BER comparison of MIMO OFDM system using equalization techniques under various fading channels

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ABSTRACT:

MIMO-OFDM (Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing) system is one of the most promising technique used in wireless environment nowadays which boost the data transmission rate efficiently with improved system coverage and enhanced reliability. In MIMO techniques, inter-symbol interference is present between the symbols. Equalization is a well-known technique for combating inter-symbol interference. The multicarrier modulation gives more advantages in inter symbol interference reduction, high data rate, higher reliability, and better performance in multipath fading. The performance is calculated in terms of Bit Error Rate (BER) versus the Signal to Noise Ratio (SNR). In this paper, the BER performance of the MIMO-OFDM system with three equalizers (ZF, ML, MMSE) for different modulation (BPSK, QPSK, 8-QAM) techniques under various multipath fading channels (AWGN (Additive White Gaussian Noise), Rayleigh and Rician channel) are implemented and the well-suited techniques have been predicted.

Key words: MIMO-OFDM, Equalizer, Modulation techniques, Multipath fading channels

1. INTRODUCTION

In the recent years wireless communications can be regarded as the fastest growing and important development areas in the communication field. In order to meet the vastly increasing demand for high-data rate multimedia applications [1],wireless communication systems need stupendous high data rates with high transmission reliability. Existing wireless technologies are very sensitive to fading so it cannot efficiently support high-data rates. In current scenario communication systems, OFDM is one of the most widespread modulation techniques. It is useful in robustness towards ISI, high spectral efficiency, low complexity, frequency selective fading, FFT and IFFT [3] implementation and equalization techniques. At present, there have been a interest to combine OFDM in combination with a MIMO transceiver system, these system named MIMO-OFDM system; which is used to increase the diversity gain and throughput. MIMO use multiple inputs at the transmitter and multiple outputs at the receiver end which is more advantageous than a single transceiver SISO (Single input Single output) system [4]. The combination of MIMO-OFDM is an important techniquebecause OFDM is capable to sustain more antennas and it simplifies equalization in MIMO systems. Usually in OFDM, fading is a major consideration [1] but MIMO channels uses the fading to increase the capacity of the entire communication network. MIMO is a frequency-selective method whereas OFDM converts it into a set of parallel frequency-flat sub channels.

Due to multi-path fading, there is a distortion of a signal, where one symbols interference with subsequent symbols, is known as Inter-symbol interference (ISI). Therefore, Equalization ideas to remove inter-symbol interference (ISI) can be used. A linear equalizer mainly used to separate the symbols without enhancing the noise. The equalization methods that we consider in the design of MIMO receiver are ZF, ML and MMSE [2].

2. SYSTEM MODEL

2.1. MIMO

Multi-antenna systems are classified into three main categories. Multiple antennas at the transmitter side and single antenna at receiver side, namely MISO. Transmitter uses single antenna whereas receiver side multiple antennas for realizing different (frequency, space) diversity schemes, namely SIMO [3]. The system with multiple transmitter and receiver antennas used for spatial multiplexing referred as MIMO. In radio communications MIMO termed as multiple antennas both on transmitter and receiver side of a specific radio link. In spatial multiplexing where different data symbols are transmitted on the radio link by different antennas on the same frequency within the same time interval. To ensure the spatial multiplexing operation consider a multipath propagation, becausechannel capacity performance is better for MIMO in scattered multipath than LOS (line of sight) environment [8]. Figure 1 illustrates the MIMO block diagram where M transmitters and N receivers are used [3].

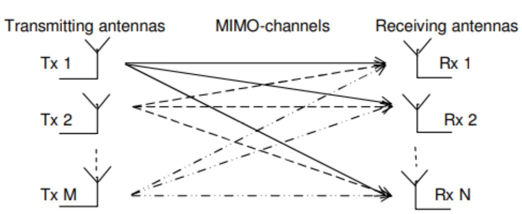

Figure 1 Block diagram of a MIMO system - M transmitters and N receivers

2.2. OFDM (ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING)

OFDM is a digital multicarrier modulation technique. In order to achieve high spectral efficiency, a set of sub-carriers are used that are orthogonal to each other [5]. To increase the spectral efficiency, this system allows the spectra of sub-carrier to overlapping where the sub-carrier signals are orthogonal to each other. The orthogonality should be maintained in order to avoid ISI. Due to multipath interference, the OFDM system is robustness to fading.

The OFDM system block diagram is shown in figure 2 [3]. It uses an overlapping signal to divide the frequency selective channel into a number of narrow band flat fading channel and instead of sending sequential data on a single carrier at a high symbol rate, the FFT encodes the block of symbol. The input data is FEC coded with convolution code andthe coded bit stream is interleaved to obtain diversity gain [3].

