JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

PERFORMANCE ENHANCEMENT OF MIMO-OFDM SYSTEM USING DIFFERENT EQUALIZATION TECHNIQUES

[1] S.Saiprathushya, [2] M.Jyothsna
[1] PG Student, [2] Assistant professor
[1] Dept of ETE,
[1] G. NARAYANAMMA INSTITUTE OF TECHNOLOGY AND SCIENCE(FOR WOMEN) HYDERABAD, INDIA

Abstract : Wireless communicationsencounter several fundamental obstacles including fading, capacity, interference, and transmission power. To achieve these objectives, multiple input multiple output (MIMO) using orthogonal frequency division multiplexing (OFDM) technology is used. MIMO-OFDM is a rapidly evolving wireless broadband technology that provides high data rate, broad coverage, and good spectral efficiency. The most important effect to consider on the receiver side is fading, which can be reduced utilising equalization techniques. The reduction in bit error rate (BER) utilising BPSK modulation demonstratedin this study using different equalisation approaches such as Zero Forcing Equaliser (ZFE), Minimum Mean Square Equaliser (MMSE) equaliser, and Maximum Likelihood Equaliser (MLE).

***IndexTerms* – MIMO-OFDM, ZF, MMSE, ML**

I. INTRODUCTION

Wireless communication technology's major objective is to deliver high data rates at a low cost. One of the most promising approaches for signal transmission across wireless channels is orthogonal frequency division multiplexing (OFDM). In OFDM, single data stream is sent over many subcarriers. The concept of OFDM is to split the overall transmitted bandwidth into a number of subcarriers that are orthogonal to each other and do not communicate with one another. One of the advantages of multi-carrier modulation over single-carrier modulation is its ability to cope with multipath fading. The bandwidth efficiency of multi carrier over single carrier is another benefit [1].

In MIMO (Multiple input Multiple output), Multiple transmit antennas are used on the transmitting side and multiple receive antennas are used on the receiving side. It is possible to boost diversity and multiplexing gain by utilising numerous antennas at the transmitter and receiver. MIMO is a potential wireless communication technology that provides high throughput, a broad coverage area, and increased dependability. One of the MIMO technologies is spatial multiplexing, which boosts data rates by sending multiple data streams over multiple transmit and receive antennas [2].

Because of its high data rate, great spectral efficiency, and resistance to multipath fading, the MIMO-OFDM system has grown in popularity. When bits are sent over a radio channel, the channels are usually multipath fading, causing ISI in the receiving signal. One of the most significant limitations of any wireless communication technology is ISI. At the receiver end, equalisation techniques are used to reduce ISI [3]. For the Rayleigh frequency flat channel, we focus on implementing several equalisation approaches such as the Zero Forcing Equaliser (ZF), the Minimum Mean Square Equaliser (MMSE), and the Maximum Likelihood Equaliser (MLE).

Linear equalisers, such as zero forcing equaliser (ZFE) or the minimum mean square equaliser (MMSE) criterion, offer a low-complexity. However, in the Zero Forcing Equaliser (ZFE) technique, the error performance is often low. Minimum Mean Square Equaliser (MMSE) is a more balanced liner equaliser because it reduces the mean square error. The Maximum Likelihood Equaliser (MLE) criterion uses a brute-force search to find the most likely combination of broadcast bits based on the received signal.

