Performance Analysis of MIMO-OFDM (802.11n System) for WLAN Channel Model

***Prof. Shivendra Singh, **Prof. Vikas Gupta, ***Shiv kumar Yadav**

*Associate prof. T.I.T. Science Deptt. of EC
**Associate prof. T.I.T. Deptt. of EC
***M.Tech. DC, T.I.T. Bhopal

Abstract

Fading is a common problem for the wireless communication system especially in urban areas where a large number of buildings reflecting the radio signals that result in interference between the reflected signals makes the fading effect since multiple selective nature of the spectrum at some specific place cancels out so the reception signal loss any part of your information in this sharply increases the communication system BER in slight motion of receiver, this paper specially analyzes the BER performance under Rayleigh fading channel conditions of MIMO-OFDM in presence of AWGN (Additive White Gaussian Noise) for different number of Transimitting, different number of users, and different path gains system analysis is performed by simulating the MIMO-OFDM using MATLAB program, and finally the paper also presents a comparison between simulated results.

Keywords: *MIMO-OFDM, AWGN (Additive White Gaussian Noise), Rayleigh fading.*

1. Introduction

Multipath fading is not a new problem for wireless communication, but the recent growth in the mobile communication system, attracted the designer to think seriously about the problem, as it is difficult to avoid this kind of problem in the transport conditions. Because the device is on the move, can not impose restrictions on it and could travel to many points that correspond to selective fading.

Multipath fading in wireless communication could occur by reflection of radio signals from different objects (multipath causes include air ducts, the ionospheric reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings) that causes the reception of signals at different phase angles at the receiver. Multipath effects include constructive and destructive interference, and phase shifting the signal. This causes Rayleigh fading. The statistical model of this standard is a distribution known as the Rayleigh distribution. Rayleigh fading with strong line of sight content is said to have a Rician distribution. In digital radio communications (such as GSM) can cause errors and multipath affect the quality of communications. The errors are due to inter-symbol interference (ISI). Equalizers are often used to correct the ISI. Alternatively, techniques can be used such as orthogonal frequency division modulation (OFDM) and RAKE receivers.

2. MIMO-OFDM

In radio, multiple-input and multiple-output, or MIMO, is the use of multiple antennas at both the transmitter and receiver to improve communication performance. The terms input and output refer to the radio channel carrying the signal, not to the devices having antennas. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) and/or to achieve a diversity gain that improves the link reliability (reduced fading). Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, WiMAX etc.

MIMO can be sub-divided into three main categories, precoding, spatial multiplexing or SM, and diversity coding.

2.1 Precoding

Precoding is multi-stream beamforming, in the narrowest definition. In more general terms, it is considered to be all spatial processing that occurs at the transmitter. In (single-stream) beamforming, the same signal is emitted from each of the transmit antennas with appropriate phase and gain weighting such that the signal power is maximized at the receiver input. The benefits of beamforming are to increase the received signal gain, by making signals emitted from different antennas add up constructively, and to reduce the multipath fading effect. In line-of-sight propagation, beamforming results in a well defined directional pattern.

However, conventional beams are not a good analogy in cellular networks, which are mainly characterized by multipath propagation. When the receiver has multiple antennas, the transmit beamforming cannot simultaneously maximize the signal level at all of the receive antennas, and precoding with multiple streams is often beneficial. Note that precoding requires knowledge of channel state information (CSI) at the transmitter and the receiver.