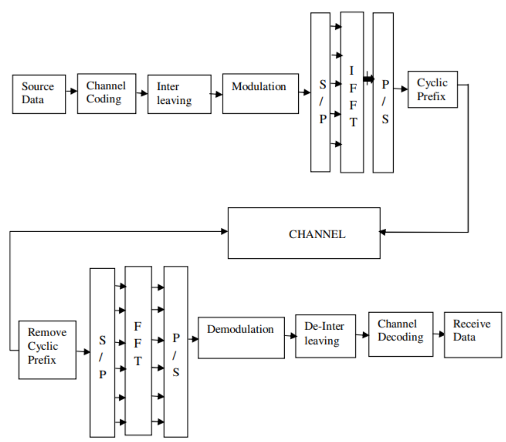

Figure 2 Block diagram of OFDM system

3. MODULATIONS TECHNIQUES

Modulation is needed in communication system to transmit digital information as the analog. Demodulation is the inverse of modulation which is used to recover the digital information by the receiver. The carrier signal of amplitude, frequency or phase is changed in modulation as analog form. In data transmission there are many digital modulation techniques. The amplitude and phase modulation only allowed in OFDM. In coherent modulation received carrier signal is phase locked at the transmitter. The digital modulation methods available are Binary phase shift keying (BPSK), Quadrature phase shift keying (QPSK), M-ary phase shift keying (16PSK), M- Quadrature amplitude modulation (M-QAM)and Pulse amplitude modulation (PAM) [7].

4. FADING CHANNEL

Due to multipath propagation fading makes the system unstable. This method describes rapid fluctuations of the phase and amplitude of the signal. To traverse a transmitted signal, the reflectors present around a transmitter and receiver forms number of finite paths. The multiple number of transmitted signal traversing at a different path is seen at receiver. Attenuation, delay or phase shift difference is experienced in every signal received [2].

Small-scale fading is interference ofn number of transmitted signals (multipath signal) arrived with small time variationto the receiver. It provides a combined signal with receiver antenna and filter. The received signal mostly changes their amplitude or phase in short time at short distance so large-scale path loss is less affected.

Small-scale fading effects are considered majorly in multipath.

•Signal strength changes at small time period

•Doppler shift variance leads to frequency modulation frequently at different multipath signals

•Multipath propagation delays due totime dispersion

No single line of sight fading is present in urban areas, because mobile antenna’s heightisplaced below to the surrounding buildingheight. The mobile receives a signal with randomly distributed amplitude or phased large number of waves. The received mobile signal is faded because at received end multipath components arevectored combined. Relative motioneffect between mobile and BS, each multipath signal experience an evident frequency shift called Doppler shift which is directly proportional to mobile velocity and motion direction to the received signal direction.Inter-symbolinterference (ISI) is independent fading occurs at different frequencies when the coherence bandwidth is less than the signal bandwidth.

AWGN, Rayleigh and Rician fading channels are used widespread.

4.1. AWGN Channel: Mostly to analyse the modulation method Additive White Gaussian Noise (AWGN) channel is preferred. In this method, a white gaussian noise is added to the signal passing through the AWGN channel. The transmitted signal gets distorted by AWGN method rather than fading because modulated signal amplitude and phase frequency are without loss and linear.

AWGN channel is widely used for analysing [5].

The mathematical equation for signal passing through AWGN channel is described as,

$$r(t) = s(t) + n(t) \qquad (1)$$

where, s(t) denotes transmitted signal, n(t) denotes to additive white gaussian noise.

4.2. Rayleigh Channel: Rayleigh fading is occurred due to multipath reception i.e., constructive and destructive interference. In In Rayleigh fading channel, direct path is not presented (No LOS) between the transmitter and receiver [3]. The Rayleigh channel is described as,

$$R(n) = \sum h(n, \tau)S(n-m) + w(n) \quad (2)$$

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

$$h(n) = \sum \alpha(n)\, e^{-j\theta(n)} \quad (3)$$

where α (n) and $\theta(n)$ are attenuation and phase shift for n^{th} path.

The flat channel is described as when signal bandwidth is less than channel coherence bandwidth. If coherence bandwidth is less than signal bandwidth then the channel is frequency-selective fading channel [1].

The Rayleigh distribution is basically the magnitude of the sum of two orthogonal Gaussian random variables and the probability distribution function (pdf) given by:

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

where,σ^2 is the time-average power of the received signal known as Rayleigh random variable.

4.3. Rician Channel: With a non-zero mean the complex gaussian distributed fading coefficient provides a Rician fading. Fading occurs when the transmitter and receiver is with strong line of sight [1]. The Rician distribution is usually characterized by the Rice factor κ,

$$\kappa = m/2\sigma^2 \quad (4)$$

which shows the relative strength of the direct LOS path component of the fading coefficient. When κ = 0 this model reduces to Rayleigh fading and as κ = ∞ the fading becomes deterministic grow towards an AWGN channel.

5. EQUALIZERS

Linear detection isused in this MIMO-OFDM method.

