International Journal of Scientific Research Engineering & Technology (IJSRET)
Volume 1 Issue 5 pp 053-058 August 2012 www.ijsret.org ISSN 2278 – 0882

MIMO-Orthogonal Frequency Division Multiplexing System over Rayleigh Fading Channel with Simulink

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ABSTRACT
In wireless communication, concept of parallel transmission of symbols is applied to achieve high throughput and better transmission quality. Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques for parallel transmission. It is used for a variety of broadband systems such as asymmetric digital subscriber lines, very-high speed digital subscriber lines, digital video and audio broadcasting, and wide local area network standards. With the rapid growth of digital communication in recent years, the need for high speed data transmission is increased. OFDM is a promising solution for achieving high data rates in mobile environment, due to its resistance to ISI, which is a common problem found in high speed data communication. A multiple-input multiple-output (MIMO) communication System combined with the orthogonal frequency division multiplexing (OFDM) modulation technique can achieve reliable high data rate transmission over broadband wireless channels. However in fading environments the bit error rate (BER) increases. The performance can be improved by using some kind of channel coding. This form of OFDM is called coded-OFDM (COFDM). In this paper our aim is to analyze the performance of MIMO-OFDM in Rayleigh fading environments. The channel coding used is Reed Solomon (RS) code with ½ and 2/3 convolution codes. The performance parameter is BER and the mapping schemes used is QAM. The bit-error rate (BER) of quadrature amplitude modulation (QAM) in flat Rayleigh fading channel is also analyzed.

I. INTRODUCTION
Orthogonal frequency division multiplexing (OFDM) is based on multicarrier communication techniques. The idea of multicarrier communications is to divide the total signal bandwidth into number of sub carriers and information is transmitted on each of the sub carriers. Unlike the conventional multicarrier communication scheme in which spectrum of each sub carrier is non-overlapping and band pass filtering is used to extract the frequency of interest, in OFDM the frequency spacing between sub carriers is selected such that the sub carriers are mathematically orthogonal to each other's. The spectra of sub carriers overlap each other but individual sub carrier can be extracted by base band processing. This overlapping property makes OFDM more spectral efficient than the conventional multicarrier communication scheme. In this new information age, high data rate and strong reliability in wire-less communication systems are becoming the dominant factors for a successful exploitation of commercial networks. MIMO-OFDM (multiple input multiple output orthogonal frequency division multiplexing), a new wireless broadband technology, has gained great popularity for its capability of high rate transmission and its robustness against Multi-path fading and other channel impairments. Wireless technology is the foundation for the much anticipated ubiquitous communication networks that will allow people and machines to transfer and receive information on the move, anytime and anywhere. This technology will enable an endless array of applications such as wireless phones, wireless Internet access, wireless local area networks (WLAN), automated highways, distance learning, video conferencing, and home audio/visual networks. There are many technical challenges that must be overcome in order to make this vision a reality. One of the toughest challenges faced by wireless engineers and system designers is the bottleneck presented by the wireless link layer as some of the applications e.g., video conferencing, and home audio/visual networks require data rates nearing 1 Gb/s. Moreover WLANs are faced with demands of providing higher data rates due to the increase in rich media content and competition from 10 Gb/s wired LANs. Designing very high speed links that offer good

range capability on the wireless channel is a hard problem for several reasons. The wireless channel is a harsh time-varying propagation environment. A signal transmitted on a wireless channel is subject to interference, propagation path loss, and delay spread, Doppler spread, shadowing and fading. Due to its high spectral efficiency, multilevel quadrature amplitude modulation (MQAM) is an attractive modulation technique for wireless communications. M-QAM has been recently proposed and studied for various non-adaptive and adaptive wireless systems. However, the severe amplitude and phase fluctuations inherent to wireless channels significantly degrade the bit-error rate (BER) performance of M-QAM. In this paper, we provide a general approach to calculate the exact BER of M-QAM in flat Rayleigh fading channels. In particular, we derive the exact BER of 16-QAM, 32-QAM, 64-QAM, 256-QAM, 512-QAM and 1024-QAM The organization of the paper is as follows. In this paper, we derive the BER performances for M-QAM constellation and examine the bit error rate (BER) performance of OFDM system with different quadrature amplitude modulation (*QAM*) schemes (4-*QAM*, 16-*QAM*, and 64-*QAM*), over Rayleigh fading channels, and quantify the effects of Doppler shift and amplifier non-linearity on the BER performance of the system. The results show that the BER degrades as the Doppler shift and the amplifier non-linearity increase.

