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Performance Analysis of MIMO OFDM Transmission System using Adaptive MMSE with Iterative PIC Equalization

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Abstract— **The combination of multiple-input multiple-output (MIMO) signal processing with orthogonal frequency division multiplexing (OFDM) is regarded as a highly promising method to achieving the high data rates of next-generation wireless communication systems operating in frequency selective fading environments. This paper is focused on the usage of the adaptive Minimum Mean Square Error (MMSE) combined with Iterative Parallel Interference Cancellation (PIC) algorithm in MIMO OFDM transmission system to improve its bit error rate (BER). This paper uses multicarrier modulations such as BPSK, QPSK, 8-PSK and 16-QAM under AWGN and multipath fading environment i.e. Rayleigh channel. Simulation results show interesting gain in term of BER v/s SNR. These detectors improved the quality of received signal in high interference environment. Adaptive MMSE with iterative PIC give best performance in noise environment compared to MMSE, adaptive MMSE and iterative PIC.**

I. INTRODUCTION

In wireless communication system, the signal from a transmitter is transmitted in radio space, typically multipath fading channels which causes inter symbols interference (ISI) and fading of the received signal. Orthogonal Frequency Division Multiplexing (OFDM) is one of the most spectral efficient methods that mitigate the severe problem of multipath propagation [1]. Multiple Input Multiple Output (MIMO) is one of the attractive techniques that uses multiple antennas at both transmitter and receiver and provides improved bit error rate (BER) or data rate compared to conventional communication systems [2].

The combination of these MIMO-OFDM techniques is very natural and beneficial since OFDM enables support of more antennas and large bandwidth since it simplifies equalization in MIMO system [1] and it is a promising approach for achieving reliable higher data rates transmission over broad band wireless channel by exploiting the robustness of OFDM to fading [3].

Equalization technique is the one that is used in order to mitigate the fading effects at the receiver before demodulation that improve the quality of received signal in a high interference environment [1]. Maximum likelihood (ML) detector is the best detector that minimizes the bit error rate (BER) but it is practically difficult as it has computational complexity [4]. MMSE equalizer is a linear equalizer that minimizes mean square error (MSE). As a result, the total noise power and ISI components in the output are minimized. Still, it requires an accurate estimate of the amount of noise present in the system which is hard to obtain in practical systems [1, 4]. Therefore, different Adaptive Filters can be implemented such that it can improve the performance without increasing the complexity significantly. Adaptive MMSE estimation [2] consists of incorporating the outcomes of the previous estimates as a prior information and allows to consider the MMSE expression as a function of the channel response.

Parallel Interference Cancellation (PIC) is the low complexity nonlinear detection technique that detects all symbols by subtracting interference from the received block. PIC detection is used to reduce the complexity and prevents error propagation. The detection performance and throughput can be improved by using iteration process [5].

II. LITERATURE REVIEW

A. System Description

Consider a MIMO OFDM system with two transmitting antennas and two receiving antennas as shown in fig. 1. The binary data are converted into digitally modulated signal by using BPSK, QPSK, 8PSK and 16-QAM according to the channel conditions in the modulation block. The 16-QAM is used when the channel may suffer from multipath fading and noise. The information symbols are simultaneously transmitted over two transmitting antennae through the channels. The channels considered here are AWGN and Rayleigh fading channels and later AWGN noise is added at the receiver section. The transmitted signal will be received by the two receiving antennas through these channels at the receiver section then serial to parallel conversion occurs and parallel symbols are obtained and after passing through FFT the symbols are then converted into serial form using parallel to serial converter.

The serial data streams are separated and decoded using adaptive MMSE equalizer combines with iterative PIC detector algorithm at each element of the receiver antenna array. As the number of iteration process increases the gain improvement can be obtained. Finally, demodulation occurs and demodulated outputs and the resulting data combined to obtain the binary output data.

