International Journal on Emerging Technologies **2**(2): 72-74(2011)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

BER Performance Using 16-QAM Modulation in V-Blast MIMO System

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(Received 10 August, 2011, Accepted 14 October, 2011)

ABSTRACT : In This paper we have tried to reduce the values of BER using different number of transmitter antenna and receiver antenna combinations. The MIMO V-Blast System came into reality to improve the gain and error rate. Here we study the V-BLAST (Vertical-Bell Laboratory Layered Space Time) MIMO with ZF (Zero-Forcing), MMSE (Minimum Mean-Square Error), and QR-Decomposition detection algorithms with 16-QAM modulation scheme and simulate the model in AWGN environment. From simulation we find that instead of using equal number of transmitter and receiver antennas, we will get better performance of BER with increased no. of receiver antennas only compared to transmitters.

Keywords: MIMO, V-Blast, AWGN, SNR, MMSE, ZF, QR Decomposition.

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.

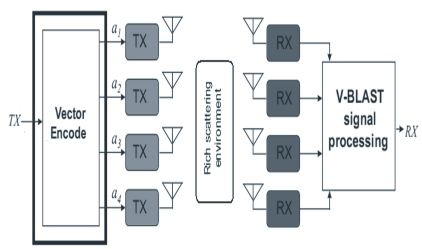

Fig. 1. A Model of V-Blast System.

The idea behind MIMO is that the signals on the transmit (TX) antennas at one end and the receive (RX) 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. 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.

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. 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), based on zero-forcing (ZF) and QR Decomposition. But the performance of this detector can be poor, especially in MIMO systems that use a less number of receiving antenna branches and equal to transmitting antennas. 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. VBLAST 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 and also V-BLAST yields higher diversity gains and improves bit error-rate (BER) performance.

In Section II, the system model is described. The V-BLAST detection techniques based on MIMO systems. In Section IV, the functionality of the proposed detectors has been described with ZF, MMSE and QR in AWGN channel. The simulation results and conclusion are provided in Section III and Section IV, respectively.

II. MODEL SYSTEM ARCHITECTURE

The V-BLAST MIMO channel model is as shown in Fig. 1. The transmitters and receivers are assumed to be 16-QAM modulators operating with co-channels as the case with the transmitters/receivers. The channel is assumed to be AWGN and the channel time variation is considered negligible over L symbol periods which comprise a data streams. The signal arriving at the receiver is

$$r = Ha + n \qquad \text{... (1)}$$

where H is the matrix channel, a is the transmitted symbol vector, and n is the channel noise. The V-BLAST detection process involves the computing of nulling vectors w_{ki}, where

$$S = \{k_1, k_2, k_3 \ldots\ldots k_{Mt}\} \qquad \text{... (2)}$$

and S is a set of permutation of the integers 1, 2 ... Mt by which orders of the components of a are extracted. The *ki-th* nulling vector is defined as the unique minimum norm vector satisfying the condition

$$w_{ki}^{T}(H)_{kj}\begin{cases}0 \text{ for } j \geq 1\\ 1 \text{ for } j = 1\end{cases} \quad \text{... (3)}$$

The output bit stream of a V-BLAST MIMO can be expressed in the min-norm vectors with a and n. The symbol cancellation and linear nulling techniques are used to perform detection. After a transmitted signal vector a is received, interferences are cancelled out using symbol cancellation so the received vector has fewer interferers. The decision statistic at the receiver is

$$y_{k1} = w_{k1}^{T} \times r \quad \text{... (4)}$$

where w_{k1} is the nulling vector. Quantization of y_{k1} is done to obtain a component. With assumption that a_{k1} is cancelled from the received vector R.

$$R = r - a_{k1}(H)_{k1} \quad \text{... (5)}$$

where $(H)_{k1}$ is the $k1$-th column of the matrix channel H. This Cancellation is repeated for components $k2$ ... kMT for the all received vectors.

The complete detection algorithm can be summarized as recursive as follows:

Initialize:

$$i \leftarrow 1$$
$$r_1 = r$$
$$G_1 = (H^H H + \sigma^2 I_{Nr})^{-1} H^H$$
$$k_1 = arg \min_j \|(G_1)_j\|^2$$

Recursive:

$$w_k = (G_i)_k$$
$$y_k = w_k^T \times r_i$$
$$\hat{s}_k = sign(y_k)$$
$$r_{i+1} = r_i - \hat{s}_k (H)_{ki}$$
$$G_{i+1} = [(H_i^H H_i) + \sigma^2 I_{Nr}]^{-1} H_i^H$$
$$k_{i+1} = arg \min \|(G_{i+1})_j\|^2$$
$$i \leftarrow i+1$$

The V-BLAST system being a Multiple-Input Multiple Output (MIMO) system that includes multiple transmitting and receiving antennas, the data being transmitted from the multiple transmitting antennas simultaneously as multiple data layers, each data layer being derived from same signal constellation, the data received at a receiver being in the form of a vector. The classification of MIMO detection techniques adopted for V-BLAST is shown in Fig. 2.

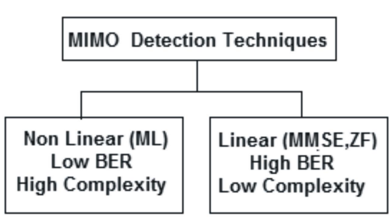

Fig. 2. Classification of MIMO Detection techniques.

