Performance study of MIMO-OFDM System with Various Equalizers

Yashvant Dhiwer
ME scholar, Communication System
SSGI Bhilai, C.G

Rakesh Mandal
Assistant professor,
SSGI Bhilai, C.G

***Abstract*—High data rate information and strong reliability in wireless communication has become the most important factor for the commercial wireless networks. Multiple Input Multiple Output (MIMO) with orthogonal frequency division multiplexing is the most popular and competitive technology for its capability of high rate transmission and its robustness against multipath fading. System quality is a major challenge for high speed data communication; because MIMO-OFDM system also experiences some degradation in quality due to inter symbol interference it occurs due to multipath fading channels.**

Here in this work following seven different equalizing techniques are implemented and their performances are compared.

1) **Zero forcing equalizer.**
2) **Minimum mean square equalizer.**
3) **Zero forcing- serial interference cancellation equalizer.**
4) **Zero forcing-SIC equalizer with optimal ordering**
5) **Minimum mean square equalizer- serial interference cancellation equalizer (MMSE-SIC)**
6) **Maximum likelihood equalizer**
7) **Maximum likelihood – VBLAST**

Keywords-Copyright Equalizer, MIMO-OFDM, ISI

I. INTRODUCTION

HIGH-DATA-RATE transmission over mobile or wireless channels is required by many applications. MIMO-OFDM , shows the capability of high data rate transmission and its robustness against multi-path fading.

MIMO-OFDM transmit stream of independent data information to increase rate of transmission over different antennas and tone. The bandwidth OFDM is divided into narrow band flat fading channels and data is transmitted on each channel. It converts frequency selective channels to many flat fading channels and to each of sub channels the MIMO is applied.

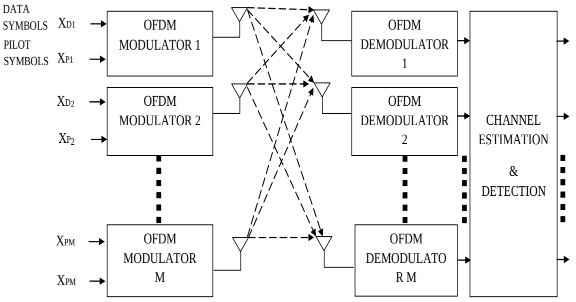

Fig.1 MIMO-OFDM System

II. LITERATURE REVIEW

Nisha et. al. analysed BER performance of the MIMO-OFDM system with two different equalizers (ZF and MMSE) for various modulation techniques i.e. BPSK, QPSK, 16-QAM and 64-QAM using multipath fading channels i.e. AWGN (Additive White Gaussian Noise), Rayleigh and Rician channel. On comparing with BPSK modulation, 64-QAM, then 16- QAM and then the QPSK modulation is more sensitive to fading for MMSE equalizer. But for ZF equalizer, when comparing with BPSK modulation, 16-QAM, then 64-QAM and then the QPSK modulation is more sensitive to fading. And also MMSE equalizer outperforms ZF equalizer. Hence their simulation results show that, with MMSE and ZF equalizers, the BER performances is better in MMSE equalizer [2].

Kajal H. Tailor et. al. discussed performance of a MIMO-OFDM system. They presented a study of various interference effects in a MIMO-OFDM system and their compensation techniques. As MIMO-OFDM system degrades in presence of RF impairments like phase noise and I/Q imbalance and other interferences like ICI (intercarrier interference) and NBI (narrowband interference). So they encourage Low-complexity estimation and compensation techniques that can jointly remove the effect of these impairments are highly desirable [2].

Jitendra Kumar et. al. analyzed performance of space-time codes for wireless multiple-antenna systems with and without channel state information (CSI) at the transmitter. They found that the performance of multiple antennas can be improved if channel state information obtained at the receiver is fed back to the transmitter. Exploiting partial channel knowledge at the transmitter, two simple channel adaptive transmission schemes, namely, channel adaptive code selection and channel adaptive transmit antenna selection can been used[3].

Sajjad Ahmed et. al. discussed the channel estimation in OFDM and its implementation using pilot based block type channel estimation techniques by LS and MMSE algorithms. They compared OFDM using BPSK and QPSK on different channels, followed by modeling the LS and MMSE estimators. As transmitted signal under goes many effects such reflection, refraction and diffraction and due to the mobility, the channel response can change rapidly over time. At receiver these channel effects must be canceled to recover the original signal. The BER of AWGN channel is approximately 10^{-4} which is better than Rayleigh fading and flat fading channel at SNR of 10dB using BPSK & QPSK on different number of taps. The MMSE is compared with LS and the MMSE performs better than the LS using 3 taps where the performance metric is mean square and symbol error rate. LS algorithm gives less complexity but MMSE algorithm provides comparatively better results [4].

