Bit Error Rate Performance of MIMO Spatial Multiplexing with MPSK Modulation over Rayleigh Fading Channel

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Abstract—Wireless communication is one of the most effective areas of technology development of our time. Wireless communications today covers a very wide array of applications. In this, we study the performance of general MIMO system, the general V-BLAST architecture with MPSK Modulation in Rayleigh fading channels. Based on bit error rate, we show the performance of the 2x2 schemes with MPSK Modulation in noisy environment. We also show the bit error rate performance of 2x2, 3x3, 4x4 systems with BPSK modulation. We see that the bit error rate performance of 2x2 systems with QPSK modulation gives us the best performance among other schemes analysed here.

Key Words: Multiple input multiple output, Rayleigh fading channel, zero forcing, VBLAST, layered Space-time code, M-ary Phase-Shift Keying

I. INTRODUCTION

Wireless communication using multiple-input multiple-output (MIMO) systems enables increased spectral efficiency for a given total transmit power. Increased capacity is achieved by introducing additional spatial channels that are exploited by using space-time coding. In this article, we survey the environmental factors that affect MIMO capacity. These factors include channel complexity, external interference, and channel estimation error. We discuss examples of space-time codes, including space-time low-density parity-check codes and space-time turbo codes, and we investigate receiver approaches, including multichannel multiuser detection (MCMUD). The ‘multichannel’ term indicates that the receiver incorporates multiple antennas by using space-time-frequency adaptive processing. The article reports the experimental performance of these codes and receivers.

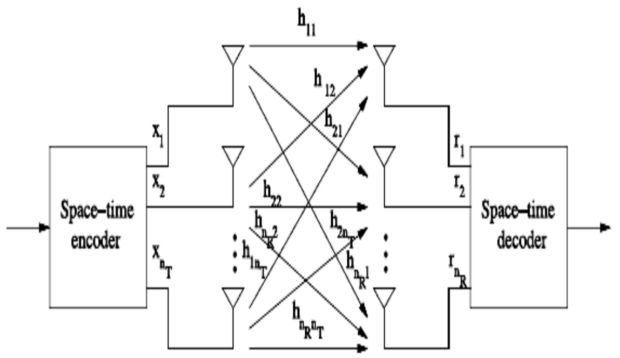

Fig. 1: Block Diagram of MIMO

Space-time trellis codes have a potential drawback that the maximum likelihood decoder complexity grows exponentially with the number of bits per symbol, thus limiting achievable data rates. Foschini proposed a layered space-time (LST) architecture that can attain a tight lower bound on the MIMO channel capacity. The distinguishing feature of this architecture is that it allows processing of multidimensional signals in the space domain by 1-D processing steps, where 1-D refers to one dimension in space. The method relies on powerful signal processing techniques at the receiver and conventional 1-D channel codes.

II. CHANNEL MODELLING

Mobile radio channels are extremely random and vary from simple light of sight to one that is severely obstructed by buildings, mountains and foliage. Apart from the locations of transmitter and receiver, the speed of motion impacts how rapidly the signal level fades as a mobile terminal moves in a space. Characterisation and modelling of the radio channel has been one of the most difficult parts of mobile radio system design. Basic propagation mechanisms are as under:

Reflection: When a propagating EM waves impinges upon an object which has very large dimensions compared to the wavelength of the propagating wave.

Diffraction: When the radio path between transmitter and receiver is obstructed by a surface that has sharp edges. So bending of waves takes place.

Scattering: Scattered waves are produced by rough surfaces, small objects or by other irregularities in the channel.

A. Rayleigh fading channel

A very common MIMO fading model is the *i.i.d. Rayleigh fading model*:

The entries of the channel gain matrix H[m] are independent, identically distributed and circular symmetric complex Gaussian. Since the matrix H_m and its angular domain representation $H^a[m]$ are related by

$$H^a[m]=U_r^* H[m] U_t \qquad (2.1)$$

and Ur and Ut are fixed unitary matrices, this means that H^a should have the same i.i.d. Gaussian distribution as H. Thus, using the modelling approach described here, we can see clearly the physical basis of the i.i.d Rayleigh fading model, in terms of both the multipath environment and the antenna arrays. There should be a significant number of multipath in *each* of the resolvable angular bins, and the energy should be equally spread out across these bins. This is the so called *richly scattered environment*. If there are very few or no paths in some of the angular directions, then the entries in H will be correlated. Moreover, the antennas should be either critically or sparsely spaced. If the antennas are densely spaced, then some entries of H^a are approximately zero and the entries in H itself are highly correlated. However, by a simple transformation, the channel can be reduced to an equivalent channel with fewer antenna switch are critically spaced.

