E-VEHICLE: AN IMPLICATION TO NEXT GENERATION TRANSPORTATION

[1]SOURAV CHAKRABORTY and [1]PROSENJIT KUMAR SUTRADHAR

[1]Final year B.Tech (ECE) Student in College of Engineering and Management, Kolaghat

K.T.P.P Township Purba Medinipur, W.B, India.

E-mail: sourav.cemk2008@gmail.com, prosenjit_sutra@yahoo.com

ABSTRACT

Casualties due to traffic accidents are increasing day by day. Think of this message being displayed on your computer screen while you were driving "there's a possibility of collision with a car in the next few minutes if you go on driving with this speed and direction". Our research is intended towards developing collision avoidance architecture for the latest Intelligent Transport System. The exchange of safety messages among vehicles and with infrastructure devices poses major challenges. Specially, safety messages have to be adaptively distributed within a certain range of a basically unbounded system. These messages are to be well coordinated and processed via different algorithms between two different cars which is embedded radar or without radar. With this motivation the author sets the objectives like achieving a data rate of 100 Mbps for full vehicular mobility, sensing of nearby vehicles using digital radar, integrating both communication and radar to have one wireless embedded system for providing concurrent vehicular communication and safety. To achieve 100 Mbps data rate, different communication technologies at the transmitter as well as at the receiver sections are tried and compared according to CALM (Continuous Air interface for Long and Medium distance) standard framed by ITU. Finally, MIMO (Multiple-Input Multiple-Output) based noble signal scheme "Hybrid BLAST STBC" at the transmitter and ML (Maximum Likehood) detector approach has evolved fulfilling the objective. This scheme combines MIMO and STBC (Space Time Block Code) to generate a system functionally superior to MIMO and STBC systems. For radar based sensing, MIMO radar is found to be more effective on road condition. Finally, authors would like to provide an implication of realistic E-vehicle for next generation transportation system. The above performances of our proposed system are compared with the conventional scheme by software simulations which validate the analytical results.

Keywords: *MIMO, STBC, HYBRID BLAST STBC, ML, CALM, E-VEHICLE.*

1. INTRODUCTION

With the commercial availability of Mercedes Benz S class vehicle, the R&D efforts in Mobile Communication & remote sensing are progressing a lot all over the world. This S class vehicle is fitted with several sensors for safety applications including Radar and also enriched with latest communication. The major limitations of such vehicles are i) on -road price is 1.1 crores. ii) Vehicle to Vehicle communication is not included so far. The challenges, therefore, are to reduce the cost and also include the latest mobile technologies like 4G to be embedded for more safety and communication purposes.Recent research on wireless communication system has shown that using MIMO at both transmitter and receiver offers the possibility of wireless communication at higher data rates through spatial multiplexing, interference cancellation techniques, improve the link reliability[1]-[4] through diversity without increasing transmitter power, and spectral efficiency compare to single antenna systems. The information-theoretic capacity of MIMO channels was shown to grow linearity with the smaller of the numbers of transmit and receive antennas [5] in rich scattering environment and sufficiently high SNR for achieving ultimate goal of high data rate and high quality of performance. In general, all these gains cannot be achieved simultaneously, as they are dependent on antenna configuration and scattering environment. Hence, good knowledge of the characteristics of the propagation environment is crucial for maximizing the achievable MIMO gains. In fact, the very demanding performance targets set for next-generation systems are virtually impossible to reach without an efficient utilization of multiple antennas both at transmitter and receiver side. However, it has poor energy performance and doesn't fully exploit the available diversity. The V-BLAST algorithm aims to maximize the capacity by using combination of spatial processing and subtractive cancellation to remove co-channel interference, provided that the number of antennas at the receiver is greater or equal to that of the transmitter. Furthermore, STBC [6] or Alamouti scheme exploits the diversity against fading that is available from employing multiple antennas at the transmitter and possible at the receiver but with a maximum code rate is achieved at two transmit antennas. Combining V-BLAST and STBC results in a layered architecture with transmit diversity in each layer. This can be called a "Hybrid BLAST STBC [7] approach" to try to exploit the advantages of both higher data rates and increased diversity gain of the MIMO system at low SNRs and at low outage probabilities. The idea of this scheme is to demultiplex a single user's data into parallel layers of information. Then, each layer is encoded by a STBC. Each code is called a group, because the total number of transmit antennas are divided into groups and each group is assigned a STBC. This architecture was first considered in [6] where they used space time trellis codes (STTC) as the component codes. For Hybrid BLAST STBC [6]-[8], the number of receive antennas should be at least equal to the total number of transmit antennas. However, for Hybrid BLAST STBC, it is equal to the number of layers. Like MIMO communications, MIMO radar offers a new paradigm for signal processing research. MIMO radar possesses significant potentials for fading mitigation, increased diversity of the target information, increase the spatial diversity of the system [9]-[11], resolution enhancement, and excellent interference rejection capability[12]-[13], improved parameter identifiability [14], and enhanced flexibility for transmit beam pattern design[15][16] and jamming suppression. Fully exploiting these potentials can result in significantly improved target detection, parameter estimation, target tracking and recognition performance. The degrees of freedom introduced by MIMO radar improve the performance of the radar systems in many different aspects.