III. PROBLEM IDENTIFICATION

Inter symbol interference (ISI) is distortion of a signal in which one symbol interferes with succeeding symbols. As the previous symbols have similar effect as noise, this leads to unreliability of channel. Multipath propagation and non-linear frequency response of a channel leads to ISI in successive symbols which blur these signals. ISI also introduces errors in the decision device at the receiver output. ISI is needed to be minimized so that digital data reaches destination with the smallest error rate. Adaptive equalization is one of the techniques to reduce.

IV. METHODOLOGY

In this work different equalizing techniques, which are implemented and their performances are compared.

A. Zero Force

The zero forcing equalizer can be designed as.

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

Zero forcing equalizer basically tries to null out the interfering terms i.e. it tries to nullify the interference due tox_2 when solving for x_1 and vice versa.

B. Zero Forcing With SIC

By applying the ZF equalization approach with SIC technique, the receiver can obtain an estimate of two transmitted symbols x_1 ,x_2 i.e.

$$\begin{bmatrix}\hat{x}_1\\ \hat{x}_2\end{bmatrix} = (H^H H)^{-1} H^H \begin{bmatrix}y_1\\ y_2\end{bmatrix} \quad (2)$$

Take one of the estimated symbols and subtract its effect from the received vector y_1 and y_2 i.e.

$$\begin{bmatrix}r_1\\ r_2\end{bmatrix} = \begin{bmatrix}y_1 - h_{1,2}\hat{x}_2\\ y_2 - h_{2,2}\hat{x}_2\end{bmatrix} = \begin{bmatrix}h_{1,1}x_1 + n_1\\ h_{2,1}x_1 + n_2\end{bmatrix} \quad (3)$$

C. ZF-SIC With Optimal Ordering

Here the system can choose whether to subtract the effect of $\hat{x}_1$first or $\hat{x}_2$first.

The received power at both the antennas corresponding to the transmitted symbol x_1 is,

$$Px_1 = |h_{1,1}|^2 + |h_{2,1}|^2 \quad (4)$$

Similarly for x_2 is,

$$Px_2 = |h_{1,2}|^2 + \quad (5)$$

If $Px_1 > Px_2$ then the receiver decides to remove the effect of $\hat{x}_1$ from the received vector $y_1$and y_2 and then Re-estimate$\hat{x}_2$. Else if $Px_1 \le Px_2$ the receiver decides to subtract effect of $\hat{x}_2$ from the received vector $y_1$and y_2, and then re-estimate $\hat{x}_1$.

D. MMSE- SIC

$$\begin{bmatrix}\hat{x}_1\\ \hat{x}_2\end{bmatrix} = [H^H H + N_0 I]^{-1} H^H \begin{bmatrix}y_1\\ y_2\end{bmatrix} \quad (6)$$

E. Maximum Likelihood Receiver

The maximum likelihood receiver tries to find $\hat{x}$ which minimizes,

$$j = |y - H\hat{x}|^2 \quad (7)$$

$$j = \left| \begin{bmatrix}y_1\\ y_2\end{bmatrix} - \begin{bmatrix}h_{1,1} & h_{1,2}\\ h_{2,1} & h_{2,2}\end{bmatrix} \begin{bmatrix}\hat{x}_1\\ \hat{x}_2\end{bmatrix} \right|^2 \quad (8)$$

F. V-Blast Maximum Likelihood

$$\hat{c} = \operatorname{argmin} [\![r - C'H]\!]_F^2$$

$$\hat{c} = \operatorname{argmin} \left[Tr[H^H . C'^H . C' . H - H^H] - 2.Real(Tr[H^H . C'^H . r]) \right] \quad (9)$$

Above equation can be re written for multiple receivers as shown in

$$c = \operatorname{argmin} \left[\sum_{m=1}^{M_r} Tr[H_m^H . C'^H . C' . H - H^H] - 2.Real(Tr[H^H . C'^H . r]) \right] \quad (10)$$

Here $.^m$ is a Hermition operator.

The main drawback of the VBLAST detection algorithms is computational complexity, because multiple calculations of the pseudo-inverse of the channel matrix are required.

V. EXPERIMENTAL RESULTS

In this work seven various demodulation techniques are studied, designed and simulated. Some of these equalization techniques are based on V-Blast algorithm. On the basis of their performance, their comparison graph is being traced. The comparison is being done by varying Signal to noise Ratio and finding their respective Bit Error Rate for various equalization technique. In the next page, Fig. 2 show that ZF equalizer for 2×2 MIMO-OFDM channel is identical for BER plot 1×1 system. It also show that the MMSE equalizer is better than ZF and it provide the result around 3db improvement over the result of Zero Forcing equalizer. Having the successive interference cancellation again improve the performance of the system ZF-SIC shows the better result than ZF and MMSE system. The performance of system can be improved by using optimal ordering along with successive interference cancellation with different linear equalize like ZF and MMSE.MMSE-SIC show quite better result than all other equalizer except maximum likelihood which has shown the best BER performance. The performance of maximum likelihood can be improved by using V-BLAST technique with it. This again improves the system performance. The MIMO-OFDM system with V-BLAST-Maximum likelihood shows the performance very close to MRC case and the throughput gain and diversity gain both can be achieved.

