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PERFORMANCE ANALYSIS OF MIMO-OFDM SYSTEM FOR DIFFERENT EQUALIZER OVER RAYLEIGH FADING CHANNEL

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ABSTRACT

In wireless communication, MIMO-OFDM has been recognized as one of the most promising and emerging technique nowadays. In this paper the BER performance of MIMO-OFDM system with different equalizer and diversity technique using multipath fading channel (i.e., Rayleigh channel) is discussed. The performance of MIMO-OFDM are calculated in terms of BER versus SNR. The result shows that, with these two techniques, the BER performance is improved.

Keywords: - MIMO-OFDM, ZF, MMSE, MRC, Rayleigh fading.

I. INTRODUCTION

Wireless communications can be regarded as the most significant and important development in a modern society. Multiple Input Multiple Output (MIMO) Orthogonal Frequency Division Multiplexing (OFDM) systems have recently emerged as key technology in wireless communication systems for increasing data rate and system performance. The effect of fading and interference can be combated to increase the capacity of the link. When data rate is transmitted at high bit rate, the channel impulse response can extend over many symbol periods which leads to Inter-Symbol Interference (ISI). ISI always caused an issue for signal recovery in wireless communication. In order to reduce the complexity of MIMO system, various detection algorithm such as Zero forcing (ZF) and Minimum Mean Square Error (MMSE) are proposed that reduce bit error rate (BER) via spatial multiplexing. BPSK modulation is treated here for simulation purpose. Simulations are done by Mat Lab software that shows BER vs. signal-noise ratio (SNR) curve of equalizer.

This combination of MIMO-OFDM 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.

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II. MIMO-OFDM

Multiple Input Multiple Output (MIMO) systems have been recently emerged as a key technology in wireless communication systems for increasing both data rates and performance. MIMO is an antenna technology that used both in transmitter and receiver equipment for wireless radio communication. MIMO uses multiple antennas to send multiple parallel signals for transmission. Wireless communication technology has shown that when multiple antennas at both transmitter and receiver are employed it provides the possibility of higher data rates compared to single antenna systems [1][2]. MIMO exploits the space dimension to improve wireless system capacity, range and reliability. In the never ending search for increased capacity in a wireless communication channel it has been shown that by using MIMO OFDM systems [3] it is possible to increase that capacity substantially. Equalizers are employed to reduce such interference. MIMO system transmits different signals from each transmit element so that the receiving antenna array receives a superposition of all the transmitted signals. MIMO has eminent features which offer significant increment in data throughput and link range without additional bandwidth and increase transmit power. Modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPP Long Term Evolution (LTE) [4-5].

Orthogonal frequency division multiplexing (OFDM) reduces receiver complexity in wireless broadband systems. The use of MIMO technology in combination with OFDM therefore seems an attractive solution for future wireless communication. In OFDM, one user is dedicated to a particular time slot to access all the sub carriers and all carriers are transmitted in parallel with same amplitude i.e. in OFDM, the user device can transmit using the entire carrier at a time. Orthogonal Frequency Division Multiplexing is a multicarrier modulation technique in which FFT space is divided into orthogonal sub-carriers. In this technique, the whole transmission bandwidth is split into many closely spaced narrow sub-channels until overlapped and are transmitted in parallel. Each sub-channel is narrow enough so that it experiences a flat fading although the overall radio propagation environment is frequency selective.

