

Improving the Data Rate of OFDM System in Rayleigh Fading Channel Using Spatial Multiplexing with Different Modulation Techniques

Mrs.C.Geetha Priya¹, Dr. Mrs. M. Sunganthi², M. Madhana Prabha³

³ Professor, ECE Dept, Thiagarajar College of Engineering, Madurai, Tamil Nadu, India

².PG Student, ECE Dept, Mepco Schlenk Engineering College, Sivakasi, Tamil Nadu, India.

¹Lecturer, ECE Dept, Mepco Schlenk Engineering College, Sivakasi, Tamil Nadu, India

Abstract. This paper proposes a method for reducing the Bit Error Rate (BER), Frame Error Rate (FER) in OFDM system using Spatial Multiplexing. Spatial multiplexing is a transmission technique in MIMO wireless communication to transmit independent and separately encoded data signals from each of the multiple transmits antennas. For different Modulation techniques to calculate the Error rate for OFDM system. Finally compare the performance using Data Rate and Error Rate.

Keywords: Bit Error Rate, Diversity, Frame Error Rate, Spatial Multiplexing.

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a combination of modulation and multiplexing. Multiplexing means independent signals, those produced by different sources. So it is used to share the spectrum with these sources. In OFDM, the multiplexing is applied to independent signals but these independent signals are a sub-set of one main signal. In OFDM the signal itself is first split into independent channels, modulated by data and then re-multiplexed to create the OFDM carrier [1].It has become the physical layer of choice for many wireless communications systems. An attractive feature of current wireless local area network (WLAN) and wireless metropolitan area network (WMAN) standards based on OFDM is the designed ability to operate in unlicensed spectrum [2]. The OFDM system is able to use a set of subcarriers that are orthogonal to each other and a higher level of spectral efficiency can be achieved [3]. The main advantages of OFDM system are that it can achieve a higher MIMO spectral efficiency due to providing flatter frequency channels. It is very easy and efficient in dealing with multi-path and it is robust again narrow-band interference [4].OFDM is computationally efficient by using FFT techniques to implement the modulation and demodulation functions. OFDM has been successfully applied to a wide variety of digital communications applications. Although OFDM has been chosen as the physical layer standard for a diversity of important systems, the theory, algorithms, and implementation techniques remain subjects of current interest [5].

2. OFDM System Description

OFDM stands for 'Orthogonal Frequencies Division Multiplexing'. Instead of modulating a single carrier as is the case with FM or AM, the idea to utilize a number of carriers, spread regularly over a frequency band, in such a way that each of them is modulated with just a small portion of the available energy [6]. Here the datas are coded by Convolution coder. An OFDM signal consists of N orthogonal subcarriers modulated by N parallel data streams. Each baseband subcarrier is of the form

$$\phi_k(t) = e^{j2\pi f_k t} \quad (1)$$

where f_k is the frequency of the k th subcarrier. One baseband OFDM symbol (without a cyclic prefix) multiplexes N modulated subcarriers:

$$s(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k \phi_k(t), \quad 0 < t < NT \quad (2)$$

where x_k is the k th complex data symbol (typically taken from a PSK or QAM symbol constellation) and NT is the length of the OFDM symbol. The subcarrier frequencies f_k are equally spaced

$$f_k = \frac{k}{NT} \quad (3)$$

which makes the subcarriers $\phi_k(t)$ on $0 < t < NT$ orthogonal[7]. WMAN provide high speed internet access to home and business subscriber, without wires. Base Station (BS) can handle thousands of Subscriber Stations (SS). BS can control all data traffic going between BS and SS through the allocation of bandwidth on the radio channel. It supports quasi mobile services. Its coverage is very high [8]. 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. 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. If there is a dominant line of sight, Rician fading may be more applicable [8]. In telecommunication, a convolutional code is a type of error-correcting code in which each m-bit information symbol (each m-bit string) to be encoded is transformed into an n-bit symbol, where m/n is the code rate ($n \geq m$) and the transformation is a function of the last k information symbols, where k is the constraint length of the code. Convolutional codes are often used to improve the performance of digital radio, mobile phones, satellite links, and Bluetooth implementations [8].

3. Spatial Multiplexing

Spatial multiplexing is a transmission technique in MIMO wireless communication to transmit independent and separately encoded data signals from each of the multiple transmits antennas [8].

Spatial multiplexing is an efficient technique to reach high data rates. To make it more resistant against rank deficient channels, it is advantageous to use linear precoding on top of spatial multiplexing [9].

