Optimal Ordering Equalization Technique for MIMO Wireless Channel

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Abstract

To achieve error-free reception of the transmitted signal implemented equalizers with optimal ordering algorithm. Equalizers with optimal ordering are used to eliminate effect of channel impairments. In this different equalization detection algorithms for multipath fading channel can be employed with linear and nonlinear equalizers.

Keywords*—Equalizer, MIMO .*

I. INTRODUCTION

Wireless technology is the most emerging technology in the field of communication. Due to the technology, data communication has become very easy. When the quantity of antennas at transmitter and receiver's increases, the path of travelling of the signal from transmitter to receiver also increases and the signal reaches the destination at different instants of time and hence efficiency increases, improved signal to noise ratio and high data rates etc. When a signal is broadcasting over a multipath fading channel, than signals are affected due to reflection, refraction and diffraction and also different modulation technique preferred at transmitter. The nature of communication channel is random therefore introduce more complexity and uncertainty to channel response. MIMO wireless multipath fading channel is designed to overcome the effects of interfacing and polarization mismatch [7]. MIMO system also improves the data transmission reliability. Multiple antenna system with space

ISSN: 2233-7857 IJFGCN

time code provides all benefits of wireless Multiple antenna system can be achieved without increasing the transmit power and required bandwidth with un-correlated channel [3][12].

Fading in multipath depends upon speed of data transfer. To reduce the effect of fading, transmission power should be increased; this improves other factors such as performance of the system but increase in transmission power results in more power consumptions by the handheld devices. Since these device works on battery which is limited for the device, it causes a major problem for them. Other techniques are also available to solve this problem such as using time and frequency diversity to solve this problem. Since the time diversity uses time interleaving, the main issue is, it suffers from large delay in slow varying channels. In frequency diversity method, a large part of frequency remains unused because of high bandwidth utilized by this method. In the wireless technology, characteristics of the signals get affected. Since the paths of signals are not fixed, it adopts multiple paths and due to this the quality of the signal gets depleted. In wireless communications with multiple antenna system is designed for reducing multipath fading, interference and polarization mismatch. MIMO system also improves the data transmission reliability [4]. Multiple antenna system with space time code provides all benefits of MIMO system can be achieved without increasing the transmit power and required bandwidth with un-correlated channel. MIMO offers significant increases in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency and link reliability and or diversity. Because of these three properties, MIMO is an important part of modern wireless communication [1][2]. Due to the channel characteristics, severe inter-symbol interference (ISI) may occur to the transmitted signals. The effect of fading and interference effects can be combated with equalizer. In this paper we have discussed different types of equalizer like ZF, MMSE, ZF-SIC, ZF-SIC and optimal ordering, MMSE-SIC and optimal ordering, ML. We discuss here the zero-forcing (ZF) detector and the minimum-mean-square error (MMSE) detector. The ZF-detector and the MMSE detector have lower computational calculations as they require only matrix operations to be carried out [10]. However, the error performance in case of both ZF and MMSE is lower as concluded from the previous papers. Our approach in this paper is to find the best equalization technique.

I. MIMO EQUALIZER

Reducing the effect of Inter symbol Interference (ISI) in MIMO system which occurs because of spatial diversity, which is one of the important objectives of equalization. Equalization can be performed by using both linear and non-linear methods. In the Linear category there are two main equalizing algorithms 1: Minimum mean square Error (MMSE) Equalizer 2: Zero Forcing (ZF) Equalizer. Maximal Likehood (ML) Equalizer in Nonlinear category.

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A. ZF-Equalizer

In wireless communication system zero forcing comes under linear equalization algorithm, it reverses the frequency response of the channel. In noise free communication channel Inter symbol interference (ISI) can be eliminated by ZF –equalizer. Consider a 2 transmitter and 3 receiver antenna systems [5][6] where all transmission path between transmitter and receiver are shown in table 1 below:

TABLE 1: Channel parameter for 2x3 antennas system

Transmitter Antenna	Receive antenna 1st	Receive antenna 2nd	Receive antenna 3rd
1	h_1	h_3	h_5
2	h_2	h_4	h_6

ISSN: 2233-7857 IJFGCN

At the time t and T+t y_1, y_3, y_5 and y_2, y_4, y_6 signals are received at the receiver end respectively, shown in table

Table 2: Signals presentation receiver end .