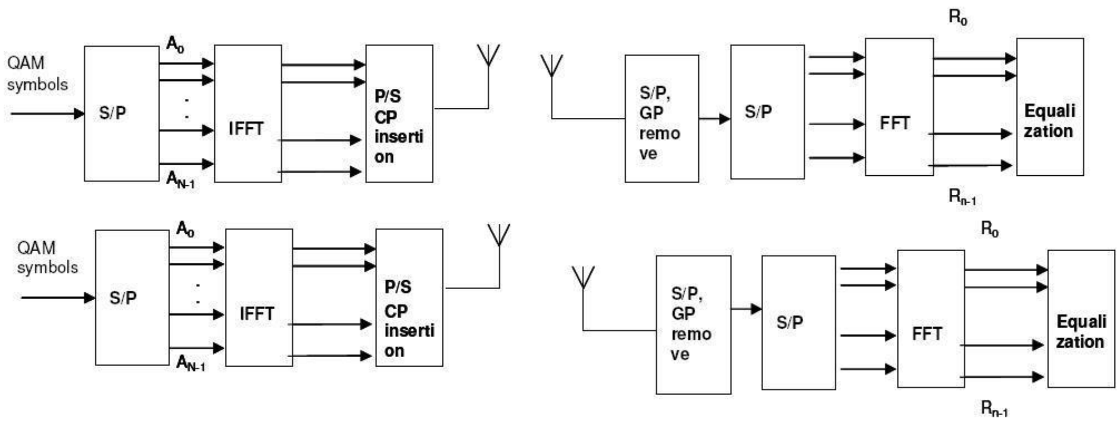

Fig.1. Block Diagram of MIMO- OFDM System

In MIMO wireless communication multipath fading is usual phenomenon that causes ISI from the transmitted signal. To remove ISI [6] from transmitted signal, BER reduction is compulsory. In this paper different equalization approach called Zero Forcing (ZF), Minimum Mean Square Error (MMSE), and Maximal Ratio

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Combining (MRC) equalizers has been discussed. The channel is a Rayleigh fading channel and the modulation as BPSK has been taken.

III. CHANNEL DESCRIPTION

3.1 Rayleigh Channel

The effects of multipath embrace constructive and destructive interference, and phase shifting of the signal. This causes Rayleigh fading. There is no line of sight (NLOS) path means no direct path between transmitter and receiver in Rayleigh fading channel [9]. The received signal can be simplified to:

$$R(n) = \sum h(n, \tau)\, S(n - m) + w(n) \quad (1)$$

Where w (n) is AWGN noise with zero mean and unit variance, $h(n)$ is channel impulse response. The Rayleigh distribution [11] is basically the magnitude of the sum of two equal independent orthogonal Gaussian random variables and the probability density function given by:

$$P(Z) = \frac{z}{\sigma^2} e^{\frac{-z^2}{2\sigma^2}} \qquad z \geq 0 \quad (2)$$

Where $\sigma 2$ is the time-average power of the received signal and eq. (1) is called a Rayleigh random variable.

IV. SIGNAL DETECTION OF MIMO - OFDM SYSTEM

MIMO-OFDM detection methods consist of linear and Non-linear detection methods. A linear is a filter that can undo the channel effect. It has no feedback path to adopt the equalizer and Non-linear equalizer has feedback to change the subsequent outputs of the equalizer.

4.1 Zero Forcing Equalizer

Zero Forcing Equalizer is a linear equalization algorithm which inverts the frequency response of the channel. The name Zero Forcing corresponds to bringing down the ISI to zero in a noise free case The Zero-Forcing Equalizer applies the inverse of the channel to the received signal, to restore the signal before the channel. For a channel with frequency response F (f) the zero forcing equalizer C (f) is constructed such that C (f) = 1 / F (f). Thus the combination of channel and equalizer gives a flat frequency response and linear phase F (f) C (f) = 1.If the channel response for a particular channel is H(s) then the input signal is multiplied by the reciprocal of this. This is intended to remove the effect of channel from the received signal, in particular the Inter symbol Interference (ISI). For simplicity let us consider a 2x2 MIMO channel, the channel is modelled as,

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} H_{1,1} & H_{1,2} \\ H_{2,1} & H_{2,2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (3)$$

Equivalently,

$$y = H x + n \quad (4)$$

To solve for x in equation (4), we need to find a matrix W which satisfies WH = I. The Zero Forcing (ZF) detector for meeting this constraint is given by,

$$W = [H^H \; H]^{-1} \; H^H \quad (5)$$

Where W- Equalization Matrix and H- Channel Matrix. Zero forcing equalizer tries to null out the interfering terms when performing the equalization.