First part of the paper is to develop proper system model and analyzed the communication processing algorithms at the transmitter and receiver with respect to capacity, BER vs. SNR. Section 2 will present simulation results for communication systems. Section 3 develops the radar system and their processing algorithm with respect to reduction of the SER can be exploited to develop a latest digital radar system and this can bring a revolution in remote sensing applications. Convergences of communication as well as radar systems are implemented through MATLAB shown in the section 4. Finally the last section of this paper presents the conclusion.

2. MIMO Communication System Model:

The input /output a relation of a narrow band single-user MIMO wireless link is modulated by a complex baseband vector notation: $\mathrm{Y} = \mathrm{HX} + \mathrm{n} \ldots.(1)$. Where H is the channel matrix and n is the additive white Gaussian noise (AWGN) vector at a given instant in time channel noise.

Furthermore, as a commonly used structure for the MIMO system, V-BLAST shares some basic modules with our general multiple antennas.

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} \ldots..(2) \ , \mathrm{H} = \begin{bmatrix} \mathrm{h}_{11} & \cdots & \mathrm{h}_{1\mathrm{M}} \\ \mathrm{h}_{21} & & \mathrm{h}_{2\mathrm{M}} \\ \vdots & \ddots & \vdots \\ \mathrm{h}_{\mathrm{N}1} & \cdots & \mathrm{h}_{\mathrm{NM}} \end{bmatrix} ..(3),$$

$$X = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_M \end{bmatrix} \ldots.(4), \qquad n = \begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_N \end{bmatrix} \ldots(5)$$

The time channel impulse response between the j-th $(j = 1,2, \ldots \ldots..\mathrm{M})$ transmit antenna and the i-th $(j = 1,2, \ldots \ldots..\mathrm{N})$ receive antenna is denoted as $\mathrm{h}_{\mathrm{i,j}}(\tau, \mathrm{t})$. This is the response at time t to an impulse applied at time $t - \tau$. The composite MIMO channel response is given by the N x M matrix H (τ, t) with antenna array.

$$\mathrm{H}(\tau,\mathrm{t}) = \begin{bmatrix} \mathrm{h}_{1,1}(\tau,\mathrm{t}) & \mathrm{h}_{1,2}(\tau,\mathrm{t}) & \ldots\ldots & \mathrm{h}_{1,\mathrm{M}}(\tau,\mathrm{t}) \\ \mathrm{h}_{2,1}(\tau,\mathrm{t}) & \mathrm{h}_{2,2}(\tau,\mathrm{t}) & \ldots\ldots & \mathrm{h}_{2,\mathrm{M}}(\tau,\mathrm{t}) \\ \vdots & \vdots & \ddots & \vdots \\ \mathrm{h}_{\mathrm{N},1}(\tau,\mathrm{t}) & \mathrm{h}_{\mathrm{N},1}(\tau,\mathrm{t}) & \ldots & \mathrm{h}_{\mathrm{N},\mathrm{M}}(\tau,\mathrm{t}) \end{bmatrix} \ldots(6)$$

The vector $\left| \mathrm{h}_{1,\mathrm{j}}(\tau,\mathrm{t}) \ \mathrm{h}_{2,\mathrm{j}}(\tau,\mathrm{t}) \ldots\ldots.. \ \mathrm{h}_{\mathrm{N},\mathrm{j}}(\tau,\mathrm{t}) \right|^T$

is referred to as the spatio-temporal signature induced by the j-th transmit antenna across the receive Furthermore, given that the signal $s_j(t)$ is launched from the j-th transmit antenna, the signal

