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Improving Diversity Using Linear and Non-Linear Signal Detection techniques

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Abstract:- This paper presents the performance analysis of V-BLAST based MIMO-OFDM system with respect to bit error rate per signal to noise ratio (BER/SNR) for various detection techniques. A 2X2 MIMO-OFDM system is used for the performance evaluation. The simulation results shows that the Improving diversity performance of V-BLAST based detection techniques is much better than the conventional methods.

Keywords:- Multiple Input Multiple Output (MIMO), OFDM, Bit Error Rate (BER), Zero Forcing (ZF), Maximum Likelihood (ML), Minimum Mean Square Error (MMSE).

I. INTRODUCTION

By using multiple antennas at both transmitter and receiver (MIMO system) the throughput can be increased by simultaneously transmitting different streams of data on the different transmit antennas but at the same carrier frequency. These parallel streams of data can be recovered at the transmitter with spatial sampling and corresponding signal process algorithm. The combination of the throughput enhancement of MIMO system with the robustness of orthogonal frequency division multiplexing (OFDM) against frequency-selective fading caused by severe multipath scattering and narrowband interference is regarded as a very promising basis for future high speed data communication [3].

Among conventional detection techniques in MIMO-OFDM communication such as zero forcing (ZF) [1], minimum mean square error (MMSE) [1] and maximum likelihood (ML) [1]. ML shows better performance at the cost of higher complexity. Therefore we have applied V-BLAST algorithm on all of the above detection techniques and then compared their performance on the basis of bit error rate per signal to noise ratio and found that the detection techniques with V-BLAST algorithm shows better performance than without V-BLAST [3].

II. BACKGROUND OF OFDM

The concept of using parallel-data transmission and frequency division multiplexing (FDM) was first published in the mid of 1960s. The basic idea was to use parallel data and FDM with overlapping sub channels to avoid the use of high-speed equalization to combat impulsive noise and multipath distortion and fully utilize bandwidth.

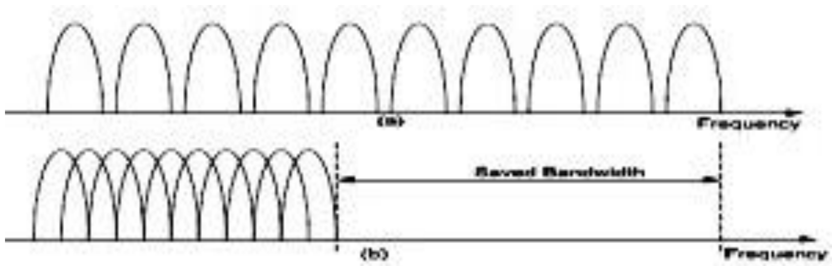


Fig.1: Concept of OFDM Signal: (a) conventional multicarrier technique (FDM) [7], (b) Orthogonal Frequency Division Multiplexing technique [7].

In Fig.1, we can observe the difference between non overlapping multicarrier modulation technique and overlapping modulation technique. From figure 1(b) it is very clear that by using overlapping modulation technique we can save much more bandwidth than the non overlapping one. Weinstein and Ebert applied the discrete Fourier transform (DFT) to parallel data transmission system as part of the modulation and demodulation process. In multicarrier transmission, bandwidth divided in many non-overlapping subcarriers but not essential that all subcarriers are orthogonal to each other as shown in fig.2.[4].

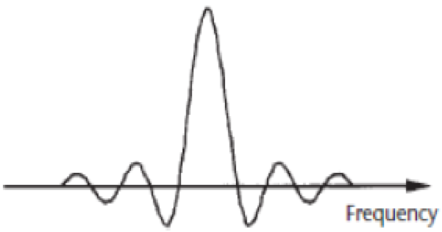


Fig.2(a): An OFDM sub channel [4] [7] [8]

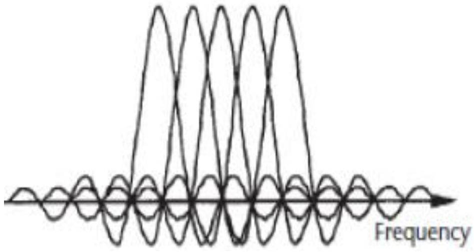


Fig.2 (b): An OFDM signal [4] [7] [8]