4.2 MMSE Equalizer

A Minimum Mean Square Error (MMSE) estimator is a method in which it minimizes the mean square error (MSE), which is a common measure of estimator quality. 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. The MMSE estimator is then defined as the estimator achieving minimal MSE. In these cases, one possibility is to seek the technique minimizing the MSE within a particular class, such as the class of linear estimators. The linear MMSE estimator is the estimator achieving minimum MSE among all estimators of the form $AY + b$. If the measurement Y is a random vector, A is a matrix and b is a vector. Let x be an unknown random variable, and let y be a known random variable. An estimator x^ (y) is any function of the measurement y, and its mean square error is given by

$$\text{MMSE} = E\,\{[X^{\wedge} X^{2}]\} \tag{6}$$

Where, the expectation is taken over x and y.

The MMSE estimator is then defined as the estimator achieving minimal MSE. In many cases, it is not possible to determine a closed form for the MMSE estimator. In these cases, one possibility is to seek the technique minimizing the MSE within a particular class, such as the class of linear estimators. The linear MMSE estimator is the estimator achieving minimum MSE among all estimators of the form AY + b. If the measurement Y is a random vector, A is a matrix and b is a vector (6).

4.3 Maximal-ratio combining

Various techniques are known to combine the signals from multiple diversity branches. In Maximum Ratio combining each signal branch is multiplied by a weight factor that is proportional to the signal amplitude. That is, branches with strong signal are further amplified, while weak signals are attenuated. In telecommunications, maximal-ratio combining is a method of diversity combining in which the signals from each channel are added together and the gain of each channel is made proportional to the RMS value of signal and inversely proportional to the mean square noise level in that channel. Different proportionality constants are used for each channel. It is also known as ratio-squared combining and pre detection combining. Maximal-ratio-combining is the optimum combiner for independent AWGN channels. Matthew R. McKay et.al. [3] Proposed multiple-input multiple-output (MIMO) transmit beam forming systems with maximum ratio combining (MRC) receivers. He also proved that MIMO-MRC achieves the maximum available spatial diversity order, spatial correlation.

The idea to boost the strong signal components and attenuate the weak signal components, as performed in MRC diversity, is exactly the same as the type of filtering and signal weighting used in matched filter. MIMO antenna systems can improve the performance and the bandwidth efficiency of a wireless communication system greatly, but the existence of the inter symbol interference (ISI) strongly limits its performance over frequency selective (FS) channels. The bit error rate (BER) of the MRC scheme is derived for binary phase-shift keying (BPSK) in flat Rayleigh fading channels. The BER analysis demonstrates that the MRC scheme can achieve a full diversity order at high signal-to-noise ratios (SNRs), as if all the transmit antennas were used. The average SNR gain of the MRC is quantified and compared with those of encoded receiver MRC and space-time block codes (STBCs). The analytical results are verified by simulation. It is shown that the MRC scheme outperforms some more complex space-time codes of the same spectral efficiency. The cost of the improved performance is a low-rate feedback channel. We also show that channel estimation errors based on pilot symbols have no impact on the diversity order over quasi-static fading channels.

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4.4. BER vs. SNR

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, often expressed as a percentage or 10 to the negative power. The definition of BER can be translated into a simple formula:

BER = number of error bits / total number of bits sent

Noise is the main enemy of BER performance. Quantization errors also reduce BER performance, through unclear reconstruction of the digital waveform. The precision of the modulation/demodulation process and the effects of filtering on signal and noise bandwidth also influence quantization errors.

V. SIMULATION PARAMETERS AND RESULTS

5.1 PARAMETERS

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has 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 [10] 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.