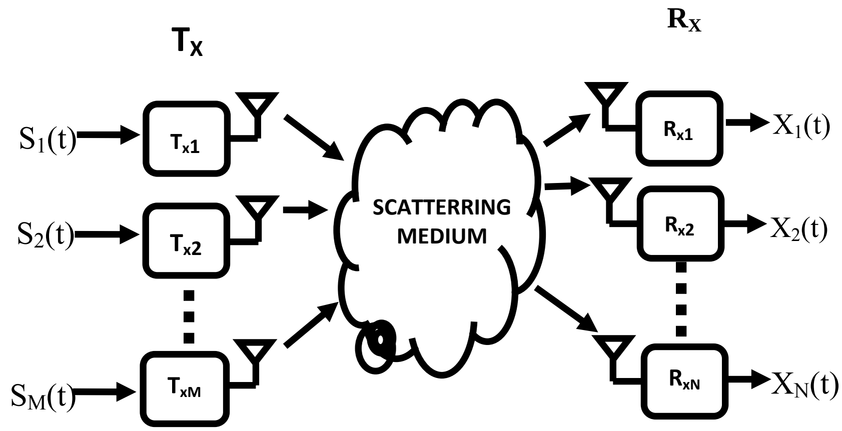

Fig. 1 MIMO radar channel using M transmits and N receives antennas.

received at the i-th receive antenna is given by $r_i(t) = \sqrt{\frac{E}{M}} \sum_{j=1}^{M} h_{ij}\, s_j(t-\tau) + n_i(t)$ .... (7)

Where, $n_i(t)$ is additive noise in the receiver.For transmit/receive beam forming with the diversity of order MN, is considered as full diversity. On the other hand the antenna gain is; Max = {M, N} ≤ antenna gain ≤ MN. So for MIMO comm. antennas are co-located and scatterers are separated but for MIMO radar antennas are separated and scatterers are co-located which is depicted in Fig.1 and Fig.5.

2.1 Results for MIMO Communication System:

2.1.1. Performance analysis of Hybrid BLAST STBC system w.r.t capacity

This section compares the capacities of the detection algorithms of Hybrid BLAST STBC, V-BLAST and STBC (Alamouti)[7] In addition, the optimal MIMO capacity is included as a reference. For Hybrid BLAST STBC, each component code is a rank two Alamouti STBC. The capacity of the different systems is estimated by generating random complex Gaussian channel realizations from which the instantaneous capacity is calculated and then the bit error ratio (BER) vs. SNR performance of the different schemes is compared with the capacity results. One main difference between Hybrid BLAST STBC and V-BLAST at the same number of transmit-receive antennas is that the earlier has more spatial diversity than the later while the later has more layers. For example, with a 4×4 MIMO system, Hybrid BLAST STBC has two layers and each layer has a transmit diversity of two. At the receiver, the first detected layer has a receive diversity of three. This is because the detector needs one antenna to null out one interfering layer and the rest provide diversity. On the other hand, V-BLAST has four layers and no transmits diversity. In addition, the first detected layer has no receive diversity because the algorithm needs three antennas to null out three interfering layers

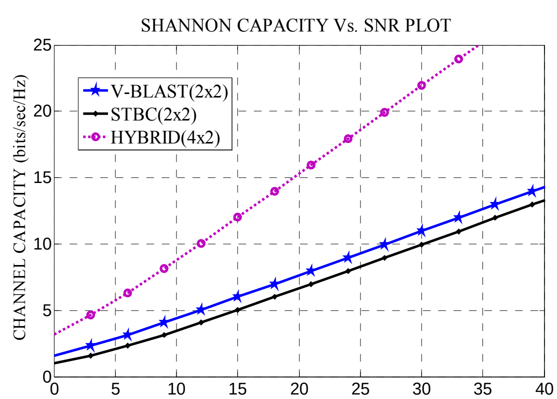

Fig. 2: Shannon capacity for 1% outage vs. SNR performance of the three schemes under consideration for MIMO system.