Time	Receive antenna 1st	Receive antenna 2nd	Receive antenna 3rd
T	y_1	y_3	y_5
T + *t*	y_2	y_4	y_6

$Y = HX + N$. Where H is channel matrix. X is Transmitted symbol. N is Noise matrix. H^H is Hermitian matrix is required for decoding the transmitted symbol. To achieve the same transmitted signal at the receiver end similar relation is used in decoding technique.
So, the symbols (estimated) can be calculated by

$$\tilde{x} = H^H y$$

Decision is based on the minimum deterministic squared error vector in ZF equalizer that can be calculated between all feasible transmit vectors $\bar{x}$ i.e. norm of error $\|\bar{y} - \bar{H}\bar{x}\|^2$ should be reduced and from the vector differentiation techniques estimated error reducing transmit vector can be given as:

$$\tilde{x} = H^H y$$

$$\bar{x} = \left(\left(\bar{H}^H \bar{H}\right)^{-1} \bar{H}^H\right)\bar{y}$$

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

where, W is equalization matrix, Square matrix H is a full rank and H^H is Hermitian matrix. This is nothing except executing multiplication process of a pseudo inverse of channel matrix with received vector. This can successfully diminish the ISI except it results in vast noise enrichment. Since the new noise vector is

$$\hat{n} = \left(\left(\bar{H}^H \bar{H}\right)^{-1} \bar{H}^H\right)^{-1} \bar{n}$$

B. Linear MMSE-Equalizer

MMSE equalizer is proposed such a manner that it reduces the average mean square error between transmitted symbol $\bar{x}$ and its estimate $\hat{x}$ at the equalizer output i.e. now the problem is Minimizing $E\left\{\|\hat{x} - \bar{x}\|^2\right\}$ and the resulting estimating vector is

$$\hat{x}_{MMSE} = P_d (P_d \bar{H}^H \bar{H} + \sigma_n^2 [I]_r) \bar{H}^H \bar{y}$$

Where, P_d is the symbol power. In this case as $h > 0$ the estimated transmit symbol value will be surrounded only. Therefore MMSE estimator is robust to noise. In addition to, at high SNR relevance it works as a ZF-receiver only as its noise element will be dominated by the symbol power and at low SNR it involves a matched filter with transfer function $\bar{H}^H$.

$$W = \left(H^H H + N_0 I\right)^{-1} H^H$$

When comparing to the equalization, apart from the $N0I$ team both the equations are comparable. When the noise term is zero, the MMSE equalization reduced to ZF equalizer [7].

ISSN: 2233-7857 IJFGCN

C. Nonlinear Maximum Likelihood (ML) Equalizer

Maximum Likelihood (ML) Equalizer is an optimum detection which provides best performance at the cost of the highest complexity, with the number of transmits antennas and the size of the signal constellation this complexity increases exponentially at the receiver. The Euclidean distance between y and H is minimized by finding a signal vector

$$\tilde{X} = \arg\min_{\hat{x}} \| y - H.\hat{x} \|^2$$

Let us consider, the orthogonal channel matrix with $H^H H = I$, where H^H is a hermitian matrix and I is the Identity matrix (Chen et al.,2010). The objective function of ML can be expressed as

$$\tilde{x} = \arg\min_{\tilde{x}} \| y - H \cdot \hat{x} \| = \arg\min_{\tilde{x}} (y - H \cdot \hat{x})^H (y - H \cdot \hat{x})$$

$$= agr\min_{\tilde{x}} (\mathrm{H}^H\ y - H^H H \cdot \hat{x})(\mathrm{H}^H\ y - H^H H \cdot \hat{x}) = \arg\min_{\tilde{x}} \| \mathrm{H}^H\ y - R \cdot \hat{x} \|^2$$

