BER PERFORMANCE ANALYSIS OF MIMO-OFDM SYSTEM USING EQUALIZER

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ABSTRACT: MIMO-OFDM (multiple input and multiple output orthogonal frequency division multiplexing) system is a new wireless broadband technology which has gained great popularity for its capability of high rate transmission and its robustness against multipath fading. Fading effects are the major effects to be considered at the receiver. Fading effects must be mitigated at the receiver before demodulation by using equalization techniques. Equalizer is used to allow recovery of the transmit symbols, which is the major factor responsible for the Bit Error Rate (BER). In this paper Zero Forcing equalization and Minimum Mean Square Error equalization techniques are presented for reduction in bit error rate for the BPSK modulation technique. The performance is evaluated in terms of BER versus SNR. The performance of MIMO-OFDM system is evaluated by using different equalizers.

Key words: MIMO, OFDM, BER, ZF and MMSE EQUALIZERS

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1. INTRODUCTION: In wireless communication technology the main objective is to provide high quality of data. Orthogonal frequency division multiplexing (OFDM) has become a more popular technique for transmission of signals over wireless channels. In OFDM, signals are transmitted in sub-channel of different frequency in parallel fashion. The frequency of sub-channel are so selected that these frequencies are orthogonal to each other and therefore do not interfere with each other. This phenomenon makes it possible to transmit the data in overlapping frequency and hence reduces the bandwidth requirement considerably. OFDM is beneficial in many aspects such as high spectral efficiency, robustness, low computational complexity, frequency selective fading, and easy to implementation using IFFT/FFT [1]. In wireless communication systems the data bits are transmitted in radio space, channels are typically multipath fading channels, which causes inter symbol interference (ISI) in the received signal. ISI is undesirable and it increases bit error rate. ISI causes due to multipath propagation and band limited channels. Whenever the modulation bandwidth exceeds the radio channel coherence bandwidth, ISI is produced. To eliminate ISI from the signal, strong equalizers are used, which requires channel impulse response (CIR) [2]. Equalizer compensate the inter symbol interference means it works in such a way that BER should be low and SNR should be high [3]. Equalization techniques have importance to design of high data rate wireless systems. Most of the wireless receivers are equipped with the equalizer which gives good result. The quality of wireless communication depends upon the three parameters i.e. rate, range and reliability of transmission. These parameters are related with each other. Simultaneous improvement in all three parameters can be accomplished with the help of new technique called MIMO assisted OFDM system. Now a day's integration of OFDM technique with MIMO system has been an area of interesting in the field of broad band wireless communication. MIMO is a frequency-selective technique. OFDM can be used to convert such a frequency-selective channel into set of parallel frequency-flat sub channels. MIMO-OFDM system can achieve reliable high data rate transmission over broad band wireless channel [4]. BPSK modulation technique is used in MIMO-OFDM system to evaluate the BER performance.

2. System model

A). OFDM System Model:

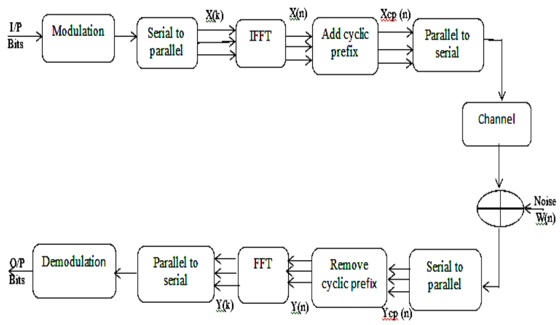

Fig. 1. Block Diagram of a Baseband OFDM transceiver System

Figure. 1 represents the basic block diagram of OFDM [5][6] system. It consist of transmitter and receiver sections, named OFDM transceiver system. The data bits inserted from the source are firstly mapped with BPSK modulation technique and after that converted from serial to parallel through convertor. Now N subcarriers are there and each sub-carrier consists of data symbol X(k) (k=0,1,….,N-1), where k shows the sub-carrier index. These N subcarriers are provided to inverse fast Fourier transform (IFFT) block. After transformation, the time domain OFDM signal at the output of the IFFT [6][7] can be written as:

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

where, n is the time domain sample index of an OFDM signal. After that, Cyclic Prefix (CP) [8] is added to mitigate the ISI effect. We get signal $\mathbf{x}_{cp}$ (n), which is sent to parallel to serial convertor again and then, this signal is sent to frequency selective multi-path fading channels [6][9] and a noisy channel with independent and identically distributed (i.i.d.) AWGN noise. The received signal can be given by

$$y_g(n) = x_g(n) * h(n) + w(n), \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$0 \le n \le N-1$$

W(n) i.i.d. additive white Gaussian noise sample and h (n)is the discrete time channel impulse response (CIR).