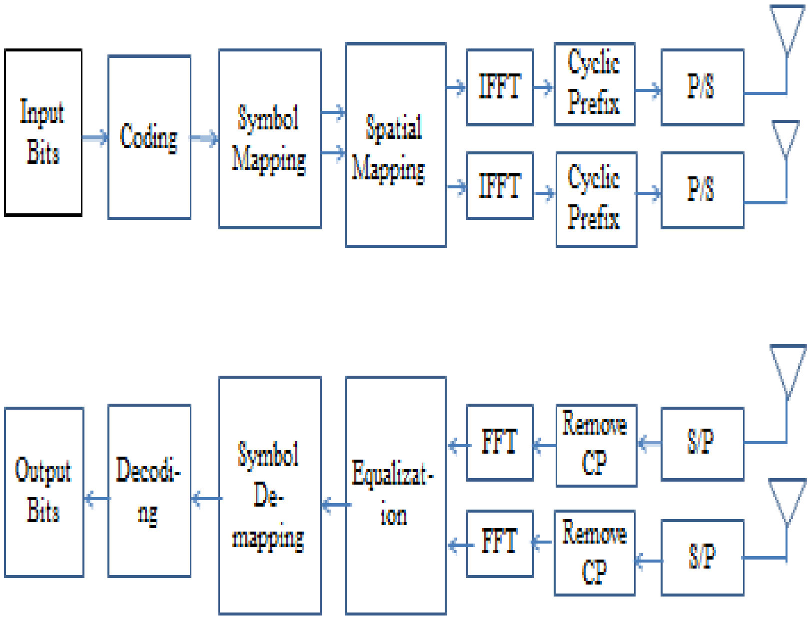

Figure 1: Block Diagram of 2x2 MIMO-OFDM Transceiver Structure

II. EQUALIZATION

Equalisation adjusts for intersymbol interference (ISI) caused by multipath within time dispersive channels. ISI occurs when the modulation bandwidth of a radio channel exceeds coherence bandwidth of a radio channel, causing modulation pulses to be spread out in time.

Equalization techniques are classified into two types: linear and non-linear equalisation. These classifications are based on how an adaptive equalization's output is used for further equaliser adjustment [14].

The decision-making device in the receiver, in general, processes the analogue signal d^(t). In order to evaluate the value of d(t), the decision maker evaluates the value of the digital data bit being received and performs a slicing or thresholding operation. The equalisation is linear if d(t) is not utilised in the feedback path to adapt the equaliser. When d(t) is sent back to modify the equalizer's future outputs, however, the equalisation becomes non-linear. Different equalisers, such as ZFE, MMSE, and MLE, are implemented and their performance is compared in this study.

A) Zero Forcing Equalizer (ZFE)

In wireless communications, a zero forcing equaliser is a type of linear equalisation technique that uses the inverse of the channel's frequency response. To recover the signal after the channels has been damaged, the zero forcing equaliser applies the inverse of the channel frequency response to the receiver end [3].

In a noise-free environment, the zero forcing equaliser reduces interymbol interference (ISI) to zero. It is a linear equalisation approach that does not take noise into account. In reality, the noise may be amplified as a result of the interference removal procedure.

The zero forcing equaliser $H_{eq}(f)$ is calculated for a channel with frequency response $H_{ch}(f)$.

$$H_{eq}(f) = \frac{1}{H_{ch}(f)}$$

As a result, the combined response of the channel with the equalizer must meet the Nyquist's first criterion.

$$H_{ch}(f)H_{eq}(f)=1 \text{ , } |f|<1<2T$$

Where the impulse response of the channel is $H_{ch}(f)$, and the equaliser impulse response of the channel is $H_{eq}(f)$. Since this filter has a limited length, it does not eliminate all ISI.

B) Minimum Mean Square Error (MMSE) Equalizer

Although the zero forcing equaliser eliminates ISI, but because it ignores noise in the system, it may not provide the greatest error rate for the communication system. The Minimum Mean Square Error (MMSE) equaliser is a different equaliser that takes noise into consideration. The filter is designed using the MMSE algorithm to reduce the error between the transmitted data and the equalisation output[3][9].

$$e(n)=d[n]-d\hat{}[n]$$

$$E\{e(n)^2\}=E[\{d[n]-d\hat{}[n]\}^2]$$

As previously stated, a zero forcing equaliser reduces interference and produces parallel SISO channels, but it also increases noise. The MMSE equaliser is used to solve this problem, with filter coefficients produced by minimising W_{MMSE}.

$$W_{MMSE}= [H^H H+N_0 I]^{-1}H^H$$

$$W_{MMSE}= [H^H H+1/SNRI]^{-1}H^H$$

Where, N_0 denotes noise variance, I denotes interference, and SNR denotes signal to noise ratio. As the SNR rises, the MMSE equaliser will equalise with the ZF equaliser.

C) Maximum Likelihood Equalizer (MLE)

In order to minimise the total error probability, the maximum likelihood equaliser outperforms both ZFE and MMSE. The complexity of MLE is kept minimum by employing a small number of transmit antennas and low constellations. ML detection determines the Euclidean distance between the received signal and the product of all possible transmitted vectors and finds the one with minimum distance. The ML examines all possible data sequences and chooses the data sequence with the maximum probability as output [10]. If we assume that the channel has N-1 memory, the received sequence at the receiver is given by

$$y_n = \sum_{I=0}^{N-1} d_{n-1} h(I) + n_n$$

Where n denotes the total number of signals transmitted, d is the transmitted sequence, and n is the noise.