The results obtained for three proposed systems by generating 10,000 sample H matrices and using these two evaluate the channel capacity at different SNRs. The results for two receive antennas are presented in Fig.2.In this case it can be seen that the (4,2) Hybrid BLAST STBC scheme provides a distinct performance advantage over the (2,2) V-Blast or STBC(Alamouti) schemes at high SNRs

.Thus hybrid method attains superior diversity gain performance to V-BLAST and can out form V-blast at spectral efficiencies of practical interest. Furthermore, at low SNRs and low outage probabilities, hybrid is more spectrally efficient depending on the increasing order of the antennas. The capacities of Hybrid BLAST STBC and V-BLAST first increase when adding more layers as expected but after a certain number of layers, a reduction in capacity occurs especially when M = 2N in Hybrid BLAST STBC and when M = N in V-BLAST. This is a result of receive diversity reduction caused by the nulling operation in the detection algorithms of both systems. In other words, the capacity could be maximized by selecting the best number of layers at a given SNR.

2.1.2. Performance analysis of Hybrid BLAST STBC system w.r.t BER for different modulation techniques.

Performance analysis of HYBRID BLAST STBC system has been carried out based on our MATLAB simulation which depicted in Fig. 3(a), 3(b) and 3(c).

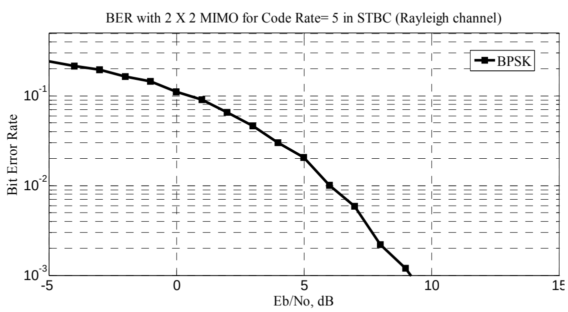

Fig.3 (a)

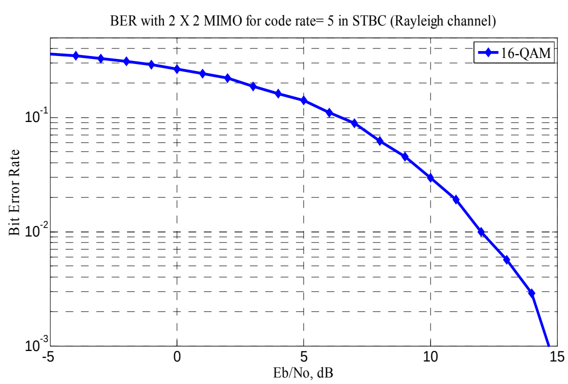

Fig.3 (b)

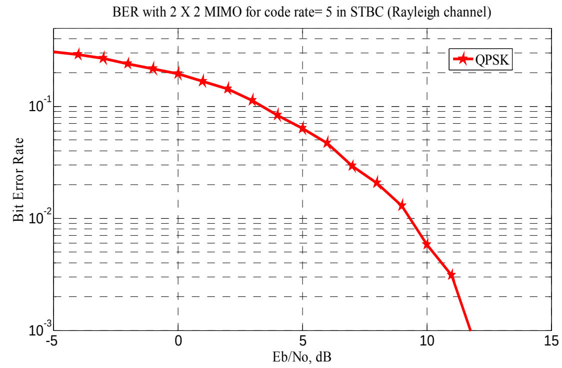

Fig.3 (c)

Fig 3(a), 3(b) and 3(c): BER vs.SNR performance with different modulation for spectral efficiency of 5 bits/s/Hz in Hybrid BLAST STBC system.

Fig. 3(a), 3(b) and 3(c) shows clearly HYBRID BLAST STBC system performance in BER vs. SNR in a Rayleigh channel. As we are considering three modulations, it can be said that the performance of QPSK is better than BPSK and 16-QAM for BER and SNR consideration, due to phenomenal improvement over the increase in the value of the SNR. For all SNR labels it is found that 16-QAM modulation is best compare to the others, but for only BER the performance of BPSK is better than the rests. Therefore QPSK has no doubt the better performance than other modulation techniques.

2.1.3. Performance analysis of Hybrid BLAST STBC system w.r.t BER for QPSK modulation and Rayleigh channel with different spectral efficiency.

