

A Model to Investigate Performance of Orthogonal Frequency Code Division Multiplexing

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Abstrak

Orthogonal Frequency Code Division Multiplexing (OFCDM) merupakan sebuah skema akses jamak yang atraktif untuk aplikasi data kecepatan tinggi pada sistem komunikasi nirkabel generasi ke-4 (4G). Beberapa penelitian sebelumnya telah melakukan investigasi terhadap kinerja OFCDM terutama berdasarkan parameter variabel spreading factor dan alokasi subcarrier. Namun demikian, ada beberapa parameter sistem yang lain juga mempunyai pengaruh terhadap kinerja OFCDM. Untuk itu, paper ini membangun sebuah model simulasi untuk menginvestigasi pengaruh beberapa parameter tersebut terhadap kinerja sistem OFCDM pada kanal Rayleigh Fading sebagai kanal yang realistik pada sistem komunikasi nirkabel. Model yang diusulkan kemudian dibuat dalam bentuk simulasi komputer dengan menggunakan pemrograman MATLAB untuk melihat pengaruh beberapa parameter terhadap kinerja OFCDM yaitu: jumlah carrier, ukuran simbol, kecepatan simbol, kecepatan bit, ukuran guard interval dan spreading factor. Hasil simulasi menunjukkan bahwa jumlah carrier yang besar, jumlah simbol yang besar, kecepatan simbol yang tinggi, kecepatan bit yang tinggi, dan spreading factor yang besar memberikan kinerja yang baik dalam bentuk Bit Error Rate (BER). Tetapi guard interval yang besar memberikan kinerja sistem yang buruk. Sehingga semua parameter tersebut perlu dipertimbangkan dalam penerapan OFCDM untuk sistem komunikasi nirkabel 4G.

Kata kunci: Akses jamak, BER, OFCDM, Pengaruh parameter, Rayleigh fading

Abstract

Orthogonal Frequency Code Division Multiplexing (OFCDM) is an attractive multiple access scheme for high data rate application in fourth-generation (4G) wireless communication system. Several previous researches were mainly investigated the performance of OFCDM based on variable spreading factor and subcarrier allocation. However, there are also several system parameters may affected the performance of OFCDM. For that purpose, this paper develops a model to investigate the impact of several parameters on the performance system of OFCDM over Rayleigh Fading channel as a realistic channel in wireless communication system. The proposed model is then created in the form of computer simulation using MATLAB programming in order to show the impact of several parameters for OFCDM's performance including number of carriers, size of symbol, symbol rate, bit rate, size of guard interval and spreading factor. The simulation results show that the higher number of carriers, larger size of symbol, higher symbol rate, higher bit rate and larger spreading factor are giving the better system's performance in terms of Bit Error Rate (BER). However, the larger guard interval is giving the worst system's performance. So all the parameters should be considered in the implementation of OFCDM for the 4G wireless communication system.

Keywords: BER, impact parameter, multiple acces, OFCDM, Rayleigh fading

1. Introduction

Wireless communication technology has grown rapidly to fulfill high demand of information technology and multimedia services. It has impact on widely bandwidth usage and highly data rate as well. Currently, WiMAX 802.16e and Long Term Evolution (LTE) are candidates for fourth-generation (4G) wireless communication system with transmission rates up to 100 Mbps with fully mobility and 1 Gbps with limited mobility [1]. There are several multiple access schemes which are offered for the 4G wireless communication system such as: Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM). The CDMA access technique is not so appropriate to be implemented in broadband channel and to

support the 4G applications due to producing Multipath Interference (MPI) [2]. OFDM system is suitable to be applied in wireless communication with high data rate and resistant to MPI, but it has no coherent frequency diversity that can cause susceptible of interference from closely cell in subcarrier. To solve the weakness of CDMA and OFDM, a combination of them has been introduced to be an attractive multiple access scheme for high data rate application in the 4G wireless communication system, known as Orthogonal Frequency Code Division Multiplexing (OFCDM) system. OFCDM is one of multiple access method which is applied in the 4G wireless technology [3]. It has been targeted to be used in downlink transmission at the rate of 100 Mbps.

