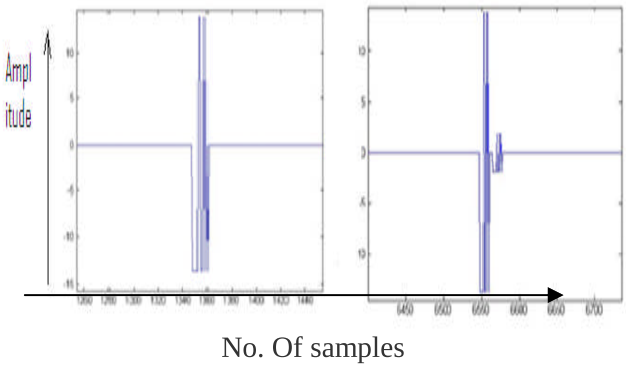


Fig. 7 Detection of Single and double target

The above figure shows the detection of targets. Since as discussed earlier about the input signal generation, therefore in the output also we can see the 13 bit barker code inside a single pulse.

2.1.5 Velocity Estimation

The velocity estimation is done using phase recovery method. It recovers the carrier phase of the input signal using the M-Power method. This feedforward, non-data-aided, clock-aided method is suitable for systems that use baseband phase shift keying (PSK) modulation. It is also suitable for systems that use baseband quadrature amplitude modulation (QAM), although the results are less accurate than those for comparable PSK systems. The alphabet size for the modulation must be an even integer. The M-Power method assumes that the carrier phase is constant over a series of consecutive symbols, and returns an estimate of the carrier phase for the series

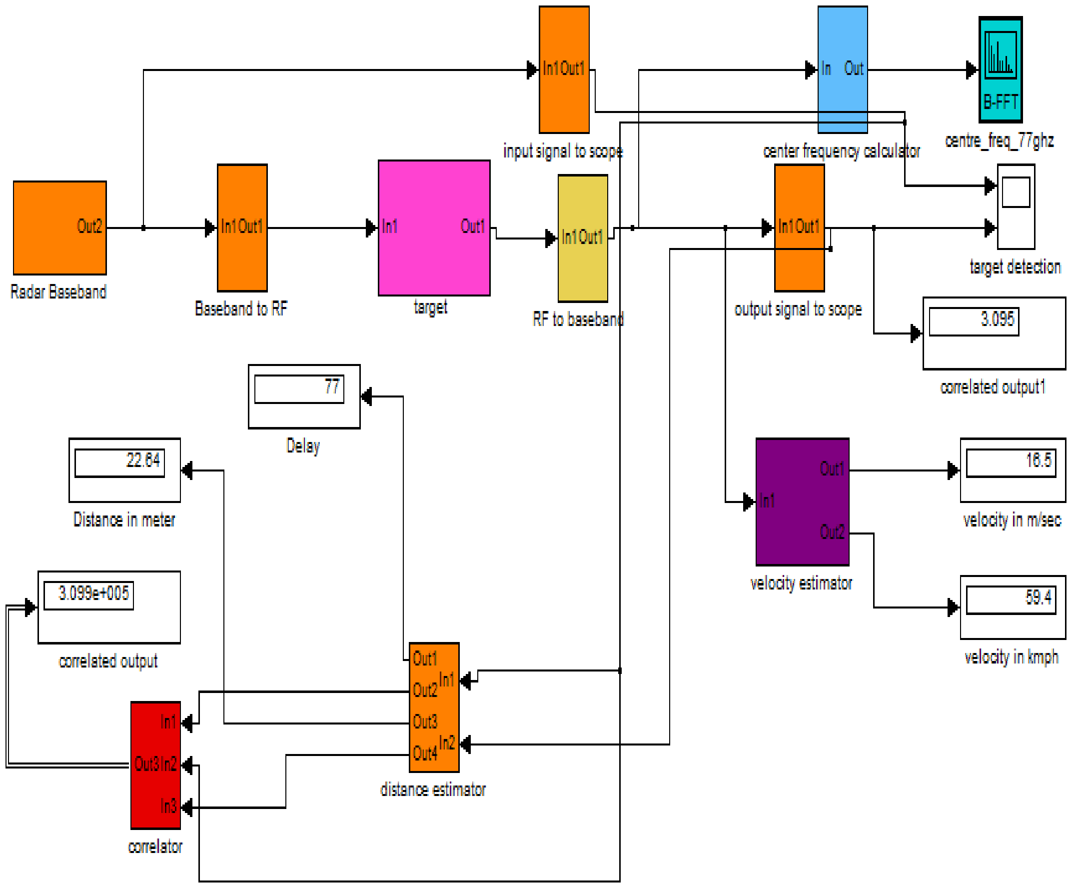


Fig 8. Simulation model for 77GHz Radar for estimation of range and velocity.