Compared to the critically spaced case, having sparser spacing makes it easier for the channel matrix to satisfy the i.i.d. Rayleigh assumption. This is because each bin now spans more distinct angular windows and thus contains more paths, from multiple transmit and receive directions. This substantiates the intuition that putting the antennas further apart makes the entries of H less dependent. On the other, if the physical environment already provides scattering in all directions, then having critical spacing of the antennas is enough to satisfy the i.i.d. Rayleigh assumption. Due to the analytical tractability, we will use the i.i.d. Rayleigh fading model quite often to evaluate performance of MIMO communication schemes, but it is important to keep in mind the assumptions on both the physical environment and the antenna arrays for the model to be valid.

III. MATHEMATICAL MODELLING OF VBLAST ARCHITECTURE

Without knowledge of the channel at the transmitter the choice of the coordinate system in which the independent data streams are multiplexed has to be fixed a priori. In conjunction with joint decoding, we will see that this transmitter architecture achieves the capacity of the fast fading channel. This architecture is also called V-BLAST in the literature.

The input information sequence, denoted by x, is first demultiplexed into n_T sub-streams and each of them is subsequently modulated by an *M*-level modulation scheme and transmitted from a transmit antenna. The signal processing chain related to an individual sub-stream is referred to as a *layer*. The modulated symbols are arranged into a transmission matrix, denoted by H, which consists of n_T rows and *L* columns, where *L* is the transmission block length. The *t*th column of the transmission matrix, denoted by x_t , consists of the modulated symbols $x_t^1, x_t^2 \ldots\ldots x_t^{n_T}$, where t = 1, 2, . . . ,*L*. At a given time *t* , the transmitter sends the *t*th column from the transmission matrix, one symbol from each antenna. That is, a transmission matrix entry x_t^i is transmitted from antenna *i* at time *t* . Vertical structuring refers to transmitting a sequence of matrix columns in the space-time domain. This simple transmission process can be combined with conventional block or convolutional one-dimensional codes, to improve the performance of the system. This term "one-dimensional" refers to the space domain, while these codes can be multidimensional in the time domain.

Consider a 2×2 MIMO system where the received signal can be represented as

$$y = Hx + n \tag{3.1}$$

where $x= [x_1 \;\; x_2]^T$ denotes two independent symbols, $n= [n_1 \;\; n_2]^T$ is AWGN and $n_i \sim CN(0,N_0)$ for i= 1, 2. Here, spatially uncorrelated channel matrix $H= [h_1 \;\; h_2]$ or

$$H= \begin{bmatrix} h_{11} & h_{21} \\ h_{12} & h_{22} \end{bmatrix} \tag{3.2}$$

Where $h_{ij} \sim CN(0,1)$ denotes channel between i[th] transmit and j[th] receive antenna.

Now, H^{-1} can be represented as

$$H^{-1} = \frac{1}{h_{11}h_{22}-h_{12}h_{21}} \begin{bmatrix} h_{22} & -h_{21} \\ -h_{12} & h_{11} \end{bmatrix} \tag{3.3}$$

Geometrically, we can interpret h_i as the direction of the signal from the transmit antenna i. to decouple the detection of the two symbols, one idea is to invert the effect of channel.

$\tilde{y}=H^{-1}y = x+H^{-1}n$

$$\begin{bmatrix} \tilde{y}_1 \\ \tilde{y}_2 \end{bmatrix} = \begin{bmatrix} \tilde{x}_1 \\ \tilde{x}_2 \end{bmatrix} + \frac{1}{h_{11}h_{22}-h_{12}h_{21}} \begin{bmatrix} h_{22}n_1 - h_{21}n_2 \\ -h_{12}n_1 + h_{11}n_2 \end{bmatrix}$$

$$\widetilde{y_1} = x_1 + \widetilde{n_1} \tag{3.4}$$

Let us focus on the detection of symbol x_1. Then, $\widetilde{n_1}$ is with zero mean and variance of

$$\frac{|h_{22}|^2 + |h_{21}|^2}{|h_{11}h_{22} - h_{21}h_{12}|^2} N_0 \tag{3.5}$$

Hence, the detection variable for x_1 can be represented as

$$\tilde{y}_1 = x_1 + \frac{\sqrt{|h_{22}|^2+|h_{21}|^2}}{h_{11}h_{22}-h_{21}h_{12}} z \tag{3.6}$$

where $z_1 \sim CN(0,N_0)$.

