Analysis of BER Reduction in QPSK Modulation Using V-Blast Algorithms for MIMO System

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Abstract: ***In wireless communications, spectrum is a scarce resource and hence imposes a high cost on the high data rate transmission. Fortunately, the emergence of multiple antenna system has opened another very resourceful dimension – space, for information transmission in the air. It has been demonstrated that multiple antenna system provides better BER and it can be further improved by using different modulation techniques. Since then, multiple-input multiple-output (MIMO) system has become one of the major focuses in the research community of wireless communications and information theory. The study of the performance limits of MIMO system becomes very important since it gives a lot of insights in understanding and designing the practical MIMO systems. There are many modulation techniques that can be applied to MIMO systems such as BPSK, QPSK, and the Vertical Bell Labs Space-Time Architecture (V-BLAST). In this paper, we study the performance of general MIMO system, the general V-BLAST architecture with Zero-Forcing (ZF), in fading channels. Based on bit error rate, we show the performance of these receiver schemes indicates that the ordered SIC detector ZF with symbol cancellation and optimal ordering to improve the performance with lower complexity and compare the computational complexity of these schemes with other existence model. Finally, the paper addresses the current questions regarding the integration of MIMO system in practical wireless systems and standards.***

Keywords: MIMO, SIC, V-BLAST

1. Introduction

In any communication system, antenna plays important role, for assuring faithful communication and improving communication efficiently, the use of multiple antenna system at transmitter and receiving end is optimized recently. Multiple inputs and multiple output technique has appeared as a firm candidate for the improvement of the wireless communication system. MIMO antenna systems are useful in many applications like LTE, WiMax, Wifi etc [1].

MIMO systems are not only applicable in transforming mutual information; it is also fruitful to improve BER. The radio wave propagating through the wireless channel undergo transmit power dissipation (path loss) and shadowing caused by obstacles on the course from transmitter to receiver that attenuate signal power through absorption, reflection, scattering and diffraction. Constructive and destructive addition of different multipath components is even introduced by the wireless channel to cause the fading effect, which is generally considered as a serious impairment to the wireless channel. The MIMO symbol detection methods are observed under frequency flat fading AWGN channel condition and by employing the Quadrature amplitude modulation (QAM) method.

The various symbol detection techniques are compared to observe their behaviour under AWGN channel condition. Maximum likelihood (ML) symbol detection method gives the best performance but because of its high complexity it can't be used. Sphere decoder reduces the complexity to some extent providing similar performance as ML estimate. The other methods used are Zero forcing and minimum mean square estimation (MMSE). These two methods are seed successively for interference cancellations improve performance to large extent along with reduction in the cost. The large scale deployment of wireless devices and the requirements of high bandwidth and high data rate applications are expected to lead to tremendous new challenges in terms of the efficient exploitation of the achievable spectral resources and constitute a substantial research challenge in the context of the emerging WLANs and other indoor multimedia networks. Due to the physical limits imposed by the mobile radio channel which cause performance degradation and make it very difficult to achieve high bit rates at low error rates over the time dispersive wireless channels. Other detrimental characteristics are co-channel interference (CCI), Doppler effect, intentional jamming in military communications and Inter symbol interference (ISI) induced by multipath fading; however, there is an irreducible error floor that imposes a limit on the maximum attainable transmission rate [4].

2. Mathematical Modelling of QPSK

Quadrature Phase Shift Keying uses four phases to encode two bit per symbol to minimize the bit error rate. QPSK transmits twice the data rate in a given bandwidth compared to BPSK - at the same BER. The engineering penalty that is paid is that QPSK transmitters and receivers are more complicated than the ones for BPSK. However, with modern electronics technology, the penalty in cost is very moderate.
The symbols in the constellation diagram in terms of the sine and cosine waves used to transmit them

$$S_n(t) = \sqrt{\frac{E_s}{T_s}} \cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right), n = 1,2,3,4 \ldots.$$

This yield the four phases $\pi/4$, $3\pi/4$, $5\pi/4$, $7\pi/4$ as needed.
This results in a two-dimensional signal space with unit basis function

$$\emptyset_1(t) = \sqrt{\frac{2}{T_s}}\ \cos(2\pi f_c t)$$

$$\emptyset_2(t) = \sqrt{\frac{2}{T_s}}\ \sin(2\pi f_c t)$$

The first basis function is used as the in-phase component of the signal and the second as the quadrature component of the signal.