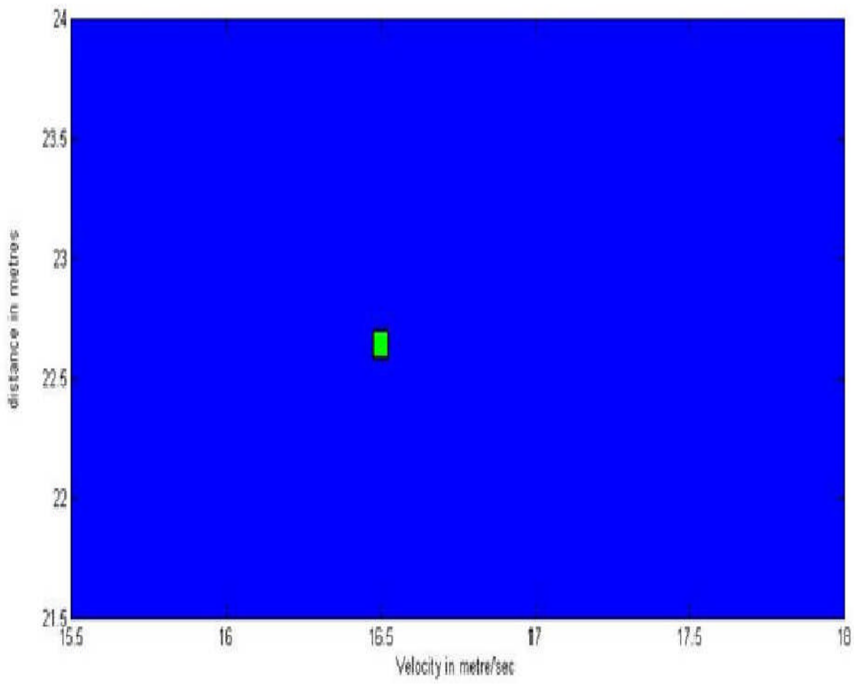


Fig.9 Velocity v/s Distance plot.

2.2 Communication Module

The communication system used in this proposed model is the HIPERLAN/2. It is High Performance Radio Local Area Network type 2 (HIPERLAN/2) shall provide high-speed communications (with a bit rate of at least 20 Mbps) between different terminals. The main goal of using this system is it supports higher data rate than that of IEEE 802.11. HiperLAN/2 uses the 5 GHz band. Since IEEE 802.11 also promises to have a data rate of 54MBPS but practically it cannot give that much of data rate.

The physical layer of HiperLAN/2 is very similar to IEEE 802.11a wireless local area networks. However, the media access control (the multiple access protocol) is Dynamic TDMA in HiperLAN/2, while CSMA/CA is used in 802.11a. It means that in IEEE 802.11a, after the transmission of first packet the second packet will not be sent until the channel is free whereas Hiperlan/2 uses TDMA technique which means it will not have to wait for the channel to be free. In a particular time slot it will send all the data.

2.2.1 Medium Access Control (MAC)

The main differences between IEEE 802.11 and HIPERLAN/2 occur in the MAC. In HIPERLAN/2 the medium access is based on a TDD/TDMA approach using a MAC frame with a period of 2ms. The control is centralized to an 'Access Point' (AP) which informs the 'Mobile Terminals' (MTs) at which point in time in the MAC frame they are allowed to transmit their data. Time slots are allocated dynamically depending on the need for transmission resources. IEEE 802.11a uses a distributed MAC protocol based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA).The Hiperlan/2 and IEEE 802.11 MAC layer is given in more detail in following section.

2.2.2 HIPERLAN/2 MAC layer

The MAC frame structure (Figure 1) comprises time slots for broadcast control (BCH), frame control (FCH), access feedback control (ACH), and data transmission in downlink (DL), uplink (UL), and directlink (DiL) phases, which are allocated dynamically depending on the need for transmission resources . An MT first has to request capacity from the AP in order to send data. This can be done in the random access channel (RCH), where contention for the same time slot is allowed.

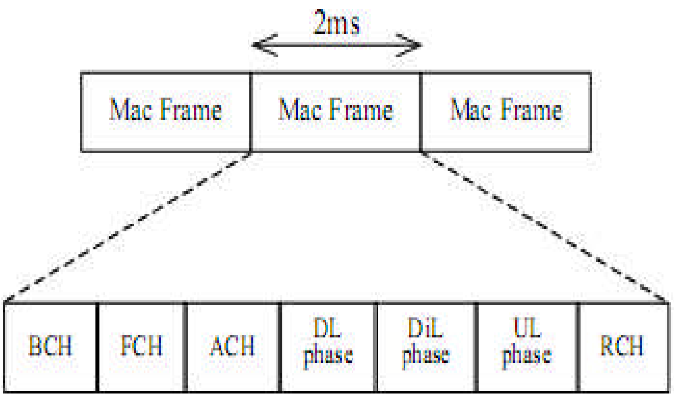


Fig.10 Hiperlan/2 MAC frame.

Downlink, uplink and directlink phases consist of two types of PDUs: long PDUs and short PDUs. The long PDUs (Figure 2) have a size of 54 bytes and contain control or user data. The payload is 49.5 bytes and the remaining 4.5 bytes are used for the PDU Type (2 bits), a sequence number (10 bits, SN) and cyclic redundancy check (CRC-24). Long PDUs are referred to as the long transport channel (LCH).