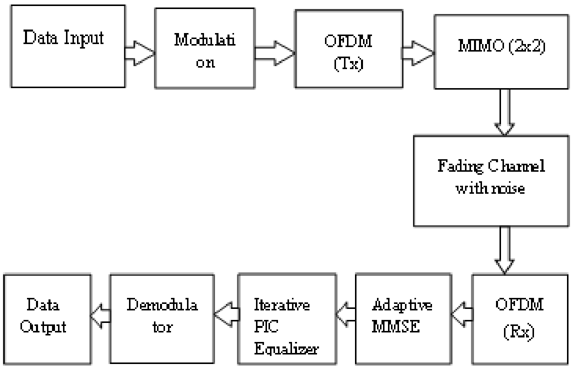

Fig. 1. Block diagram of System Model

III. MIMO OFDM Detection Algorithm

A. Adaptive MMSE Equalization

A MMSE estimator is a method in which it minimizes the mean square error (MSE) between estimated and detected values, which is a universal measure of estimator quality [6]. MMSE equalizer does not usually eliminate ISI totally but instead of minimizes the total power of the noise and ISI components in the output. It is optimal detection that seeks to balance between cancelation of the interference and reduction of noise enhancement. From the analysis of 2x2 MIMO system, the relationship output symbols, channel coefficients and input symbols can be written in matrix notation as in equation below.

$$y= H x + n \qquad (1)$$

The Minimum Mean Square Error (MMSE) equalization method tries to find a coefficient matrix W, also known as weight matrix, which minimizes the criterion:

$$E \{[W y\text{-}x] [W y\text{-}x]^H\} \qquad (2)$$

Solving above minimization criterion, equation (3) can be obtained.

$$W = [H^H H + N_o I]^{-1} H^H \qquad (3)$$

The output of the MMSE receiver is given by equation (4),

$$\hat{x} = W y \qquad (4)$$

Where, $\hat{x}$ is the estimated symbol, W is the weight matrix and y is the received symbols.

Adaptive filters can work efficiently in unknown environment and they can also be used to track the input signal of time varying characteristics such as MIMO systems. It uses least mean square (LMS) algorithm to update its weighted coefficients. LMS adaptive algorithm is very straightforward in the implementation and still very efficiently able to adjust with outer environment as per the requirement. Only limitation of the performance arises by choice of the step size parameters. For this process initially received signals (r[k]) are passes through the MMSE equalizer first.

Let the received signals are r[k] and the outputs of equalizer are y[k]. The outputs of equalizer are compared with the known or desired output values, shown in the fig. 2 as d[k]. The error computation block will compute the error, as in (5)

$$e[k]=d[k]-y[k] \qquad (5)$$

or, $\quad e[k]=d[k]- W(k)\, r[k]$

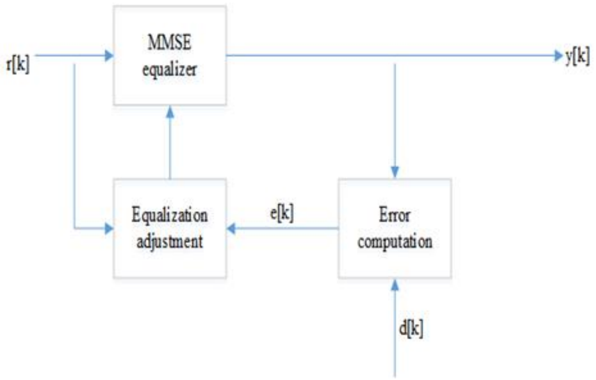

Fig. 2. Adaptive MMSE

Here, for the adjustment of the weight, W matrix in the MMSE equalizer, LMS is used. LMS adaptive algorithm will update the weight as:

$$W[k+1] = W[k] + \mu \; r[k]\, e[k] \qquad 6)$$

Here, μ is constant step-size that controls the speed and accuracy of the equalizer tap adaptation.

