Analysis of Bit Error Rate and Signal to Noise Ratio for MIMO System using OFDM

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Abstract- The major research in wireless communication is the design multiple antenna. MIMO Technology is used to enhance the system performance in terms of bit error rate and signal to noise ratio. The effect of Fading and Interference can be minimized to increase the performance of a MIMO system. MIMO system uses Multiple Transmit and Receive antennas which exhibit the multipath propagation in scattering environment. The matrix channel plays a vital role in the enhancement performance of a MIMO system since the modulation techniques, data rate, power allocation and antenna weights, size are dependent on the channel capacity. In order to reduce the complexity of MIMO system, detection techniques are presented but the complexity of algorithms are greater than that of equalizer based techniques such as Zero Forcing (ZF), Minimum mean square Error techniques (MMST). In this work BER and signal to noise ratio analysis are presented using different equalizers and then optimum equalization technique is implemented.

Keywords – *Minimum mean square Error Technique (MMST), Multiple Input Multiple Output Systems (MIMO), Rayleigh Channels, Bit Error Rate (BER), Binary Phase Shift Keying (BPSK), Fast Fading, Adaptive Equalization.*

I. INTRODUCTION

Wireless communications has played major role with the most significant and important development in a modern society. Wireless communication systems need high data rates and high transmission reliability in order to meet the 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 effect. In present day's communication, OFDM [1] is widely used and one of the most suitable modulation techniques. It is beneficial in many areas of wireless as well as optical communication in terms of high spectral efficiency, robustness, low complexity, frequency selective fading, and ease of implementation with IFFT/FFT and equalization techniques. Recently the use of OFDM in a MIMO [2] transceiver system, named MIMO OFDM [3][6] system; which is used to increase the gain and system capacity. MIMO as the name indicates; used multiple inputs at the transmitter and multiple outputs at the receiver 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. Thus OFDM is most suitable techniques since OFDM able to require more antennas since it simplify equalization techniques in MIMO systems.

Usually in OFDM, fading effect is considered as a problem in wireless network but MIMO channels uses the fading to increase the system capacity of the entire wireless 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 presented as the infrastructure for the next generation.

II. CHANNEL DESCRIPTION

In this paper three channels are used in our paper: AWGN, Rayleigh and Rician fading channels.

AWGN Channel: Additive white Gaussian noise (AWGN) channel is commonly used for analyzing modulation techniques. In MIMO system, the AWGN channel adds a white Gaussian noise to the signal. It implies that the channel's amplitude frequency response is flat (thus the unlimited or infinite bandwidth) and phase frequency response is linear for all frequencies so that modulated signals go through it without any change in amplitude and phase distortion. Fading does not exist for this channel. The transmitted signal gets distorted

.AWGN channel is widely used for analysis purpose only.

The mathematical expression in receiving signal is:

$$r(t) = s(t) + n(t)$$

This passes through the AWGN channel where s(t) is transmitted signal and n(t) is background noise or additive white Gaussian noise

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

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

Where w(n) is AWGN noise with zero mean and unit variance, h(n) is channel impulse response i.e.

Where α (n) and (n) are attenuation and phase shift for nth path. If the coherence bandwidth of the channel is larger than signal bandwidth, the channel is called flat; otherwise it is frequency-selective fading channel. In this paper, MIMO OFDM is simulated under frequency-selective fading channel. The Rayleigh distribution is basically the magnitude of the sum of two equal independent orthogonal Gaussian random variables and the probability density.

Rician Channel: There is a dominant Line-of-Sight (LOS) path between the transmitter and receiver; the complex Gaussian distributed fading coefficient should be modeled with a non-zero mean, gives rise to the Rician fading. It also exhibits, Rayleigh fading with strong line of sight (LOS). The Rician distribution is usually characterized by the Rice factor,

$$K = \frac{m}{2\sigma^2},$$

This shows the relative strength of the direct LOS path component of the fading coefficient.

MMSE always performs better than the ZF equalizer and is Complication of implementation.

III. SIGNAL DETECTION TECHNIQUES FOR MIMO-OFDM SYSTEM

MIMO-OFDM detection techniques consist linear and nonlinear detection methods. This work presents linear detection methods.