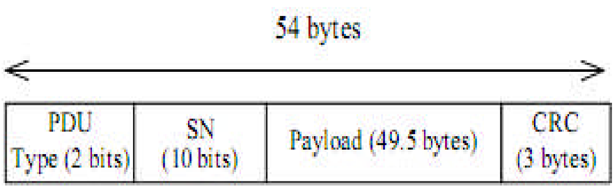


Fig. 11 format of long PDUs.

Short PDUs contain only control data and have a size of 9 bytes. They may contain resource requests, ARQ messages etc. and they are referred to as the short transport channel (SCH).Traffic from multiple connections to/from one MT can be multiplexed onto one PDU train, which contains long and short PDUs. A physical burst (Figure 11) is composed of the PDU train payload and a preamble and is the unit to be transmitted via the physical layer.

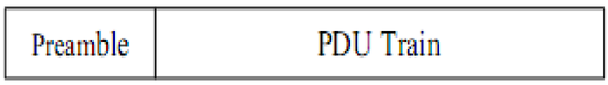


Fig. 12 HIPERLAN/2 Physical Burst Format.

2.2.3 IEEE 802.11 MAC

As stated earlier IEEE 802.11 uses a distributed MAC protocol based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). A mobile terminal must sense the medium for a specific time interval and if the medium is idle it can start transmitting the packet [2,6]. Otherwise the transmission is deferred and a backoff process begins, which means that the terminal has to wait for a time interval. Once the backoff time has expired, the terminal can access the medium again [10]. Because a collision in a wireless environment is undetectable, a positive acknowledgement is used to notify that a frame has been successfully received. If this acknowledgement is not received the terminal will retransmit the packet.

Figure 12 shows the format of a complete packet (PPDU) in 802.11a, including the preamble, header and Physical Layer Service Data Unit (PSDU or payload).

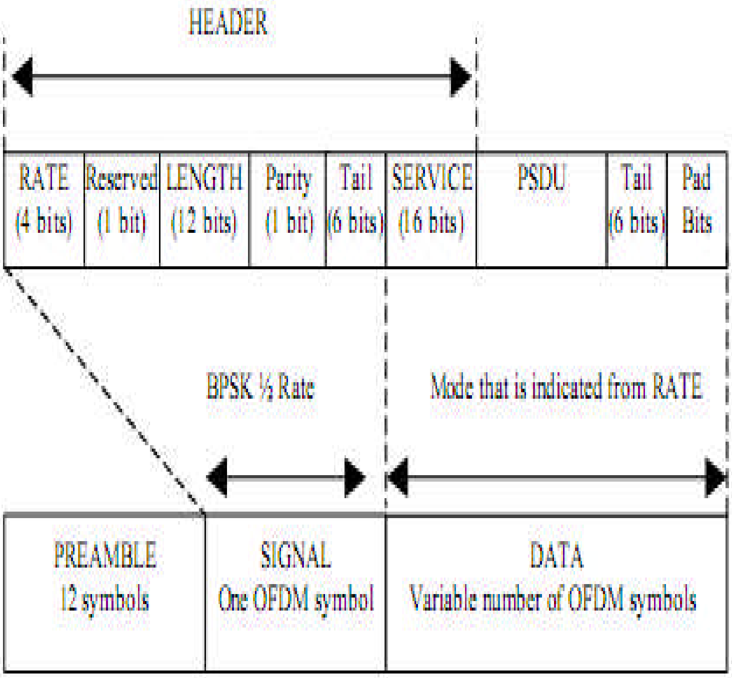


Fig. 13: PPDU Frame Format [2]

The header contains information about the length of the payload and the transmission rate, a parity bit and six zero tail bits. The header is always transmitted using the lowest rate transmission mode in order to ensure robust reception. Hence, it is mapped onto a single BPSK modulated OFDM symbol.

The rate field conveys information about the type of modulation and the coding rate used in the rest of the packet. The length field takes a value between 1 and 4095 and specifies the number of bytes in the PSDU.

The six tail bits are used to reset the convolutional encoder and to terminate the code trellis in the decoder. The first 7 bits of the service field are set to zero and are used to initialize the descrambler. The remaining nine bits are reserved for future use.

The pad bits are used to ensure that the number of bits in the PPDU maps to an integer number of OFDM symbols.

3. Simulation description of Communication module

Communication module used in this proposal is the HIPERLAN/2. The reason of choosing this is its several advantages over the IEEE 802.11(which has been discussed earlier).

The general description of HIPERLAN/2 model is given below:

The block diagram of the simulation setup for HIPERLAN/2 model is shown in the fig.13. In our transceiver model, binary data bits are generated and then channel coded by a convolutional encoder. The forward error correction code rate is normally 1/2. [27, 28] Optional puncturing omits some of the encoded bits in the transmitter, increasing the bit rate, and inserts a dummy 'zero' metric into the convolutional decoder on the receiver side in place of omitted bits The 1/2 code rate can be increased to 2/3, 3/4 or 9/16 by a suitable puncturing code. Interleaving, with a block size corresponding to the number of bits in an OFDM symbol, reduces the effect of frequency selective fading in the radio channels. It also prevents error bursts from being input to the convolutional decode process in the receiver. Binary values are then mapped to QAM (BPSK, QPSK) symbols, which are normalized to achieve the same average power for all transmission mappings. The IFFT converts all the mapped symbols in the frequency domain into a time domain signal for transmission.

