BER Performance improvement in MIMO OFDM System using MMSE Equalizer

R.Sathiyakala[1], P.Revathi [2], V.A.Vinnila Granap[3]

[1]Associate Prof, Department of ECE ,Sree Sowdambika College of Engineering , Aruppukottai, Tamil Nadu , India.

[2, 3]Students, Department of ECE, Sree Sowdambika College of Engineering, Aruppukottai, Tamil Nadu , India.

E mail: [1]sathyakkala@yahoo.com [2]p.revathiperumal97@gmail.com, [3]Vinnila.granap@gmail.com

Abstract

Combination of multiple antennas with orthogonal frequency division multiple access technique is called as MIMO OFDM. In wireless communication system, MIMO OFDM has been proposed as an efficient technique for providing high data rates, spectral efficiency and the coverage area, low power consuming and very efficient in 3G and 4G technologies. Multiple Input Multiple Output and orthogonal frequency division multiplexing system have an assuring ability to increase the capacity and performance with acceptable bit error rate (BER) proportionally with the increase of antennas and due to this the system has grabbed the attention of wireless academic community in industry. MIMO OFDM is one of the prominent equalizer techniques which nullify the noise by using the minimum mean square error (MMSE) detection. The performance parameters of MIMO OFDM in terms of BER and channel capacity are determined and it is analyzed for detector schemes such as MMSE MIMO OFDM System.

Keywords: MIMO, OFDM, MMSE, BER, ISI.

1. Introduction

Fourth generation wireless technology is expected to provide high bit rate multimedia communication capability. In OFDM computationally efficient fast fourier transform is used to transmit data in parallel of orthogonal sub carriers which maintained even in frequency selective fading. In MIMO system there is a path/channel among each of the transmitters and receiver antennas. MIMO leads to the high data rate transmitters without increasing the bandwidth. The capacity of MIMO wireless channel can be approached by the use of spatial diversity. Bit error rate and capacity can be improved when the multiple antennas are applied at transmitter and receiver side and also with the help of equalizer techniques at the receiver side.

2. OFDM:

Orthogonal frequency division multiplexing is a technology where wide frequency band is splitted into many small frequencies and carry data onto each of these sub carriers. Numerous closely spaced orthogonal sub carrier signals with overlapping spectra are emitted to carry data. Each sub carrier is modulated with a conventional modulation scheme at a low symbol rate. This maintains total data rates similar to conventional single carrier modulation schemes in the same bandwidth. The main advantage of OFDM over single carrier schemes is its ability to cope with severe channel conditions without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate inter symbol interference (ISI) and utilize echoes and time spreading to achieve a diversity gain, i.e. a signal to noise ratio improvement.

3. MIMO:

Multiple Input Multiple Output is a method for multiplying the capacity of a radio link using multiple transmit and receive antennas to exploit multipath propagation. MIMO has become an essential element of wireless communication including IEEE standards. In modern usage, “MIMO” specifically refers to a practical technique for sending and receiving more than one data signal simultaneously over the same radio channel by exploiting multipath propagation. SISO/SIMO/MISO is special cases of MIMO. Multiple input and single output (MISO) is a special case when the transmitter has multiple antennas and the receiver has a single antenna. Single input multiple output (SIMO) is a special case when the transmitter has a single antenna and the receiver has multiple antenna. Single input single output (SISO) is a conventional radio system where neither transmitter nor receiver has multiple antennas. MIMO OFDM combines multiple input multiple output technology, which multiples capacity by transmitting different signals over multiple antennas, and orthogonal frequency division multiplexing, which divides a radio channel into a large number of closely spaced sub channels to provide more reliable communication at high speeds. By dividing high rate data stream into numerous low rate data streams, OFDM enables longer duration symbols. A cyclic prefix (CP) may be inserted to create a guard interval that prevents ISI entirely. If the guard interval is longer than the delay spread the difference in delays experience by symbols transmitted over the channel- then there will be no overlap between adjacent symbols and consequently no inter symbol interference. Though the CP slightly reduces spectral capacity by consuming a small percentage of the available bandwidth, the elimination of ISI makes it an exceedingly worthwhile tradeoff.