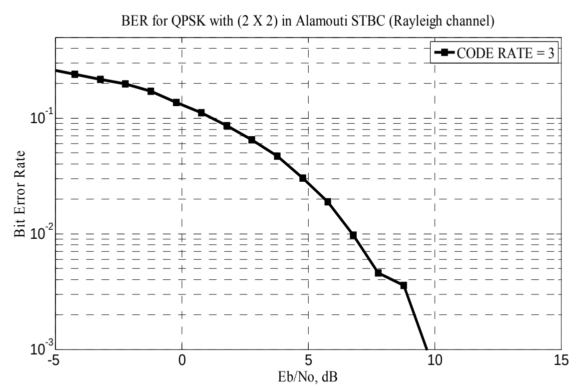

Fig.4 (a)

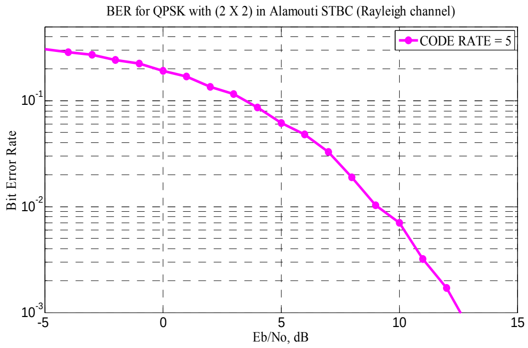

Fig.4 (b)

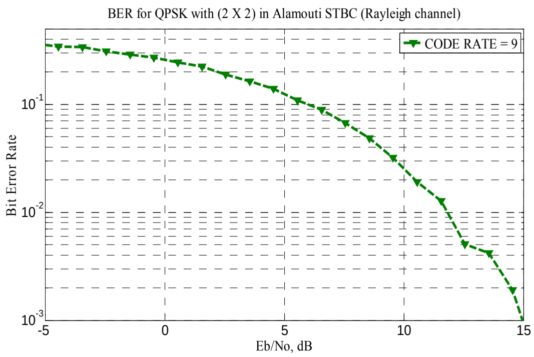

Fig.4(c)

Fig. 4(a), 4(b), 4(c): BER vs.SNR performance with QPSK modulation for different spectral efficiency.

It is noticeable that the overall system performance of QPSK is better compare to other modulation schemes.With increasing the code rate, BER performance improves in comparison with lower code rate.

Thus for all SNR levels, Hybrid BLAST STBC system has the least BER, and hence enhance the diversity gain because the lower the error in the received signals, the higher is the detection.

2.2 Optimization of MIMO detector:

There are many schemes in broadband wireless communication that can be applied to MIMO systems such as space time block codes, space time trellis codes, and the Vertical Bell Labs Space-Time Architecture (V-BLAST). But we wants to optimize a novel signal detector scheme called MIMO detectors to enhance the performance in MIMO channels. We study the general MIMO system, the general V-BLAST architecture with Maximum Likelihood (ML), Zero- Forcing (ZF), and Minimum Mean- Square Error (MMSE), linear and nonlinear detectors and simulate this structure in Rayleigh fading channel and AWGN channel with different modulation techniques. Base on frame error rates and bit error rates, we compare the performance and the computational complexity of these schemes with other existence models. The results shown that V-BLAST implements a detection technique i.e. SIC receiver, based on ZF or MMSE combined with symbol cancellation and optimal ordering to improve the performance with lower complexity, although ML receiver appears to have the best SER performance-BLAST achieves symbol error rates close to the ML scheme while retaining the low-complexity nature of the V-BLAST [18].

3. MIMO Radar Signal Model

MIMO radar architecture shown in Fig.5 employs multiple transmit waveforms and has the ability to