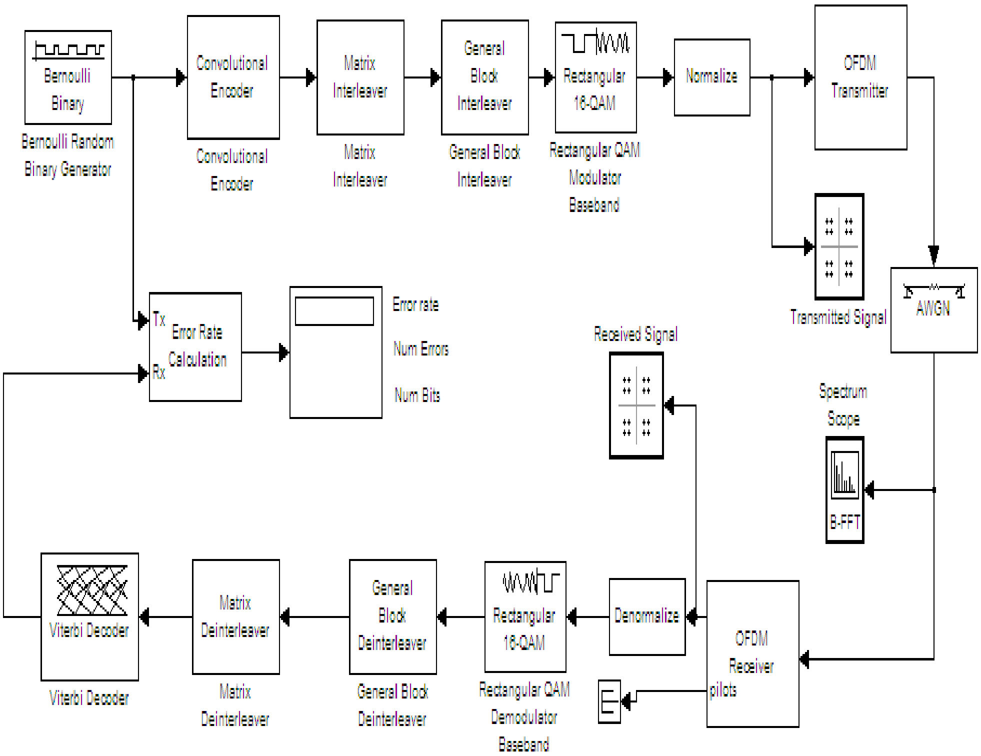


Fig.14 simulation model of HIPERLAN/2

Zero padding (the addition of extra zero bits in the OFDM symbol) is used to avoid aliasing. Cyclic prefixing can be implemented by adding the last few bits of a symbol at the beginning of the symbol and is used for both timing and frequency synchronization. On the receiver side, most of the functions are just the opposite of the equivalent transmitter blocks. The time domain signal is converted into the frequency domain by the FFT and symbols are extracted by a QAM (QPSK or BPSK) demodulator. Removal of pilot carriers, frame synchronization and elimination of cyclic prefixes are performed beforehand in the receiver block. After denormalization, frames are passed through a de-interleaving process. Viterbi algorithm is used to decode convolutionally encoded input data. With the Viterbi algorithm, the zero-valued dummy bit has no effect on the outcome of the decoder. Finally the received data bits are compared to the transmitted bits by a bit error calculator.

The BER plot of the system is as shown:

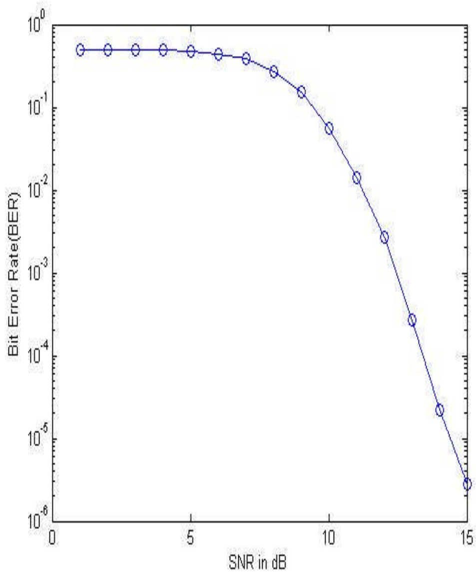


Fig.15 BER plot of HIPERLAN/2

4. Simulation model description of Integrated Radar and Communication

Integration diagram of both the modules viz. radar and communication is given in fig.20. From radar, the desired outputs are the distance and velocity information. Both the extracted data are to be transmitted through the communication system to the target vehicle.

5. Results

Table 1 : distance and velocity estimation table.