Table 5.1 Simulation parameters

PARAMETERS	**VALUES**
Modulation	BPSK
Channel Model	Rayleigh
Noise Model	AWGN
FFT and IFFT point	64
Sub-carrier number	52
no. of transmit antenna	2
No. of receiver antenna	2

5.2 RESULTS

The BER analysis of MIMO – OFDM system using ZF, MMSE, and MRC equalizer simulation results are performed by MATLAB software are shown as follow:

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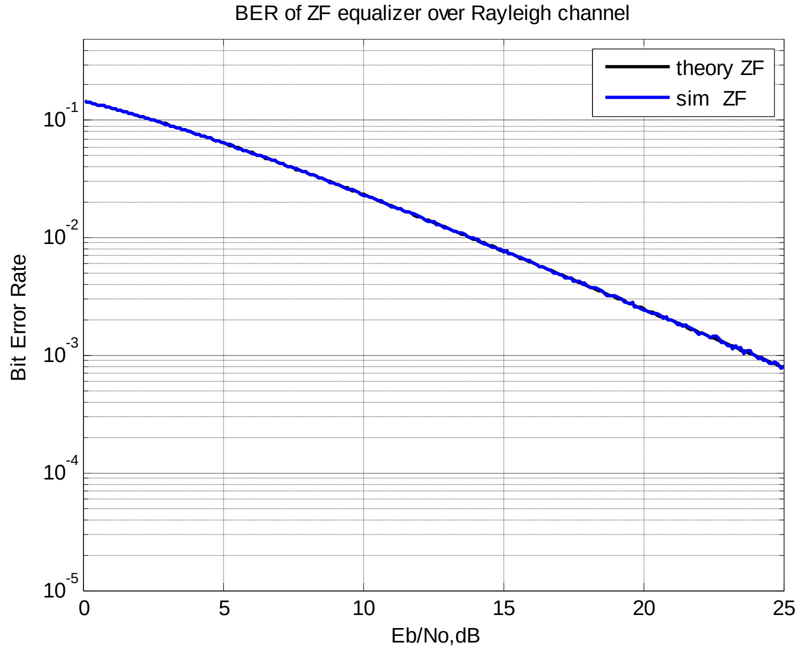

Fig.5..1 BER analysis of MIMO- OFDM system using ZF equalizer.

Figure 5..1 shows the graph of MIMO-OFDM for ZF equalizer respectively. Simulation results represents that the BER values. For BPSK at the BER value of 10^{-2} we get Eb/No value of 12.85 dB for Rayleigh channel.

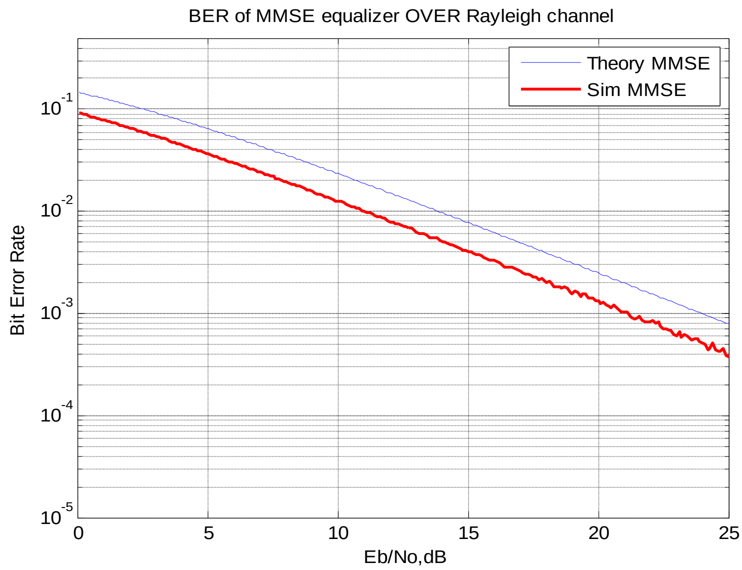

Fig.5.2 BER analysis of MIMO-OFDM system using MMSE equalizer.

In Fig.5.2 results show that BPSK is performing best in all the modulation because of fewer bits per symbols. For BPSK at the BER value of 10^{-2} we get Eb/No value of 13.6 dB for Rayleigh channel in above graph. It represents the channel behaviour for MMSE equalizer.