B. Parallel Interference Cancellation (PIC)

The PIC detection uses the reconstructed signal to improve the detection performance by using an iterative process [1]. In parallel interference cancellation, all interfering users are cancelled (subtracted) concurrently (in parallel) from the received signal in order to reduce the time delay. The advantage of the PIC receiver is that the process of cancellation is quite fast and there is no delay incorporated at the receiver. But the problem with this type of receiver is that the receiver complexity is quite large. Also, the performance of the receiver is not reliable for there is a possibility of improper cancellation. The MMSE detector minimizes the mean square error between the actually transmitted symbols and the output of the linear detector is

$$W= [H^H H+N_o I]^{-1} H^H \qquad (7)$$

By using MMSE detector the output of the first stage is:

$$d = Dec\,(W.y) \qquad (8)$$

Where, W is the parameter of the Equalization matrix which is assumed to be known and Dec (.) is the decision operation. In each a vector symbol is nulled.

This can be written as

$$S=I.d \qquad (9)$$

Where, I is identity matrix and d is rough Estimated symbols of MMSE.

The PIC detection algorithm can be expressed as

$$R=y-H.S \qquad (10)$$

Hence, S is the estimated symbol of MMSE Equalizer. The estimated symbol using the detection scheme of the appropriate column of the channel matrix

$$Z= Dec\,(W.R) \qquad (11)$$

Where,

R is the output of PIC Equalizer

W is the parameter of MMSE Equalization matrix

Z is the estimated symbols of PIC Equalizer

C. Iterative Parallel Interference Cancellation (PIC)

At the iteration process the output of the PIC detector is given as input. In every iteration, extrinsic information is extracted from detecting and decoding stages and is then used as prior information in the next iteration. In every new iteration, the prior information becomes more reliable and hence a greater amount of interference can be cancelled. The significant part of interference cancellation is in the first iteration.

The iterative PIC algorithm is described as below:

Input : H, r

Output : S

Steps:

1: S=Q (Inv (H). r)

2: For i= 1: n_T

3: $r=r-\sum_j H(:, j) . S_j$

4: S_j=Q (Inv (H) .r)

5: End

Here, H(:,j) implies the response for a block, since we are performing parallel interference cancellation, this is a must. Basically, : sign implies a complete block of that loop. H implies channel response and r as the input. S_j is the correlation matrix and Q represents the correlation between inverse of channel response and the input and S implies the output.

IV. RESULTS

The Tab.1 shows the simulation parameters used in the proposed model. Fig. 3 compares the bit error rate (BER) of 2x2 MIMO-OFDM at different modulation techniques using MMSE.

TABLE I. LIST OF SIMULATION PARAMETERS:

Parameters	Specifications
Antenna Configurations	2x2
Channel model	Rayleigh
Modulation	BPSK,QPSK,8-PSK, 16-QAM
Noise model	AWGN
FFT length	64
CP Length	16

Similarly figures 4, 5 6 show the comparison of BER at different modulation techniques using Adaptive MMSE, iterative PIC and Adaptive MMSE with iterative PIC equalization in 2x2 MIMO OFDM systems respectively.

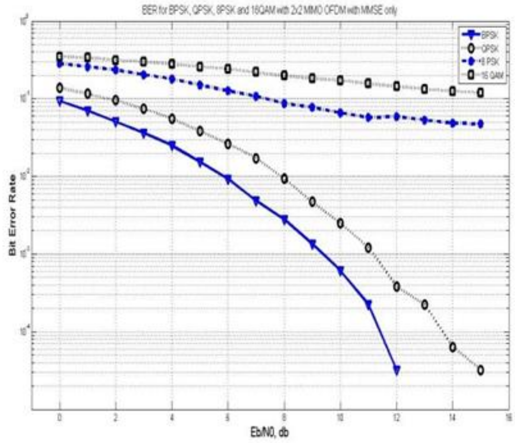

Fig. 3. Comparison of BER for BPSK, QPSK, 8PSK and 16-QAM with MMSE Equalization

Tab.2 shows the summarization of BER performance at different modulation techniques. The proposed equalization technique i.e, Adaptive MMSE with iterative PIC equalization is quite effective in all simulation configurations. However, Iterative PIC detection is better in the diversity gain and when the interference comes from the other layers is completely canceled.