Actual distance & velocity	Estimated distance & velocity from radar	Estimated distance & velocity from complete system (int. radar & comm.)
8m, 12m/sec	7.938m, 12 m/sec	8m, 12m/sec
9.4m, 13.5m/sec	9.308m, 13.5m/sec	9m,14m/sec
13.8m,22.4m/sec	13.82m,22.4m/sec	14m,22m/sec
22.5m,16.5m/sec	22.64m,16.5m/sec	23m, 17m/sec

The above table shows the estimation of distance and velocity from radar and from the complete system i.e. integrated radar and communication. There is a very little variation in the estimated and the actual data. Our communication module cannot send the data in decimal format. Therefore, before sending the data, it has to convert it in integer format. This is the only limitation of the communication system.

6. Open field radar test results

The simulation model for radar was realized using hardware. The baseband signal was generated using arbitrary waveform generator **AWG 5014C,** baseband to RF conversion was done using vector signal generator **Rhode & Schwarz's VSG,** horn antennas for transmission and receiving, digitizer, vector signal analyzer (VSA) installed in computer.

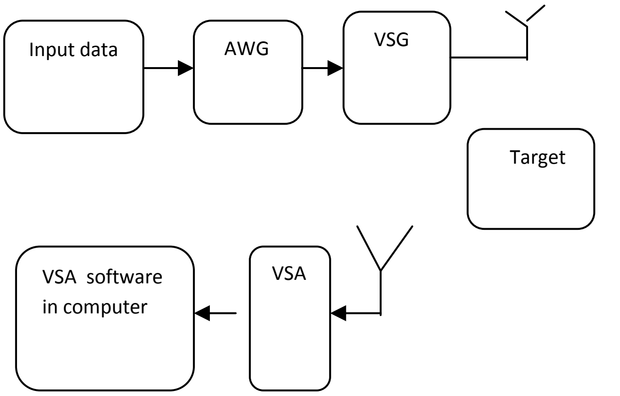


Fig. 16 Experimental setup.

The above setup shown is the hardware setup for realization of RADAR. Its corresponding instrument setup is as follows:

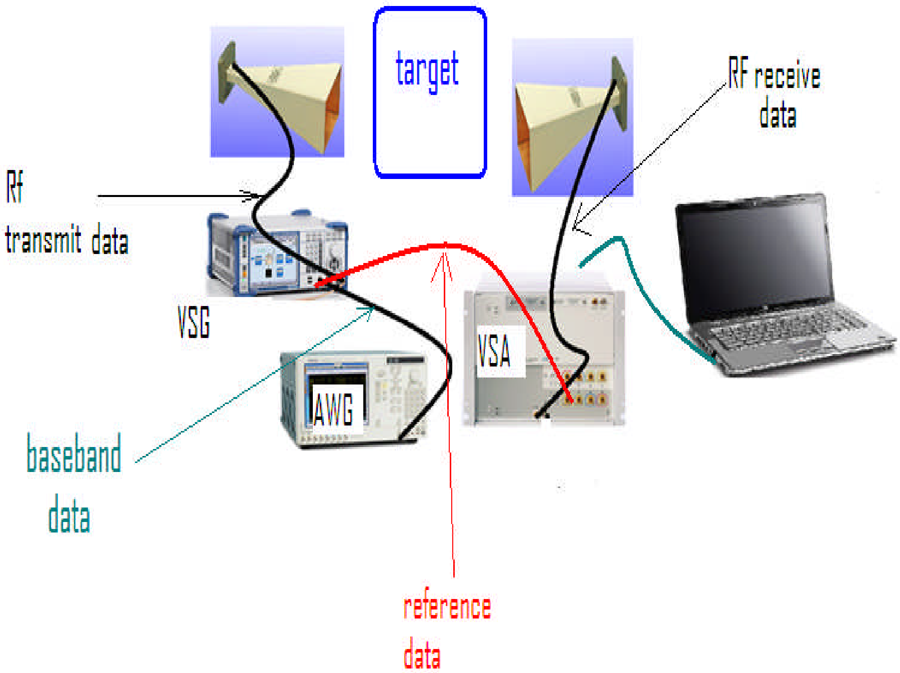
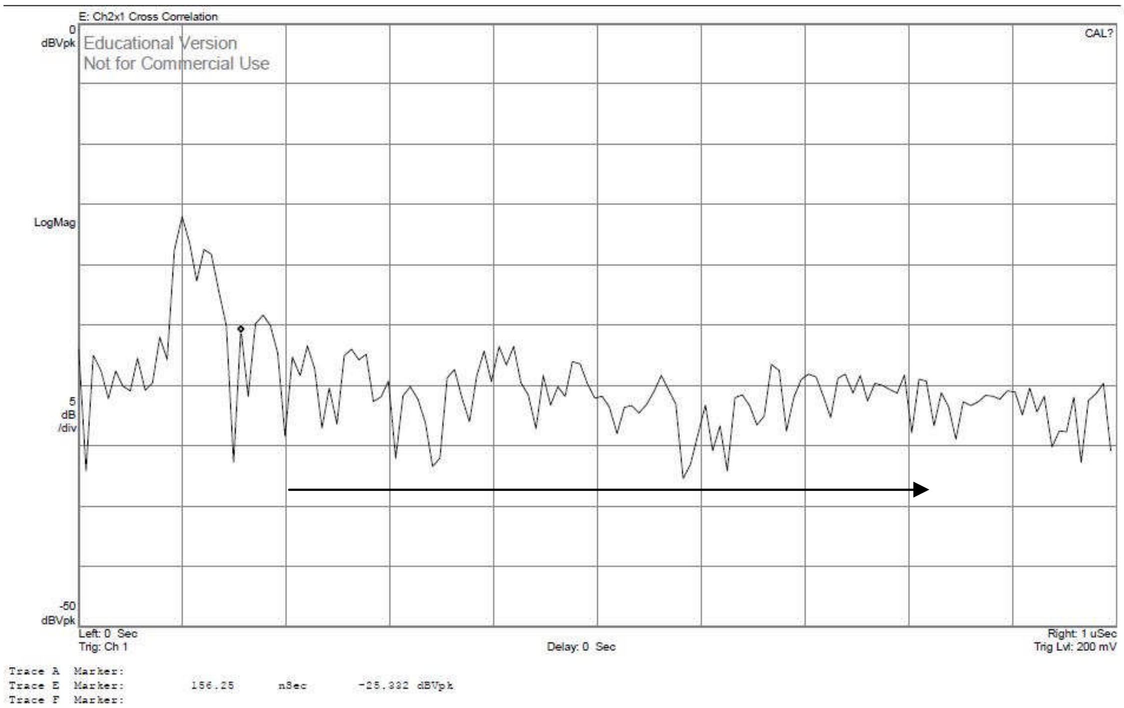