OFCDM uses data spreading in both time and frequency domain, where each data stream is segmented into multiple sub-streams and spread over multiple carriers and several OFCDM symbols, exploiting additional frequency and time diversity [4]. Spreading code of OFCDM is two-dimensional (2D) spreading from Variable Spreading Factor (VSF) that only has information code at the different time-frequency block. It can adaptively control the frequency and time according to the propagation conditions, channel load and radio parameters [5]. Furthermore, it is also changed flexibility according to the cell structure, radio link conditions, and link parameters [6]. Based on the fact that OFCDM technology not only has advantage from 2D spreading but also has capability to adapt the diverse propagation environments. Besides the advantages, OFCDM has several problems that are the orthogonality of code is lost by fading [6, 7, 13], carrier frequency offset (CFO) can degrade the system performance [5], subcarrier allocation based on spreading factor has also impact on the performance [8, 9] and the other system parameters especially for Rayleigh Fading channel as a realistic wireless communication channel [7, 10]. The performance evaluation for OFCDM has been conducted in several previous works in [5] - [12]. Most of the previous works were mainly considering VSF and carrier offset (subcarrier) for evaluating the performance of OFCDM [5, 9-11]. However, the evaluation of all impact parameters on the performance of OFCDM system is important to the implementation of the 4G wireless communications.

This paper proposes a model to investigate the performance of OFCDM by considering the impact of several parameters on its performance over Rayleigh Fading channel. Wireless communication channel is typically severe multipath propagation due to multipath scattering from the objects of mobile station. The scattering produces the fluctuation of the received signal envelope that is Rayleigh distributed. Based on the fact, this paper simulates the impact of the OFCDM system parameters over Rayleigh Fading channel. Furthermore, several major parameters that have impact on the performance of OFCDM are identified including spreading factor (SF), number of carrier, number of symbol, symbol rate, bit rate and guard interval size. To demonstrate the feasibility of an OFCDM system and investigate how its performance is changed by varying several major parameters, a simulation model of OFCDM system is proposed. Then, computer simulation is conducted by using MATLAB programming to show the impact of the parameters. However, the detail MATLAB code is not discussed here due to the length of paper. With a completed MATLAB program, the impact of several major parameter on the performance of OFCDM system can be investigated. In the simulation, every parameter is varied to three different values. Simulation results show that the parameters have the impact for the performance of OFCDM in terms of Bit Error Rate (BER).

The rest of paper is organized as follows. In section 2, system simulation model is described. The simulation results for investigating the impact of several parameters on the performance of OFCDM are presented in Section 3. Finally, we conclude with a brief summary of results.

2. System Simulation Model

A simple simulation model of OFCDM system is developed in this paper to investigate the performance of OFCDM as shown in Figure 1. No pilot signal is considered in the simulation but it is assumed that receiver has known the information of channel response, signal level and noise. This model consists of transmitter, channel, receiver and BER calculation. Computer simulation is developed using MATLAB code. However, the detail simulation code is not discussed in this paper. The simulation is started from generating input data by data random generator, developing OFCDM symbol in the transmitter, and adding noise fading factor in the

transmission system performance. The receiver is carry out the reverse process of the transmitter. Then, BER is calculated by comparing the transmitted data with the received data.