II. SYSTEM MODEL

The basic idea underlying OFDM systems is the division of the available frequency spectrum into several sub carriers. To obtain a high spectral efficiency, the frequency responses of the sub carriers are overlapping and orthogonal, hence the name OFDM. This orthogonally can be completely maintained with a small price in a loss in SNR, even though the signal passes through a time dispersive fading channel, by introducing a cyclic prefix (CP). A block diagram of OFDM system is shown in Figure 1. The binary information is first grouped, coded, and mapped according to the modulation in a “signal mapper.” After the guard band is inserted, an N-point inverse discrete-time Fourier transform (IDFT) block transforms the data sequence into time domain. Following the IDFT block, a cyclic extension of time length, chosen to be larger than the expected delay spread, is inserted to avoid intersymbol and intercarrier interferences. At the receiver side, after passing through the analog-to-digital converter (ADC) and removing the CP, the DFT is used to transform the data back to frequency domain. Lastly, the binary information data is obtained back after the demodulation and channel decoding.

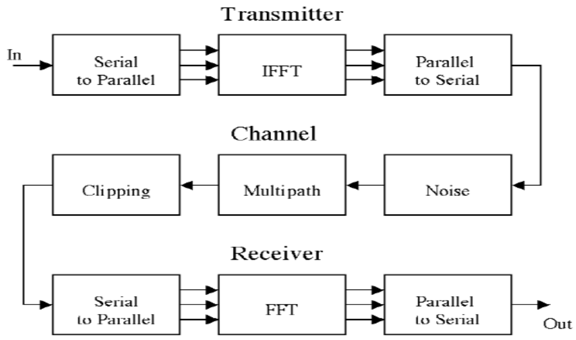

Fig. 1: Block diagram of OFDM system

A. OFDM Design Issues

There are certain key factors needed to take under serious consideration when developing and designing OFDM system.

1. ***Useful symbol duration:*** The size of symbol or length of symbol in respect of time effect the number of carriers and spacing between them. It is helpful in measuring latency etc. Larger symbol duration is helpful in accommodation delay profile of channel and cause increment number of subcarrier, reduces subcarrier spacing and higher the FFT size. There may arise issue of subcarrier offset and instability of OFDM symbol. Subcarrier spacing and number of carriers depend up on application and requirement. In mobile environment due to Doppler shift subcarrier spacing is chosen to be large.

2. ***Number of carriers:*** Number of subcarrier chosen depends up on channel bandwidth, data rate, through put requirements and territory (ruler, urban etc). If number of carriers is N then it would be reciprocal of duration of symbol in time T i.e. Selection of number of carrier depends on FFT size supported by FFT module. For higher number of carrier there would be higher number of complex point processing by FFT.

3. ***Modulation scheme:*** It is one of the advantage of OFDM that different modulation scheme can be applied to each sub channel depends on channel condition, data rate, robustness, throughput and channel bandwidth. There could be different modulation scheme applied specified by complex number i.e. QPSK, 16 QAM, 64 QAM. Modulation to each sub

channel can be made adaptive after getting information and estimation of channel at transmitter.