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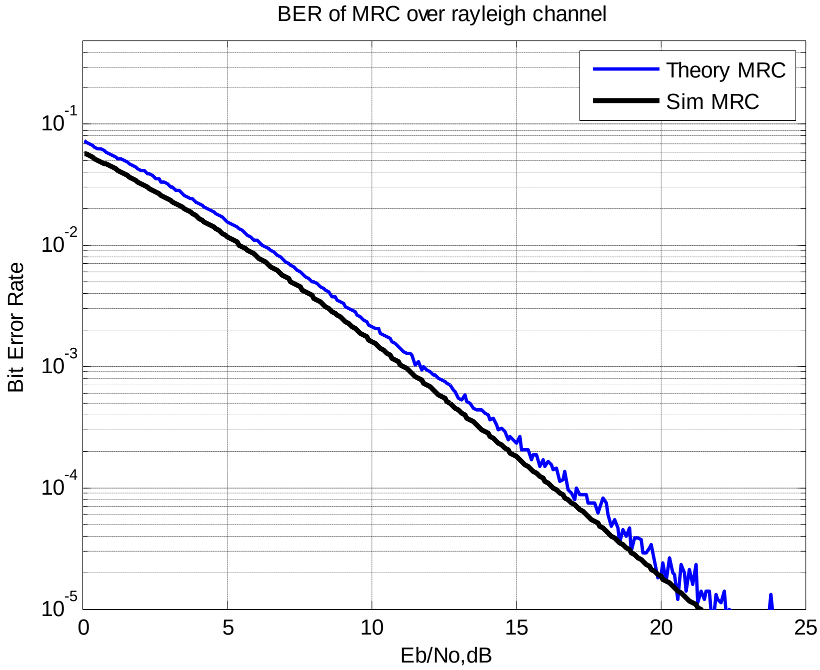

Fig.5.3. BER analysis of MIMO-OFDM system using MRC equalizer.

In Fig.5.3 results show that BPSK is performing best in all the modulation because of less bit per symbols. For BPSK at the BER value of 10^{-4} we get Eb/No value of 16dB for Rayleigh channel in above graph. It represents the channel behaviour for MRC equalizer.

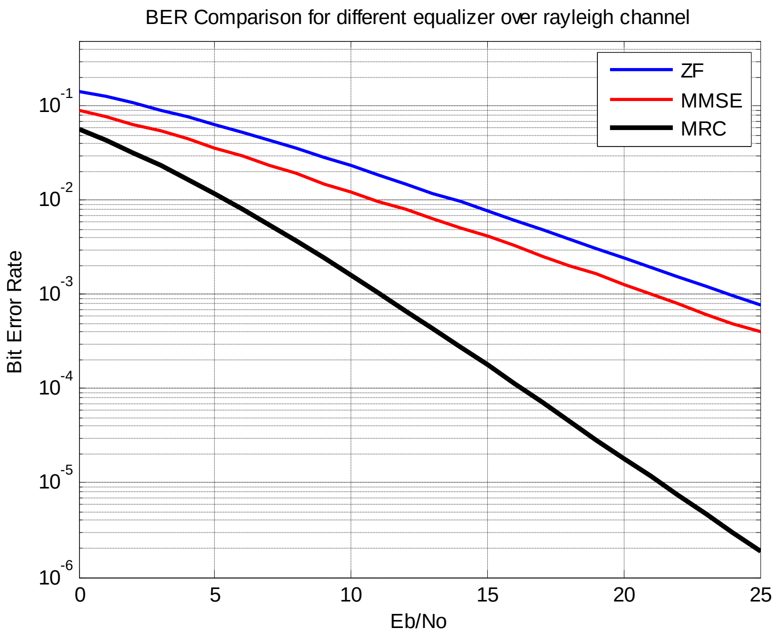

Fig.5.4 Comparison of BER analysis using different equalizer.

Performance of MRC equalizers over ZF and MMSE has been described by the Fig.5.4 .From this graphical analysis, it is evident that BER tends to decrease dramatically for MRC equalizer compared to ZF and MMSE equalizers.

VI. CONCLUSION

In this paper, the comparative study of optimal BER in MIMO –OFDM system for BPSK modulation with different equalizers such as ZF, MMSE, and MRC is presented. The performance analysis is carried out for 2x2 configurations under Rayleigh fading channel. The BER performance of the system using MRC equalizer is better than the equalizers such as ZF and MMSE.

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