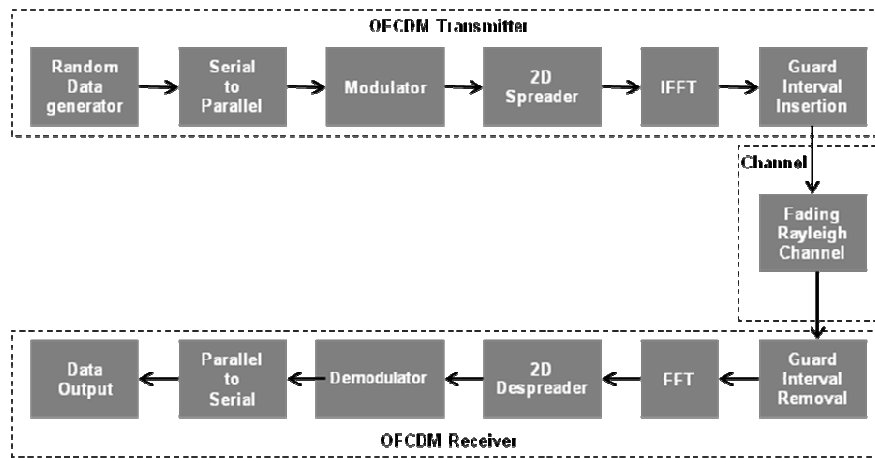


Figure 1 Block diagram of OFCDM simulation.

OFCDM transmitter consists of random data generator, serial to paralel, modulator, 2D spreader, Inverse Fast Fourier Transform (IFFT) and guard interval insertion. A number of input bits is generated randomly using random data generator which is uniform distribution because the probability bit "0" and "1" are the same. Output of the random data generator has different output power level according to output bit. Threshold level is set to 0.5. If generated random level is larger than or the same as 0.5, so bit "1" will be sent. Bit "0" is going to be sent if generated random level is smaller than 0.5 [14]. The incoming data is first covered from serial to parallel. Input from Serial to Parallel Converter is the number of bits which are going to be transmitted. Serial to Parallel Converter is useful to change data stream which is one row and several colours to be several rows and colours. The result from Serial to Parallel block is a matrix of information bits with number of rows for many subcarriers which are to be used for every symbol. Parallel data are obtained and then are mapped based on the used modulation technique at the modulator. Modulation technique is mapped data into constellation real (in-phase) and Imaginary constellation (quadrature), which is known as IQ constellation. Quadrature Phase Shift Keying (QPSK) modulation is preferred in OFCDM model system in which two bits are modulated for every symbol. Furthermore, the modulated signal is converted to parallel sequential N/SF by using 2D spreader, where N is number of symbols and SF is spreading factor. Here SF is expressed as $SF = SF_{time} \times SF_{freq}$, where SF_{time} and SF_{freq} represent the spreading factor in the time and frequency domain, respectively. Then, the data are duplicated to parallel form at SF . In this model, the size of SF is 4, 8, and 16 [15]. Moreover, IFFT is converted to parallel data in frequency domain to be parallel data in time domain. In addition, the use of IFFT will give computation per unit efficiently. The use of Fast Fourier Transform (FFT) will guarantee orthogonality among subcarrier. Guard interval is a time interval inserted between OFCDM symbols to avoid Intersymbol Interference caused by multipath distortion. It is duplicate of the last OFCDM symbol because receiver can integrate each of multipath with integer level from sinusoid cycle when demodulation of OFCDM is processed with FFT.

In a realistic wireless communication channel, signal propagation takes place in the atmosphere and near the ground. A signal can travel from transmitter to receiver over multipath fading. Therefore, Rayleigh Fading channel is used in our simulation where the distributed Gaussian random arrays are generated by randn function in MATLAB and the summation of their envelope is computed to give Rayleigh Fading process. OFCDM symbols are transmitted into channel which is affected by Fading Rayleigh. The fading causes fluctuations in amplitude signal, phase, and angel of arrival of the received signal. Furthermore, multipath propagation is occured when the receiver is received two or more the same signals.

OFCDM receiver consists of guard interval removal, FFT, 2D despreader, demodulator, parallel to serial and data output. OFCDM signal is received by receiver in order to be processed until became to data output. The received signal is usually corrupted by noise fading and channel distortion. The guard interval will be removed by guard interval removal and then the signal is processed at the receiver block. This is to separate original signal and guard interval which might have impacted of intersymbol interference due to multipath. The received signal must be the original signal without guard interval. FFT is used to change time domain signal to frequency domain. The output from FFT is frequency signal of subcarrier. Despreading process in the receiver is used to gain data symbol from output of spreading process at the transmitter. Then, demodulation is remap the symbol into information bits which is modulated at the transmitter. The symbol is remapped into bits by doing amplitude detection from that symbol. Furthermore, parallel to serial converter is important to reconvert signal after demodulating into serial in order to gain output data in frequency domain.