Zero Forcing Equalizer: This shows a linear equalization algorithm used in wireless communication systems, which inverts the frequency response of the channel at the receiver to restore the signal before the channel. ZF algorithms considers the signal at the 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 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:

$R(k) = H(k)\,X(k) + n(k)$

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 (k) and output signal (k) as in exploits that this is a SNR formula in terms of diversity:

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:

$X_{ZF} = H^{-1}R = x + H^{-1}n$

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

Minimum Mean Square Error (MMSE)

Equalizer: A MMSE estimator is a method in which it minimizes the mean square error (MSE), which is a universal measure of estimator quality. The most important characteristic of MMSE equalizer is that it does not usually eliminate ISI totally but instead of minimizes the total power of the noise and ISI components in the output. Let us assume that x be an unknown random variable and R be a known random variable, then

$$R = HX + n.$$

An estimator x (R) is any function of the measurement y, and its mean square error is given by

$$MSE = E\left\{(\hat{X} - X)^2\right\}$$

IV BIT ERROR RATE (BER)

In digital transmission, the no. of bit errors is the number of receiving bits of a signal data over a communication channel that has been changed because of noise, noise, distortion, interference or bit synchronization redundancy. 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 is given by-

$$BER = No.\ of\ \ errors / Total\ \ no.\ of\ \ Bits\ sent$$

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

V. SIGNAL TO NOISE RATIO (SNR)

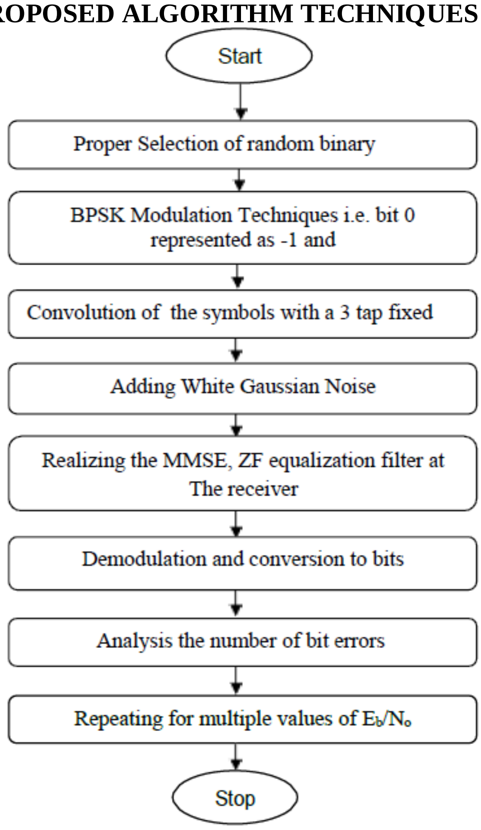
The SNR is the ratio of the received signal power over the noise power in the frequency range of the process. SNR is inversely related to BER, that is high BER causes low SNR. High BER causes an increase in packet loss, enhance in delay and decrease throughput. SNR is an indicator usually measures the clarity of the signal in a circuit or a wired/wireless transmission channel and measure in decibel (dB). The SNR is the ratio between the wanted signal and the unwanted background noise.

$$SNR = \frac{Signal}{P_{Noise}}$$

SNR formula in terms of diversity:

$$BER \propto \frac{1}{SNR^{d}}$$

VI. PROPOSED ALGORITHM TECHNIQUES



VII. SIMULATION RESULTS

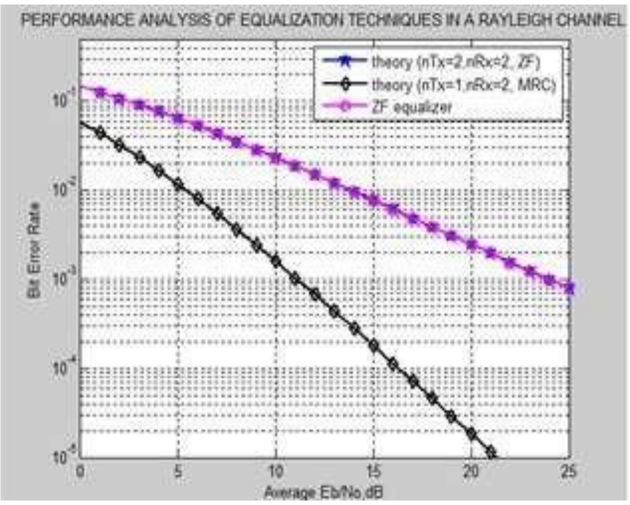


Fig. 1 BER for 2X2 MIMO Channel with ZF Equalizer

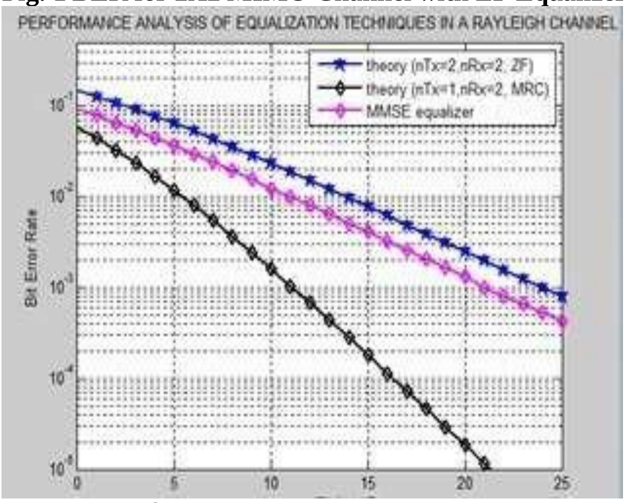


Fig. 2 BER for 2X2 MIMO with MMSE Equalization for BPSK in Rayleigh Channel

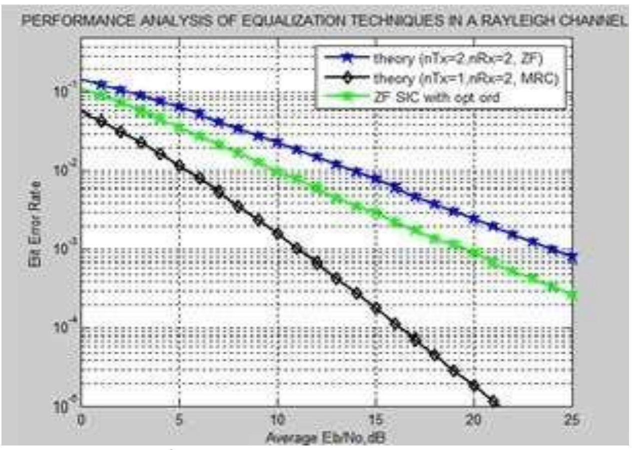


Fig. 3 BER for BPSK in 2X2 MIMO Channel with Zero Forcing Successive Interference Cancellation Equalization

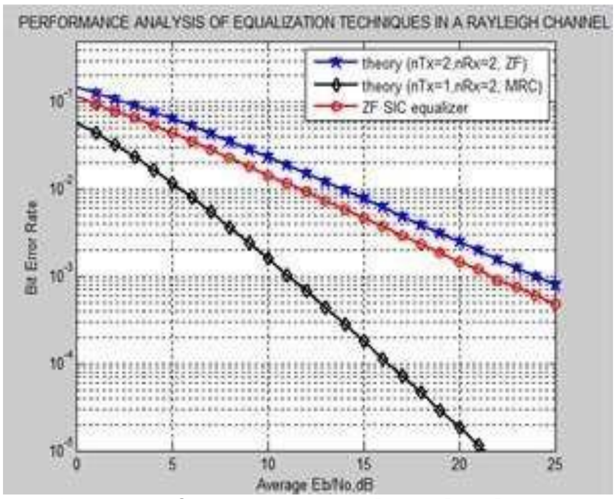


Fig. 4 BER for 2X2 MIMO Channel with MMSE Equalization with Optimal Ordering

VIII SIMULATION RESULTS

The simulation MMSE equalizer results in around 3.2-3.4 dB of improvement when compared with Zero Forcing equalizer. Zero Forcing with Successive interference cancellation (ZF-SIC) process compared to Zero Forcing equalization gives in around 2.2-2.6 dB of improvement for BER. ZF-SIC with optimal ordering compared to ZF-SIC, results in around 2.0 dB of improvement for BER.

IX CONCLUSION

Minimum Mean Square Error Equalization techniques can use for ISI even in mobile fading channel with high efficiency. Zero Forcing equalizer gives better performance only in theoretically when noise is zero. Its performance even worse in mobile fading environments. Minimum Mean Square Error equalizer uses LMS to compensate ISI.

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