The concept of diversity and spatial multiplexing is also applicable to multiuser systems. Consider a cellular system with one base-station and many remote terminals geographically scattered in a single cell. Diversity in this multiuser system may be understood as follows: since not all remote terminals are likely to experience deep fades at the same time, the total throughput of the multiuser system is resilient to channel fading. Thus, diversity occurs not only across the antennas within each user, but also across the different users. This type of diversity is referred to as multiuser diversity [10].

The Characteristics of spatial multiplexing is no bandwidth expansion. And then Space-time equalization needed in the receiver, conventionally number of receiver antenna is greater than number of transmitter antenna. The data streams can be separated by the equalizer, if fading processes of the spatial channels are (nearly) independent [11].

Two transmission formats are allowed for the two antenna configuration, each format has it own diversity tradeoffs. The following matrices define the transmission format with the row index indicating the antenna number and column index indicating the subchannel symbol time. The entries define the transmission from a subchannel used for this transmission configuration [13].

Transmission format A uses Matrix A (Alamouti Matrix)

$$A = \begin{bmatrix} S_1 & -S_2^* \\ S_2 & S_1^* \end{bmatrix} \quad (4)$$

Transmission format B uses Matrix B (Spatial Multiplexing Matrix)

$$B = \begin{bmatrix} S_1 \\ S_2 \end{bmatrix} \quad (5)$$

4. OFDM Digital Communication Block

The general Block diagram of multicarrier OFDM Digital Communication system is shown in the Fig 1. It consists of Serial to Parallel converter, Modulator, Parallel to Serial converter, Digital to Analog converter, Demodulator, Analog to Digital Converter and Detector. Here the input data can be converted into Serial to Parallel format and that datas are modulated by using inverse DFT. Before going to convert the date from parallel to serial, the cyclic prefix is added to the data. This output is transmitted through Channel. At the Receiver side the analog data can be converted into digital form.

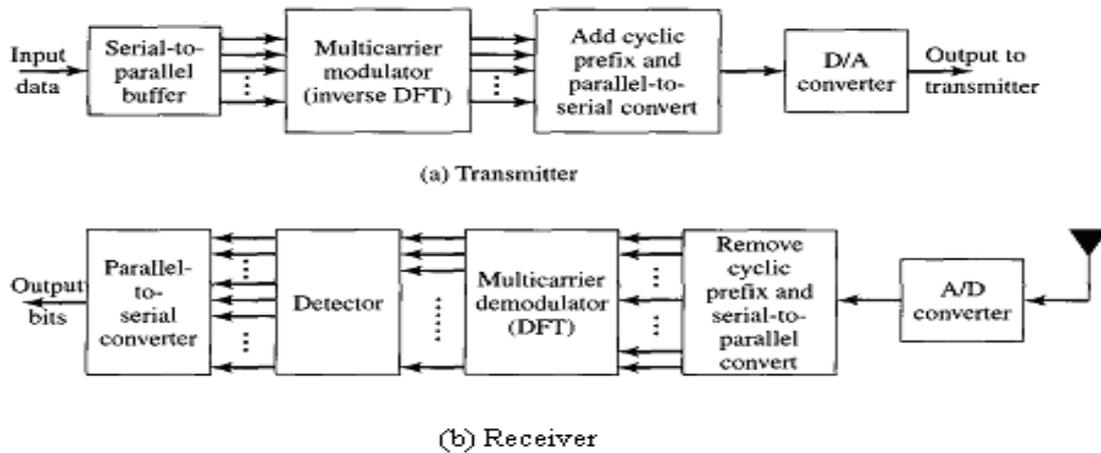


Fig 1: Block diagram of a multicarrier OFDM.

The cyclic prefix can be removed from the digital data and then the serial data is converted into parallel data by using Serial to Parallel converter. Finally the parallel data can be demodulated by using DFT and detected, then converted into serial data.

5. Advanced Design System (ADS)

Advanced Design System (ADS) is a powerful electronic design automation software system. It offers complete design integration to designers of products such as cellular and portable phones, pagers, wireless networks, radar and satellite communications systems, and high-speed digital serial links.

Advanced Design System is the industry leader in high-frequency design. It supports system and RF design engineers developing all types of RF designs, from simple to the most complex, from RF/microwave modules to integrated MMICs for communications and aerospace/defense applications.