III. RESEARCH METHODOLOGY

A) OFDM System Model

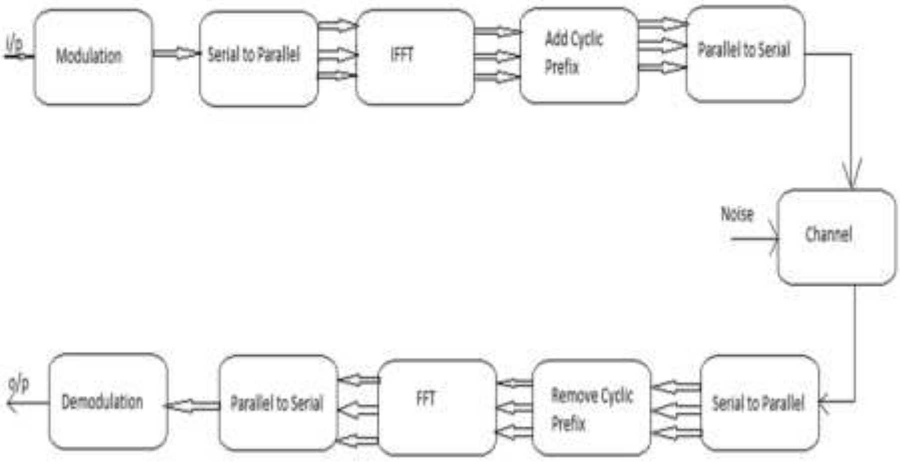

Figure 2: Block Diagram of OFDM Transceiver Structure

The basic block diagram of the OFDM System [4][15] is depicts in Figure 2. The OFDM transceiver system is made up of transmitter and receiver portions. The bits are first translated into data symbols using the BPSK modulation technique, and then the serial streams are converted to parallel streams using a converter. It has N sub-carriers, each of which has the data symbol X(k), where k=0,1,2,...N-1 and k is the sub-carrier index. The N sub-carriers are then subjected to the Inverse Fast Fourier Transform (IFFT). After transformation, the time domain OFDM signal at the output of IFFT [5][6] can be expressed as .

$$X(n) = \sum_{k=0}^{N-1} X(k) \exp\left(\frac{j2\pi kn}{N}\right)$$

In the time domain of an OFDM signal, n is the sample index. A cyclic prefix is added to the end of the OFDM transmitter to mitigate the ISI effect, and the output of the cyclic prefix is $X_{cp}(n)$, which coverts parallel streams into serial streams using a parallel to serial converter, and the signal is then sent through a frequency selective multipath fading channel, and a noisy channel with independent and identically distributed AWGN noise [7]. The received signal can be expressed as

$$Y_g(n)=x_g(n)*h(n)+W(n)$$

Where W(n) is an additive white Gaussian noise sample that is independent and identically distributed, and h(n) is the discrete time channel impulse response (CIR).

Using a serial to parallel converter, the receiver will first convert serial streams into a number of parallel sub-streams before removing the cyclic prefix. The received signal is de-multiplexed using the fast Fourier transform (FFT) once the cyclic prefix has been removed. On the kth receiving subcarrier, the output of FFT in frequency domain signal [6] can be written as

$$\mathrm{y(k)} = \frac{1}{N} \sum_{n=0}^{N-1} y(n) \exp\left(\frac{-\mathrm{j}2\pi\mathrm{kN}}{N}\right)$$

B) MIMO System Model

MIMO (Multiple Input Multiple Output) is a multi-antenna system that uses multiple antennas on both the transmitter and receiver sides. There is a fading channel between each transmit and receive antenna in a MIMO system. A high number of fading channels are present in a MIMO system. MIMO is a new technology that uses spatial multiplexing to enhance data rates [8].

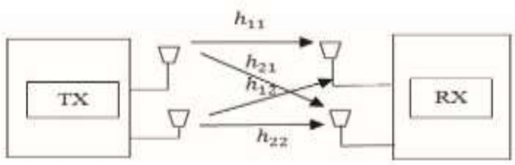

Figure 3: 2x2 MIMO system

The channel matrix is given by

$$[H] = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$$

C) MIMO-OFDM System Model

A 2x2 MIMO-OFDM system is depicted in Figure 1. The convolution encoder receives the input bit stream at first. The binary bits are then transferred into a modulation method like BPSK. The MIMO approach employed here is spatial multiplexing. In order to achieve OFDM modulation, the Inverse Fast Fourier Transform (IFFT) is used first, followed by the addition of a cyclic prefix. All sequences are parallel to serial transformed to generate an OFDM block. The Rayleigh flat fading channel is assumed here. All transmitted signals are detected and transferred to a serial to parallel converter, which is then supplied to an OFDM demodulator, which removes the cyclic prefix. After that, each OFDM block undergoes an FFT operation before being given to the MIMO decoder. Multipath MIMO channels create inter symbol interference, which distorts the MIMO [11][12] transmitted signal and causes bit errors at the receiver end. Equalization will help to reduce ISI. Equalizers are used to reduce the ISI at the receiver end of the channel, and various equalisation techniques such as ZF, MMSE, and ML are used. The approximated signal is retrieved when demodulation and decoding are performed.

