An Efficient Comparison Ofmimo-Ofdm Detection Using Spatial Multiplexingtechniques

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ABSTRACT

Multiple Input Multiple Output (MIMO) systems have recently emerged as a key technology in wireless communication systems for increasing both data rates and system performance. 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 proposes a novel signal detector scheme called MIMO detectors to enhance the performance in MIMO channels. , we study the general MIMO system, the general V-BLAST architecture with Maximum Likelihood (ML), Zero- Forcing (ZF), Minimum Mean-Square Error (MMSE), and Ordered Successive Interference Cancellation (SIC) detectors and simulate this structure in Rayleigh fading channel. Also compares the performances of MIMO system with different modulation techniques in Fading and AWGN channels. Base on frame error rates and bit error rates, we compare the performance and the computational complexity of these schemes with other existence model. Simulations shown that V-BLAST implements a detection technique, i.e. SIC receiver, based on ZF or MMSE combined with symbol cancellation and optimal ordering to improve the performance with lower complexity, although ML receiver appears to have the best SER performance-BLAST achieves symbol error rates close to the ML scheme while retaining the low-complexity nature of the V-BLAST.

Indexterms: *MIMO, V-BLAST, ZF, MMSE SIC and ML.*

I. INTRODUCTION

Future wireless communication networks will need tosupport extremely high data rates in order to meet the rapidly growing demand for broadband applications such as high quality audio and video. Existing wireless communication technologies cannot efficiently support broadband data rates, due to their sensitivity to fading.
Recent research on wireless communication systems has shown that using MIMO at both transmitter and receiver offers the possibility of wireless communication at higher data rates, enormous increase in performance and spectral efficiency compared to single antenna systems. The information-theoretic capacity of MIMO channels was shown to grow linearly with the smaller of the numbers of transmit and receiver antennas in rich scattering environments, and at sufficiently high signal-to-noise (SNR) ratios [1].MIMO wireless systems are motivated by two ultimate goals of wireless communications: high-data-rate and high-performance [2],[3].During recent years, various space-time (ST) coding schemes have been proposed to collect spatial diversity and/orachieve high rates. Among them, V-BLAST (Vertical Bell Labs Layered Space-Time) transmission has been widely adopted for its high spectral efficiency and low implementation complexity [4]. When maximum-likelihood (ML) detector is employed, V-BLAST systems also enjoy receives diversity, but the decoding complexity is exponentially increased by the number of transmit antennas.

Although some (near-) ML schemes (e.g., sphere decoding (SD), semi-definite programming (SDP)) can be used to reduce the decoding complexity, at low signal to noise ratio (SNR) or when a large number of transmit antennas and/or high signal constellations are employed, the complexity of near-ML schemes is still high. Some suboptimal detectors have been developed, e.g., successive interference cancellations (SIC), decision feedback equalizer (DFE), which are unable to collect receive diversity [5]. To further reduce the complexity, one may apply linear detectors such as zero-forcing (ZF) and minimum mean square error (MMSE) equalizers. It is well-known that linear detectors have inferior performance relative to that of ML detector. However, unlike ML detector, the expected performance (e.g., diversity order) of linear equalizers has not been quantified directly. The mutual information of ZF equalizer has been studied in [6] with channel state information at the transmitter.
In this paper, we propose a modified V-BLAST system, which introduces different delay offsets for each substreme in the transmitter. At the receiver, we can employ ZF strategy to recover information and the introduction of delay offsets enables the requirement of Nr to be relaxed to $Nr \geq 1$ (in the conventional V-BLAST, $Nr \geq Nt$. Where, Nr and Nt are the receiver and transmitter antennas respectively. We will verify the performance improvement by theoretical analysis and simulation results. From our analysis, with ZF decoding,

the diversity order can reach Mr in the modified V-BLAST system. But the increase of the diversity order is at the cost of the multiplexing gain.The main goal of our paper is to study the MIMO detectors schemes and quantify the diversity orders collected by linear equalizers for V-BLAST. Also optimize the ultimate detector and modulation technique that yields a better error performance than general V-BLAST. The rest of this paper is organized as follows. In Section 2, the MIMO system model is introduced. Section 3 gives the performances of MIMO system with different modulation techniques in Fading and AWGN channels and Section 4 gives the performance analysis of the linear equalizers optimize the ultimate detector.