At the receiver, firstly serial to parallel conversion occurs and cyclic prefix removed. After removing the CP, the received samples are sent to a fast Fourier transform (FFT)block to de-multiplex the multi-carrier signals. Then the output of the FFT [6] in frequency domain signal on the kth receiving subcarrier can be expressed as:

$$y(k) = \frac{1}{N}\sum_{n=0}^{N-1} y(n)\exp(\frac{-j2\pi kn}{N})$$
$$= X(k)H(k) + W(k) \; 0 \le k \le N\text{-}1\ldots\ldots(3)$$

where, W(k) is noise in time domain and H(k) is the channel frequency response.

B). MIMO system model: Multiple antennas can be used at the transmitter and receiver. This arrangement is called a multiple input multiple output (MIMO) system. In MIMO system there is a channel/path between each of the transmitters and each of the receiver antennas [10].Uncorrelated received signal can achieved by keeping well spacing between the transmitter and receiver. In this paper 2×2 MIMO system is used.

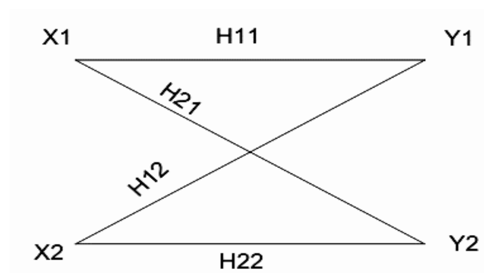

Fig.2 Channel matrix

The channel matrix is given by

$$[H] = \begin{bmatrix} H_{11}\, H_{12} \\ H_{21}\, H_{22} \end{bmatrix}$$

If X represents the transmitted signal from transmitted antenna and R represents the received signal, then the transmitted samples go through the multipath channel and would reach at the receiver. This could represented as,

$$R = HX + n$$

Where n is the noise.

3. CHANNELDESCRIPTION:-

Rayleigh fading channel is used in this paper.

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution. Rayleigh fading is the effect of heavily built-up urban environments on radio signals.[12][13] Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may be more applicable. The Rayleigh distribution is basically the magnitude of the sum of two equal independent orthogonal Gaussian random variables and the probability density function(pdf) is given by:

$$p(z) = \frac{z}{\sigma^2} e^{\frac{-z^2}{2\sigma^2}}, z \geq 0 \quad \ldots\ldots\ldots\ldots\ldots(4)$$

Where σ^2 is the time-average power of the received signal and eq. (4) is called Probability density function.

4. SIGNAL DETECTION OF MIMO-OFDM SYSTEM

MIMO-OFDM detection methods consist of linear and nonlinear detection methods. We are using only linear detection methods in this paper

A) Zero Forcing Equalizer: -

This is a linear equalization algorithm used in communication systems, which inverts the frequency response of the channel at the receiver to restore the signal before the channel [11]. ZF algorithm considers as the signal of each transmitting antenna output as the desired signal, and consider the remaining part as a disturbance, so the mutual interference between the different transmitting antennas can be completely neglected. ZF equalizers ignore the additive noise and may considerably amplify noise for channels with spectral nulls. Mathematical expression of sub-channel in the MIMO-OFDM system is as follows:

$$R(K) = H(K).X(K) + n(k) \ldots\ldots\ldots\ldots(5)$$

Where, R(k), X(k)and$n$(k)respectively expresses output signal, the input signal and noise vector of the (k)sub-channels in MIMO-OFDM system. The relation between input X(k) and output signal R(k) as in eq. (5) exploits that this is a linear equalizer. A ZF detection algorithm for MIMO OFDM is the most simple and basic algorithm, and the basic idea of ZF algorithm is kept of MIMO-channel interference by multiplying received signal and the inverse matrix of channel matrix. Zero- Forcing solution of MIMO-OFDM system is as follows:

$$X_{ZF} = H^{-1}R = x + H^{-1}n \ \ldots\ldots\ldots\ldots(6)$$

in which H^{-1} is the channel matrix for the generalized inverse matrix.