4. EQUALIZER:

Equalizer is a digital filter which provides an approximate inverse of channel frequency response. Equalizer is to alleviate the effets of ISI (Inter Symbol Interference) to reduce the probability of errors that occur without suppression of ISI, but this reduction of ISI effect has to be balanced with the prevention of noise power enhancement. Equalizer needs arises from the channel which has phase dispersion and amplitude which results in the interface of transmitted signals with one another. It works when SNR is high and BER is low. Minimum Mean Square Error (MMSE) estimator is an estimation method which minimizes the Mean Square Error (MSE) of the fitted values of a dependent variable; which is a usually measure of estimator quality. MMSE equalizer is that it does not usually eliminate ISI completely but reduces the total power of the noise and ISI components in the output. There are two types of Equalizer 1)Linear Equalizer 2) Non Linear Equalizer. Minimum Mean Square Error is a linear equalization techniques used in communication. The main disadvantage of OFDM is high peak to average power ratio. The peak values of some of the transmitted signals are larger than the typical values. Here also use equalizer like MMSE with different channels eg. AWGN channel. MMSE estimator is an estimation method which minimizes the Mean Square Error of the fitted values of a dependent variable; which is usually a measure of estimator quality.

Advantages:

- It minimizes the noise enhancement.
- It improves the BER Performance.

Disadvantage:

- It does not eliminate the ISI Component.

5. EXISTING TECHNOLOGY

A Minimum Mean Square Error estimator defines the approach which reduces the Mean Square Error MSE, which is a common measure of estimator quality [1]. Adaptive filter uses the LMS algorithm. It was proposed by Prof. Windrow. In adaptive filters parameters are changed due to received sequence from transmitter [2]. Binary Phase Shift keying signal is fed in a 2 input and 2 output receiver systems; bit error rate differs drastically for different equalization techniques [3]. BPSK and QPSK outputs for different transmitter and receiver antennas are discussed in [7]. BER analysis of BPSK has low BER [8]. If the variance of the signal to noise ratio is known and the signal has zero mean, SNR can be 2. If the signal and noise ratio are measured across the same impedance, the SNR can be obtained by calculating the square of the amplitude ratio [9]. Transmit data with the help of OFDM technique in which large number of closely spaced orthogonal sub carriers is used and they carry data and performance is plotted by bit error rate verses signal to noise ratio [12]. Minimum Mean Square Error equalizer, which does not usually eliminate ISI completely but instead, minimizes the total power of the noise and ISI components in the output [13]. Binary symmetric channel which is used in analysis of decoding error probability in case of non bursty bit errors on Additive White Gaussian noise channel without fading [5]. To simplify space time structure, layering is done where streams of data are independently coded and decoded. To detect the layered space time structure, the number of receiver antennas should be greater or equal to the number of transmitter antennas [6]. BPSK is the simplest kind of phase shift keying (PSK). It uses 2 phases that are separated by 180 degree then may also be termed 2 PSK [4]. When signal passes through AWGN channel a white Gaussian noise is added and phase of frequency response is linear for all frequencies that mean modulated signals pass through it without any amplitude loss and without phase distortion and so fading does not exist or occur [10]. Multiple channel have been the reward for the transmission of data, there are various method of fading channel in the wireless system which implicate RICIAN, AWGN, Nakagami & Rayleigh fading channel [11].

6. PROPOSED METHODOLOGY

Inter Symbol Interference is a major problem in wireless communication systems, as noise gets added in the message signal at the time of transmission. If the channel response of any channel is given by H(s) then input signal is multiplied by the reciprocal of the response. Finally the target is to remove the channel effect from the receiving signal, particularly the ISI. In this work, ISI is tried to reduce by using MMSE equalizer and further the results are compared.

An equalizer within a receiver compensates the average range of expected channel amplitude and delay characteristics. On the basis of feedback provided, an equalizer is designed for its linearity. Input of decision box is feedback then equalizer is non linear otherwise it is linear. An equalizer is usually implemented at the baseband or at IF in a receiver. Since in baseband the complex envelope expression can be used to represent band pass waveforms, the channel response, demodulated signal and Minimum Mean Square Error equalizer are usually implemented at the base band signal.

