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PERFORMANCE ANALYSIS OF V-BLAST MIMO SYSTEM IN RICIAN CHANNEL ENVIRONMENT.

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***Abstract*— The vertical Bell labs layered space-time (V-BLAST) system is a multi-input multi-output (MIMO) system designed to achieve good multiplexing gain. This paper we study the V-BLAST MIMO system architecture with Zero- Forcing (ZF), Minimum Mean- Square Error (MMSE), and Ordered Successive Interference Cancellation (SIC) detectors and simulate this structure in Rician fading channel. Also compares the performances of MIMO system with different modulation techniques in scattering environment. In this paper we compare the performance of different detector system based on the bit error rate. From simulation we find that by combining SIC with MMSE or SIC with ZF provide better performance than normal receiver consisting simple MMSE or ZF respectively.**

***Keywords*— MIMO; MMSE; ZF; SIC.**

I. INTRODUCTION

Wireless communication using MIMO has recently emerged as one of the most significant technical breakthroughs in modern communications technology. MIMO systems establish an arbitrary wireless communication a link for which the transmitting end as well as the receiving end is equipped with multiple antenna elements as illustrated in Fig. 1.

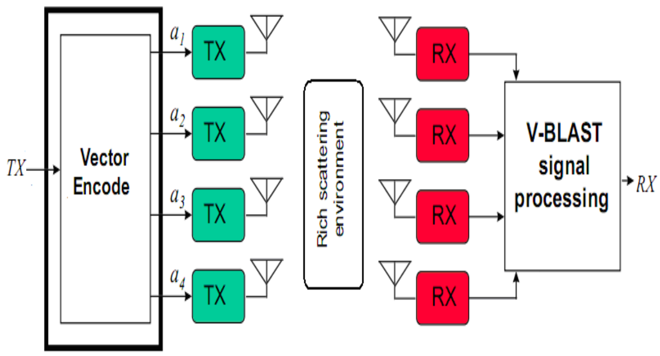


Fig. 1. Block diagram of BLAST system.

The idea behind MIMO is that the signals on the transmit (T_X) antennas at one end and the receive (R_X) antennas at the other end are "combined" in such a way that the quality (Bit Error Rate or BER) or the data rate (bits/sec) of the communication for each MIMO user will be improved. Such an advantage can be used to increase both the network's quality of service and the operator's revenues significantly [1] Ultimate goals of the future generation wireless communication system are high-data-rate, high-performance and optimum utilization of the bandwidth. MIMO wireless systems help to achieve that goal. [2], [3].

The achievable capacity and performance depend on the channel conditions and on the structure of the transmit signal. In order to achieve the goal the design MIMO system architecture influences the complexity of the transmitter and, particularly the receiver. The MIMO coding techniques can be split into three groups such as: space-time coding (STC), space division multiplexing (SDM) and beam forming [4]. A large number of low complexity linear MIMO detectors have been studied so far; generally these linear detectors are based on minimum mean-square error (MMSE) and based on zero-forcing (ZF). But the performance of this detector can be poor, especially in MIMO systems that use a small number of receiving antenna branches. To improve performance, a so-called vertical Bell laboratories layered space-time (V-BLAST) algorithm has been introduced; this performs successive interference cancellations in the appropriate order [5-6-7]. V-BLAST system with Successive Interference Cancellation (SIC) detector helps to achieve the high spectral efficiency with reasonable decoding complexity, in rich scattering environments through exploiting spatial dimension [8] and also V-BLAST yields higher diversity gains and improves bit-error-rate (BER) performance [9].

II. SYSTEM MODEL

We consider a narrowband MIMO spatial multiplexing system with M_T transmit and M_R receiver antennas. Let X = $[x1.....xM_T]^T$ denote the vector of transmit symbol such that E $[x_i^2]$ = Es/M_T, where i = 1, 2, .M_T. Here, the superscript T denotes transpose, E[xi] represent the expectation value of each symbol corresponding to each transmitting antennas and Es is the total transmit energy. In V-BLAST system the data stream are de multiplexed into M_T sub-streams of equal length. This sub streams are generally known as called layers. After de multiplexing, this sub-stream is mapped by using M-array phase shift keying (M-PSK) or M-array quadrature amplitude modulation (M-QAM) scheme and modulated streams are simultaneously transmitted over the M_T antennas. Now, let H be the channel matrix of $[M_T \times M_R]$ dimension and $Y = [y_1.....y_{MR}]^T$ denote the received vector. The channel output can be written as

$$y = Hx + N \text{ -------------------------- (1)}$$

where H is.