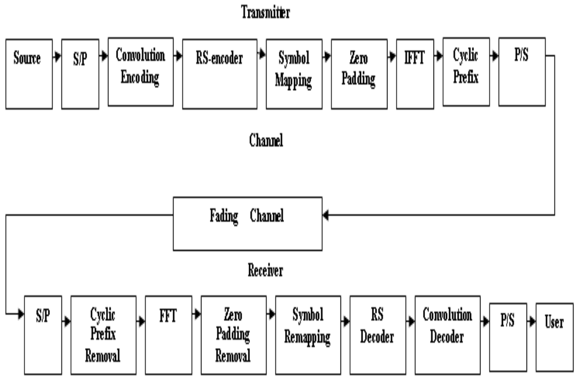

Fig. 2: Coded OFDM System with RS and Convolution code

Figure 2 presents a classical OFDM transmission scheme that uses Fast Fourier Transform (FFT). The input data sequence is baseband modulated, using a digital modulation scheme. Various modulation schemes could be employed such as BPSK, QPSK (also with their differential form) and QAM with several different signal constellations. There are also forms of OFDM where a distinct modulation on each sub channel is performed (e.g. transmitting more bits using an adequate modulation method on the carriers that are more "confident", like in ADSL systems). The modulation is performed on each parallel sub stream that is on the symbols belonging to adjacent DFT frames. The data symbols are parallelized in N different sub streams. Each sub stream will modulate a separate carrier through the IFFT modulation block, which is the key element of OFDM scheme. A cyclic prefix is inserted in order to eliminate the inter symbol interference (ICI) and inter block interference (IBI). This cyclic prefix of length L is a circular extension of the IFFT-modulated symbol, obtained by copying the last L samples of the symbol in front of it. The data is back-serial converted, forming an OFDM symbol that modulates a high-frequency carrier before transmitting through the channel. The radio channel is generally referred as a linear time variant system. To the receiver, the inverse operations are performed; the data is down converted to the baseband and the cyclic prefix is removed. The coherent FFT demodulator will ideally retrieve the exact form of transmitted symbols. The data is serial converted and the appropriated demodulation scheme is used to estimate the transmitted symbols.

B. Advantages of OFDM

- As OFDM is a parallel transmission system which converts the problem of frequency selective fading to flat fading by distributing data to sub channels, It is seems to be better candidate to combat multipath fading and randomizing the errors in burst.
  - In OFDM systems equalization is made very simpler and reduces the complexity at receiver, equalization is only applied to effected sub channel to reduce the error rate.
  - Delay profile of channel is nicely handled by insertion of appropriate size guard band.
  - OFDM provides a higher spectral efficiency due to orthogonality amongst the sub carriers.
  - OFDM is major role playing in development of standards of a broadband access and compatible with existence infrastructure.
  - Subcarrier spacing could be adjustable according to requirements of an applications and data rate; it supports different modulation schemes for different sub channels.

C. Disadvantages of OFDM

- There exists high peak to average power ratio which could drift the system into the region of non-linearity and saturation, which reduces the power efficiency of systems.
- The insertion of guard band reduces the spectral efficiency and thus total channel capacity is decrease.
- In mobile environment the Doppler shift, carrier off set in case of higher number of carriers and spreading of OFDM symbol out of band spectrum are practical problems of OFDM systems. There also exist problem of synchronization —at the receiver end it is possible difficulty to find starting point of FFT symbol.

III. NEED FOR MIMO-OFDM

The growing demand of multimedia services and the growth of Internet related contents lead to increasing interest to high speed communications. The requirement for wide bandwidth and flexibility imposes the use of efficient transmission methods that would fit to the characteristics of wideband channels especially in wireless environment where the channel is very challenging. In wireless environment the signal is propagating from the transmitter to the receiver along number of different paths, collectively referred as multipath. While propagating the signal power drops of due to the following effects: path loss, macroscopic fading and microscopic fading. Fading of the signal can be mitigated by different diversity techniques. To obtain diversity, the signal is transmitted through multiple (ideally) independent fading paths e.g. in time,

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frequency or space and combined constructively at the receiver.