Hence, the signal constellation consists of the signal-space 4 points

$$(\pm\sqrt{\frac{E_s}{2}}, \pm\sqrt{\frac{E_s}{2}})$$

The factors of 1/2 indicate that the total power is split equally between the two carriers.

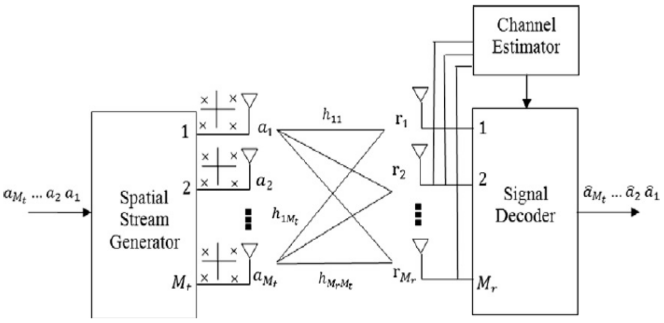

Figure 1: Block diagram of V-Blast Architecture [1]

3. V-Blast QPSK Modeling Using ZF Technique

A data bit sequence having elements x_1, x_2, x_3… may be transmit, one element per time slot using single transmitter, single receiver system. But if the speed of transmission is to be increased, the number of transmitter and receiver antenna can be increased, and they can be taken in pairs. If two transmitter and receiver antennas are used to transmit the same sequence, the need of required time frames will be reduced to half of the above defined. Now for reducing the bit error rate and for making faithful transmission of data bits, different modulation techniques and algorithms are used. Here V-Blast algorithms is been used for making faithful transmission of data signals. The MIMO communication model consists of an antenna array of n_T element at the transmitter end and n_R elements at the receiver.

MIMO systems are an extension of smart antennas systems. Traditional smart antenna systems employ multiple antennas at the receiver, whereas in a general MIMO system multiple antennas are employed both at the transmitter and the receiver. The addition of multiple antennas at the transmitter combined with advanced signal processing algorithms at the transmitter and the receiver yields significant advantage over traditional smart antenna systems - both in terms of capacity and diversity advantage. In the case MIMO, we can send different signals using the same bandwidth and still be able to decode correctly at the receiver. Thus, it is like we are creating a channel for each one of the transmitters. The capacity of each one of these channels is roughly equal to[2].

$$Capcity = B.log_2\left[1 + \frac{N}{M}\, SNR\right](\frac{bps}{Hz})$$

The V-Blast algorithm, zero forcing approach in QPSK modulation does the random paring of message signals. These message signals are then coded in digital bits o n the basis of amplitude of Message signal. The Zero Forcing equalization matrix is given by

W = inv (H^H*H)*H^H.

We can reduce the decoding complexity of the ML receiver significantly by employing linear receiver front-ends to separate the transmitted data streams and then independently decode each of the streams. Simple linear receiver with low computational complexity and suffers from noise enhancement. It works best with high SNR. The solution of the ZF is given by [2]

$$\hat{x} = (H * H)^{-1}Hx = H^{+}x$$

Where, $(\ )^{+}$ represents the pseudo-inverse. The ZF receiver converts the joint decoding problem into M single stream decoding problems thereby significantly reducing receiver complexity. This complexity reduction comes at the expense of noise enhancement which in general results in a significant performance degradation (compared to the ML decoder). The diversity order achieved by each of the individual data streams equals N - M + 1.

