A New BER and SNR Calculations for MIMO System

Allanki Sanyasi Rao, S. Srinivas

Abstract- Multiple Antenna Communication has become one of the major focuses in wireless communication research. MIMO Technology is used to enhance the system capacity. The effect of Fading and Interference can be combated to increase the capacity of a link. MIMO system uses Multiple Transmit and Multiple Receive antennas which exploit the multipath propagation in rich scattering environment. The matrix channel plays a pivotal role in the throughput of a MIMO link since the modulation, data rate, power allocation and antenna weights are dependent on the channel gain. Alternative in order to reduce the complexity of MIMO system, detection techniques are proposed but the complexity of algorithmic schemes are in higher than that of equalizer based techniques such as Zero Forcing (ZF), Minimum mean square Error Methods (MMSE) and Maximal Ratio Combining (MRC). In this paper BER analysis is presented using different equalizers and then optimum equalization method is suggested.

Keywords – Minimum mean square Error Methods (MMSE), Multiple Input Multiple Output Systems (MIMO), Rayleigh Channels, Bit Error Rate (BER), Zero Forcing (ZF), Maximal Ratio Combining (MRC), Successive Interference Cancellation (SIC), Binary Phase Shift Keying (BPSK), Fast Fading, Adaptive Equalization.

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 widespread 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.

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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. CHANNEL DESCRIPTION

We choose three most widely used channels in our paper: AWGN, Rayleigh and Rician fading channels.

AWGN Channel: Additive white Gaussian noise (AWGN) channel is a basic or commonly used channel model for analyzing modulation schemes. In this model, the AWGN channel adds a white Gaussian noise to the signal that passes through it. This implies that the channel's amplitude frequency response is flat (thus with unlimited or infinite bandwidth) and phase frequency response is linear for all frequencies so that modulated signals go through it without any amplitude loss and phase distortion. Fading does not exist for this channel. The transmitted signal gets distorted .AWGN channel is a standard channel used for analysis purpose only.

The mathematical expression in receiving signal is:

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

that 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 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. 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 function (pdf) given by:

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

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where $\sigma 2$ is the time-average power of the received signal is called a Rayleigh random variable.

Rician Channel: In environments where there is a dominant Line-of-Sight (LOS) path between the transmitter and the receiver, the complex Gaussian distributed fading coefficient should be modeled with a non-zero mean, giving rise to the Rician fading. Or also say that, Rayleigh fading with strong line of sight (LOS) content is said to have a Rician distribution, or to be Rician fading. The Rician distribution is usually characterized by the Rice factor,

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

shows the relative strength of the direct LOS path component of the fading coefficient. This model reduces to Rayleigh fading when κ = 0.

III. 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.

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 . 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:

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

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 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:

$$XZF = H{-}1R = x + H{-}1\, n$$

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

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

where the expectation is taken over both X and R. The MMSE always performs better than the ZF equalizer and is of the same complications of implementation.

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:

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

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.

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

SNR formula in terms of diversity:

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

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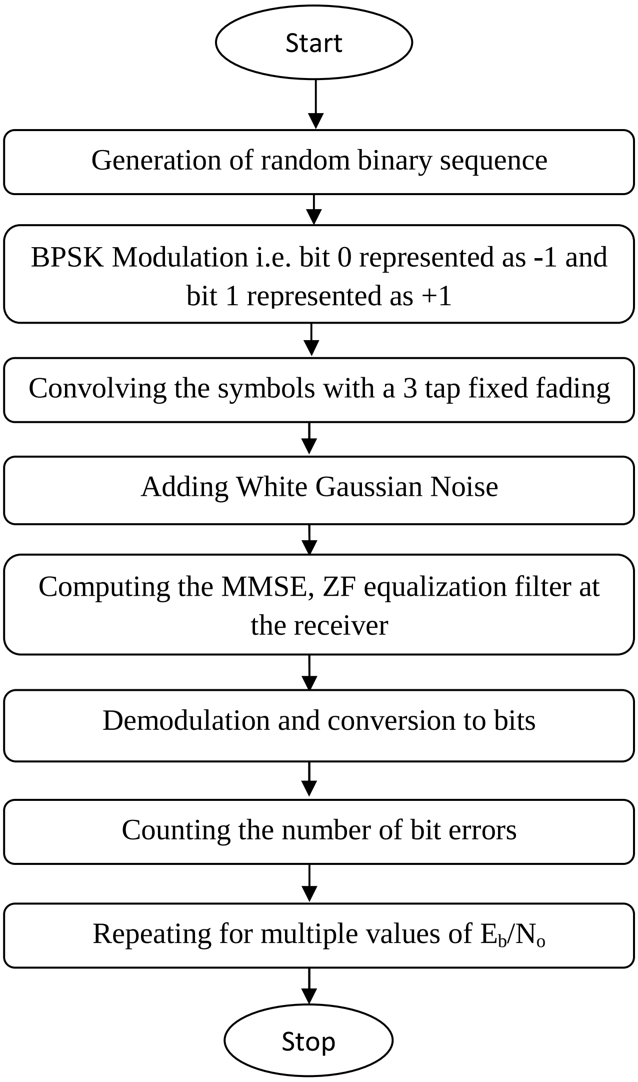
VI. PROPOSED ALGORITHM



