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BER Analysis of MIMO-OFDM System Using Different equalizer

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Abstract: The most widely used modulation technique for wireless communications is Orthogonal Frequency Division Multiplexing (OFDM).The demand of high bit rate has increased in recent wireless communication networks. Multiple Input Multiple Output (MIMO) technology has the ability to improve the problem of traffic capacity in the wireless networks. MIMO systems can be defined as the use of multiple antennas at both the transmitting and receiving ends of a wireless communication network. The systems 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 effects to be considered at the receiver. Fading effects must be mitigated at the receiver before demodulation by using equalization techniques. 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.

Keywords: MIMO, OFDM, BER, ZF and MMSE EQUALIZERS.

I. INTRODUCTION

Wireless communications can be regarded as the most significant and important development in a modern society. Wireless communication systems need tremendously high data rates and high transmission reliability in order to meet the hastily increasing demand for multimedia applications such as high quality audio and video. Existing wireless technologies cannot efficiently support high data rates, because of these technologies are very sensitive to fading. In present day's communication, OFDM [1] is a wide spread and one of the most promising modulation techniques. It is beneficial in many areas such as high spectral efficiency, robustness, low computational complexity, frequency selective fading, and ease of implementation using IFFT/FFT and equalization schemes. Recently, there have been a lot of interest to use OFDM in combination with a MIMO [2] transceiver system, named MIMO OFDM [3] [6] system; which is used to increase the diversity gain and system capacity. MIMO as the name indicates; used multiple inputs at the transmitter and multiple outputs at the receiver end which is advantageous rather than a single transceiver (SISO-Single input Single output) systems.

MIMO wireless systems are motivated by two vital goals: high-data-rate and high performance. This combination of MIMOOFDM is a very promising feature since OFDM able to sustain of more antennas since it simplify equalization in MIMO systems Usually in OFDM, fading is considered as a problem in wireless network but MIMO channels uses the fading to increase the capacity of the entire communication network. MIMO is a frequency-selective technique. OFDM can be used to convert such a frequency-selective channel into a set of parallel frequency-flat sub channels.

MIMO-OFDM technology has been investigated as the infrastructure for the next generation wireless/ multimedia networks.

II. SYSTEM MODEL

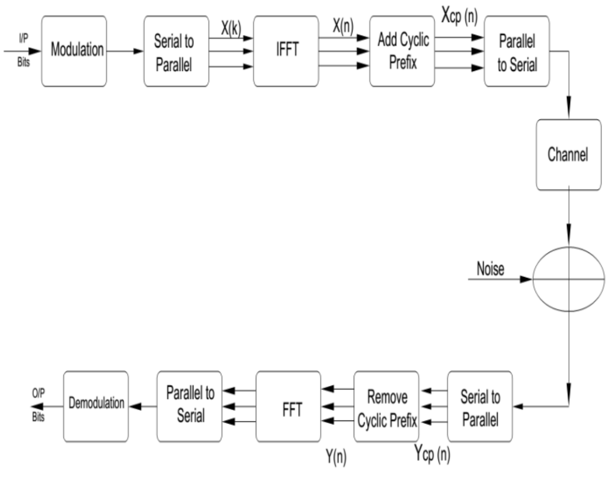


Fig1 OFDM system model

Figure. 1 represents the basic block diagram of OFDM [34][35] 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:

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

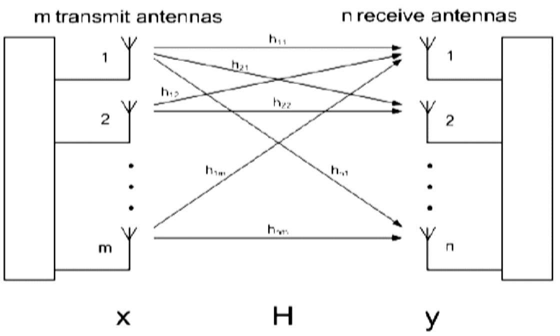
where, n is the time domain sample index of an OFDM signal. After that, Cyclic Prefix (CP) [36] is added to mitigate the ISI effect. We get signal $x_{cp}(n)$, which is sent to parallel to serial convertor again and then, this signal is sent to frequency selective multi-path fading channels [35][37] and a noisy channel with independent and identically distributed (i.i.d.) AWGN noise. The received signal can be given by

$$y_g(n) = x_g(n) * h(n) + w(n), \quad \ldots\ldots\ldots\ldots (2)$$
$$0 \le n \le N-1$$

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 [35] in frequency domain signal on the kthreceiving subcarrier can be expressed as:

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

MIMO SYSTEM MODEL
A MIMO system typically consists of m transmit and n receive antennas (Figure 2). By using the same channel, every antenna receives not only the direct components intended for it, but also the indirect components intended for the other antennas. A time-independent, narrowband channel is assumed. The direct connection from antenna 1 to 1 is specified with h11, etc., while the indirect connection from antenna 1to 2 is identified as cross component h21, etc. From this is obtained transmission matrix H with the dimensions n x m.



$$H = \begin{bmatrix} h_{11} & h_{12} & h_{..} & h_{1m} \\ h_{21} & h_{22} & h_{..} & h_{2m} \\ h_{..} & h_{..} & h_{..} & h_{.m} \\ h_{n1} & h_{n2} & h_{n.} & h_{nm} \end{bmatrix} \text{ Channel Matrix H}$$

Fig2.MIMO system model

III. CHANNEL DESCRIPTION

Rayleigh channel
The Rayleigh fading model is particularly useful in scenarios where the signal may be considered to be scattered between the transmitter and receiver. In this form of scenario there is no single signal path that dominates and a statistical approach is required to the analysis of the overall nature of the radio communications channel The Rayleigh fading model can be used to analyze radio signal propagation on a statistical basis. It operates best under conditions when there is no dominant signal (e.g. direct line of sight signal), and in many instances cellular telephones being used in a dense urban environment fall into this category. Other examples where no dominant path generally exists are for ionospheric propagation where the signal reaches the receiver via a huge number of individual paths. Propagation using tropospheric ducting also exhibits the same patterns. Accordingly all these examples are ideal for the use of the Rayleigh fading or propagation model.

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:

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

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

IV. SIGNAL DETECTION OF MIMO OFDM SYSTEM

Thair are different types of equalizer such as linear and non linear equalizer. But we are using only linear equalizer.

1. 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 [43]. 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

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matrix of channel matrix. Zero- Forcing solution of MIMO-OFDM system is as follows:

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

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

2. 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

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

where, the expectation is taken over both X and Y. When it is not possible to determine 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.

V. BIT ERROR RATE (BER)

In digital transmission, the number of bit errors is the number of received bits of a data stream over communication channels 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.

VI. 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.

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

VII. RESULTS AND DISCUSSIONS

Table 1 Simulation parameters

parameters	value
Modulation	BPSK,QPSK
Channel model	RAYLEIGH
Noise model	AWGN
Fft&Ifft	64
No of subcarrier	52

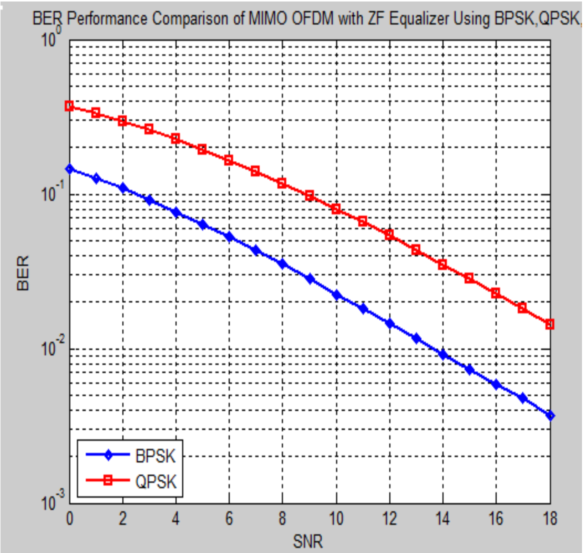

Fig2. BER analysis of MIMO- OFDM system using ZF equalizer

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, QPSK modulation gives the least bit error rate in MMSE equalizer than the ZF equalizer

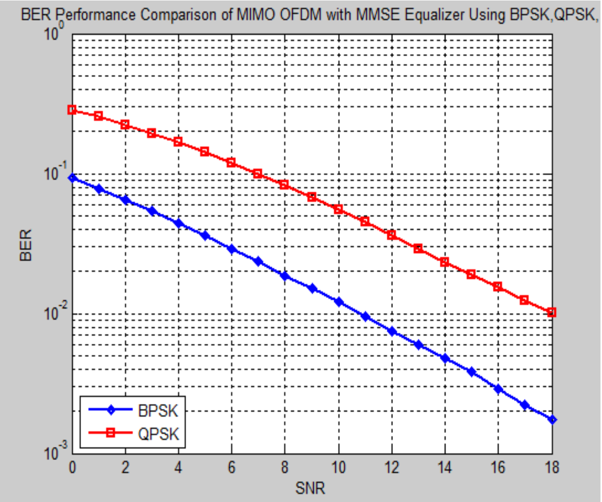

Fig3.BER analysis of MIMO OFDM system using MMSE equalizer

VIII. 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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