III. TYPES OF ANTENNA

A. SISO

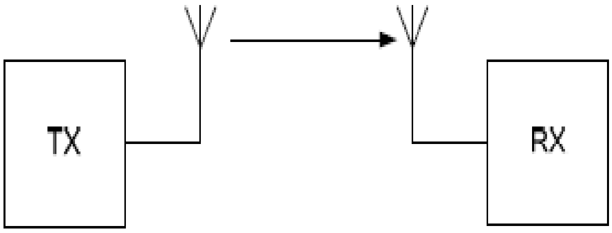


Fig.3: SISO (Single Input Single Output) [1]

Single Input Single Output is the classical method in wireless communication and the most common antenna configuration, using one antenna at transmitter and one at the receiver. It is used in radio, TV broadcast and in technology as WI-FI, Bluetooth.

B. SIMO

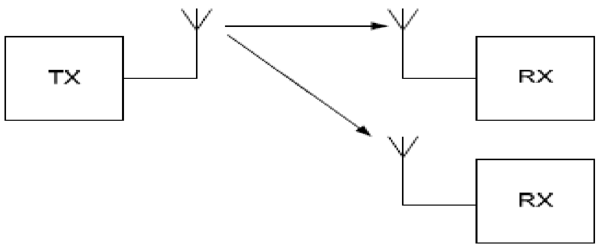


Fig.4: SIMO (Single Input Multiple Output) [1]

Single Input Multiple Output is the system using one antenna at transmitter and Multiple at the receiver. It provides receiver diversity which receive the strongest signal from several transmit antennas. Generally, it is used in Uplink environment.

C. MISO

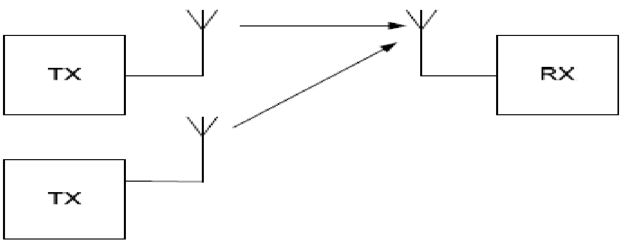


Fig.5: MISO (Multiple Input Single Output) [1]

In Multiple Input Single Output two or more number of antennas is used in the transmitter and one antenna at the receiver. It provides transmit diversity because of multiple antenna at a transmitter side. MISO technology has applications in WLAN, MAN and Digital Television (DTV). Commonly, it is used in downlink scenarios.

D. MIMO

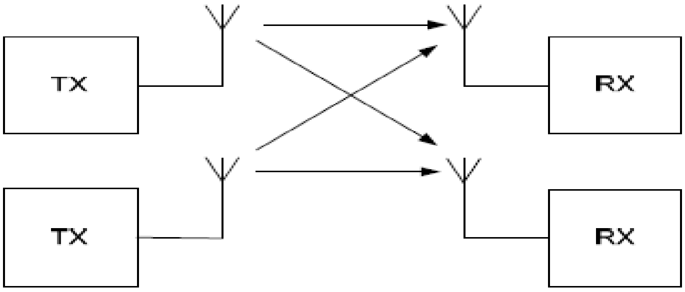


Fig.6: MIMO (Multiple Input Multiple Output) [1]

Multiple Input Multiple Output antennas at both sides which provides transmit diversity and receiver diversity. It is applicable in every kind of networks like PAN, LAN, WLAN, WAN, MAN. MIMO system can be applied in different ways to receive either a diversity gain, capacity gain or to overcome signal fading.

IV. MIMO SYSTEM MODEL

Multiple Input Multiple Output (MIMO) systems yield vast capacity increases when the rich scattering environment is properly exploited [1]. When examining the performance of MIMO systems, the MIMO channel must be modelled properly. The MIMO channel models used throughout this thesis are described in this section. The primary MIMO channel model under consideration is the quasi-static, frequency non-selective, Rayleigh fading channel model.