Letting $y'_i, r_{i,j}$ and $\hat{x}_i$ stand for the elements of and, respectively. Assuming that all transmitted data symbols are taken from the same signal constellation with size C, the ML detection must search over C^{n_T} possible signal vectors to obtain $\hat{x}$. One of the disadvantages of ML detection is, for high level modulation and more number of antennas, this detection becomes highly complex which are very difficult to manage [4]. Some algorithm have been proposed in this work aims to achieve near optimum performance with limited complexity. Some sub-optimum algorithms have been proposed, that aims to achieve near optimum performance with limited complexity. Flow Diagram shows that steps of execution of proposed work in case MMSE equalizer.

II. OPTIMAL ORDERING

A. ZF-OSIC with Optimal Ordering

In classical Successive Interference Cancellation, the receiver arbitrarily takes one of the estimated symbols, and subtracts its effect from the received symbols. However, we can have more intelligence in choosing whether we should subtract the effect of x_1 first or $\tilde{x}_2$ first. To make that decision, let us find out the transmit symbol (after multiplication with the channel) which came at higher power at the receiver.

B. MMSE SIC with optimal ordering

SIC with optimal ordering improve the performance with ZF equalization. The concept of SIC is extended to the MMSE equalization. The MMSE approach tries to find a coefficient W which minimizes the criterion. MIMO System can be taken as a special multi-user system. At the receive side, each antenna receives a combined signal containing data signals transmitted from different antennas. Consider the signal x_i from the transmit antenna T_i and the other data signals become interfaces to x_i .The interference cancellation techniques can be applied in the signal detection of MIMO system. The basic idea is firstly use linear detection to recover the data signal x_{n_T} from transmitting antenna T_{n_T} then the interference caused by x_{n_T} can be canceled out from the received signals. After interference cancellation, linear detections are used again to recover the data signal. The linear detection and successive interference cancellation (SIC) process go on until x_i is obtained. When ZF or MMSE detection is applied with OSIC, the scheme is known as ZF-OSIC or MMSE-OSIC. Design process System with t transmitting and r receiving antenna is to be designed . In the case of the ZF/MMSE-OSIC algorithm can be realized in a simple way with the orthogonal channel matrix taken from the above

ISSN: 2233-7857 IJFGCN

III. RESULT

Figure 1, 2 and 3 shows the BER vs. SNR Assessment of linear equalizer with OSIC and ML equalizer for 2x2, 2x3 and 2x4 to compare the performance of Rayleigh faded environment. Graph shows both MMSE-SIC and ZF-SIC with optimal ordering have the same data rate but the BER (Bit Error Rate) is less in MMSE-OSIC as compare to ZF-OSIC and further BER of ML is less than the MMSE-OSIC.