In addition, BER calculation method in this research is Monte Carlo method that is a comparison between sequence bits at transmitter and detection bits at the receiver. Then, BER is calculated by comparing the incorrect data bits with the generated data bits. Monte Carlo simulation method is relatively simple to estimate the BER, but it is time consuming for running the simulation.

3. Simulation Result

In this paper, computer simulation has been done by MATLAB programming to investigate the impact of several parameters on the performance of OFCDM over Fading Rayleigh channel. Simulation results show BER performance of several parameters such as: number of carrier, symbol rate, bit rate, number of symbol, size of guard interval and spreading factor. Simulation parameters in this simulation are shown in Table 1. Every parameter simulation has three different values except the level of modulation and threshold. The BER is targeted for 10^{-6} .

Tabel 1. Simulation Parameters.

System Parameter	Value(s)
Number of parallel channels	128, 512, 1024
FFT/IFFT size	128, 512, 1024
Number of carrier	128, 512, 1024
Number of OFCDM symbol for one loop	2, 6, 8
QPSK modulation level	2
Symbol rate	250 kBauds, 2,5 MBauds, 25 MBauds
Bit rate per carrier	500 kbps, 1 Mbps, 10 Mbps
Size of guard interval	16, 32, 64
Size of spreading factor (SF)	4, 8, 16
Threshold	0,5
Target E_b/N_0	10 – 50 dB
Target BER	10^{-6}

3.1. Impact of number of Carrier

The BER against E_b/N_0 has been simulated for different number of carriers (128, 512 and 1024 carriers). Figure 2 shows the simulation result for the performance of OFCDM which is affected by number of carrier over Fading Rayleigh channel. It can be seen that the larger number of carriers performs better BER performance in which the BER at number of carrier of 1024 is smaller than that of 128 and 512. For example, when E_b/N_0 is equal to 50 dB, the BER for number of carriers of 128, 512 and 1024 are $3,1 \times 10^{-7}$, $2,325 \times 10^{-7}$ and $1,938 \times 10^{-7}$, respectively. So more carriers, it gives the better BER performance. This is true because the received signal can be approximated and recovered even better from contaminated by interference. However, there will be possible more power consumption. Therefore, the number of carrier in the OFCDM has impact on its performance. Practically, a larger number of carrier (e.g., 1024) is employed.

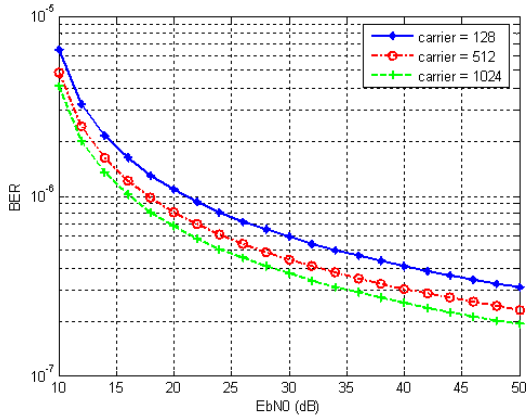


Figure 2. BER vs E_b/N_0 by varying the number of carriers.

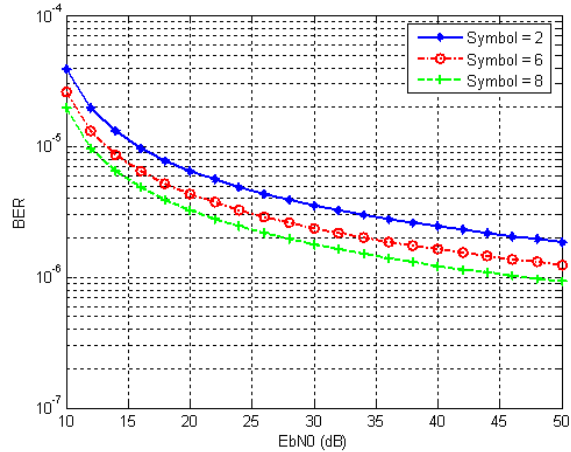


Figure 3. BER vs E_b/N_0 by varying size of symbols in one loop.