The MIMO signal model is described as

$$r = Hx + n \qquad (1.1)$$

Where r is N_r*1 received signal vector, H is N_r*N_t the channel matrix, x is N_t*1 transmitted vector and n is N_r*1 Gaussian noise vector [1].

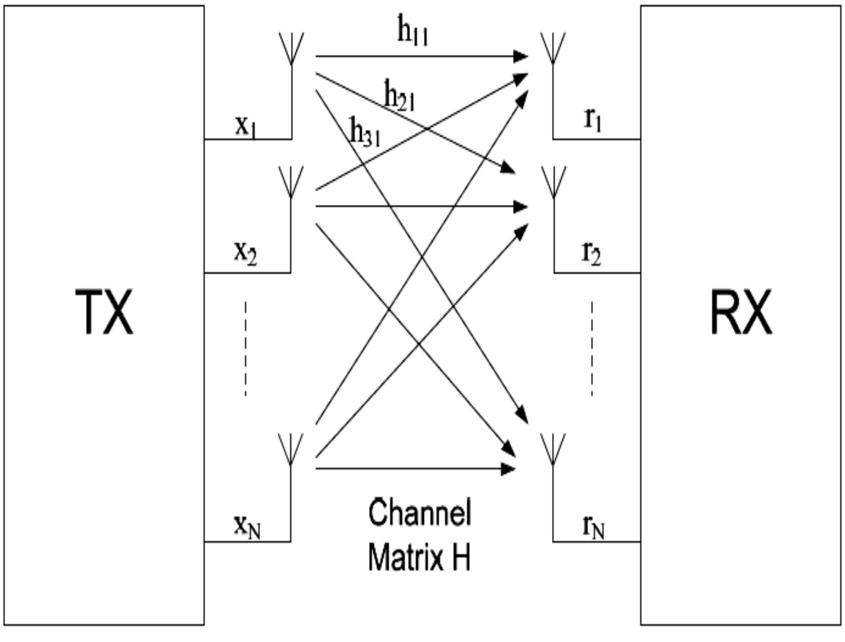


Fig.7: MIMO System Model [1]

Fig.7 shows a block diagram of a MIMO system with N_t transmit antennas and N_r receive antennas. The channel for a MIMO system can be represented by

$$H = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1N} \\ h_{21} & h_{22} & \cdots & h_{2Nt} \\ h_{Nr1} & h_{Nr2} & \cdots & h_{NrNt} \end{bmatrix} \qquad (1.2)$$

Under the quasi-static assumption, the channel remains constant over the length of a frame, changing independently between consecutive frames. When the antenna elements are spaced sufficiently apart (at least half a wavelength, for indoor applications) and there are enough scatterers present that the received signal at any receive antenna is the sum of several multipath components, the channel paths are modelled as independent and uncorrelated. The channel undergoes frequency non-selective fading when the coherence bandwidth of the channel is large compared to the bandwidth of the transmitted signal [1].

V. V-BLAST ARCHITECTURE

V-BLAST is called Vertical Bell Labs Space-Time Architecture. Among conventional detection techniques in MIMO-OFDM communication such as zero forcing (ZF), minimum mean square error (MMSE) and maximum likelihood (ML), ML shows better performance at the cost of higher complexity.

Therefore we have applied V-BLAST algorithm on all of the above detection techniques and then compared their performance on the basis of bit error rate per signal to noise ratio and found that the detection techniques with V-BLAST algorithm shows better performance than without V-BLAST.

Even the complexity of the system reduces by using V-BLAST algorithm and the simulation results show that the performance of V-BLAST based MMSE is close to that of ML technique, with much lower complexity. Therefore V-BLAST based detection techniques can be preferred over conventional methods in MIMO-OFDM system with high data transmission capacity where high efficiency is required with lower complexity.

The analysis presented in this paper shows the performance comparison of conventional detection techniques in MIMO-OFDM communication with that of V-BLAST based techniques and hence shows that better performance can be achieved by using V-BLAST based detection techniques.