Fig. 17 Hardware setup for radar realization.



Time delay in nsec

Fig. 18 detection of two targets in VSA.

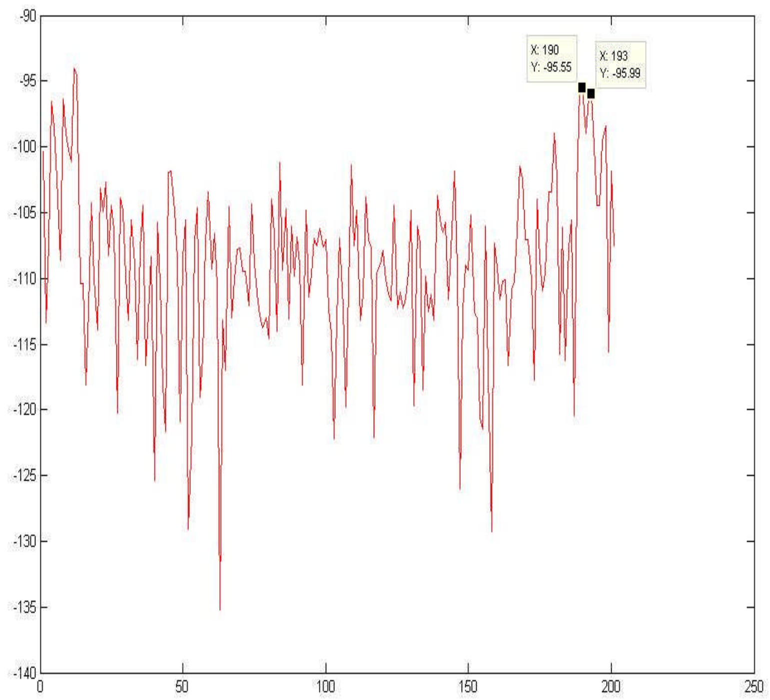


Fig.19 detection of two targets in range using frequency hoping.

Fig. 18 shows the detection of two targets in VSA for instantaneous bandwidth of 100MHz.

The range resolution for 100MHz bandwidth will be 1.5m, i.e., anything kept apart this distance will be resolute successfully.

Fig.19 shows the detection of two targets in range using the method frequency hopping. Due to hardware limitations we cannot go to bandwidth above 350MHz. Therefore the need of frequency hopping arises in this case. Using this method we can go to higher bandwidth. The first target was detected at the position of 190 samples and the second was at 193. There was a difference of three range cell.

1 range cell=0.15m (for BW of 1 GHz, the range resolution is .15m)
3 range cell=0.15m x 3=0.45m (estimated distance between two plates)

The two plates were kept at a distance of 0.45m. It is interesting to see that our estimated distance was also the same.

7. Conclusion

Simulation of integrated radar and communication was the principal objective of this work. In this process, an ultra wide band radar having bandwidth in GHz range has been developed and was successfully simulated within the system. Since the radar is of ultra wide band frequency, centered at 77 GHz (millimeter wave band), has a much better range resolution capability. The only limitation of the system is it cannot transmit data in decimal format. Further work is going on to solve this problem.

References

[1]A 60.5GHz Millimeter Wave Spread Spectrum Radarand Communication System Using a Co-use Antenna-Masahiro Watanabe, Tadamasa Fukae,Yuki Kawahara, Tasuku Teshirogi,Akihito Kato, Katsuyoshi Sato, Masayuki Fujise.