Spatial multiplexing is MIMO techniques that achieves a high transmission rate without requiring more bandwidth or transmit power. It uses multiple antennas on both the transmitter and receiver sides to carry numerous data streams in the same frequency band at the same time [11]. This will be the standard mathematical model for spatial multiplexing which is given by

$$Y=Hx+n$$

Figure 3 depicts a 2X2 MIMO system with two transmit antennas and two receive antennas, with S1 and S2 denoting the symbols broadcast in parallel by TX1 and TX2. RX1 and RX2 receive a signal, which is expressed as

$$r1=h_{11}S1+h_{12}S2+n1$$
$$r2=h_{21}S1+h_{22}S2+n2$$

Additive white Gaussian noise (AWGN) is represented by n1 and n2. The channel impulse response (CIR) coefficients between TX1 and TX2 and RX1 are h11 and h12. The channel impulse response (CIR) coefficients between TX1 and TX2 and RX2 are h21 and h22. This can be written in matrix form as

$$\begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}$$

IV. RESULTS AND DISCUSSION

In this session, simulation results of 2X2 MIMO-OFDM systems are shown in terms of Bit Error Rate (BER) with respect to variations in signal to noise ratio (SNR). Results are shown using Binary phase shift keying (BPSK) modulation scheme under Rayleigh frequency flat channel.

Each plot has three subplots correspond to ZF, MMSE and ML equalization techniques. Fig 4 shows BER comparisons of ZF, MMSE and ML in 2X2 MIMO systems. BER reduces monotonically to 10^{-2} at SNR of about 14dB using ZF, about 11dB using MMSE, about 6dB using ML equalization techniques. We found that the ML equaliser performed the best when compared to ZF, MMSE, and other equalisers.

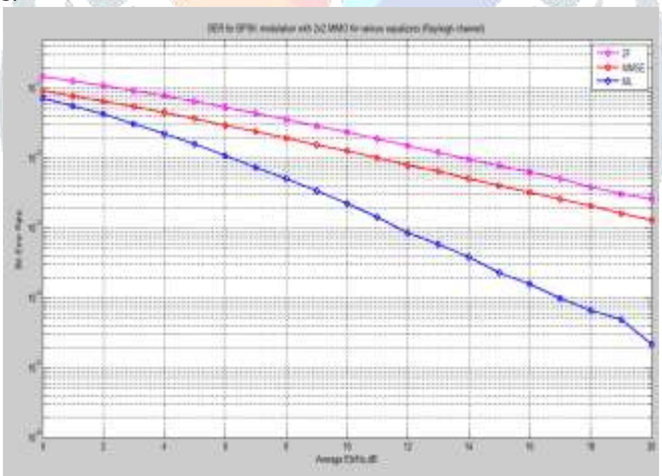

Figure 4: BER comparison for BPSK in 2X2 MIMO system

In a 2X2 MIMO-OFDM system, BER comparisons of ZF, MMSE, and ML are shown in Fig 5. At SNRs of approximately 8dB using ZF, about 4dB using MMSE, and about 1dB using ML equalisers, BER drops monotonically to 10-2. By comparing ZF, MMSE, and ML equalisation techniques, we found that the ML equalisation approach gives the best results. When comparing figures 4 and 5 that is systems with and without OFDM, we achieved better performance using OFDM system.