VI. V-BLAST TRANSMITTER

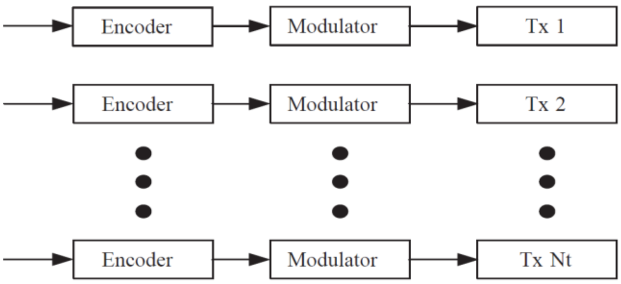


Fig.8: Transmitter of a general V-BLAST system.

Fig. 8 shows the transmitter in a general V-BLAST system. The difference between the MIMO transmitter antenna and V-BLAST transmitter system is that in a V-BLAST system, all the symbols are transmitted by different transmitting antennas and independent from each other. The coded bits from the same codeword are transmitted by the same transmitter, which also means they will go through the same channel vector. The encoder and the modulator being used in a V-BLAST system are as same as MIMO Transmitter antenna system.

VII. V-BLAST RECEIVER

Fig. 9 is a receiver being used in a general V-BLAST system. As the streams are independently encoded, we need to separate the Nt transmitted streams after demodulation and then decode them separately with their own decoders. Decoders and the demodulator being used in a general V-BLAST receiver are as same as MIMO receiver antenna system.

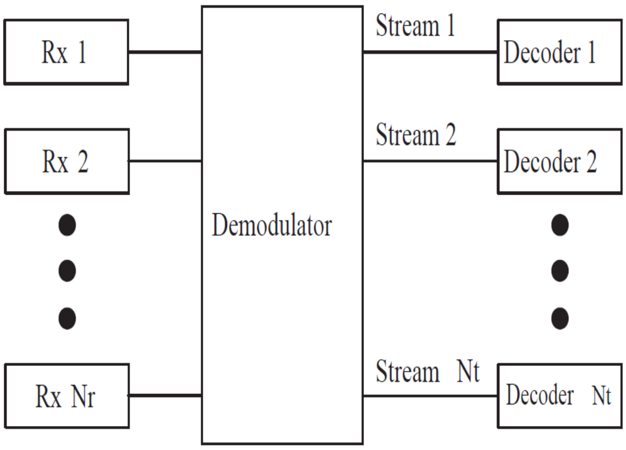


Fig.9: Receiver of a General V-BLAST System

Fig. 9 is the general V-BLAST receiver with joint detection and the complexity grows exponentially with the number of data streams. As a result, simpler detecting rule that provides soft information to feed to the decoders of the individual data streams is an active area of research; we will modify the receiver architecture in Fig. 9 so that linear operations can be used to convert the problem of joint detection into individual detection. In Conjunction with successive cancellation of data streams, we can achieve the capacity of a fast fading MIMO channel. With ordering strategy, we can get a better performance of the V-BLAST architecture in a slow fading channel.

VIII. LINEAR DETECTION

A. Zero Forcing (ZF)

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. So the equation for filter matrix G for zero forcing will be,

$$G = (H^H H)^{-1} H^H \quad (1.3)$$

In this way the received signal is detected by zero forcing detectors. If V-BLAST algorithm is applied on ZF detector, equation 1.3 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].

B. Minimum Mean Square Error (MMSE)

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,

$$G = (H^H H + \frac{N_t}{SNR} I_{N_r})^{-1} H^H \quad (1.4)$$

IX. NONLINEAR DETECTION

A. Maximum Likelihood (ML)

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].