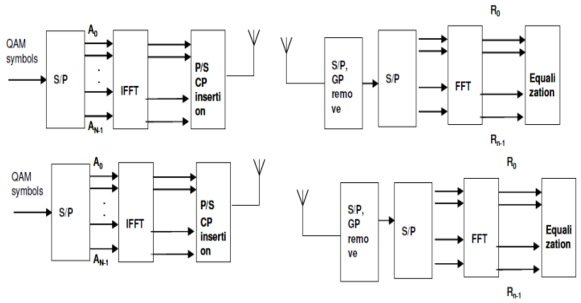

Fig. 3: MIMO-OFDM transceiver

To achieve a high system capacity for multimedia applications in wireless communications, various methods have been proposed in recent years. Among them, the multiple input – multiple output (MIMO) system using multiple antennas at both the transmitter and the receiver has attracted a lot of research interest due to its potential to increase the system capacity without extra bandwidth. Multiple input- multiple-output (MIMO) exploits spatial diversity by having several transmit and receive antennas. Previous work has shown that the system capacity could be linearly increased with the number of antennas when the system is operating over flat fading channels. In real situations, multipath propagation usually occurs and causes the MIMO channels to be frequency selective. To combat the effect of frequency selective fading, MIMO is generally combined with orthogonal frequency-division multiplexing (OFDM) technique.

OFDM transforms the frequency-selective fading channels into parallel flat fading sub channels, as long as the cyclic prefix (CP) inserted at the beginning of each OFDM symbol is longer than or equal to the channel length. The channel length means the length of impulse response of the channel as discrete sequence. The signals on each subcarrier can be easily detected by a time-domain or frequency-domain equalizer. Otherwise the effect of frequency-selective fading cannot be completely eliminated, and inter-carrier interference (ICI) and inter-symbol interference (ISI) will be introduced in the received signal. Equalization techniques that could flexibly detect the signals in both cases are thus important in MIMO-OFDM systems.

A. Multipath Environment

In wireless environment, transmitted signal follow several propagation paths. Many of these paths, having reflected from surrounding objects, reach the receiver with different propagation delays. This multipath leads to delay spread, intersymbol interference (ISI), fading and random phase distortion.

B. Capacity

In paper, the capacity of conventional MIMO, MIMO-OFDM and spread MIMO-OFDM in presence of multipath is studied. Spread MIMO-OFDM is MIMO with OFDM and CDMA i.e. above MIMO-OFDM a spreading code is used in the signal. In the single user case the results showed that capacity for the conventional MIMO without ISI is the highest and they state that it is the upper bound of capacity limit. MIMO-OFDM and spread MIMO-OFDM give more capacity than conventional MIMO in presence of multipath and based on their results MIMO-OFDM and spread MIMO-OFDM would be similarly impacted by multipath. This seems reasonable since OFDM with long enough cyclic prefix is a powerful mean to mitigate multipath. In multiuser channel spread MIMO-OFDM provides more capacity than the other schemes.

IV. MIMO - OFDM PERFORMANCE ANALYSIS

MIMO - OFDM performance analysis presented in this section is based on computer simulations. The basic scenario of our simulation is represented by the MIMO - OFDM transmission system performing through multipath fading transmission channel. The encoder of MIMO - OFDM system uses integer-Input RS Encoder block which creates a Reed-Solomon code with message length 239 and codeword length 255. Modulate or mapped the input signal using the quadrature amplitude modulation method, the symbols can be either binary-demapped or Gray-demapped. Similarly, the Binary-Output RS Decoder block recovers a binary message vector from a binary Reed-Solomon codeword vector. For proper decoding, the parameter values in this block should match those in the corresponding integer-Input RS Encoder block. The simulation results of MIMO - OFDM system is shown below:

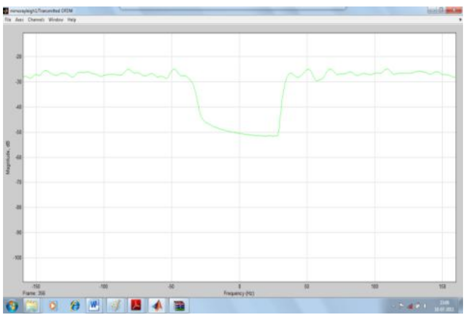

Fig.4. MIMO - OFDM Transmitted Signal.

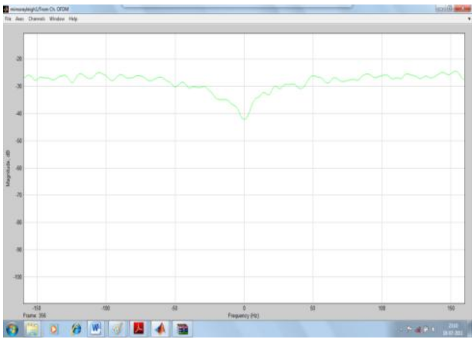

Fig.5. MIMO - OFDM Received Signal.