[2] Masahiro Watanabe, Kenji Inomata, Shinsaku Noda, Katsuji Okazaki, Tadamasa Fukae,Hiroshi Naganawa, Masami Akiyama –"A Sideways Looking Radar for Inter-Vehicle Communication: -DEMO2000; Sept. 2001;IVEC2001; No.J-25, pp; Tottori, Japan

[3] Yuji Sekine, Yuki Kawahara, Masanao Kobayashi, Tasuku Teshirogi, Akihito Kato, Masayuki Fujise.
" Millimeter-Wave Radar/Communication Co-use Antenna" Oct. 2001; ITST2001; No.S7-4; pp.249-254;
Yokosuka, Japan

[4] Masahiro Watanabe, Shinsaku Noda, Katsuji Okazaki, Tadamasa Fukae, Akihito Kato, Sato Katsuyoshi, Masayuki Fujise:"60.5 GHz Millimeter Wave Spread Spectrum Radar for Inter-Vehicle Communications"

[5] Xu Shaojian, Chen Bing, Zhang Ping –"Radar-Communication Integration Based on DSSS Techniques".

[6] G. C. Tavik, C.L.H., and J. B.Evins.:"The Advanced Multifunction RF Concept". IEEE Transactions on Microwave Theory and Techniques, 2005. vol. 53: p. pp. 1009-1020

[7] L. Ting-jun, R.J.-c., Z. Yuanlli, and Z. Jin-ua,"Research of Radar-communication Integration". Modern Radar, 2001. vol. 23: p.pp. 1-2,(in Chinese).

[8] P.K.Hughes , J.Y.C., "Overview of advanced mulitifunction RF system (AMRFS)".presented at Proc. IEEE International Conference on Phased Array Systems and Technology, 2000.

[9] E. Fishler, A.H., R. Blum, D. Chizhik, L.Cimini, and R. Valenzuela, "MIMO radar: an idea whose time has come". presented at Proceedings of the IEEE Radar Conference, Philadelphia, PA, 2004.

[10]P. Antonki, R.B., and R. Brown and "Bistatic Radar Denial/Embedded Communications via Waveform Diversity". presented at IEEE Radar Conf, May 2001.

[11] L. Lin, L.J., and Z. Eryang, "The Optimum Interference Suppressor in Direct Sequence Spread Spectrum". presented at ICSP'04,2004.

[12] Y. Wang, Q.X., S. Zhou, and W. Wu, "Adaptive Algorithm based on Pilot-Channel for Multiuser Detection" presented at ICSP2000, 2000.

[13] Xu S. J., Chen Y. and Zhang:" P INTEGRATED RADAR AND COMMUNICATION BASED ON DS-UWB"

[14] Taylor J. D., "Introduction to ultra-wideband radar systems". Boca Raton: CRC Press, 2000.

[15] Oppermann I., Hamalainen M., and Iinatti J.," UWB theory and applications". Chichester: John Wiley & Sons Ltd, 2004.

[16] Roberton M. and Brown E. R., "Integrated Radar and Communications based on Chirped Spread-Spectrum Techniques," IEEE MTT-S Digest, pp. 611-614, 2003

[17] Padilla M., "Labs project advances next-generation secure wireless networks," Sandia Lab News, vol. 57, No. 19, pp. 1-4, 2005.

[18] Fishler E., Haimovich A., Blum R., Chizhik D., Cimini L., and Valenzuela R., "MIMO radar: an idea whose time has come," Proceedings of the IEEE Radar Conference, pp. 71-78, 2004.

[19] Khan H. A., Malik W. Q., Edwards D. J., and Ste-vens C. J., "Ultra wideband Multiple-Input Multi-ple-Output radar," Proceedings of the IEEE Radar Conference 2005.

[20] Christian Sturm and Werner Wiesbeck :"JOINT INTEGRATION OF DIGITAL BEAM-FORMING RADAR WITH COMMUNICATION"

[21] J. G. Proakis. Digital Communications, McGraw-Hill,(1989).

[22] Martin Braun∗, Christian Sturm, Andreas Niethammer, Friedrich K. Jondral:" Parametrization of Joint OFDM-based Radar and Communication Systems for Vehicular Applications"

[23] Arun Kumar Singh, Samerendra Nath Sur, Amit Agarwal, Rabindranath Bera:" A Complete Simulation of Target Detection and Estimation Using 77 GHz Radar" ISSN 0975-5462,vol. 4 No.02,feb 2012.

[24] Angela Doufexi, Simon Armour, Peter Karlsson, Andrew Nix,David Bull," A Comparison of HIPERLAN/2 and IEEE 802.11a"

[25] J.Khun-Jush, G.Malmgren, P.Schramm, J.Torsner "Overview and Performance of the HIPERLAN/2 –A Standard for Broadband Wireless Communications," IEEE VTC'00 Spring (Tokyo).

[26] R.van Nee, G.Awater, M, Morikura, H. Takanashi, M.Webster, K.W.Halford, "New High-Rate Wireless LAN Standards", IEEE Communications Magazine, Vol.37, No.12, December 1999, pp.82-88.