B) Minimum Mean Square Equalizer: -

MMSE equalizer is a more balanced linear equalizer that does not eliminate ISI entirely but minimizes total noise power and ISI components in the output. In wireless communications, MMSE equalizer approach minimizes the mean square error (MSE), which is a common measure of estimator quality. Let X is an unknown random variable, and let Y is a known random variable. An estimator $\breve{X}_y$ is any function of the measurement Y, and its MSE is given by

$$MSE = E\{(\breve{X} - X)^2\} \ \ldots\ldots\ldots\ldots\ldots\ldots.(7)$$

where, the expectation is taken over both X and Y. When it is not possible todetermine a closed form for the MMSE equalizer then minimize the MSE within a particular class, such as the class of linear equalizers. Assuming the case where two symbols are interfered with each other. In the first time slot, the received signal on the first receive antenna is,

$$y_1 = h_{1,1}x_1 + h_{1,2}x_2 + n_1 = [h_{1,1}\ h_{1,2}]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_1$$

$$y_2 = h_{2,1}x_1 + h_{2,2}x_2 + n_2 = [h_{2,1}\ h_{2,2}]\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n_2$$

In matrix form, the above equation can be expressed as:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{1,1}\ h_{1,2} \\ h_{2,1}\ h_{2,2} \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}$$

The above wireless channel is modulated by the theorem Y =H x + n. The MMSE approach tries to find a coefficient W which minimizes the criterion,

$$E\{[W_{y-x}][W_{y-x}]^H\}$$

To solve X we need to find a matrix W which satisfies WH =1. The MMSE equalizer for satisfying this constraint is given by,

$$W = [H^H H + N_0 I]^{-1} H^H \quad \text{---------} \ (8)$$

Where, W- equalization matrix and H- channel matrix.

5.BIT ERROR RATE (BER):- In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors. The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval.

The bit error rate or bit error ratio (BER) is defined as the rate at which errors occur in a transmission system during a studied time interval. BER is a unit less quantity.

6. SIGNAL TO NOISE RATIO (SNR):- There are a number of ways in which the noise performance, and hence the sensitivity of a radio receiver can be measured. The most obvious method is to compare the signal and noise levels for a known signal level, i.e. the signal to noise (S/N) ratio or SNR. Obviously the greater the difference between the signal and the unwanted noise, i.e. the greater the S/N ratio or SNR, the better the radio receiver sensitivity performance.

$$SNR = \frac{P_{signal}}{P_{noise}}$$

7. RESULTS AND DISCUSSION

The parameters used in the experiment are as shown in below table 1.

Parameters	**Value**
Modulation	BPSK
Channel model	AWGN, Rayleigh
Noise model	AWGN
FFT & IFFT Point	64
Sub-carrier Number	52

Table 1.

On the basis of experiment performed,it is found that when binary phase shift keying signal is fed in a 2 input and 2 output receiver system, bit error rate differs drastically for the ZF and MMSE equalizer.

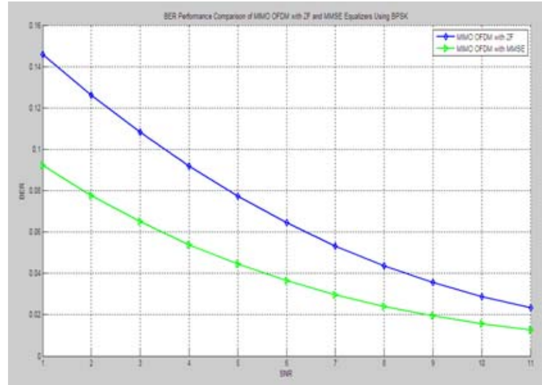

Fig.4 BER for MIMO-OFDM using MMSE equalizer for Rayleigh channel

Fig.3 and fig.4 represents the BER values as a function of SNR for the MIMO-OFDM system for ZF and MMSE equalizers respectively with Rayleigh channel. By analyzing these two graphs it is observed that BPSK modulation gives the least bit error rate in MMSE equalizer than the ZF equalizer.

8. CONCLUSION

In this paper the BER performance is evaluated for BPSK modulation and Rayleigh fading channel. It is found that MMSE equalizer performs better as compared to ZF equalizer.

Further work can be extended with using different modulation techniques and using other equalizers.

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