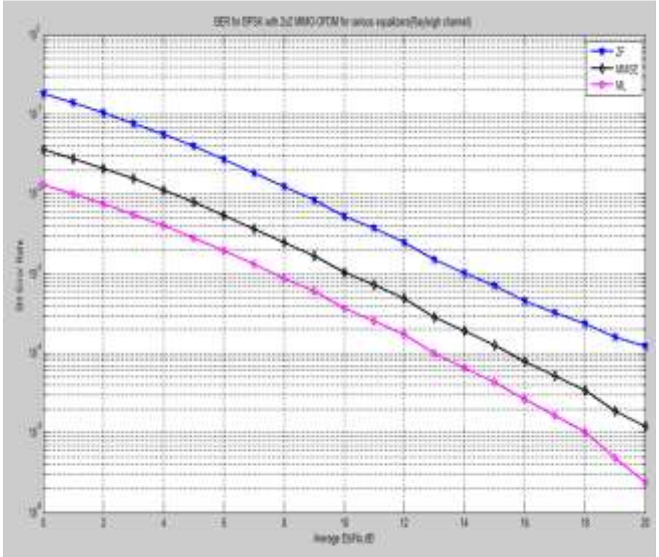

Figure 5: BER comparison for BPSK in 2X2 MIMO-OFDM system

V. CONCLUSION

In this study, the simulation results of various equalization techniques with and without OFDM system are demonistrated. Simulation results are carried under Rayleigh frequency flat channel for BPSK modulation technique. In comparison to a system without OFDM, such as MIMO systems, we achieved better performance by integrating the system with OFDM. When comparing systems with and without OFDM, we found that utilising OFDM results in overall gains of 6 dB using ZF, 7 dB using MMSE, and 5 dB using ML at BER of 10^{-2}. Furthermore, we found that we got the best performance in both situations, i.e. the system with and without OFDM using ML equalisation approach.

References

[1] G.L. Stuber, J.R. Barry, S.W. McLaughlin, Ye Li, “ Broadband MIMO-OFDM wieless Communications”, IEEE, Vol-92, No-2,pp.271-294, Feb 2007.

[2] Jaikaran Singh, Pallavi Bhatnagar and Mukesh Tiwari,” Performance of MIMO-OFDM System for Rayleigh Fading channel”, International Journal of Science and Advanced Technology, Vol.-1, no.-3, May 2011.

[3] Bhasker Gupta, Davinder S. Saini and Gagan Gupta,” BER Performance Improvement in OFDM System with ZFE and MMSE Equalizers”, IEEE Communications Letters, Vol.-6, no., pp. 193-197, April 2011.

[4] S. K. Chaparala, S. K. Borra, “Performance Evaluation of OFDM Systems with Rayleigh and AWGN Channels”, International Journal of Innovative Research in Computer and Communication Engineering, Vol.5, No.7, pp. 13222-13227, August 2017.

[5] C. Tim, Allert Van Zelst, and W.Schenk,” Implementation of a MIMO OFDM Based Wireless LAN System”, IEEE Transaction on Signal Processing, Vol.-52, Issue.-2,pp.483-494. February 2006.

[6] Yu-Song Shi, Titan-Ming Ma and Ying-Guan Wang, “A Low Complexity MMSE for OFDM Systems over Frequency Selective Fading Channels”, IEEE Communications Letters, vol.-16, no.-3, March 2012.

[7] Theodore S. Rappaport, "Wireless Communications", 2nd Edition, Prentice Hall of India, 2002.

[8] Kai Yu and Bjorn Ottersten,” Model for MIMO Propagation Channel”, Wiley Journal on Wireless Comm and Mobile Computing, Vol.-2, Issue.-7.pp.653-666, November 2005.

[9] K. Satya Prasad, ShaileshShankhi,” Performance Analysis of Channel Estimation Based on MMSE Equalizer in MIMO-OFDM System”, International Journal of Advanced Innovative Research, Vol. 2, Issue. 8, ISSN: 2278-7844, pp.no.-155-159, March 2015.

[10] Sung –Hyun Moon, Jin-Sung and Inkyu Lee, “A New Reduced Complexity ML Detection Scheme for MIMO Systems”, IEEE Journals and Magazines, Vol.5, No 4, pp. 132-1310, April 2010.

[11] S. Swain, N. Sethy, “BER Analysis of MIMO-OFDM System in Different Fading Channel”, International Journal of Application , Vol. 2, No. 4, pp. 405-409, July 2013.

[12]YudhishthirRaut,MitalleAgrawal,”BER Analysis of MIMO OFDM Systems for AWGN and Rayleigh Fading Channel”, International Journal of Computer Applications, Vol.-34, No.-9, November 2011.

[13] S. M. Alamouti, "A simple transmit diversity technique for wireless communications”, IEEE J. Select. Areas communication, Vol.-16, No.-8,pp. 1451-1458, Oct 1998.

[14] A. Sappal, G.Mallik,” Adaptive Equalization Algorithm Overview”, International journal of advanced computer science and applications, Vol-2, No-3, Mar 2011.

[15] A. Naveena, K. Pranathi, “A Survey on Channel Estimation in Multicarrier Modulation Schemes” Science, Technology and Development Journal, ISSN: 0950-0707, Vol X, Issue III, March 2021.