A Minimum Mean Square Error (MMSE) estimator describes the approach which minimizes the Mean Square Error (MSE), which is a common measure of estimator quality. The main feature of MMSE equalizer is that it does not usually eliminate ISI completely but, minimizes the total power of the noise and ISI components in the output. Assuming that the information sequence is wide sense stationary the original information symbols and the output of the equalizer I_k is given by MSE. Figure 1 shows the basic block diagram of OFDM technique.

$$MSE = E\left[e_k^2\right] = E\left[\left(I_k - \hat{I}_k\right)^2\right]$$

For FIR filter of order 2L+1 as the equalizer, mean square error is given by

$$MSE = E\left[\left(I_k - \sum_{j=-j}^{L} \hat{I}_{k-j} h_{E-j}\right)^2\right]$$

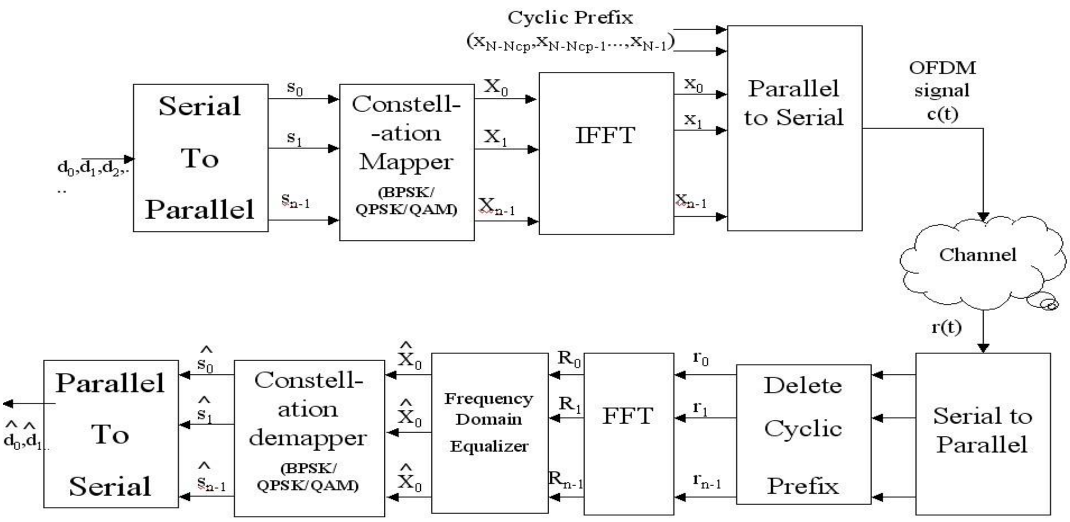

Figure 1. Block Diagram of OFDM

$$MSE = E\left[\left(I_k - \hat{I}_k^T h_E\right)^2\right]$$

OFDM is a multicarrier modulation. The input data stream is modulated by a QPSK, resulting in a complex symbol stream x[0],x[1],x[N-1]. The symbol stream is passed through a serial to parallel converter, whose output is a set of N parallel QPSK symbol x[0], x[1], x[N-1] corresponding to the symbol transmitted over each of the subcarriers. In order to generate s(t) the frequency components are converted into time samples by performing an inverse DFT on these N symbol, which is efficiently implemented using the IFFT algorithm. The Cyclic Prefix is added to OFDM symbol, and the resulting time samples are ordered by the parallel to serial converter and passed through digital to analog converter, resulting in the baseband OFDM signal x(t). The transmitted signal is filtered by the channel impulse response and corrupted by additive noise, resulting in the received signal r(t). The signal is down converted to baseband signal and filtered to remove the high frequency components. The demodulator can use the channel gain to recover the original QPSK symbol by dividing out these gains: x[i]=y[i]/H[i]. This process is called Frequency equalization. The effect of flat fading on X[i] is removed by this equalization and received SNR is unchanged. An alternative for using the cyclic prefix is to use a prefix consisting of all zero symbols.