VII. SIMULATION RESULTS

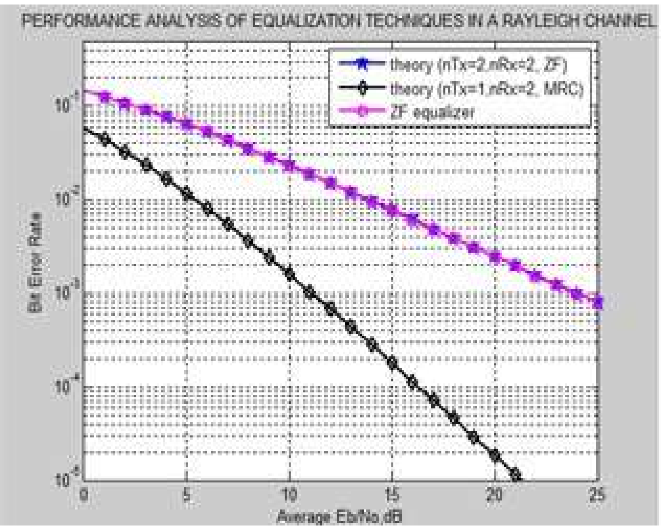


Fig. 1 BER Plot for 2X2 MIMO Channel with ZF Equalizer

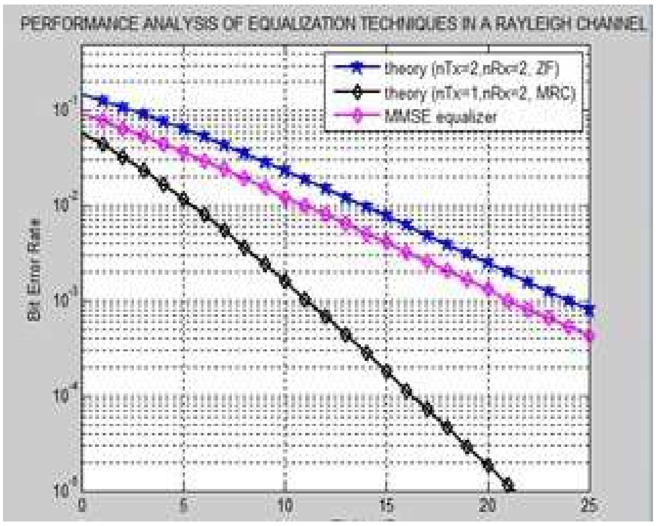


Fig. 2 ER Plot for 2X2 MIMO with MMSE Equalization for BPSK in Rayleigh Channel

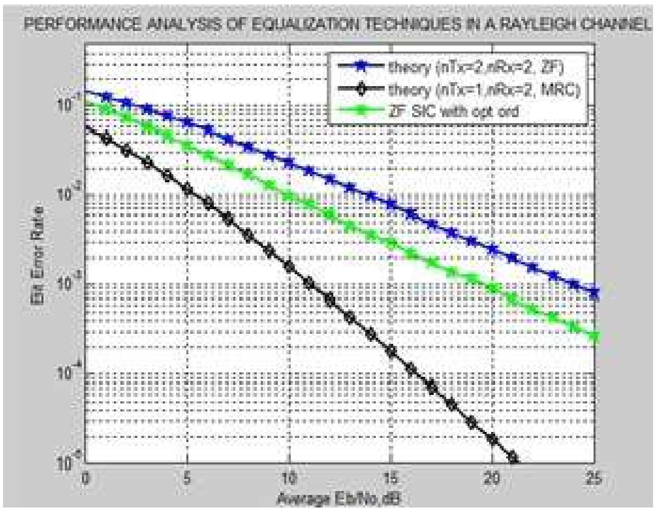


Fig. 3 BER Plot for BPSK in 2X2 MIMO Channel with Zero Forcing Successive Interference Cancellation Equalization

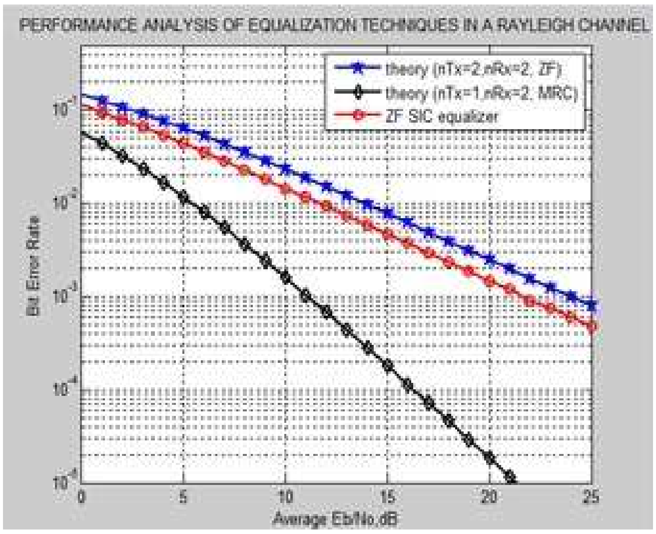


Fig. 4 BER Plot for 2X2 MIMO Channel with MMSE – SIC Equalization with Optimal Ordering

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VIII. CONCLUSION

Equalization techniques can combat for ISI even in mobile fading channel with high efficiency. Zero Forcing equalizer gives better performance only in theoretical assumptions that too when noise is zero. Its performance even worse in mobile fading environments. MMSE equalizer uses LMS to compensate ISI. The MMSE equalizer results in around 3dB 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 2.2dB of improvement for BER. ZF-SIC with optimal ordering compared to ZF-SIC, results in around 2dB of improvement for BER.

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