4. Comparative Analysis between BPSK and QPSK Methodology

The simulation result of BPSK modulated signal transmitted over Rayleigh fading channel and receiver designed using zero forcing approach is given in fig – II

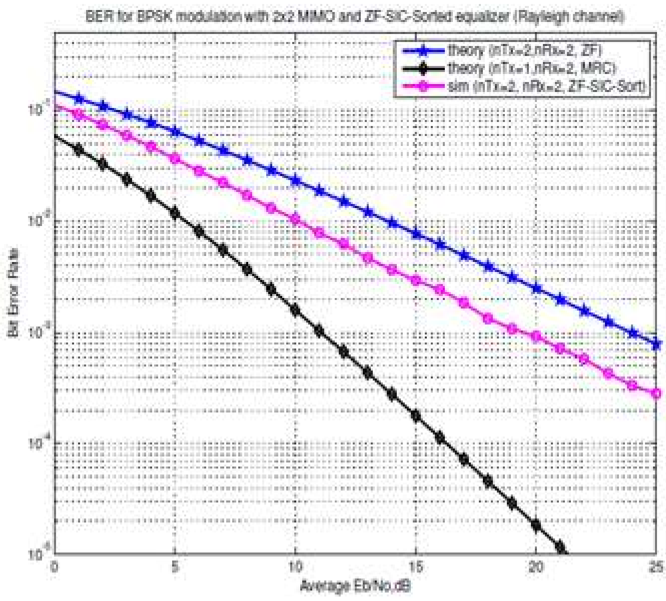

Figure 2: BER analysis for BPSK modulation with 2x2 MIMO and ZF

If we analyze the result shown in simulated graph then we can say that BER is reduced up to level of 10^{-3} with Eb/No ratio changes from 0 to 25. The V-Blast zero forcing approach gives promising results for 1 Tx and 2 Rx antenna system as shown in Fig-II. Now Fig-III shows the BER analysis for a 2x2 MIMO system transmitting signal using QPSK modulation technique and receiver is designed using V-Blast zero forcing approach. By the study of the result of this simulation, we can say that BER for 2x2 MIMO system is greatly reduced to 10^{-6} level and it remains approximately constant for the entire range of Eb/No ratio i.e. 0 to 25.

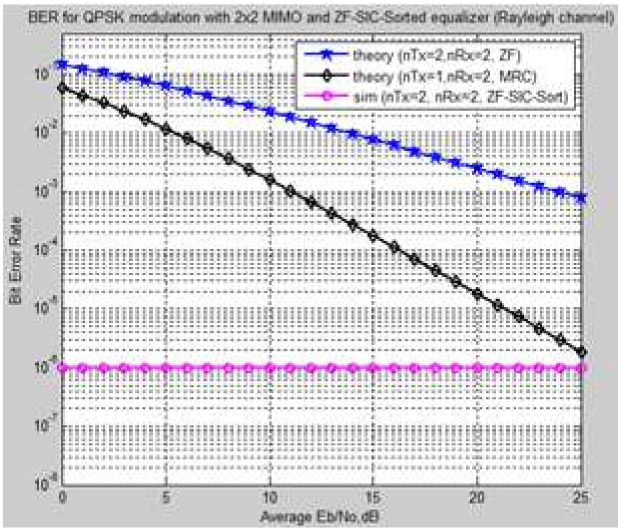

Figure 3: *BER analysis for QPSK modulation with 2x2 MIMO and ZF*

Table 1:

Modulation Method	*BPSK*	*QPSK*
Time Frame Required for Transmission	N/2	N/4
BER (Min)	10^{-3}	10-6

The time frame required for the transmission of data bits will be half for QPSK modulation as compared to BPSK modulation technique. It would directly double the speed of communication. BER is decreased to 10^{-6} as compared to 10^{-3} of BPSK modulation, which will clearly signify that communication will become more faithful.

5. Conclusion

In this paper, we provide a general multiple antenna system, the general V- BLAST system and analyzed the performance of V-BLAST with QPSK modulation and ZF technique. With the analysis of result of simulation we can conclude that speed of data transmission rate is doubled and BER is reduced by 10 times.

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