A. *The Decision Rule*

These signals are then sent to the zero forcing detector which, for each of the signals x_1 and x_2 use the decision rule expressed below.

Choose x_i iff

The detection variable

$$\tilde{y}_1 = x_1 + \frac{\sqrt{|h_{22}|^2+|h_{21}|^2}}{h_{11}h_{22}-h_{21}h_{12}} z \tag{3.7}$$

$\tilde{y}_1 \geq 0$, the detected symbol is 1.
$\tilde{y}_1 \leq 0$, the detected symbol is 0.

Choose x_i iff

The detection variable

$$\tilde{y}_2 = x_2 + \frac{\sqrt{|h_{11}|^2+|h_{12}|^2}}{h_{11}h_{22}-h_{21}h_{12}} z \tag{3.8}$$

$\tilde{y}_2 \geq 0$, the detected symbol is 1.
$\tilde{y}_2 \leq 0$, the detected symbol is 0.

IV. ENCODING AND DECODING ALGORITHM

A. *Introduction*

This section illustrates the performance of VBLAST through simulation .MatLab is been used as a tool to carry out the simulation. Following simulation set-up has been developed in MatLab environment.

B. *Simulation set up*

The simulation set up is composed of four distinct parts, namely the bit generator, the LST-encoder, the channel and the ML decoder.

C. *Information Bit Generator*

Information Bit Generator the sequence of bits composed of 0 and 1 using uniformly distributed random number. The mean value and variance value of input bits are 0.5 and 0.25 respectively.

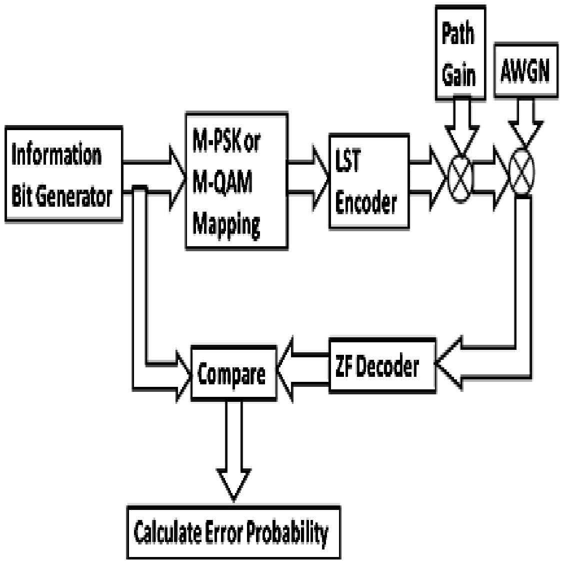

Fig. 2: Block diagram of simulation

D. M-PSK Mapping

M-PSK MappingBPSK,4-PSK,8-PSK modulation have been used .The bit sequence is divided into symbols which are composed of several bits e.g., 2 bits represent one symbol for Q-PSK ,and then each symbol is been mapped to the constellation point using Gray-coded ordering .The gray coded symbol is changed to the complex output form.

E. Layered Space Time Coding

Layered Space Time Coding generates encoder matrix (2x2) and transmit to the channel. Generation matrix.

F. Channel

Channel is considered as Rayleigh flat fading channel. The dominant factor is the path gain form each transmit antenna to each receive antenna. The path gain is the independent complex Gaussian random variables with variance 0.7 per real and imaginary parts. Additionally, the usual additive white Gaussian noise corrupts the signal. The AWGN and the Rayleigh fading channel are generated using.

nj = randn (1,N) + J * randn (1,N)

hj = 0.7 * ((randn (1,N) + J * randn (1,N)) (4.1)

G. Zero forcing (ZF) decoding

ZF decoding algorithm is been used to decode the received complex signal. Decoding algorithm and equations are given in section III.

H. Bit Error Rate

Bit Error Rate of the system is been computed as the ratio of incorrect data bits divided by the total number of data bits transmitted and the probability of bit error rate can be calculated as following equation:

$$Pb = Q\left(\sqrt{2\frac{Eb}{No}}\right) \quad (4.2)$$

V. ANALYSIS OF SIMULATION RESULTS & CONCLUSION

We plot the graphs of simulation to analyze the performances of various system are plotted below.

