A New Transmission Scheme for MIMO - OFDM using V Blast Architecture

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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 very promising gain in capacity without increasing the use of spectrum, reliability, throughput, power consumption and less sensitivity to fading, hence leading to a breakthrough in the data rate of wireless communication systems. 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 schemes 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). This paper presents the performance analysis of V-BLAST based multiple input mul- tiple output orthogonal frequency division multiplexing (MIMO-OFDM) system with respect to bit error rate per signal to noise ratio (BER/SNR) for various detection techniques.

Keywords—Multiple Input Multiple Output (MIMO), OFDM, STBC, Bit Error Rate(BER), Maximum Receiving Ratio Combin- ing(MRRC), Alamouti Scheme, V-BLAST.

INTRODUCTION

During the past decades, wireless communication has bene- fitted from substantial advances and it is considered as the key enabling technique of innovative future consumer products. High transmission data rate, spectral efficiency and reliabil- ity are necessary for future wireless communication system. Unlike Gaussian channels, wireless channels suffer from at- tenuation due to multipath in the channel. Multiple copies of a single transmission arrive at the receiver at slightly different times. Without diversity techniques, severe attenuation makes it difficult for the receiver to determine the transmitted signal [1]. Specifically, the employment of multiple antennas at both the transmitter and the receiver, which is widely referred to as the MIMO techniques, constitutes a cost-effective approach to high throughput wireless communication and remote sensing. The concept MIMO for both wired and wireless systems was first introduced by Jack Winter in 1987 for two basic communication systems. The first was for communication between multiple mobiles and a base station with multiple antennas and the second for communication between two mobiles each with multiple antennas.Where, he introduced a technique of transmitting data from multiple users over the same frequency/time channel using multiple antennas at boththe transmitter and receiver ends. In 1996,Raleigh proposed new approaches for improving the efficiency of MIMO systems which inspired numerous further contributions for two suitable architectures for its realization known as Vertical Bell-Labs Layered Space-Time (V-BLAST) algorithm has been proposed by Foschini, which is capable of achieving a substantial part of the MIMO capacity. It is capable of achieving high spectral ef- ficiency which being relatively simple to implement. The basic motive was to increase the data rate in a constrained spectrum. The promises of information theoretic MIMO analysis for the channel capacity were the main trigger for this enthusiasm and also ignited the study of related area such as MIMO channel modeling Space time signal processing, Space Time coding etc. The objective of such multi channel diagonalization into partition or distribute multi user signals into disjoint space and resultant channel gains are maximized to optimize the overall system capacity under the constraint of a fixed transmit power. Also improve the quality (BER).

MIMO Channel Models

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. A MIMO channel is a wireless link between M transmits and N receive antennas. It consists of MN elements that represent the MIMO channel coefficients. The multiple transmit and receive antennas could belong to a single user modem or it could be distributed among different users. The later configuration is called distributed MIMO and cooperative communications. Statistical MIMO channel models offer flexibility in selecting the channel parameters, temporal and spatial correlations. Fig.1 (a), (b), (c) and (d) shows conceptual diagram of existing technology, smart antenna system and MIMO channels respectively.

MIMO System Channel Capacity

Multipath propagation has long been regarded as impairment because it causes signal fading. To mitigate this problem, diversity techniques were developed. Antenna diversity is a widespread form of diversity. Information theory has shown that with multipath propagation, multiple antennas at both transmitter and receiver can establish essentially multiple parallel channels that operate simultaneously, on the same frequency band at the same total radiated power.