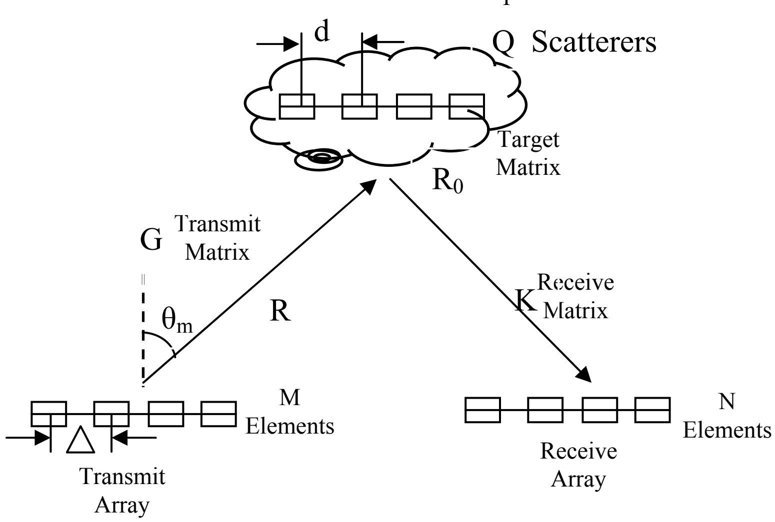

Fig.5 MIMO radar channel

jointly process signals received at multiple antennas ,independent waveforms are omni-directional beam pattern and diverse beam patterns created by controlling correlations among transmitted waveforms. Antenna elements of MIMO radar can be co-located or distributed. The MIMO radar scheme is based on a system with M transmitting radars and N receiving radars, widely distributed. It is assumed to be both time and phase synchronized. MIMO radar offers the potential for detection/estimation performance through diversity gain and resolution performance through spatial resolution gain. The performance enhancement of the different radar signal detection is considered from an aspect of improving the SNR, and is to utilize the best modulation techniques for only AWGN channel over the whole process. The rank of the channel matrix can be used to determine the number of dominant scatterers or the number of targets in the range resolution cell. With suitable processing, this property of MIMO radar can be applied to enhance radar resolution by allowing the measurement of one scatterer at a time.

3.1. Results for optimization of MIMO radar system modulation for communication application:

The performance of MIMO radar system performance in SER vs. SNR [17] with different modulation is shown in the Fig.6. As we are considering three modulations, it can be said that the performance of QPSK is better than BPSK & 16-QAM, due to phenomenal improvement over the increase in the value of the SNR. If we consider only the SNR then we are finding that the BPSK is best compare to the others, but if we take only the SNR value then 16-QAM is performing better than the rests. And as we are taking both of them then QPSK has no doubt the better performance.

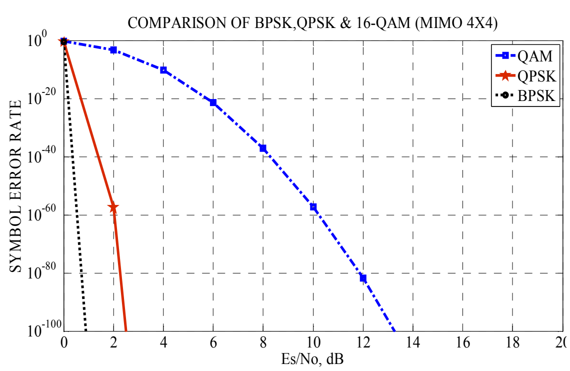

Fig.6 Performance of MIMO system with different modulation techniques.

3.2. Results for optimization of MIMO radar system channel:

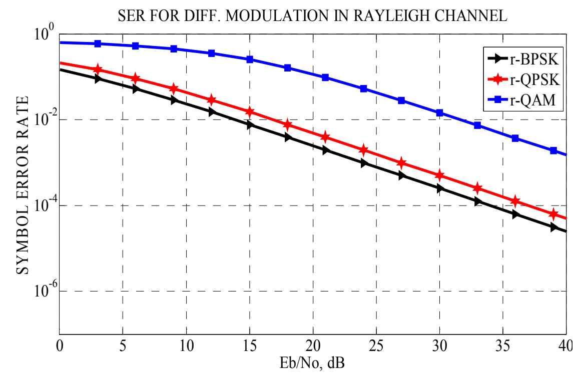

Fig.7 (a)

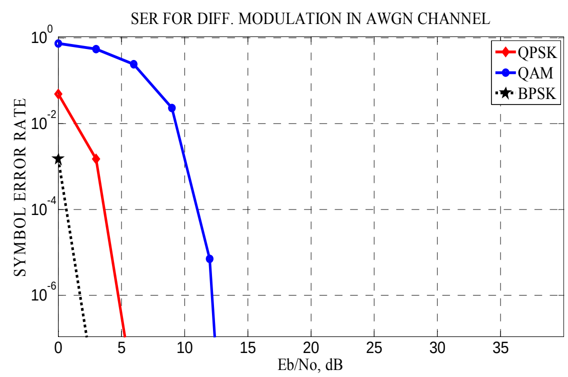

Fig.7 (b): SER for different modulation in AWGN and Rayleigh channel.

Fig.7 (a) and Fig.7 (b) shows clearly that the overall system performance of Rayleigh channel is better in comparison with other channels with respect to probability density function as well as SER vs. SNR. For all SNR levels, MIMO system has the least SER, and hence enhance the diversity gain because the lower the error in the received signals, the higher is the detection.