$$H = \begin{bmatrix} h_{11} \,......... & .h_{1,M_T} \\ . & \\ h_{M_R,1} \,....... & h_{M_R,M_T} \end{bmatrix} \text{ --------------- (2)}$$

$$= \left[h_1, h_2, h_3 \,...... \; h_{M_T} \right]$$

is the M_R X M_T channel matrix with each element $h_{r,t}$ represents the channel fading coefficient from t-th transmit antenna to r-th receive antenna. N is $[M_R \times 1]$ white Gaussian noise vector.

Zero Forcing (ZF):

Zero forcing receiver [10], is a Simple linear receiver, with low computational complexity. It minimizes interference but suffers from noise enhancement. ZF receiver works best with high SNR level. Zero forcing implements matrix (pseudo)-inverse (+). The ZF estimated received signal is given by:

$$\hat{x} = (H^H H)^{-1} H^H .x = H^+ x \text{ ---------------------- (3)}$$

where the Zero forcing decoding matrix is as follows :

$$S_{ZF} = (H^H H)^{-1} H^H$$

where superscript H denotes hermitian transpose.

Minimum Mean Square Error (MMSE):

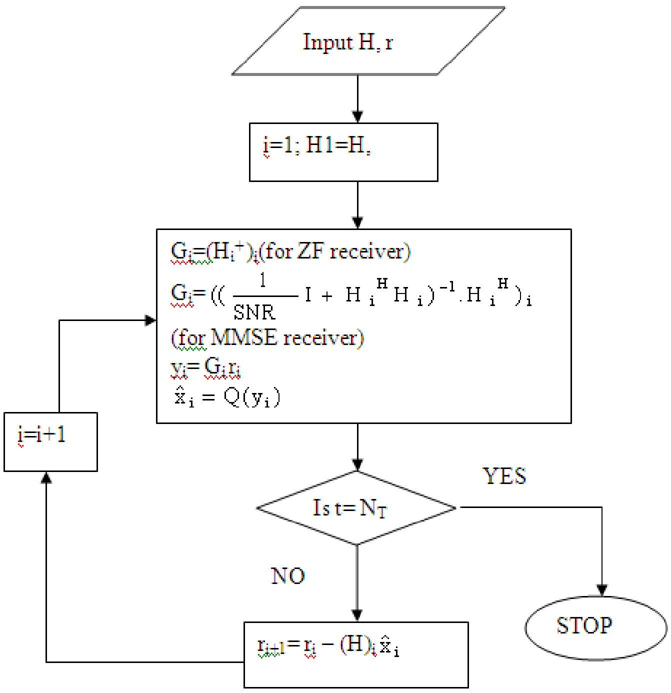
At very high SNR level decorrelator completely suppress the interference, therefore it provide better performance at higher SNR level. Now in low SNR level condition the maximal ratio combining receiver provide better performance. Therefore in order to design an optimal receiver it is necessary to converge this two advantages in a single receiver. In MMSE receiver this two features are optimally combined. MMSE receiver is another type of linear detector which minimizes the mean squared error between the transmitted symbols. MMSE detector helps to jointly minimized both the noise and interference or we can say that the MMSE detector seeks to balance between cancellation of the interference and reduction of noise enhancement. Therefore MMSE detector outperforms the ZF detector in the presence of noise.
MMSE receiver gives a solution of:

$$\hat{x} = \left(\frac{1}{SNR} I + H^H H\right)^{-1} .H^H x \quad \text{........... (4)}$$

The above two linear equalization algorithm is based on multiplying the received vector by a detection matrix and then decoding the symbols separately. Another approach in VBLAST receiver design is successive interference cancellation to achieve better performance at the cost of much higher complexity.