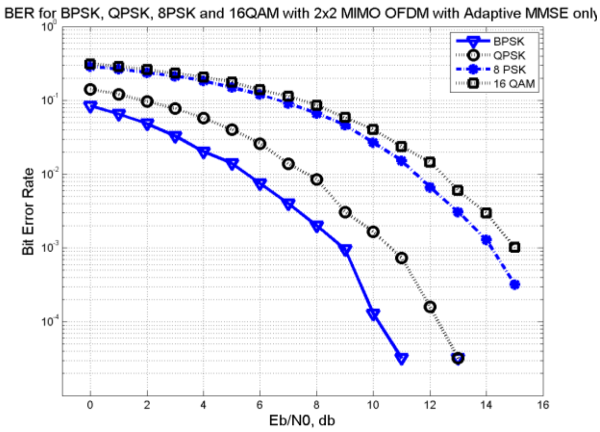

Fig. 4. Comparison of BER for BPSK, QPSK, 8PSK and 16-QAM with Adaptive MMSE

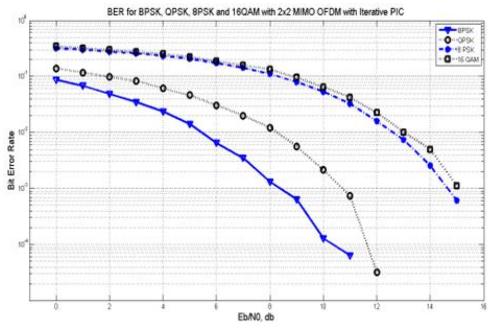

Fig. 5. Comparison of BER for BPSK, QPSK, 8PSK and 16-QAM with Iterative PIC

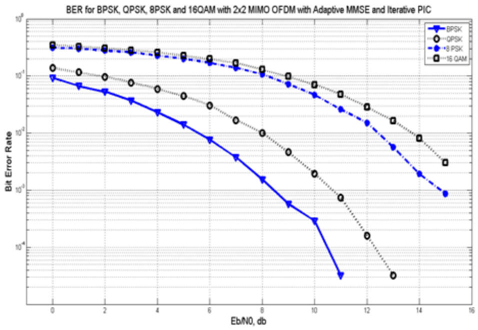

Fig. 6. Comparison of BER for BPSK, QPSK, 8PSK and 16-QAM with Adaptive MMSE with iterative

TABLE II. COMPARISON OF BER FOR DIFFERENT MODULATION TECHNIQUES AT SNR 4DB

Methods	**SNR : 4dB**			
	BPSK	**QPSK**	**8 PSK**	**16 QAM**
MMSE	0.03054	0.06871	0.20923	0.25541
Adaptive MMSE	0.02022	0.05519	0.17792	0.19926
MMSE with Iterative PIC	0.01237	0.04112	0.12328	0.12503
Adaptive MMSE with Iterative PIC	0.01084	0.04061	0.12277	0.10254

V. CONCLUSION

The combination of MIMO OFDM systems are used to improve the spectrum efficiency of wireless link reliability in wireless communication systems. Iterative PIC scheme for MIMO-OFDM systems transmission including the feasibility of using the a priori information of the transmit sequence of MMSE compensation. By iterative process, gain improvement can be obtained and the adaptive MMSE significantly outperforms the conventional MMSE detection. Performance of iterative PIC detection technique is better compared to MMSE, adaptive MMSE, and PIC using BPSK, QPSK, 8PSK and 16- QAM modulation scheme in high interference environments.

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