X. SIMULATION RESULT

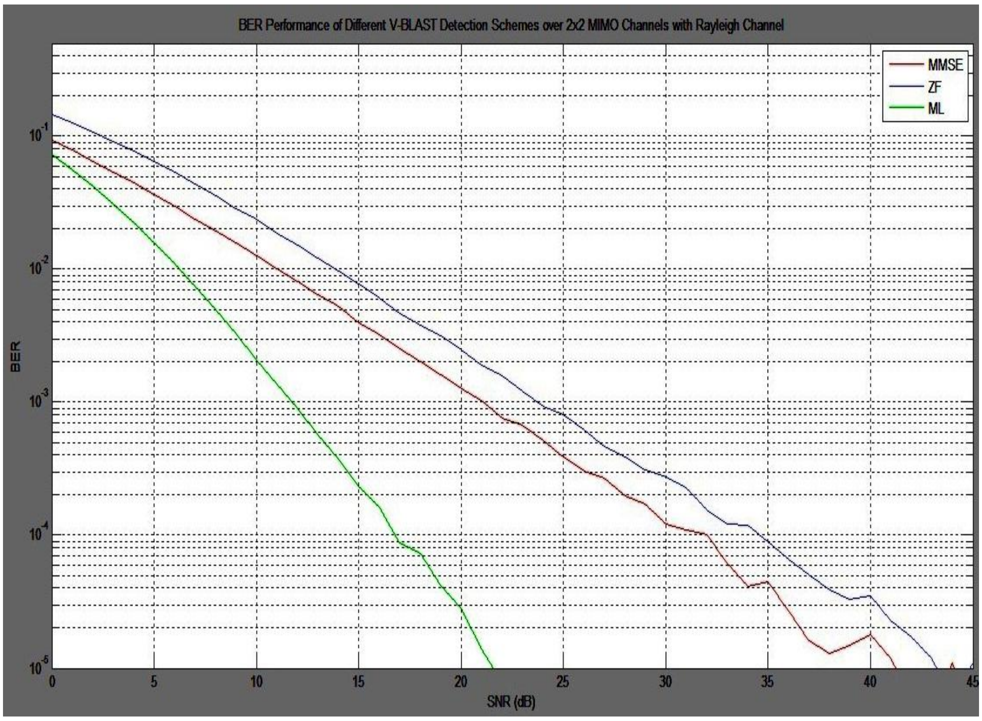
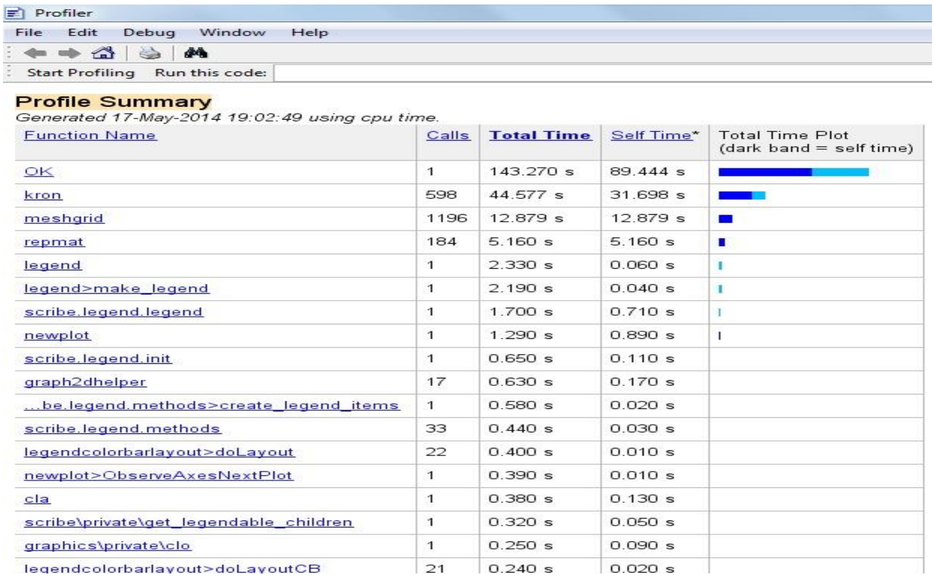


Fig.10: BER vs. SNR Ratio for V-BLAST Techniques

Table I Comparison of BER performance with different V-BLAST techniques

Bit Error Rate	Signal To Noise Ratio (SNR)		
	ZF	MMSE	ML
10^{-3}	24dB	21dB	12dB
10^{-4}	35dB	32dB	17dB
Performance	Low	Medium	High

XI. PROFILE SUMMARY



Profiler
File Edit Debug Window Help
Start Profiling Run this code:

Profile Summary
Generated 17-May-2014 19:02:49 using cpu time.