3.2. Impact of Symbol

OFCDM provides access by allocating a block of 2D symbol. Impact of the number of symbol in one loop for OFCDM performance over fading Rayleigh channel is figured out clearly in Figure 3. The size of symbol used in the simulation is 2, 6, and 8, respectively. Based on the Figure 3, the better performance was obtained in which BER versus E_b/N_0 at 8 is lower than that of 2 and 6 symbols. As a result, when E_b/N_0 is equal to 30 dB, the BER with number of symbol of 2, 6 and 8 are $3,551 \times 10^{-6}$, $2,367 \times 10^{-6}$ and $1,776 \times 10^{-6}$, respectively. So the bigger number of symbols achieves better BER performance. This because there will be no interference among symbols when orthogonal spreading codes are used. In other word, the used code have zero cross correlation and thus will eliminate all the interference from unwanted signal. Therefore, size of symbol has impact to the performance of OFCDM.

3.3. Impact of Symbol Rate

Figure 4 demonstrates the BER performance of OFCDM over Fading Rayleigh channel which is influenced by Symbol Rate (SR). To evaluate the impact of SR, there are three different size of SR in the simulation that are 250 kBauds, 2,5 MBauds and 25 MBauds, respectively. The result shows that the higher symbol rate is given, the better performance is performed. Based on the figure, when E_b/N_0 is equal to 40 dB, the BER at rate of 250 kBauds, 2,5 MBauds and 25 MBauds are $3,255 \times 10^{-6}$, $2,848 \times 10^{-6}$, and $2,035 \times 10^{-6}$, respectively. It is noticeable to say that the performance of OFCDM also has been affected by the size of SR. The higher SR enables high bit rate transmission but requires greater bandwidth.

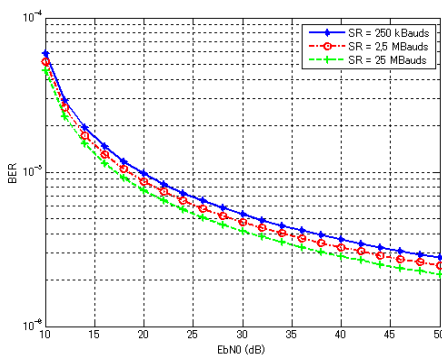


Figure 4. BER vs E_b/N_0 by varying symbol rates.

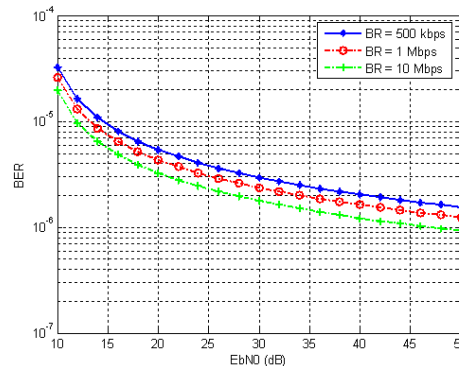


Figure 5. BER vs E_b/N_0 by varying bit rate values.

3.4. Impact of Bit Rate

The impact of bit rate on BER performance of OFCDM is clearly illustrated in Figure 5. Simulated bit rates are 500 kbps, 1 Mbps and 10 Mbps, respectively. The result reveals that higher bit rate gives better performance, where BER vs E_b/N_0 at bit rate of 10 Mbps is smaller than that of 500 kbps, and 1 Mbps. For example, when E_b/N_0 is equal to 50 dB, BER at bit rates of 500 kbps, 1 Mbps, and 10 Mbps are $1,55 \times 10^{-6}$, $1,24 \times 10^{-6}$, and $9,301 \times 10^{-7}$, respectively. So the highest bit rate is still achieved a lower BER. This is crucial for the succesful transmission of OFCDM data with acceptable BER performance.