VI. CONCLUSIONS AND FUTURE WORK

An equalization technique is required at receiver section of high data rate wireless systems to reduce inter symbol interference in fading channels which can also be improved by using VBLAST technique. In this work, performances of 2x2 MIMO OFDM System with BPSK as input signal with different equalization techniques with and without VBLAST has been studied and best equalizer in Rayleigh multipath fading environment is tried to found out. To counter Inter Symbol Interference, LMS criterion in utilized in MMSE Equalizer. Hence MMSE is giving better result than ZF it provide 3dB improvement. However its result is further increased by 2.2dB if system is performed with Zero Forcing successive Interference Cancellation Technique. The output of the system can be improved by using optimal ordering in existing equalization techniques like Zero Forcing-successive Interference Cancellation Technique with optimal ordering But MMSE-SIC give better result than ZF-SIC with optimal ordering but among all these three techniques discussed, Maximum Likelihood Equalization Technique with V-BLAST is givinglowest and fastest regression in BER with increase in signal to noise ratio. So performance of Maximum likelihood-VBLAST is best than other equalization techniques.

This work can be enhanced by utilizing under listed propositions.

1. This system is a 2 input 2 output MIMO-OFDM system, which can be enhance to more numbers of inputs and outputs channels.
2. Path of signal transmission, assumed here is Rayleigh Channel. This system can be checked for Rician Channel also.
3. System designed is for minimizing effect of Inter Symbol Interference only. So a system can also be thought of which can reduce problems of PAPR and ICI.

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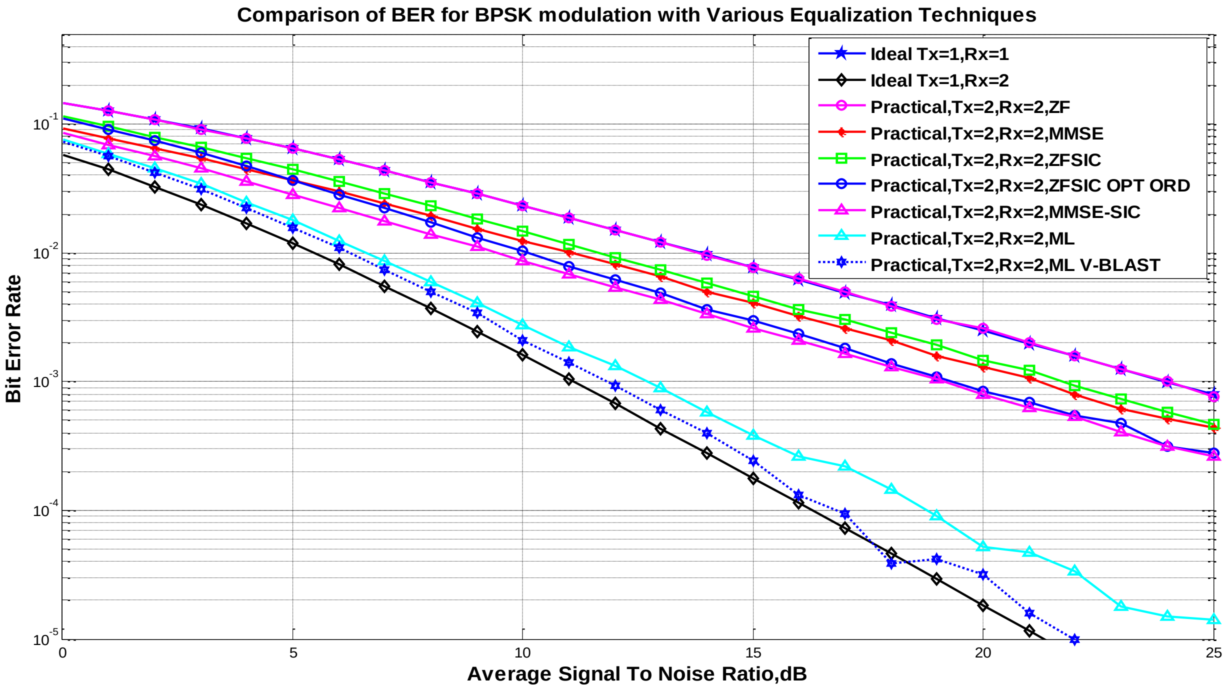

Fig.2 BER Plot For 2×2 MIMO-OFDM System for BPSK Modulation in Rayleigh Channel