II. MIMO SYSTEM MODEL

In this paper, we consider a conventional MIMO SM system with transmitNttransmit antennas and Nr receive antennas where Nt≤Nr as shown in Figure 1.5. Independent data streams *a*, *b*, and *c*, are encoded and modulated before being transmitted. Herein, consider a transmitted vector x=[x_1, $x_{2...}$xNt] ^{T} whose elements are drawn independently from a complex constellation set Ω, e.g. Quadrature Amplitude Modulation (QAM) constellation. The vector is then transmitted via a MIMO channel characterized by the channel matrix Hwhose element is the $h_{i,j}$ CN (0,1)[1] complex channel coefficient between the *j*th transmit and *i*th receive antennas. The received vector r=[r, r… $rNr_]$ ^{T} can then be given as following,

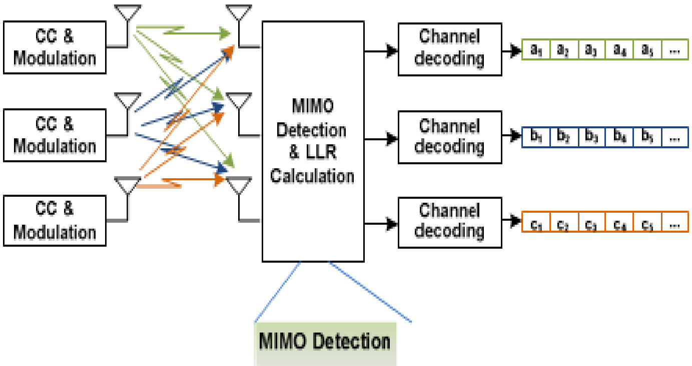

Fig. 1.SMsystemmodelincludingboth transmitterandreceiver main functionalblocks

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

Where the elements of the vector n= [n_1, $n_{2,}$…,$n_{Nr]}$ ^{T} are drawn from independent and identically distributed (i.i.d.) circular symmetric Gaussian random variables. The system model of(2.1) is then given in the matrix form as following.

$$= \qquad \begin{bmatrix} h_{11} \\ \vdots \\ h_{N_r1} \end{bmatrix}$$

I. SPATIAL MULTIPLEXING AND DETECTION PROBLEM

Spatialmultiplexing(SM)Seemstobetheultimatesolutiontoincreasethesystemcapacitywithouttheneedtoad ditionalspectralresources.Thebasicideaehindsmisthatadatastreamisdemultiplexedintontindependentsubstreamsass howninfigure1,Andeachsubstreamisthenmappedintoconstellationsymbolsandfedtoitsrespectiveantenna.Thesymb olsaretakenfromaqamconstellation.Theencodingprocessissimplyabittosymbolmappingforeachsubstream,Andalls ubstreamsaremappedindependently.Thetotaltransmitpowerisequallydividedamongthenttransmitantennas.Atthere ceiverside,Themainchallengeresidesindesigningpowerfulsignalprocessingtechniques,I.E.,Detectiontechniques,C apableofseparatingthosetransmittedsignalswithacceptablecomplexityandachievedperformance.Givenperfectchan nelknowledgeatthereceiver,Avarietyoftechniquesincludinglinear,Successive,Treesearchandmaximumlikelihoodd ecodingcanbeusedtoremovetheeffectofthechannelandrecoverthetransmittedsubstreams,Seeforexample.Differentr esearchactivitieshavebeencarriedouttoshowthatthespatialmultiplexingcoceptthasthepotentialtosignificantlyincre asespectralefficiency,.Furtherresearchhasbeencarriedoutoncreatingandevaluatingenhancementstothespatialmulti plexingconcepts,Suchascombiningwithothermodulationschemeslikeofdm(OrthogonalFrequencyDivisionMultipl exing).Ingeneral,thistechniqueassumeschannelknowledgeatthereceiverandtheperformancecanbefurtherimproved when theknowledge ofthechannelresponseis available at the transmitter. However, SM does not work well in low

SNRenvironmentsasitismoredifficultforthereceivertorecognizethemultipleuncorrelatedpathsofthesignals .ThemainchallengeinthepracticalrealizationofMIMOwirelesssystemsliesintheefficientimplementationofthedetect orwhichneedstoseparatethespatiallymultiplexeddatastreams.Sofar,severalalgorithmsofferingvarioustradeoffsbetweenperformanceandcomputationalcomplexityhavebeendeveloped.Lineardetection(lowcomplexity,lowperformance)constitutesoneextremeofthecomplexity/performanceregion,whileMaximumLikelihoodDetector(MLD)detectionalgorithmhasanoppositeextreme(highcomplexity,optimumperformance).Maximum Likelihood Detector (MLD) is considered as theoptimum detector for the system of (1.1) that could effectively recover the transmitted signal at thereceiver based on the following minimum distance criterion,