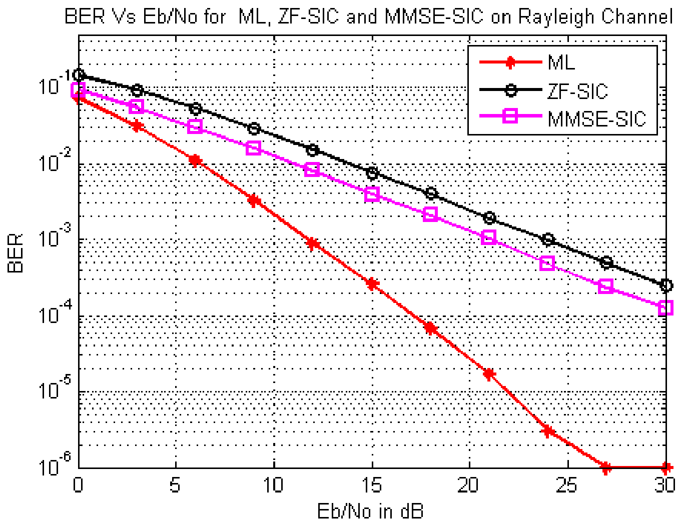

Fig. 1: Performance of 2x2 multiple antenna system with different equalizer

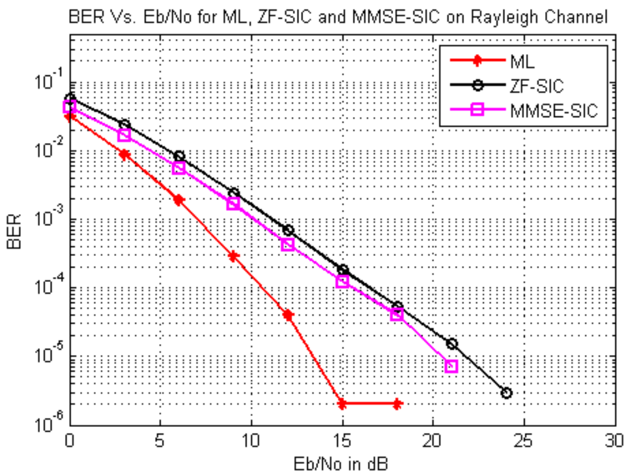

Figure 4: Performance of 2x3 multiple antenna system with different equalizer

ISSN: 2233-7857 IJFGCN

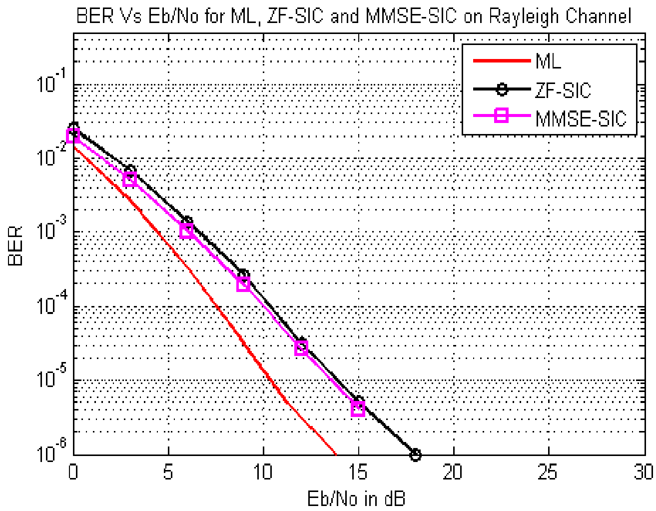

Figure 3: Performance of 2x4 multiple antenna system with different equalizer

TABLE III COMPARISON TABLE

Parameter BER	Antenna System	ZF-SIC SNR in dB	MMSE-SIC SNR in dB	ML SNR in dB
At 10^{-3}	2x2 MIMO	24.00dB	21.00dB	11.80dB
At 10^{-4}	2x3 MIMO	16.30 dB	15.80 dB	10.80 dB
At 10^{-5}	2x4 MIMO	14.00dB	13.80dB	10.20 dB

From the table it clears that when number of antenna at the receiver increases, performance improves. 2x4 antenna systems give better result than the 2x2 and 2x3 antenna systems.

IV. CONCLUSION

The performances of different equalizing techniques were compared for two transmit and two, three and four receiver antenna systems in Rayleigh fading multipath channel. By using BPKS modulation 2x2 MIMO systems were implemented with ZF-SIC, MMSE-SIC and MRC diversity technique and comparison was done. Also comparison with MMSE-SIC, ZF_SIC and ML equalizer by using QPSK modulation scheme was done. ML equalizer giver better performance than MMSE-SIC and ZF-SIC but the implementation of ML equalizer is very difficult.

ISSN: 2233-7857 IJFGCN

ACKNOWLEDGEMENT

We wish to thanks the Management, Principal and Colleagues of Shri Shankaracharya Institute of Professional Management and Technology, Raipur for assistance or encouragement in preparing this paper. Special thanks to TEQIP-III, CSVTU, Bhilai for their kind cooperation.

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