Use ADS and its highly integrated links and support as a basis for your design verification solution. ADS can be used for virtual prototyping, debugging, or as an aid in manufacturing test. To enhance engineering productivity and shorten time-to-market, ADS software offers a high level of design automation and applications intelligence. This proven software environment is easily extensible: and it is possible to customize ADS by adding features focused on your particular application needs. ADS runs on PCs and workstations, with complete file compatibility between platforms and across networks [14].

This software is used for simulation.

- WMAN_OFDM_UL_MIMO_Fading
- WMAN_OFDM_DL_MIMO_Fading

These are the two blocks which are used in this simulation. The General Block diagram for this OFDM block is shown in the below figures.

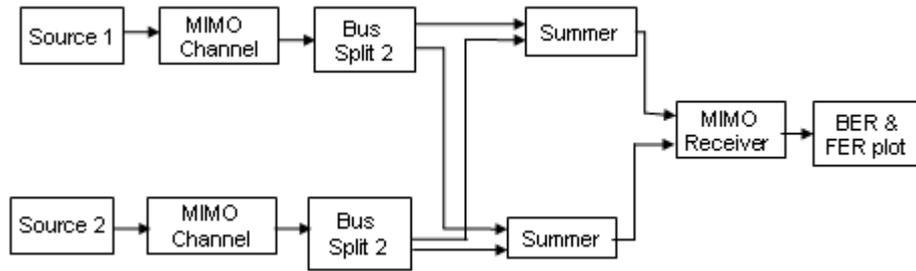


Fig 2. General Block Diagram for WMAN OFDM UL MIMO Fading

In this uplink Block, Fig 2 Consist of Input Source, MIMO Channel, Bus Split, summer, MIMO Receiver and BER & FER Plot. Here the Two Sources are generating two different datas that can be transmitted through MIMO Channel (Rayleigh Fading Channel). And then each data will be Splitted by Bus Split. At in the Receiver Side Summer is used for merging the Splitted data. It is received by the Receiver and finally plots the Bit Error Rate (BER), Frame Error Rate (FER) with respect to $E_b N_0$.

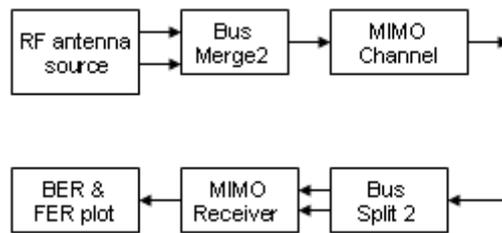


Fig 3. General Block Diagram for WMAN OFDM DL MIMO Fading

The above Fig 3 is the OFDM Downlink; this Block consists of RF Antenna Source, Bus Merge, MIMO Channel, Bus Split, MIMO Receive and BER & FER plot. It has the Two Antenna Source at a time it will generate two Data Symbols. These two datas are merged by Bus Merge. It will be transmitted through the MIMO Rayleigh Fading Channel. At in the receiver side the datas are Splitted and then received. Finally BER and FER values are plotted with respect to $E_b N_0$. In Source Block the various parameters are Bandwidth, FFT Size, Frame Mode, Frame Duration, Number of Burst, Coding Type and most important parameter is STC Matrix. STC means Space Time Code Matrix. Here two types of STC Matrices used that are Alamouti Matrix (Matrix A) and other one is Spatial Multiplexing Matrix (Matrix B). The Matrix A dimension is 2×2 . In this Matrix, the row index indicates the antenna number and column index indicating the subchannel symbol time. The Matrix B dimension is 2×1 . But the error rates (BER & FER) are less when using Matrix B compare to Matrix A.

6. WMAN OFDM uplink and down link specification

This specification, targeted for operation in the 10-66 GHz frequency band, is designed with a high degree of flexibility in order to allow service providers the ability to optimize system deployments with respect to cell planning, cost, radio capabilities, services, and capacity. In order to allow for flexible spectrum usage, both TDD and FDD configurations are supported.

The uplink is based on a combination of TDMA and DAMA. In particular, the uplink channel is divided into a number of time slots. The number of slots assigned for various uses is controlled by the medium access control (MAC) in the base station (BS) and may vary over time for optimal performance. The downlink channel is TDM, with the information for each subscriber station (SS) multiplexed onto a single stream of data and received by all SSs within the same sector. To support half-duplex FDD SSs, provision is also made for a TDMA portion of the downlink. The downlink includes a Transmission convergence sublayer that inserts a pointer byte at the beginning of the payload to help the receiver identify the beginning of a MAC protocol data unit (PDU). Data bits coming from the transmission convergence sublayer are randomized, FEC encoder, and mapped to a QPSK, 16-QAM or 64-QAM signal constellation.