3.5. Impact of Guard Interval

The impact of number guard interval (GI) in OFCDM simulation over Rayleigh Fading channel is depicted in Figure 6. Size of GI in this simulation is 16, 32, and 64, respectively. It can be seen that BER for the lower of GI is smaller than the larger one. For example, E_b/N_0 is equal to 30 dB, BER for GI of 16, 32, and 64 are $5,9191 \times 10^{-7}$, $2,367 \times 10^{-6}$, and $1,125 \times 10^{-5}$, respectively. It is clearly shown that to achieve better BER performance the size of GI should be small. The larger of GI can reduce the transmission efficiency because no new information can be transmitted during the guard interval. So the GI must be chosen sufficiently small for a good performance.

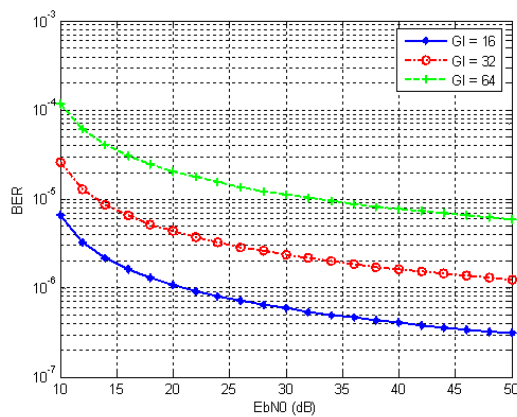


Figure 6. BER vs E_b/N_0 by varying size of guard intervals.

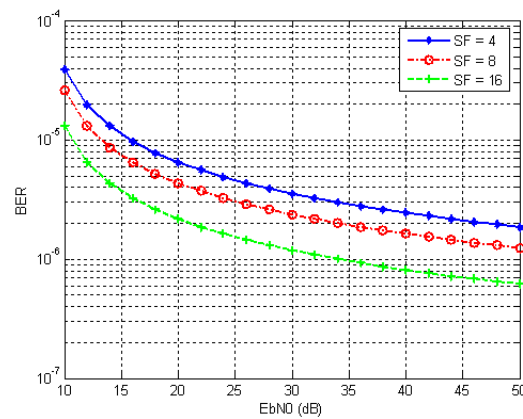


Figure 7. BER vs E_b/N_0 by varying size of spreading factors.

3.6. Impact of Spreading Factor

Spreading factor (SF) is the last parameter of OFCDM system that is going to discuss in this paper. The impact of number of SF in OFCDM simulation at Rayleigh Fading channel is shown in Figure 7. The SF is set to 4, 8 and 16 in this simulation. As can be seen in the Figure 7, the higher of SF gives better performance since it has better interference rejection. As a comparison, when E_b/N_0 is equal to 50 dB, BER for SF of 4, 8, and 16 are $1,86 \times 10^{-6}$, $1,24 \times 10^{-6}$, and $6,2 \times 10^{-7}$, respectively. Therefore, the BER is improved as the SF increases because the spreading codes can cancel correlated noise. The higher SF also decreases the impact of cell interference. However, the higher SF reduces the actual throughput.

4. Conclusion

In this paper, we have investigated the impact of several parameters on the performance of OFCDM system over Rayleigh Fading channel. A model to investigate the performance of OFCDM system has been proposed. The investigated parameters of OFCDM system are number of carriers, size of symbol, symbol rate, bit rate, guard interval and spreading factor. Further computer simulation model of OFCDM system has been introduced to obtain the performance in terms of BER and E_b/N_0 . The computer simulation has been done by using MATLAB programming to simulate the impact of the investigated parameters on the OFCDM's performance. Each of investigated parameter has been examined in three different

values in the simulation. The results shown that the larger number of carrier, higher of symbol rate, higher of bit rate and large of spreading factor were given better performance of OFCDM. In the larger carriers, the received signal can approximated and recovered from contaminated by interference. OFCDM with higher symbol rate enables high rate transmission. Higher bit rate is preferred for the successful transmission with acceptable BER in OFCDM. While large spreading factors decreases impact of cell interference. Conversely, when the larger of guard interval was given, the system performance is worsen. So guard interval should be small for a good performance since larger guard interval reduces transmission efficiency. Based on the results, the investigated parameters in this paper should be considered for the future implementation of OFCDM in the 4G wireless communications.

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