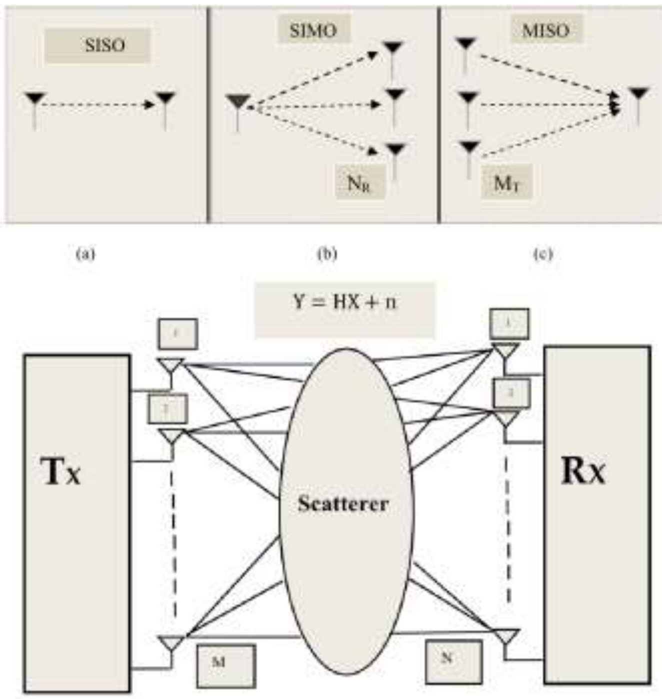


Fig. 1

Antenna correlation varies drastically as a function of the scattering environment, the distance between transmitter and receiver, the antenna configurations, and the Doppler spread. Recent research has shown that multipath propagation can in fact contribute to capacity.Channel capacity is the maximum infor- mation rate that can be transmitted and received with arbitrarily low probability of error at the receiver. A common representa- tion of the channel capacity is within a unit bandwidth of the channel and can be expressed in bps/Hz. This representation is also known as spectral (bandwidth) efficiency. MIMO channel capacity depends heavily on the statistical properties and antenna element correlations of the channel. Representing the input and output of a memory less channel with the random variables X and Y respectively, the channel capacity is defined as the maximum of the mutual information between X and Y: A channel is said to memory less if the probability distribution

$$C = \max_{p(x)} I(X;Y)$$

of the output depends only on the input at that time and is conditionally independent of previous channel inputs or outputs.

Capacity of MIMO System

For the MIMO system, we have M antennas at transmitter and N antennas at receiver. We analyze the capacity of MIMO channel in two cases:

Same signal transmitted by each antenna: In this case, the MIMO system can be view in effect as a combination of the SIMO and MISO channels. We have:

$$SNR \approx \frac{N^2M^2.\text{signal power}}{N.M.(\text{noise})} = M.N.SNR$$

So the capacity of MIMO channels in this case is:

$$C_{MIMO} = B.\log_2[1 + M.N.SNR](BPS/H_Z)$$

Thus, we can see that the channel capacity for the MIMO systems is higher than that of SIMO and MIMO system. But in this case, the capacity is increasing inside the log function. This means that trying to increase the data rate by simply transmitting more power is extremely costly.

Different signal transmitted by each antenna: The big idea in MIMO is that 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:

$$C_{MIMO} = B.\log_2\left[1 + \frac{N}{M}.SNR\right](BPS/H_Z)$$

The plot for total capacity for different MIMO channel unknown as shown in Fig

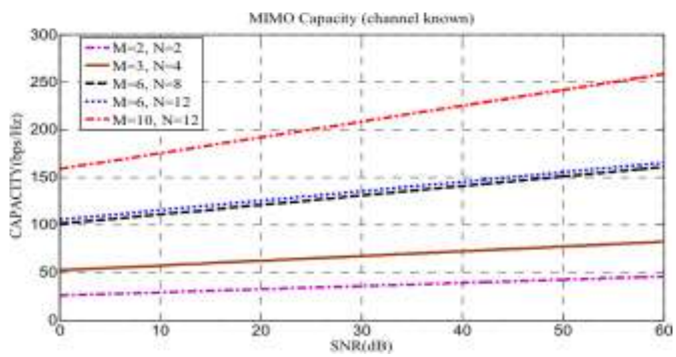


Fig. 2

Thus, we can get linear increase in capacity of the MIMO channels with respect to the number of transmitting antennas.