Successive interference cancellation (SIC):

The SIC is a non linear MIMO detection technique. In successive interference cancellation (SIC) [11] [12] [13] the interfering signal of a particular user is suppressed after making a decision on that user's bit. At the receiver successive interference cancellation technique nulls the interferers by linearly weighting the received signal vector with a zero-forcing nulling vector (ZF-BLAST) or MMSE nulling vector (MMSE-BLAST). In general, it is found that the MMSE detector out perform the ZF detector because it takes into account the cumulative effect of the signal and noise and represents a trade-off between noise amplification and interference suppression [14]. It gives a reasonable trade off between complexity and performance.
Thus, at each stage the number of interfering signal decreases. Flow chart for the MMSE- SIC of ZF-SIC is given below.



The probability of error for coherent BPSK over Rician fading channel:

The probability density function (PDF) [15] of instantaneous signal to noise ratio (SNR) under Rician fading given by The SNR pdf of a Rician fading channel is given by

$$f_\gamma(\gamma) = \frac{(1+K)}{\gamma_s} \exp\left[-K - \frac{(1+K)\gamma}{\gamma_s}\right] I_0\left(2\sqrt{\frac{k(1+K)\gamma}{\gamma_s}}\right), \gamma \geq 0, \quad \text{----- (5)}$$

$$\gamma_S(\gamma) = \frac{E_S}{N_0} \text{ is the average SNR.}$$

Where K= is the Rician factor, I_0 (.) is the zero-order modified Bessel function of the first kind. The Rician factor K can define as the ratio of the LOS component energy to the diffuse (multipath) component energy. If K=0 we get the Rayleigh distribution, whereas the channel approaches the no fading case (AWGN channel) as K increases.

The error probability can be calculated by averaging the conditional probability of error over the pdf of γ, i.e.

$$P(\varepsilon) = \int_0^{\infty} P(\varepsilon \mid \gamma) f_{\gamma}(\gamma)\, d\lambda \quad \text{-------------------- (6)}$$

Now, the conditional error probability for the coherent BPSK is given by

$$P(\varepsilon \mid \gamma) = \frac{1}{\pi}\int_0^{\pi/2} \exp\{-\gamma \sin^2(\frac{\pi}{2})\sec^2\theta\} d\theta$$

$$= \frac{1}{\pi}\int_0^{\pi/2} \exp\{-\gamma \sec^2\theta\} d\theta \quad \text{- ------ (7)}$$

The probability of error for coherent BPSK over Rician fading channel can be calculated, by substituting $P(\varepsilon \mid \gamma)$ and $f_{\gamma}(\gamma)$ as in equation (5) and (7) respectively into equation (6), as given below.

$$P(\varepsilon) = \frac{1}{\pi}\left(\frac{1+K}{\gamma_S}\right)\int_0^{\pi/2} \frac{\exp\left(-\frac{K\sin^2(\frac{\pi}{2})\sec^2\theta}{\frac{1+K}{\gamma_S}+\sin^2(\frac{\pi}{2})\sec^2\theta}\right)}{\frac{1+K}{\gamma_S}+\sin^2(\frac{\pi}{2})\sec^2\theta} d\lambda$$

$$= \frac{1}{\pi}\int_0^{\pi/2} \exp\left(-\frac{K\gamma_S}{\gamma_S+(1+K)\sin^2\theta}\right)\frac{(1+K)\sin^2\theta}{\gamma_S+(1+K)\sin^2\theta} d\theta \quad \text{------ (8)}$$

III. SIMULATION RESULT

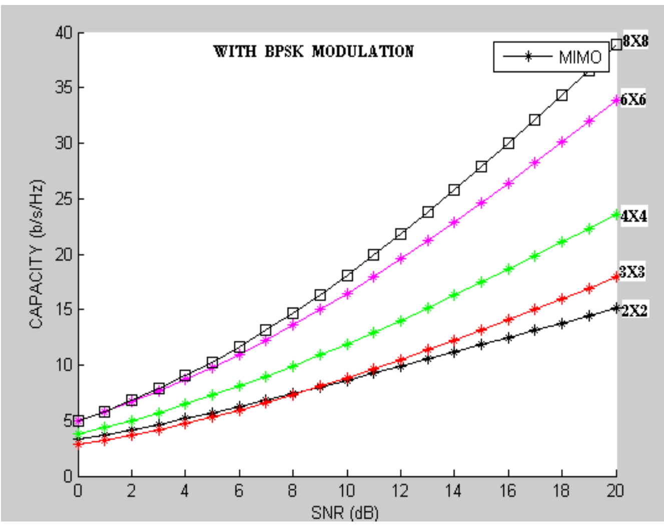


Fig: 1 CAPACITY Vs SNR curve for different MIMO system.