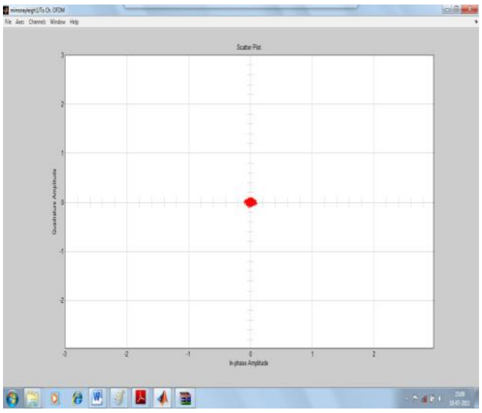

Fig.6. Scatter Plot of MIMO - OFDM transmitted Signal by using QAM Modulation.

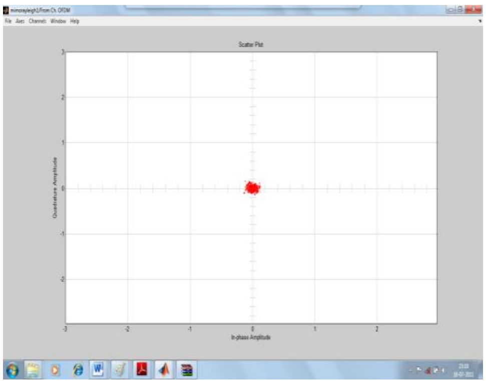

Fig.7. Scatter Plot of MIMO - OFDM Received Signal by using QAM Modulation.

Fig. 4 shows the MIMO - OFDM transmitted signal to the channel. This signal is passed through the multipath fading. After passing this signal from channel we get the MIMO - OFDM received signal as shown in Fig. 5 which is full of distortions but this distortion is less as compared in the case of CDMA system. The scatter plot is used to reveal the modulation characteristics, such as pulse shaping or channel distortions of the signal. Fig. 6 shows the scatter plot of MIMO - OFDM transmitted signal by using QAM modulation. The scatter plot illustrates the effect of fading on the signal constellation. Similarly Fig. 7 shows the scatter plot of MIMO - OFDM received signal by using QAM modulation. In the MIMO - OFDM system the received signal has more fading effects as compared to MIMO - OFDM transmitted signal which results in more errors in MIMO - OFDM system. But due to the use of Reed – Solomon encoder and decoder in MIMO - OFDM system which acts as an error check code the BER of MIMO - OFDM is decreased.

V. CONCLUSION

In this paper, IEEE 802.16e MIMO-OFDM PHY layer was implemented using SIMULINK in order to evaluate the PHY layer performance under frequency selective channel. The implemented PHY layer supports all the modulation and coding schemes as defined in the specification. The BER is used to compare the performance of different modulation and coding scheme under AWGN and multipath fading channel. It is observed that the lower modulation and coding scheme provides better performance with less SNR, accept for schemes employing rate 3/4 codes have noticeable degradation compare to other schemes under multipath fading. Results showed that under frequency selective fading channel it is more important to have a coding scheme that have higher error correction capability, than having modulation that is more tolerate to the noise. The design of MIMO-OFDM transceiver system based on simulation has been described in this paper where FFT algorithm and several types of modulation schemes has been implemented in this system in order to analyze the effect of modulations schemes against the noisy channel. The system performance has been evaluated on Rayleigh fading channel and BER versus signal to-noise (SNR) ratio has been measured for each modulation scheme. However, it reduces the transmission data capacity. Meanwhile, QAM can operate in a low noise link with the increased data capacity where the SNR should be more than 22.5 dB to obtain a low bit error rate.

REFERENCES

[1] P. M. Fortune, L. Hanzo, and R. Steele, *On the computation of 16- QAM and 64-QAM performance in Rayleigh-fading channels*, Inst. Electron. Commun. Eng. Trans. Commun., vol. E75-B, pp. 466–475, 1992.