5.1. Zero forcing Equalizer: An ISI channel is finite-impulse response (FIR) filter with noise, an inverse filter is used to compensate channel response function. Zero forcing equalizer is used in communication systems as linear equalization method to restore the signal by inverse channel to invert the frequency response at receiver side. By considering each transmitting antenna output (frequency response is one) as a desired signal and ignore zero response output. In absence of noise, it is the best method to avoid ISI. It doesn't consider noise but it enhanced in interference elimination [1].

$$R(k) = H(k)X(k) + n(k) \quad (5)$$

where, $R(k)$ is output signal, $X(k)$ is input signal,$n(k)$ denotesnoise.

5.2. Maximum Likelihood Equaliser: Maximum-Likelihood equalizers provide optimal equalization of time variations in the propagation channel characteristics. To extract the desired signal in noisy environment the ML or Maximum Likelihood equalizer technique is used. To find the term m such that J can be minimized [3].

$$J= |y - H_m|^2 \quad (6)$$

The relation can be again expressed in the terms of received signal, channel parameter and m.

$$J_{+1,+1} = \left\| \begin{bmatrix} y1 \\ y2 \end{bmatrix} - \begin{bmatrix} h1,1 & h1,2 \\ h2,1 & h2,2 \end{bmatrix} \begin{bmatrix} m1 \\ m2 \end{bmatrix} \right\|^2$$

5.3. MINIMUM MEAN SQUARE ERROR (MMSE): To minimize the mean square error universal quality method MMSE is performed. The ISI is not eliminated at the output in this method but compensate noise and interference components [1]. Assume x as an unknown random variable and R be a known random variable,

$$R = HX + n \quad (7)$$

its mean square error is given by

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

where the expectation is taken over both X and R. The MMSE have less implementation complexity and better performance than the ZF equalizer.

6. BIT ERROR RATE (BER):

In digital transmission systems, the number 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 specified 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 [3]:

BER = number of errors / total number of bits sent

Noise is the major factor that affects BER performance. Even if reconstructed digital waveform is affected by quantization error, then degrades the performance.

7. BER PERFORMANCE OF BPSK, QAM, QPSK UNDER VARIOUS EQUALIZERS:

The BER performance is analysed using different modulation techniques such as BPSK, QAM, QPSK with different equalizer ZF, ML and MMSE under various fading channel. The results are shown for three different equalizers for modulation techniques under AWGN channels are shown below as figure 3illustrates BER performance for BPSK, figure 4 illustrates 8-QAM performance and figure 5 illustrates QPSK performance.

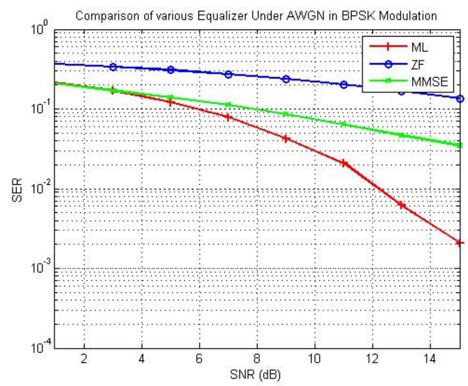

Figure 3 BER performance of BPSK modulation

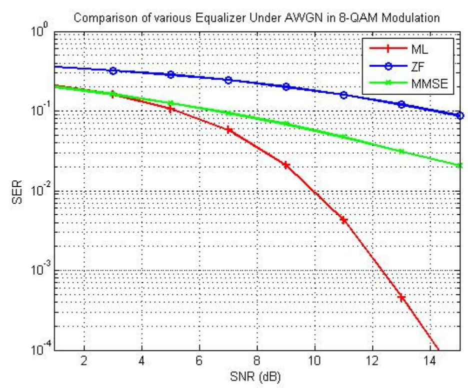

Figure 4 BER performance of 8-QAM modulation

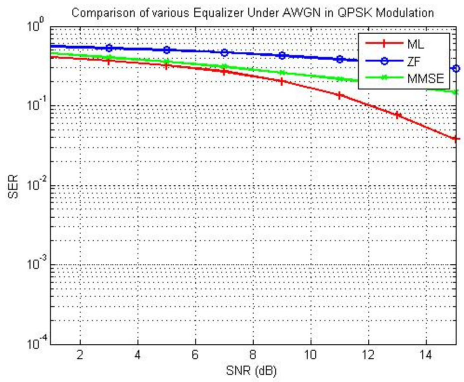

Figure 5 BER performance of QPSK modulation

8. CONCLUSION:

The BER performance of the MIMO-OFDM system with three equalizers (ZF, ML, MMSE) for different modulation (BPSK, QPSK, 8-QAM) techniques under various multipath fading channels (AWGN (Additive White Gaussian Noise), Rayleigh and Rician channel) are implemented and the well-suited techniques are identified. The AWGN channel is suited for different modulation methods as well as MMSE equalizer results best BER and in future various modulation techniques will be proposed with three different equalizers for analysing the performance.

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