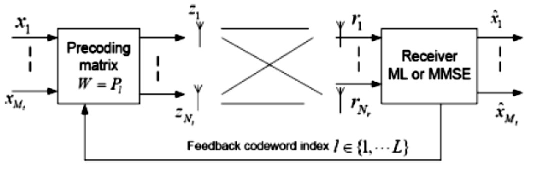

Figure 1: Precoding procedure in MIMO-OFDM

2.2 Spatial multiplexing

Spatial multiplexing requires MIMO antenna configuration. In spatial multiplexing, a high rate signal is split into multiple lower rate streams and each stream is transmitted from a different transmit antenna in the same frequency channel. If these signals arrive at the receiver antenna array with sufficiently different spatial signatures and the receiver has accurate CSI, it can separate these streams into (almost) parallel channels. Spatial multiplexing is a very powerful technique for increasing channel capacity at higher signal-to-noise ratios (SNR). The maximum number of spatial streams is limited by the lesser of the number of antennas at the transmitter or receiver. Spatial multiplexing can be used without CSI at the transmitter, but can be combined with precoding if CSI is available. Spatial multiplexing can also be used for simultaneous transmission to multiple receivers, known as space-division multiple access or multi-user MIMO, in which case CSI is required at the transmitter.[9] The scheduling of receivers with different spatial signatures allows good separability.

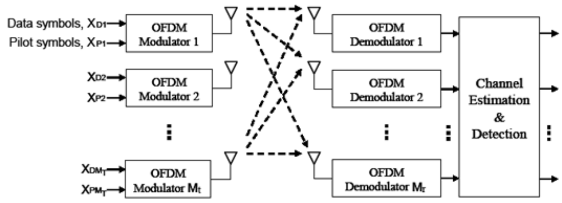

Figure 2: Spatial multiplexing in MIMO-OFDM

2.3 Diversity Coding

Diversity Coding techniques are used when there is no channel knowledge at the transmitter. In diversity methods, a single stream (unlike multiple streams in spatial multiplexing) is transmitted, but the signal is coded using techniques called space-time coding. The signal is emitted from each of the transmit antennas with full or near orthogonal coding. Diversity coding exploits the independent fading in the multiple antenna links to enhance signal diversity. Because there is no channel knowledge, there is no beamforming or array gain from diversity coding. Diversity coding can be combined with spatial multiplexing when some channel knowledge is available at the transmitter.

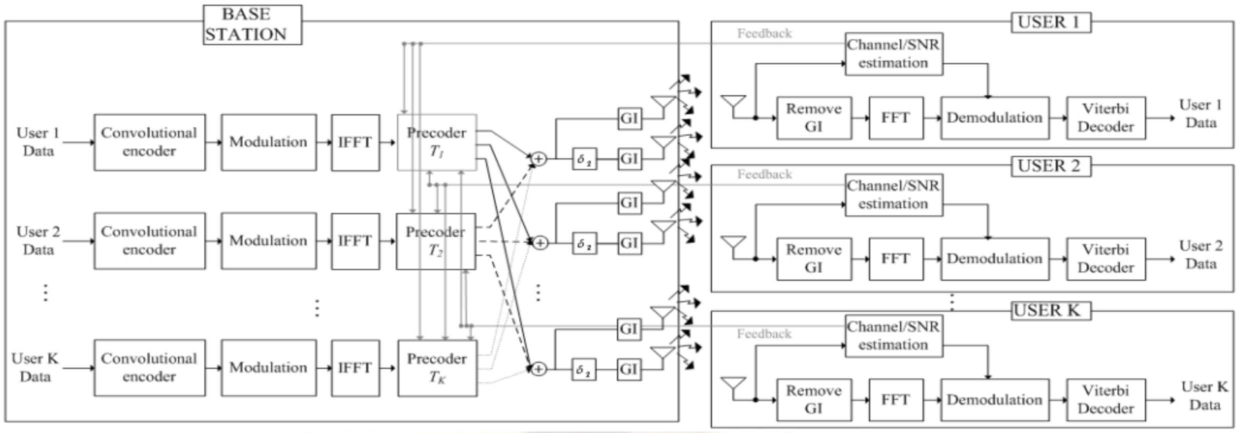

Figure 3: Complete Block Diagram of MIMO-OFDM System [1]

3. The Rayleigh Fading

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver.

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modelled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed.

Calling this random variable R, it will have a probability density function:

$$p_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, r \geq 0$$

Were $\Omega = E(R^2)$.