The plot for MIMO capacity under different transmitter and receiver configuration is shown in Fig: 1. It compare the channel capacity of different order MIMO system in Rician fading condition.

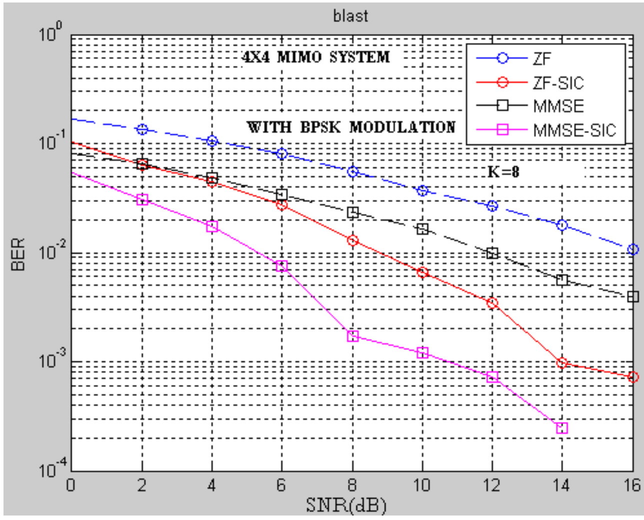


Fig: 2 BER Vs SNR curve for 4X4 MIMO system with different receiver.

Fig 2 shows the BER Vs SNR (Eb/N0) curves for different MIMO receiver system. It depicts a comparative study for the performance of different receiver (detector) system in a 4x4 MIMO system in Rician channel condition with Rician factor, K=8. From figure it is clear the ZF-SIC receiver provides better performance than ZE receiver whereas MMSE-SIC receiver provides better performance than MMSE receiver in Rician channel condition. Overall in Rician channel condition MMSE-SIC outperform the other receivers in terms of BER performance.

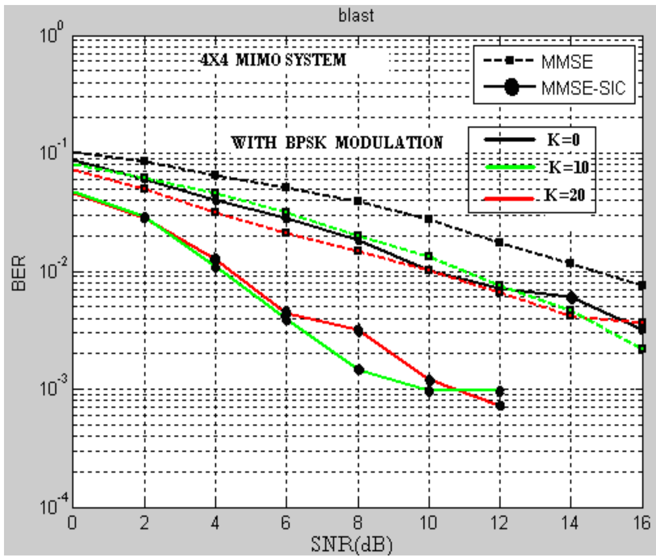


Fig: 3 BER Vs SNR curve for 4X4 MIMO system with different K for MMSE and MMSE-SIC receiver.

Figure 3 represents the performance analysis of 4x4 MIMO system in Rician channel condition with different values of Rician factor (k). From figure we find that for a particular vale of Rician K factor say K=0 and at a particular BER value 10^{-2}, there is approximately 4.4 dB SNR difference between the MMSE and MMSE-SIC receiver performance. And also with the increase in Rician factor K value the channel become flat in frequency domain. Under this flat fading condition the performance of the MMSE-SIC improves significantly with respect to MMSE receiver. From figure we find that for K=10 and for a particular BER 10^{-2}, there is approximately 7 dB SNR difference between the MMSE and MMSE-SIC receiver performance.