$$\tilde{x} = arg_{x_k \in \{x_1, x_2, \dots, x_n\}} min\|r - Hx_k\|^2$$

Where x is the estimated symbol vector. Using the above criterion, MLD compares thereceivedsignal with all possible transmitted signal vector which is modified by channel matrix *H* and estimates transmit symbol vector *x*. Although MLD achieves the best performance and diversity order, it requires a brute-force search which has an exponential complexity in the number of transmit antennas and constellation set size. For example, if the modulation scheme is 64-QAM and 4 transmit antenna, a totalof 644 = 16777216 comparisons per symbol are required to be performed for eachtransmitted symbol. Thus, for high problem size, i.e. high modulation order and high transmit antenna (*Nt*), MLD becomes infeasible.The computational complexity of a MIMO detection algorithm depends on the symbol constellation size and the number of spatially multiplexed data streams, but often on the instantaneous MIMO channel realization and the signal-to-noise ratio. On the other hand, the overall decoding effort is typically constrained by system bandwidth, latency requirements, and limitations on power consumption. In order to solve the detection problem in MIMO systems, research has been focused on sub-optimal detection techniques which are powerful in terms of error performance and are practical for implementation purposes as well that are efficient in terms of both performance and computational complexity. Two such techniques are Sphere Decoding (SD) and QR Decomposition with M-algorithm (QRD-M) which utilize restrict tree search mechanisms.

III. AVERAGE BER-ANALYSIS

A. V-BLAST Zero Forcing (ZF) ZF characteristic:

The Zero-Forcing V-BLAST algorithm (ZF-VBLAST) is based on detecting the components of *x* one by one. For the first decision, the pseudo-inverse, i.e., *G* equals *H* † , of the matrix *H* is obtained. Assume that the noise components are *i.i.d*. and that the noise is independent of *x* . Then, the row of *G*, with the least Euclideannorm, corresponds to the required component of *x* . That is,

$$k_1 = argmin(\|g\|^2)$$
$$\tilde{x}_{k_1} = g_{k_1} r^1$$
$$\tilde{x}_{k_1} = Q(\tilde{x}_{k_1})$$

Obviously, incorrect symbol detection in the early stages will create errors in the following stages; i.e. error propagation. This is a severe problem with cancellation based detection techniques particularly when the number of transmit and receive antennas are the same. The first detected symbol's performance is quite poor as it has no diversity. To reduce the effect of error propagation and to optimize theperformance of VBLAST technique, it has been shown in that the order of detection can increase the performance considerably. By detecting the symbols withlargest channel coefficient magnitude first, the effect of the noise vector producing an incorrect symbol can be reduced, and reducing error propagation as result.

B. MinimumMeanSquareError

Minimum Mean Square Error (MMSE) approach alleviates the noise enhancement problem by taking into consideration the noise power when constructing the filtering matrix using the MMSE performance-base criterion. The vector estimates produced by an MMSE filtering matrix becomes

$$x = [[(H^H H + (\sigma^2 I))^{-1}] \; H^H] \, r,$$

The MMSE detector converges to the ZF detector, but at low SNR it prevents the worst Eigen values from being inverted.At low SNR, MMSE becomes Matched Filter.

C. Ml Scheme

A detector that always returns an optimal solution satisfying is called a Maximum Likelihood (ML) detector.

$$s_* = argmax\ P(V\ is\ observed\ /\ S\ was\ sent)$$

If we further assume that the additive noise n is white and Gaussian, then we can express the ML detection the minimization of the squared Euclidean distance metric to a target vector v over an M-dimensional infinite discrete search set:

=

where borrowing terminology from the optimization literature we call the elements of s optimization variables and
the objective function.

II. Observation & Results

SNR	BER(QPSK)	
	MMSE-SIC	ML
0	0.2252	0.2252
2	0.18	0.1782
4	0.1326	0.1326
6	0.957	0.08895
8	0.0594	0.0533
10	0.03575	0.0301
12	0.0209	0.0165
14	0.0119	0.0075
16	0.0075	0.0036

Zero Forcing equaliser performs well only in theoretical assumptions that are when noise is zero. Its performance degrades in mobile fading environment.