7. Cyclic Prefix:

Use of cyclic prefix is a key element of enabling the OFDM signal to operate reliably. Cyclic Prefix acts as a buffer or guard interval to protect the OFDM signals from inter symbol interference. When Start Of Packet (SOP) takes place in medium then there will be short training symbol from which the coarse and fine are calculated. To find whether the medium is free for access the mobile has to sense it to have communication, and this process is called as Clear Channel Assessment (CCA). Since the subcarriers are orthogonal in OFDM, the overlapping of them is permitted thus carrier multiplexing is used in OFDM. The guard time is implemented in OFDM so that the interference can be reduced.

Cyclic extension is used to face the problem of inter symbol and the inter carrier interference. The same is eliminated at the receiver end before detection process. The cyclic prefix helps to avoid ISI problem. The CP acts as guard space with OFDM symbols, thus the OFDM technique is an effective technique suitable for wireless communication. Though it is sensitive to phase and frequency noises the receiver is designed carefully and applying design techniques, the OFDM system is made robust to these noise effects and enhances the applications are of wireless communication.

QPSK is a form of phase shift keying in which two bits are modulated at once, selecting one of four possible carrier phase shifts $\left(0^{\circ},90^{\circ},180^{\circ},270^{\circ}\right)$ QPSK allows the signal to carry twice as much information as ordinary PSK using the same bandwidth.

Benefits of QPSK

- In QPSK modulation, two bits are carried by one single analog carrier. Hence bandwidth is twice efficient when compared to BPSK modulation. Here symbol rate is half of the raw bit rate
- QPSK is a bandwidth efficient modulation technique because two bits are carried by a single carrier.

Drawbacks of QPSK

- In QPSK modulation technique, one complex symbol represents two binary bits. QPSK receiver is more complex when compared to BPSK receiver due to four states needed to receive binary data information.
- Due to above reason, QPSK is not power efficient modulation technique when compared to other modulation types as more power is required to transmit two bits.

8. Result analysis

Random binary data stream is generated and modulated with QPSK modulation. After taking Inverse Fast Fourier Transform (IFFT) cyclic prefix is added and data is transmitted serially through Additive White Gaussian Noise Channel. Again at the receiver side serial data is received and converted to parallel, cyclic prefix is removed Fast Fourier Transform is taken and QPSK demodulation is performed. BER is reduced by using MMSE equalizer. BER performance is compared for both without using MMSE equalizer and after using MMSE equalizer. Figure 2 shows the SNR Vs BER graph.

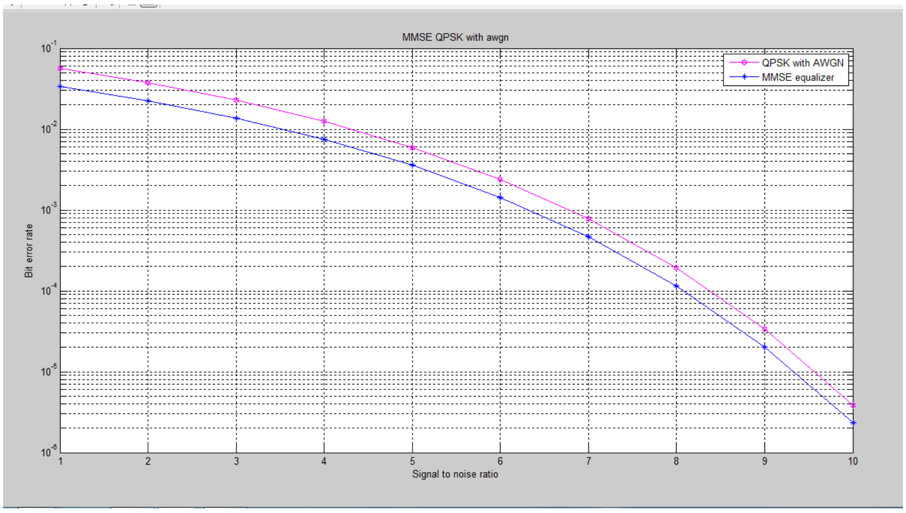

Figure 2. SNR Vs BER

9. CONCLUSION

MIMO-OFDM is a major technology enabling demanding new applications with huge market potential and facilitating significant growth in existing applications. This technology combines Multiple-Input Multiple-Output wireless technology with Orthogonal Frequency Division Multiplexing technology. From the above discussion Minimum Mean Square Error equalizer minimizes the bit error rate of occurrence and thereby it can be used to improve signal quality.

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