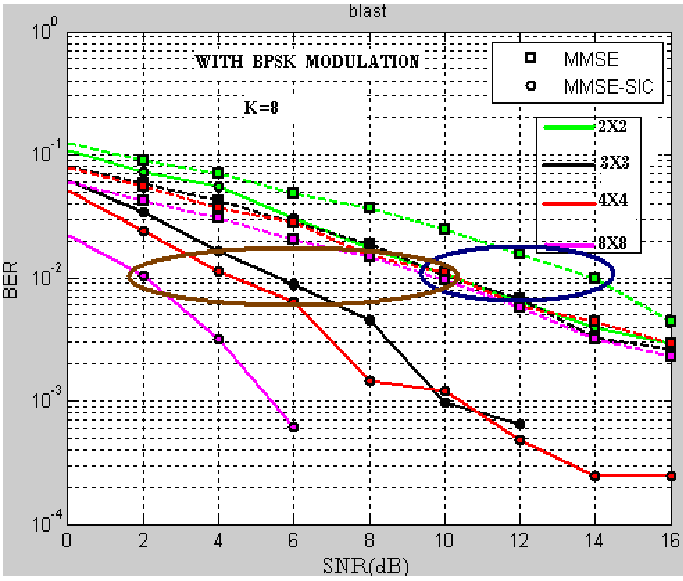


Fig: 4 BER Vs SNR curve for Different MIMO system for MMSE and MMSE-SIC receiver (with K=8).

Figure 4 represents the performance analysis of different MIMO system in Rician channel condition with Rician factor k=8. From figure it is clear that in Rician channel condition MMSE-SIC outperform MMSE MIMO receiver. As in figure we find that with the increase in the diversity order, the relative difference in SNR level for a particular BER value between MMSE and MMSE-SIC increases accordingly. For 2x2 MIMO system the SNR level difference is approximately 4 dB whereas for 8x8 system it is around 8 dB.

Figure 5 shows a comparative study between different MIMO system with ZF-SIC and MMSE-SIC receiver. As in figure MMSE-SIC receiver provide better performance with respect to ZF-SIC receiver. For consideration of 4 dB SNR, the performance of MIMO system with MMSE-SIC receiver is not only better than MMSE,ZF and ZF-SIC receiver but also provide better overall system performance with the increasing diversity order.

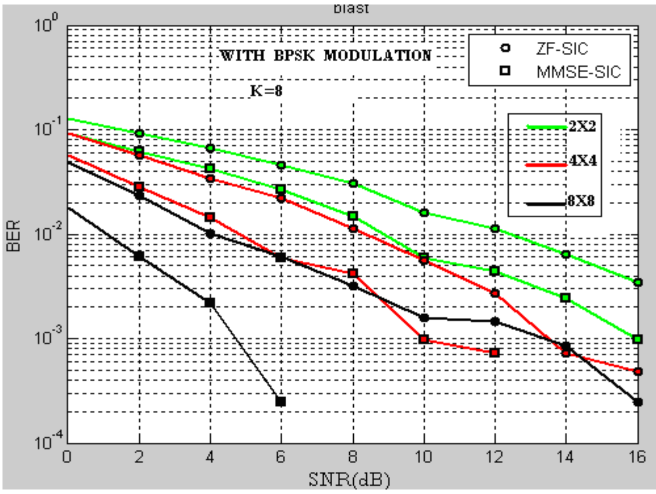


Fig: 5 BER Vs SNR curve for Different MIMO system for MMSE-SIC and ZF-SIC receiver (with K=8).

IV. CONCLUSIONS

In this paper we have presented the performance comparison of different MIMO receiver systems over Rician fading channel. From simulated results we find that ZF and MMSE receivers with successive interference canceller (SIC) provide better performance than the traditional non-linear ZF and MMSE receivers. And also with the increase of number of antennas in MIMO system MMSE-SIC provide significantly better BER performance than that of ZF-SIC. Therefore in Rician fading condition successive interference canceller plays an important role to minimize the intersymbol interference and thereby improving the BER performance of the system. In this way, V-BLAST MIMO is an important key to provide a higher performance gain and enabling the future prospect of high data rate wireless broadband service.

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