Often, the gain and phase elements of a channel's distortion are conveniently represented as a complex number. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modeled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes [9].

4. Performance Simulation

Computer simulations are done to simulate SNR vs. BER performance of MIMO-OFDM for different fading channels and noise conditions, different number of subcarriers and to analyze the effect of number of users in BER. To make the results more useful, the results are generated for varying number of users and for different number of subcarriers. Throughout the simulation, the information symbol is BPSK modulated at the transmitters and detected by using the maximum likelihood method in the demodulation at the receiver. A cyclic prefix is added to protect the symbol. Walsh codes are chosen as the spreading codes of the system. The simulation codes are written for MATLAB, and simulated on Pentium class processor.

5. Simulated Results

All results are calculated for 10^4 bits of transmission, the length of spreading code is same as number of sub-carriers and results are collected for each SNR step changing from 1 to 50 dB with a step size of 1 dB. For the Rayleigh channel four paths are considered.

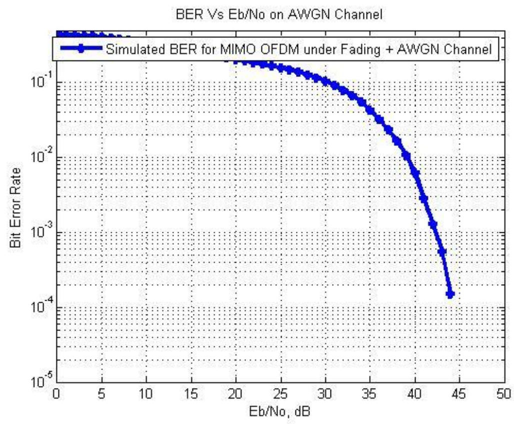

Figure 4.1: SNR Vs BER for two user 4 sub-carriers.

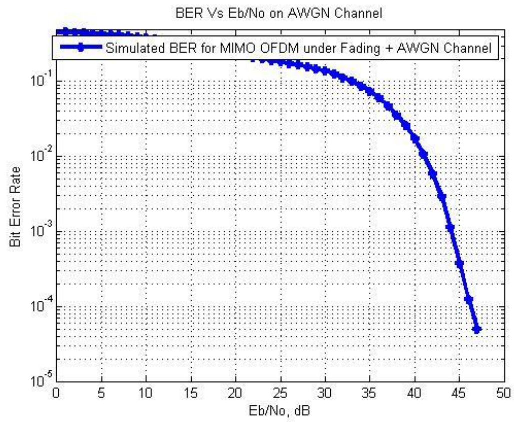

Figure 5.2: SNR vs BER for two users 8 sub-carriers.

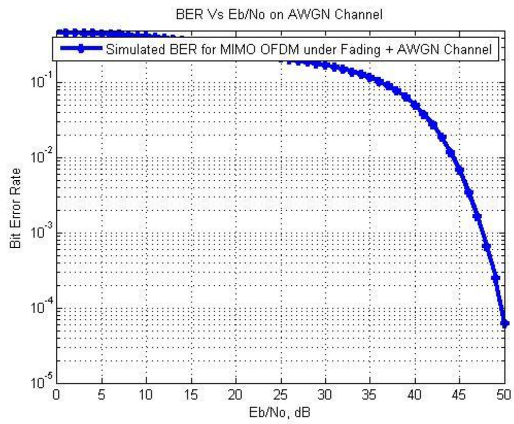

Figure 5.2: SNR vs BER for two users 16 sub-carriers.

6. Conclusion

Simulation results shows that the increase in sub-carriers increases the effects of multipath fading, as the comparison in figure 5.1 results significant reduction on BER curve with higher sub-carriers (from 4 to 16). The results of Matlab simulation show the performance of 802.11n wireless system in Raleigh channel environment. So the simulated of this paper can be applied to analyze many systems in the advanced wireless communication.

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