So, the key principle at work here is that it is more beneficial to transmit data using many different low-powered channels than using one single, high-powered channel. In the practical case of time-varying and randomly fading wireless channel, it shown that the capacity of M x N MIMO system for known Channel is

$$C_{MIMO} = B.\log_2\left|\det\left[I_N + \frac{SNR}{M}.HH^*\right]\right|(BPS/H_Z)$$

The plot for MIMO capacity under known channel is as shown in Fig.

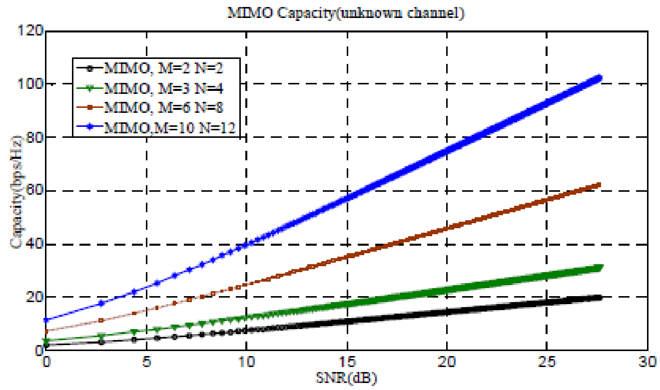


Fig. 3

We can see that the advantage of MIMO systems is sig- nificant in capacity. MIMO is best when SNR and angular spread are large but for Small angular spread or presence of a dominant path (e.g. LOS) reduce MIMO performance.

V-Blast Architecture

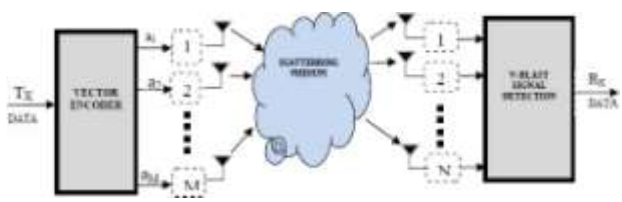


Fig. 4

One of the earliest communication systems that were pro- posed to take advantage of the promising capacity of MIMO channels is the BLAST architecture. It achieves high spectral efficiencies by spatially multiplexing coded or uncoded sym- bols over the MIMO fading channel. Symbols are transmitted through M antennas. Each receiver antenna receives a super- position of faded symbols. The ML decoder would select the set of symbols that are closest in Euclidean distance to the received N signals. However, it is hard to implement due to its exponential complexity. More practical decoding architectures were proposed in the literature.

V-Blast Technique

The transmission is described as follows. A data stream is demultiplexed into M sub-streams termed layers. For D-BLAST at each transmission time, the layers circularly shift across the M transmit antennas resulting in a diagonal structure across space and time. On the other hand, the layers are arranged horizontally across space and time for VBLAST and the cycling operation is removed before transmission is shown in Fig 4.1 At the receiver, as mentioned previously, the received signals at each receive antenna is a superposition of M faded symbols plus additive white Gaussian noise (AWGN). Although the layers are arranged Differently for the two BLAST systems across space and time, the detection process for both systems is performed vertically for each received vector. Without loss of generality, assume that the first symbol is to be detected. The detection process consists of two main operations:

Interference Suppression (Nulling): The suppression op- eration nulls out interference by projecting the received vector onto the null subspace (perpendicular subspace) of the sub- space spanned by the interfering signals. After that, normal detection of the first symbol is performed