[27] K.N.Prakash, N.Swetha Lakshmi, K.Akshay "Mobile Operated Campus Application For Retrieval Of College Server Data Using Wi Fi Connection", Advances in Computer Science and its Applications (ISSN 2166-2924) Vol. 1, No. 2, June 2012
Copyright ©World Science Publisher, United States

[28] Shih-Wei Lin , So-Tsung Chou, Chou-Yuan Lee, and Zne-Jung Lee" A Hybrid Approach for Vehicle Routing Problem with Time Windows" Advances in Intelligent Transportation Systems, Vol. 1, No. 1, March 2012, Copyright ©World Science Publisher, United States

[29] Avanaksh Singh Sambyal, Prikhshayat Singh" Routing Misbehavior in MANets and How it Impact QoS!" Advances in Computer Science and its Applications (ISSN: 2166-2924) Vol. 1, No. 1, March 2012

Vitae

Mr. Arun Kumar Singh: Born in 1988 in Bihar, India, received his B.tech, M.tech Degree in Electronics and Communication Engineering dept. from Sikkim Manipal Institute of Technology. His area of interest is remote sensing, mobile communication and satellite communication.

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 Ex-Dean(R&D), Professor and Head of the Department, Electronics & Communication Engineering, Sikkim Manipal Institute of Technology, Sikkim

Samarendra Nath Sur: Born in 1984 at Hooghly, WestBengal, INDIA. Received M.Sc. (Electronics Science) from Jadavpur University in the year 2007 and pursuing M.Tech from Sikkim Manipal University. Currently working as Asst Professor, E&C Dept, Sikkim Manipal University, India. Broadband Wireless Communication, 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.

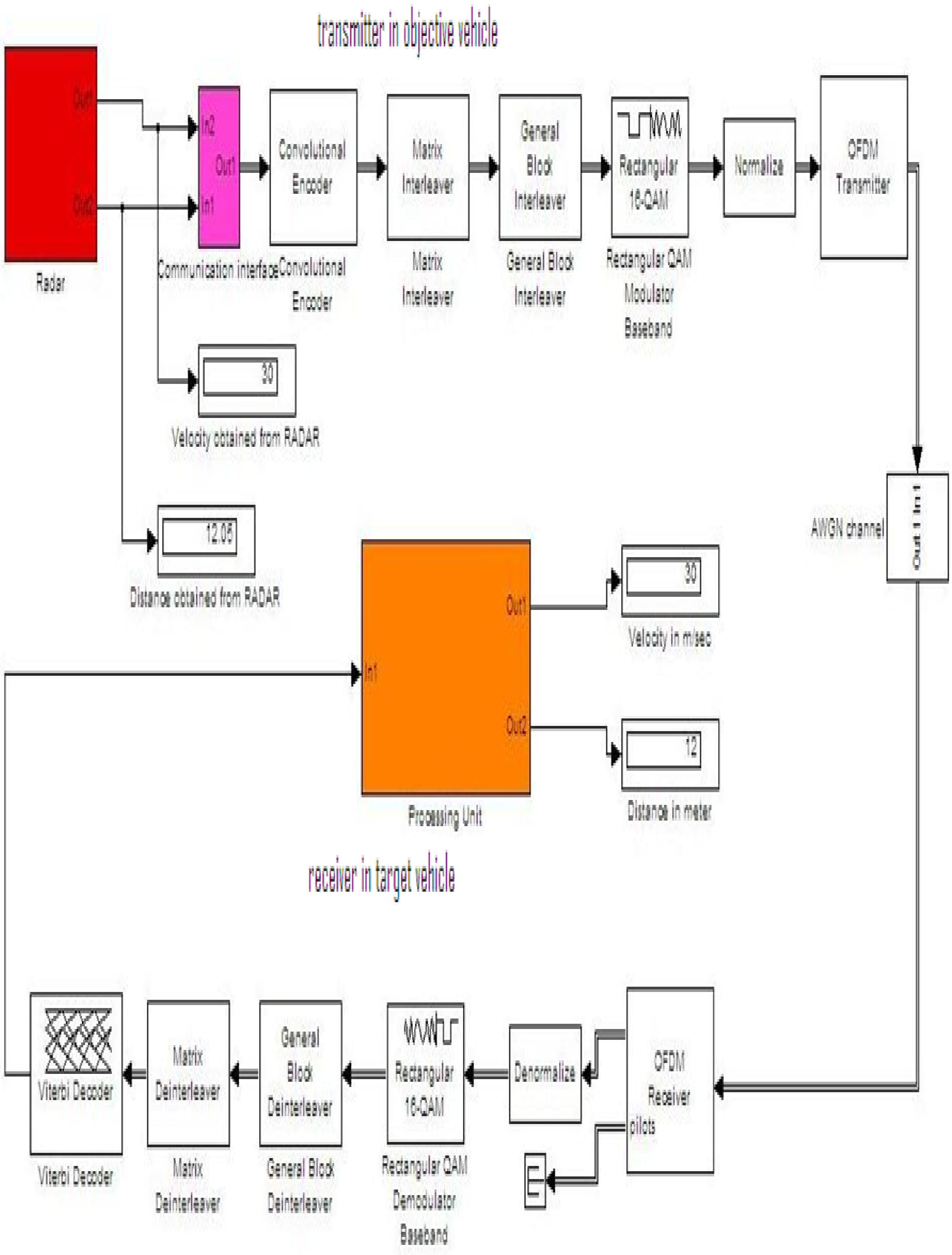


Fig. 20 Integrated Radar and Communication