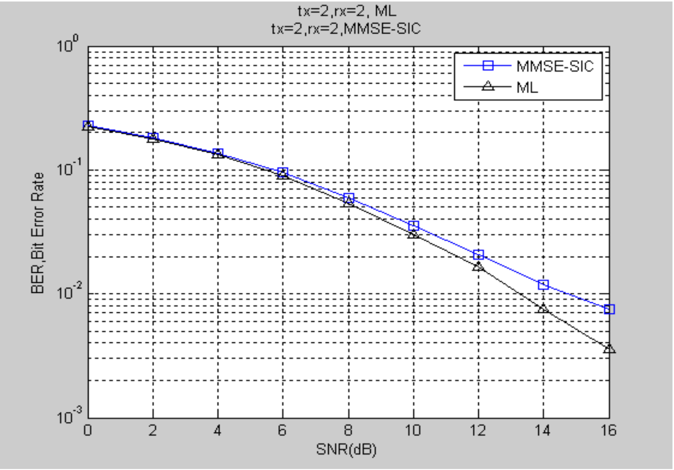

Figure 2 Comparison between ML and MMSE-SIC

SNR	Bit Error Rate (BPSK)			
In dB	**ZF**	**ZF-SIC**	**MMSE**	**MMSE-SIC**
2	0.1643	0.1264	0.1081	0.08975
4	0.1238	0.08513	0.07625	0.05187
6	0.08962	0.05613	0.05325	0.02788
8	0.0625	0.03413	0.03662	0.0155
10	0.03875	0.01988	0.0235	0.005625
12	0.02575	0.01225	0.01487	0.0025
14	0.01775	0.006025	0.0095	0.00125

Zero forcing with Successive interference cancellation improves the performance of equalizer. This process improves the estimator performance on the next component compared to the previous one. Compared to Zero Forcing equalization alone case, addition of successive interference cancellation results in around 1.8 dB of improvement for BER.Minimum Mean Square Equalization with simple successive interference cancellation case, addition ofoptimal ordering results in improvement in the BER as the SNR increases

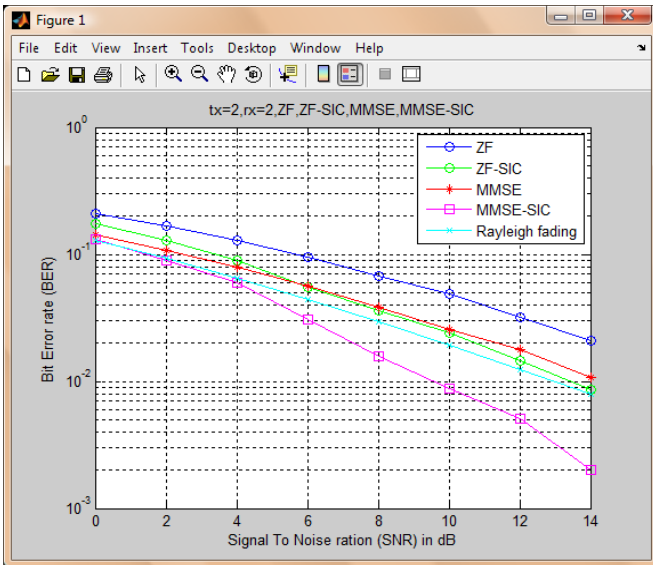

Figure 3Comparison between ZF,ZF-SIC, MMSE andMMSE-SIC

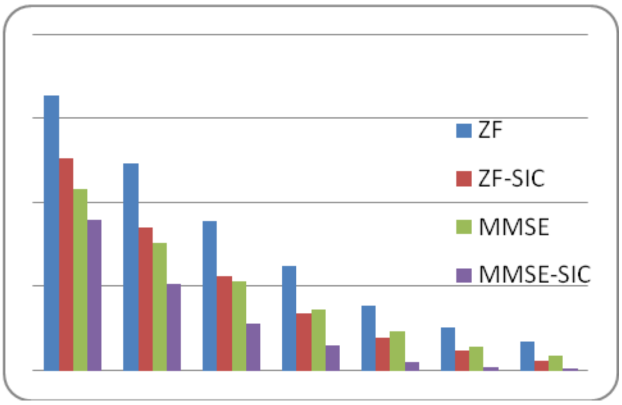

Figure 4Comparison between ZF,ZF-SIC, MMSE andMMSE-SIC

IV. CONCLUSION

Equalisation techniques are of enormous importance in the design of high data rate wireless systems. They can combat for inter symbol interference even in mobile fading Channel with high efficiency.In this paper we analyzed the performance of linear detectors for MIMO Spatial Multiplexing systems in Rayleigh fading channel and AWGN channel for BPSK modulation, which exhibited the best trade-off between performance and complexity among Spatial Multiplexing techniques. We show that conventional linear equalizers can only collect diversity Nr-– Nt +1 for MIMO systems though they have very low complexity and also different equalization techniques has been analysed to find out suitable equaliser for 2x2 MIMO channel in Rayleigh multipath fading environment. Zero-forcing performs well in theoretical assumption but the condition to fulfil is the absent of noise. MMSE uses LMS(Least Mean Square) criteria to compensate ISI. ML improves the system performance as it compares then next or upcoming symbol with the previous received symbol and also offers low error probability compares to that ZF, MMSE & ML. From the simulation models and given input ML shows the best performance.

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