Interference Cancellation (Subtraction): The contribution of the detected symbol is subtracted from the received vector [1].BLAST detection algorithm combines linear (interference suppression) and nonlinear (serial cancellation) algorithms. This is similar to the decorrelating decision feedback multiuser detection algorithm. A drawback of BLAST algorithms is the propagation of decision errors. Also, the Interference nulling operation requires that the number of receive antennas be greater than or equal to the number of transmit antennas. Fur- thermore, due to the interference suppression, early detected symbols benefit from lower receives diversity than later ones. Thus, the algorithm results in unequal diversity advantage for each symbol. There are few differences between V-BLAST and D-BLAST. While the layers of the V-BLAST can be coded or uncoded, the D-BLAST is intended to be used only with coded layers. This is the reason behind cycling which provides more spatial diversity for each layer particularly over slowly fading channels. Further, due to the diagonal structure of D- BLAST, each layer benefits from the same diversity advantage while V-BLAST layers have unequal diversity advantages. However, DBLAST requires advanced inter-stream coding techniques to optimize the performance of the code across space and time. Finally, some space-time is wasted at the start and the end of the burst for DBLAST. V-BLAST takes a single data stream and demultiplexed it into M sub-streams with M is the number of transmitter antennas. Each sub-stream is encoded into symbols and fed to a separate trans- mitter. The modulation method in these systems usually is M Quadrature Amplitude Modulation (MQAM). QAM combines phase modulation with amplitude modulation, making it an efficient method for transmitting data over a limited bandwidth channel. BLAST's receiver operate co-channel, each receiving the signals emanating from all M of the transmitting antennas. For the sake of simplicity, it is also assumed that the channel- time variation is negligible over the L symbol periods in a burst.

PERFORMANCE ANALYSIS OF MIMO TECHNOLOGY USING V-BLAST TECHNIQUES

Maximum Likelihood

ML is a non-linear detection technique. The BER/SNR results of ML are better than MMSE detector but at the cost of additional complexity. So ML is used in applications where high efficiency is requires. Now if we apply V-BLAST algorithm on ML, the performance will be better than ML detector [3].

Zero Forcing

Zero Forcing is a linear detection technique. The pseudo inverse of the signal is applied to the received signal in order to make a decision about one user. In this way the received signal is detected by zero forcing detectors. If V-BLAST algorithm is applied on ZF detector, equation will be applied on ZF filter matrix. ZF with V-BLAST shows better performance in comparison to normal ZF in terms of BER/SNR [3].

Minimum Mean Square Error

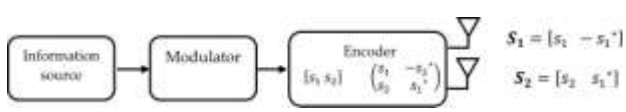
MMSE is also a linear detection technique but more reliable than ZF in case of noisy channel . MMSE does not apply pseudo inverse of signal to make decision about one user, instead it attenuates them to noise level thereby reducing the diversity order. From the filter matrix for MMSE is, Now V- BLAST algorithm can be applied over above filter matrix and results can be generated [3].

PV-BLAST with Maximal Ratio Combining (MRC)

MRC combines the information from all the received branches in order to maximize the ratio of signal to noise power, which gives it its name. MRC works by weighting each branch with a complex factor and then adding up the branches, MRC is intuitively appealing: the total SNR is achieved by simply adding up the branch SNRs when the appropriate weighting coefficients are used.

STBC (Space-Time Block Codes)

STBC is a class of linear coding for MIMO systems that aims to maximize the system diversity gain rather than the data rate. A very popular STBC for a two transmit antennas setup was developed by Alamouti, which is illustrated in Fig5.4.1. It is designed for 2x2 MIMO systems and its simplicity and high frequency have led to its wide adoption in MIMO systems. In this scheme orthogonal signals are transmitted from each antenna, which greatly simplifies receiver design. This particular scheme is restricted to using M = 2 antennas at the transmitter but can any number of receive antennas N .Two QAM symbols S1 and S2 for transmission by the Alamouti scheme are encoded in both the space and time domain at the two transmitter antennas over the consecutive symbol periods as shown in equation.



$$S = [s_1 \quad s_2] = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}$$

The information bits are first modulated using a modulation scheme (for example QPSK). The encoder then takes a block of two modulated symbols s1 and s2 in each encoding operation and gives to the transmit antennas according to the code matrix. In a fast fading channel, the BER is of primary interest since the channel varies every symbol time; while in a slow fading situation, the FER (Frequency error rate) is more important because channel stays the same for a frame.