The V-BLAST MIMO detection method comprising the following steps:

(*i*) Calculating a matrix on the basis of channel matrix of the V-BLAST system post-detection Signal to Noise Ratio (SNR).

(*ii*) Updating the channel matrix by deleting a column that corresponds to a maximum diagonal entry of the matrix, the maximum diagonal entry corresponding to a minimum

(*iii*) Calculating y with updated received vectors for a data layer, the data layer corresponding to the maximum diagonal entry, y being the size of the signal constellation, the updated received vectors being calculated for all possible constellation points of the signal constellation of the data layer, the data layer corresponding to the maximum diagonal entry corresponds to the minimum post-detection SNR.

(*vi*) Obtaining a set of reduced possible solution vectors from the SIC iterations and F. Detecting a solution vector nearest to the received vector from the set of the reduced possible solution vectors.

A. Zero Forcing (ZF)

This is a simple linear receiver detection technique with low computational complexity and suffers from noise enhancement. It works best with high SNR. The solution of the ZF is given by

$$S = H^H X$$

and $$H^{\#} = (H^* H) - IH^* \quad \text{... (6)}$$

where $H^{\#}$ represents the pseudo-inverse of H.

B. Minimum Mean Square Error (MMSE)

The MMSE receiver suppresses both the interference and noise components, whereas the *ZF* receiver removes only the interference components. This implies that the mean square error between the transmitted symbols and the estimate of the receiver is minimized. Hence, MMSE is superior to *ZF* in the presence of noise.

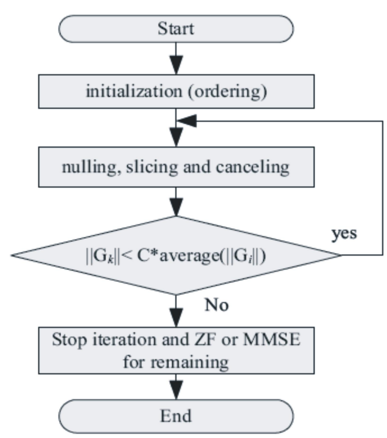

Fig. 3. Flow Chart of the algorithm.

$$S = H^* (HH^* + R_n)^{-1} X \quad \text{... (8)}$$

where R_n represents noise/interference covariance.

C. Q-R Decomposition

The effective way of solving matrix inversion problem is using *QR* decomposition. Let *Q* is unitary matrix and *R* is upper triangular matrix, then $V = QR$, where *Q* is unitary matrix and *R* is an upper triangular matrix. The *QR* decomposition is given by

$$V^{-1} = (QR)^{-1} = R^{-1}Q^{-1} = R^{-1}Q^{H} \tag{9}$$

where $(\ )^H$ is Hermitian Transpose.

III. RESULTS AND DISCUSSIONS

The simulation results for a V-BLAST MIMO system using 16-QAM in AWGN Channels are shown in Fig.4. In this curve the no. of transmitters is 2 and receiver is 8, 12 and 16 subsequently taking to see the effect on BER.

The comparison curves, shows the BER is improving with the increase in number of receivers, and in from the result it is clear that MMSE scheme gives best results, shown in Fig. 4.

Fig. 5 shows the comparison curve of 4 transmitter antennas and variable no. of receiver antennas, and we are watching that the here also BER is also improving ZF and QR decomposition techniques with increase in receiver antennas.

From above curve one result is also derived that the value of BER and SNR we are getting is better if we increase the receiver antennas as compared to increase in transmitter antennas.

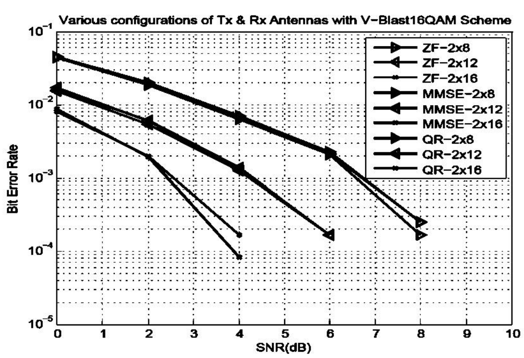

Fig. 4. Performance of BER for 2 transmitters and *N* receivers with *ZF*, MMSE and *QR*.

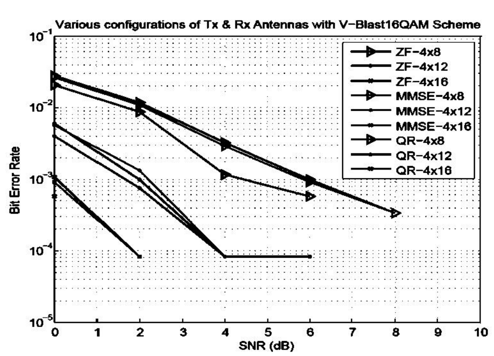

Fig. 5. Performance of BER for 4 transmitters and *N* receivers with *ZF*, MMSE and *QR*.

IV. CONCLUSIONS

In this paper, we present an asymptotic analysis of the V-BLAST scheme at high SNR region. Both the ZF -V-BLAST, MMSE-V -BLAST and QR-V-BLAST are analyzed with respect to their SNR and BER performances. Even we extended our analysis with linear and non-linear detectors like MMSE-OSIC and ZF-OSIC estimators and found that MMSE method is the best solution in detectors in 16-QAM.

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