Function Name	Calls	Total Time	Self Time*	Total Time Plot (dark band = self time)
OK	1	143.270 s	89.444 s	
kron	598	44.577 s	31.698 s	
meshgrid	1196	12.879 s	12.879 s	
repmat	184	5.160 s	5.160 s	
legend	1	2.330 s	0.060 s	
legend>make_legend	1	2.190 s	0.040 s	
scribe.legend.legend	1	1.700 s	0.710 s	
newplot	1	1.290 s	0.890 s	
scribe.legend.init	1	0.650 s	0.110 s	
graph2dhelper	17	0.630 s	0.170 s	
...be.legend.methods>create_legend_items	1	0.580 s	0.020 s	
scribe.legend.methods	33	0.440 s	0.030 s	
legendcolorbarlayout>doLayout	22	0.400 s	0.010 s	
newplot>ObserveAxesNextPlot	1	0.390 s	0.010 s	
cla	1	0.380 s	0.130 s	
scribe\private\get_legendable_children	1	0.320 s	0.050 s	
graphics\private\clo	1	0.250 s	0.090 s	
legendcolorbarlayout>doLayoutCB	21	0.240 s	0.020 s	

Fig.11: Profile Summary of V-BLAST Techniques Result

XII. BAR GRAPH OF V-BLAST RESULT

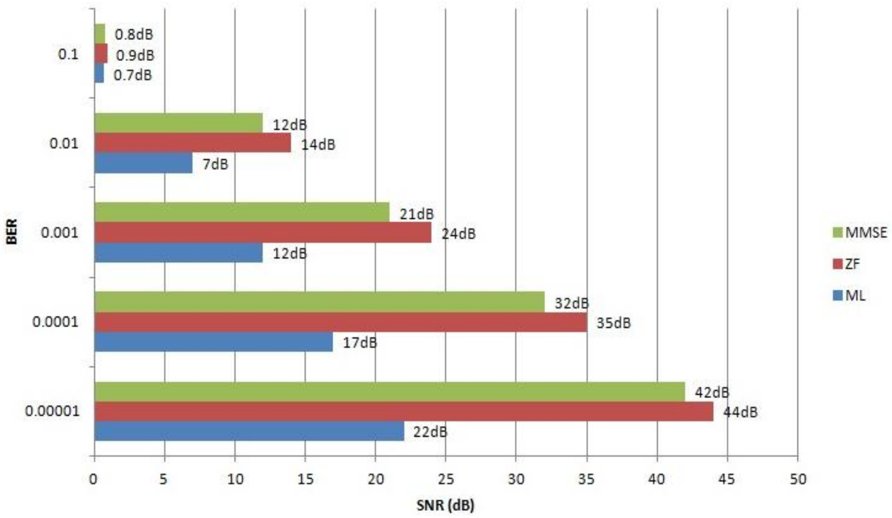


Fig.12: BAR Graph of V-BLAST Result

XIII. CONCLUSION

As diversity increases at the receiver end BER is reduced. MIMO code was designed in such a way that it can be raised up to 2xN receiver. The results of the simulations, in which BER performance of different schemes is, computed shows that MIMO-OFDM with space time coding can provide high data rate transmission and there is no need to increase the transmit power and expansion of bandwidth. And after that We are working in various V-BLAST techniques and improve BER vs. SNR response.

XIV. FUTURE SCOPE

The main focus of this paper was BER performance for different V-BLAST Techniques. In future we can combine MIMO and OFDM and extend it for Hybrid V-BLAST ARCHITECTURE [9] for higher diversity of antennas. And also It's extended MIMO – IDMA. One can also work on work space. Moreover, further work can also be done to enhance the capacity of the channel..

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