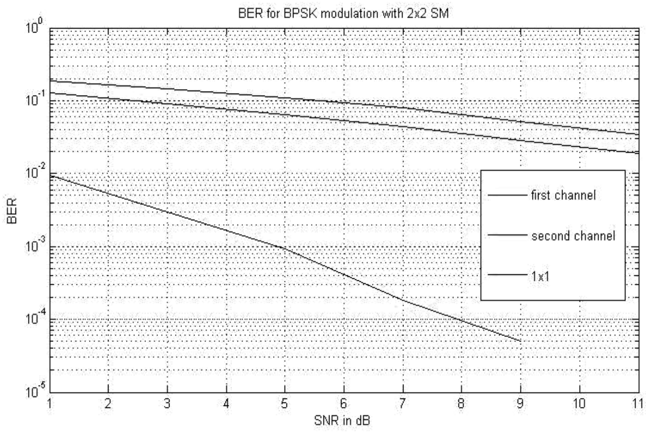

Fig. 3: BER vs SNR of BPSK with Nt=Nr=2

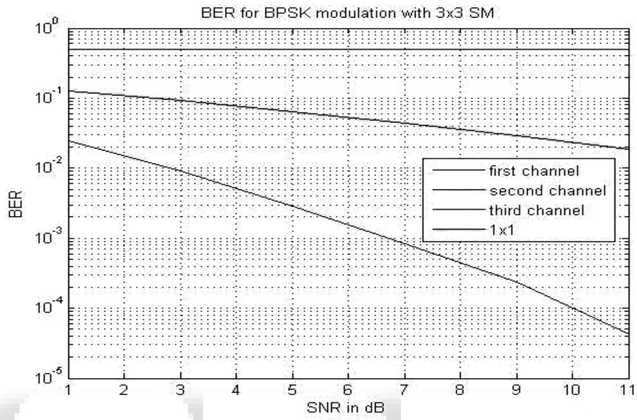

Fig. 4: BER vs SNR of BPSK with Nt=Nr=3

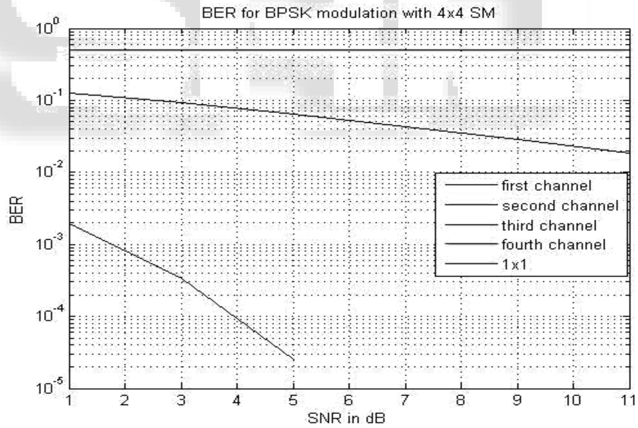

Fig. 5: BER vs SNR of BPSK with Nt=Nr=4

Figures 3,4, and 5 shows that the BER decreases as we goes to increse the no. of transmit and receive antennas.

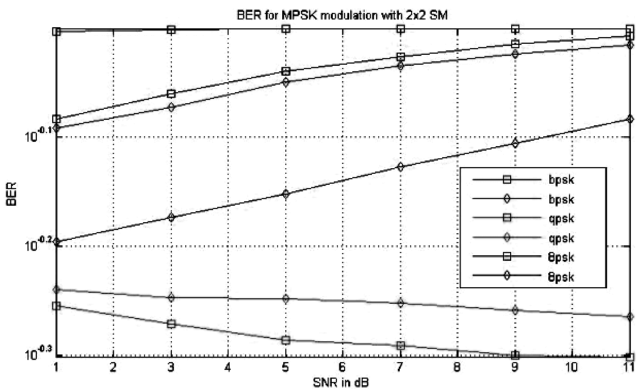

Fig. 6: BER vs SNR of BPSK, QPSK, 8PSK with Nt=Nr=2

VI. CONCLUSION

We have studied the performance of spatial multiplexing VBLAST of 2x2 system with MPSK modulation in i.i.d Rayleigh fading channel and 2x2, 3x3 & 4x4 with BPSK modulation in Rayleigh fading channel. So by studying the above graphs we seen that the BER performance is increased and improved in QPSK modulation then other methods.

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