[2] Ramjee Prasad, *OFDM for Wireless Communications Systems*, Artech House, Inc. Publications.

[3] N. Kinoshita, S. Sampei, E. Moriyama, H.Sasaoka,Y.Kamio, K.Hiramatsu, K. Miya, K. Inogai, and K. Homma, *Field experiments on 16QAM/TDMA and trellis coded 16QAM/TDMA systems for digital*

land mobile radio communications, Inst. Electron. Commun. Eng. Trans. Commun., vol. E77-B, pp. 911–920, July 1994.
[4] W. T. Webb and R. Steele, V*ariable rate QAM for mobile radio*, IEEETrans. Commun., vol. 43, pp. 2223–2230, July 1995.
[5] A. Goldsmith and S. G. Chua, *Variable-rate variable-power M-QAM for fading channels*, IEEE Trans. Commun., vol. 45, pp. 1218–1230, Oct. 1997.
[6] J.-J. Van de Beek, O. Edfors, M. Sandell, S. K. Wilson, andP. O. Borjesson, *on channel estimation in OFDM systems*, in Proc. IEEE 45th Vehicular Technology Conf., Chicago, IL, Jul. 1995, pp. 815–819.
[7] Ezio Biglieri, Robert Calder bank, Robert Calderbank,Anthony Constantinides, Andrea Goldsmith, ArogyaswamiPaulraj, H. Vincent Poor, *MIMO Wireless Communications*, Cambridge Press.
[8] Lennert Jacobs, Marc Moeneclaey, *Effect of MMSE channel estimation on BER performance of orthogonal space-time block codes in Rayleigh fading channels*, IEEE Trans. Commun., vol. 57, pp. 1242-1245,May. 2009.
[9] O.Daoud, A.-R Al-Qawasmi, "Efficient Performance Of Cofdm- Based DVB T," in IEEE International Multi-Conference on Systems, Signals and Devices, 2009, pp. 1-4.
[10] Gayarti, S. Prabhu and P.Mohana Shankar, "Simulation of flat fading using MATLAB for classroom instruction," in IEEE Transactions on Education, vo1.45. No.1, Feb 2002.
[11] Lingzhi Cao. N.C Beaulieu, "A simple efficient method for generating independent Nakagami-m fading samples," in Vehicular Technology Conference,IEEE 61st publication, vol.I,2005,pp. 44-47.
[12] Iskander, Cyril-Daniel, "A MATLAB-based Object-Oriented Approach to Multipath Fading Channel Simulation", a MATLAB Central submission available in www.mathworks.com.
[13] S.Elnoubi, S.A. Chahine, H.Abdallah, "BER performance of GMSK in Nakagami fading channels," in IEEE Twenty-First National Radio Science Conference,March 2004,pp.C13- 1-8.
[14] Li Tang , Zhu Hongbo , "Analysis and simulation of Nakagami fading channel with MATLAB," in IEEE Asia-Pacific Conference on Environmental Electromagnetics, 2003,pp.490- 494.
[15] M.X. Chang and Y.T. Su, "Performance Analysis of Equalized OFDM Systems in Rayleigh Fading", in IEEE Transactions Wireless Communication, vol.I, No. 4, Oct. 2002,pp. 721–732.
[16] V. Subotic, S. Primak, "BER Analysis of Equalized OFDM Systems in Nakagami, m<1Fading," in Wireless Personal Communications: An International Journal**,** vol. 40, Issue 3,Feb. 2007,pp. 281 – 290.
[17] K.-W. Yip,T.-S. Ng, "A simulation model for Nakagami-m fading channels" in IEEE Transaction on Communication, vol. 48, no. 2, Feb. 2000, pp. 214–221.
[18] K.Thenmozhi, V.Prithiviraj, "Suitability of Coded Orthogonal Frequency Division Multiplexing (COFDM) for Multimedia Data Transmission in Wireless Telemedicine Applications," in IEEE Conference on Computational Intelligence and Multimedia Applications,2007, vol. 4, Dec.2007, pp.288 – 292.