The uplink is based upon TDMA burst transmission. Each burst is designed to carry variable-length MAC PDUs. The transmitter randomizes the incoming data, FEC encodes it, and map coded bits to a QPSK, 16-QAM, 64-QAM constellation [13].

7. Simulation Results

The performance measurement BER and FER for these matrices Matrix A and B for $E_b/N_0 = 10$ is obtained as 0.4995675, 0.00933 and 1, 0.081 respectively. The error rates are very high in Matrix A compared to Matrix B.

The further processes are done only using Matrix B because it has better performance. In both the uplink and downlink block the Matrix B is used for calculating BER and FER. At the same time by changing the modulation the performance is evaluated for different SNR values. The graph is plotted between E_b/N_0 and Error Rates is given below. Fig 4. Shows the comparison between Signal to Noise Ratio and bit error rate at various modulation techniques using Matrix B.

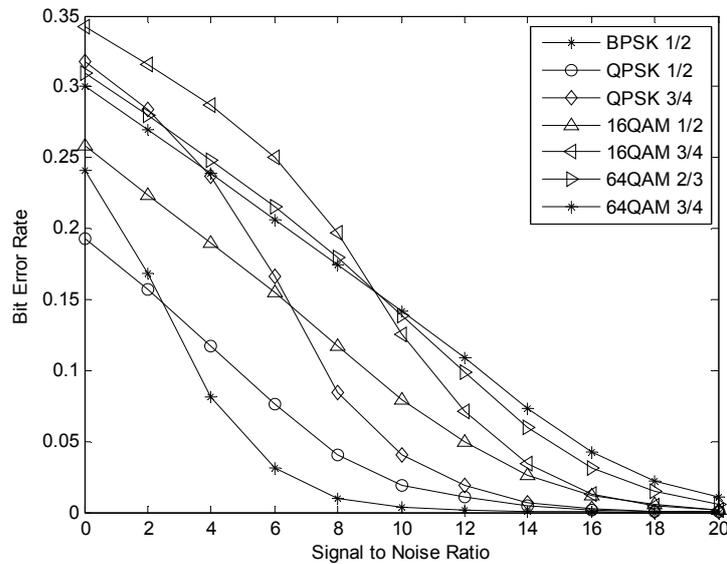


Fig 4. BER comparison for various modulations

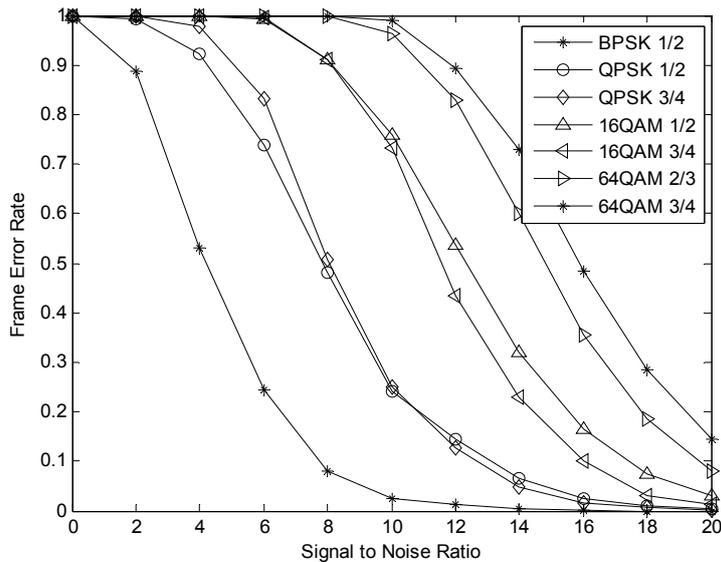


Fig 5. FER comparison for various modulations

8. Conclusion

In this paper, the performance of OFDM system is increased by using Spatial Multiplexing in Rayleigh Fading Channel. Here the performance is with respect to two types of Matrices, Alamouti and Spatial Multiplexing Matrix. Compared to Alamouti matrix the Spatial Multiplexing Matrix gives better result. Then different Modulation Techniques was used to obtain the bit error rate performance. Comparing these results, BPSK gives the less Error Rate. But comparing the Data rate of the each Modulation the 64QAM was better.

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