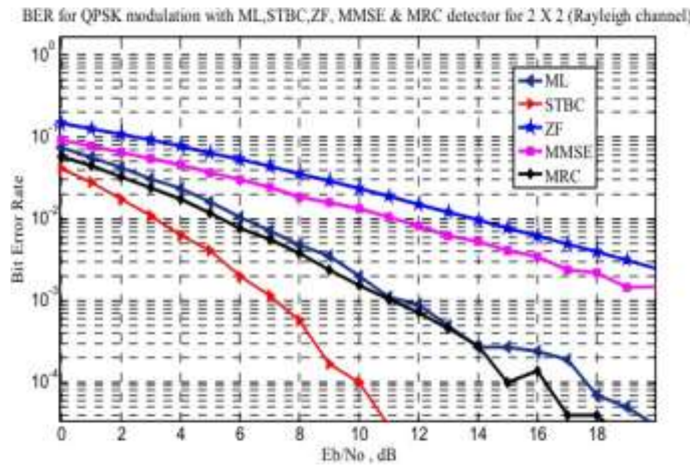


Fig. 5

RESULTS

In V-Blast System,we can observe that for 4 channel the BER is near about 10-3. This system is good for high speed wireless communication because the data is transmitted inde- pendently through different channel therefore time required is less to transmit the data the only disadvantage of this system is BER because at receiver side the data is weak due to fading effect. Therefore the choice of this system is depend on user. In STBC based system as shown , the BER is 10-2 for 4 channel we can conclude that BER is improve because in this system we have send multiple copies of data through different antenna at receiver side using MLD decoding we will get our data with less error. But in this system at same time we are sending same copies of data therefore the data transfer rate