4. Implementation of Communication and Radar systems for Vehicular operation:

In our proposed model shown in Fig.8 we set a receiving power range for every vehicle as our prediction. For Motor cycle receiving power is set to 0.5 units, for taxi it is 0.8 units and for bus it is 3 units. By simulation it is indicated that received power is 0.8 which indicates that the target is obviously taxi. In this way concurrent communication and safety is established for prototype E-vehicle operation

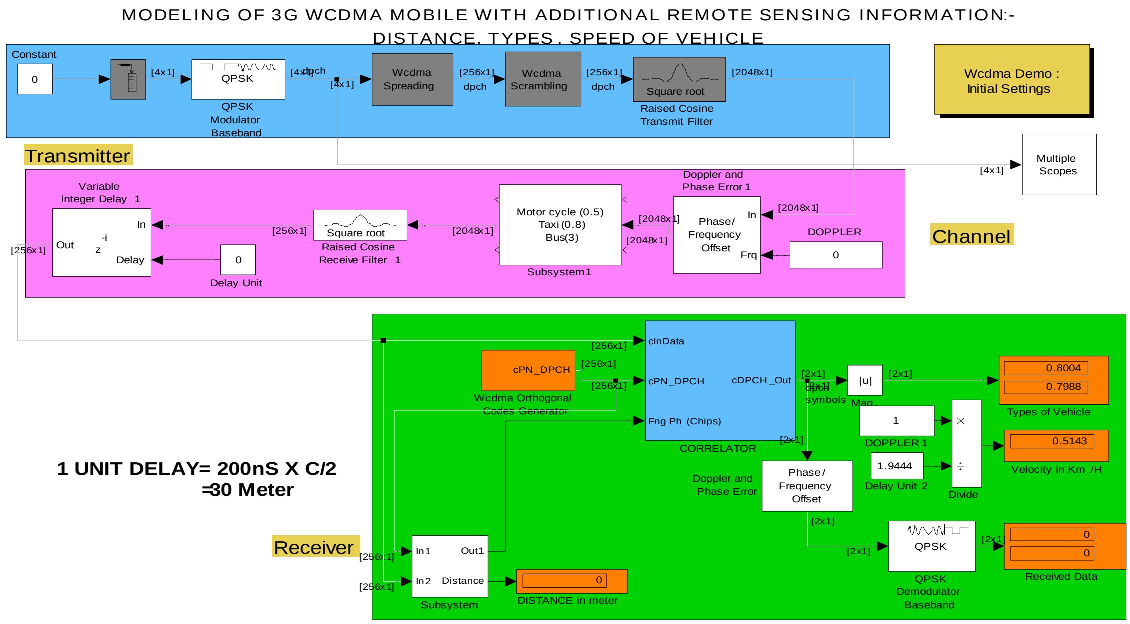

Fig.8. Detection of target using integration of Communication and Radar systems.

CONCLUSION

In this paper, the Shannon capacity of the three techniques will be investigated theoretically. Then the analysis will also be complemented by detailed simulation studies of the algorithms, investigating the bit error ratio performance of the three receivers. The result will show that in some cases the Hybrid BLAST STBC algorithms can significantly outperform the V-BLAST and STBC techniques. Also the results show that Hybrid BLAST STBC is more spectrally efficient at low as well as high SNR by simultaneously transmitting symbols through all transmit-antennas without introducing any structure at the transmitter to aid detection at the receiver and at low outage probabilities than VBLAST. We investigated and compared the inherent performance limitations of different modulation techniques for different radar systems and optimize the ultimate system. Finally this paper addresses the implementation towards E-vehicle for concurrent safety and communication application.

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Sourav Chakraborty is final year B.Tech student in the Department of Electronics & Communication Engineering at College of Engineering and Management, Kolaghat, under WBUT, 2007-2011 batch, West Bengal, India. His areas of interest are in Microwave /Millimeter wave based Broadband Wireless Mobile Communication and digital electronics. He has published multiple publications in international journals.

Prosenjit Kumar Sutradhar is final year B.Tech student in the Department of Electronics & Communication Engineering at College of Engineering and Management, Kolaghat, under WBUT, 2007-2011 batch, West Bengal, India. His areas of interest are in Microwave /Millimeter wave based Broadband Wireless Mobile Communication and digital electronics. He has published multiple publications in international journals

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