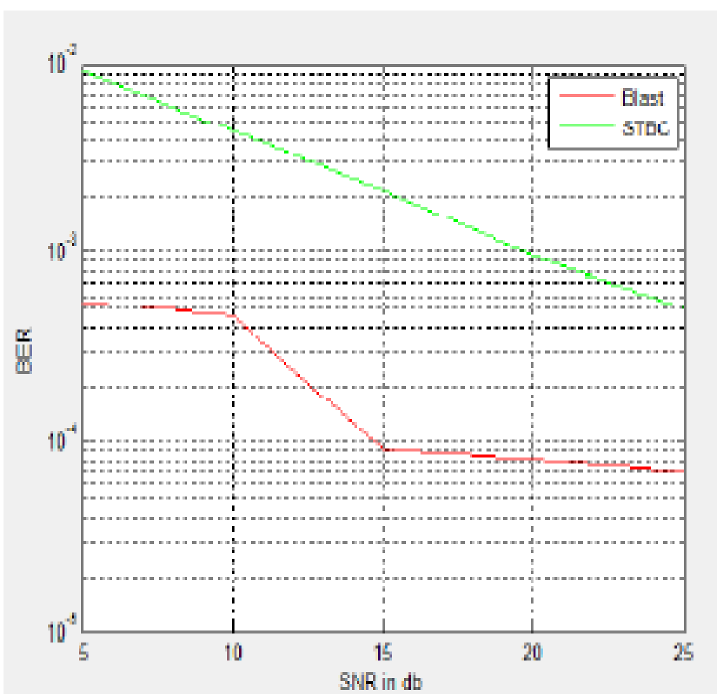


Fig. 6

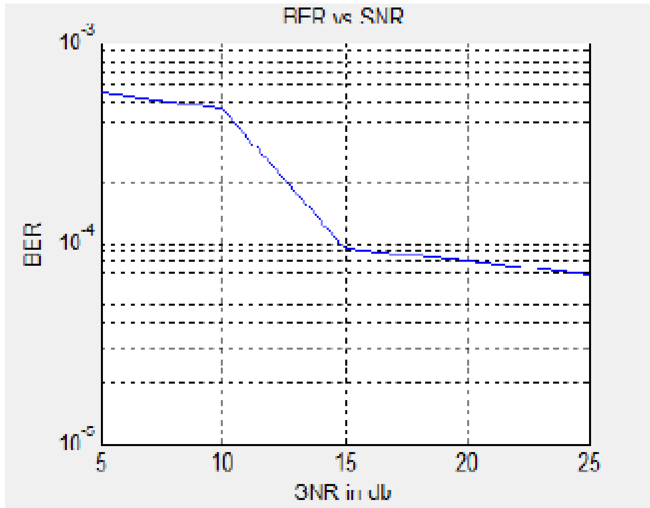


Fig. 7

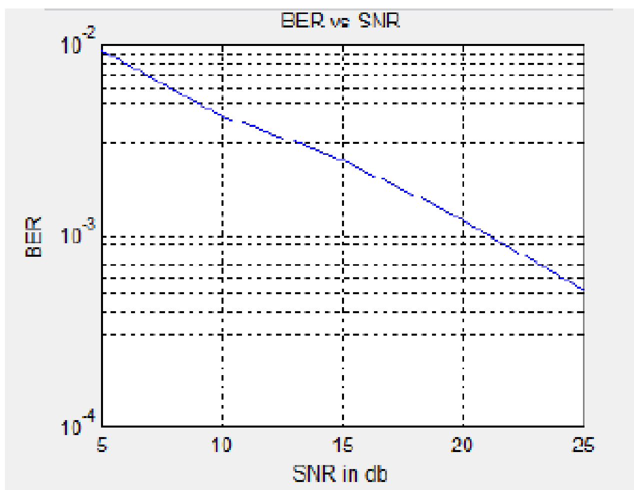


Fig. 8

of this system is not so good. Now we can conclude from last result. that by considering BER as parameter that STBC system is good for error less transmission but if we require high speed transmisssion we will consider V-BLAST for that. require high speed transmisssion we will consider VBLAST for that.

CONCLUSION

In this paper, we provide a general multiple antenna system, the general V- BLAST system and analyzed the performance of V-BLAST with several detectors (ML, ZF, MMSE, STBC, and MRC) in slow fading channels. We first provide a comprehensive summary of capacity results for single-user MIMO channels. These results indicate that the capacity gain obtained from multiple antennas heavily depends on the amount of channel knowledge at either the receiver or transmitter, the channel SNR, and the correlation between the channel gains on each antenna element. We then focus attention on the capacity regions for MIMO broadcast and multiple accesses under known channels or unknown channels. In contrast to single-user MIMO channels, capacity results for these mul- tiuser MIMO channels are quite difficult to obtain, even for constant channels. We summarize capacity results for the MIMO broadcast and multiple access channels for channels that are either constant or fading with perfect instantaneous knowledge of the antenna gains at both transmitter(s) and receiver(s). We also show that the MIMO multiple access and broadcast capacity regions are intimately related via a duality transformation. This transformation is not only useful for prov- ing capacity theorems; it also facilitates finding the optimal transmission strategy of the nonconvex MIMO broadcast chan- nel using convex optimization techniques applied to the dual MIMO multiple access channel. Furthermore, we introduced SIC schemes to improve the independent coded V-BLAST system. We showed that in V-BLAST systems, performance is limited by error propagation. Therefore, we proposed ordering schemes to combat error propagation. The results of these schemes are compared in the Fig 8. We showed the benefits of ordering strategy over Successive Interference Cancellation and proposed an ordering strategy with ML detection at the first stage. We applied this strategy to the general V-BLAST system and got a higher performance gain. In this way, MIMO is an important key for enabling the wireless industry to deliver on the vast potential and promise of wireless broadband.

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