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An Efficient Energy Scheme OFDM Based on Signal Transmission in LTE Environment

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Abstruct

Orthogonal Frequency Division Multiplexing (OFDM) has been utilized in several wireless communication systems, due to its robustness in multipath environments and relatively low complexity, which allow to achieve high performance and better transmission quality.

This paper proposes an easy, efficient energy scheme based on OFDM for signal transceiving in LTE environment through reducing the length of the Cyclic Prefix (CP) to have an optimum, appropriate number of frame sub-carriers applied on different fading conditions of the communication channel (AWGN, Rayleigh).

Simulation programmed using MATLAB box communication system tools show that the proposed system nearly maintains the same bit error rate (BER) about 10^{-6} in an AWGN channel with SNR about 10dB and (2.6% to 4.9%) energy saving. While the BER improves in Rayleigh fading channel up to 10^{-5} with SNR increases up to 9dB and (1.6% to 3.5%) energy saving where this improvement decrease bandwidth and increases energy efficient in wireless communication.

Key words: OFDM, Cyclic Prefix, LTE, Energy Efficient.

Table (1): Abbreviations and Acronym.

Abbreviations	Acronym
3GPP	Third Generation Partnership Project
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
CP	Cyclic Prefix
DAC	Digital to Analog converter
dB	Decibel
DS	Doppler Spread
EE	energy efficiency
FFT	Fast Fourier Transform
FS	Frequency Selective
ICI	Inter-Carrier Interference
IFFT	Inverse Fourier Transform
ISI	Inter-symbol Interference
ITU	International Telecommunication Union
LTE	Long Time Evolution
OFDM	Orthogonal Frequency Division Multiplexing
S/P	Serial to Parallel
SNR	Signal to Noise Rate

1. Introduction

Mobile communication technologies have developed very quickly where high reliability characteristics in the mobile environment represents a crucial condition for users [1]. Mobile communications systems have changed from single-carrier systems to OFDM multi-carrier systems, where single-carrier systems require complex equalizers to compensate for the effects of the channel, while OFDM is simpler and overcome multipath efficiently-Fading using a CP [2].

Technology is required to support these higher data rates with maximum spectral efficiency, which leads the way toward OFDM since it successfully applied to many types of digital communications due to its high spectral efficiency [3].

Recently, OFDM adopted by LTE in the third generation, LTE Partnership Project (3GPP), which supports scalable bandwidth from 1.25 MHz to 20 MHz with 15 kHz subcarrier spacing, depending on the bandwidth. Fast Fourier Transform (FFT) size ranges from 128 to 2048 where LTE uses OFDM for downlink data transmission and Inverse Fast Fourier Transform (IFFT) for uplink transmission.[4][5]

In wireless communications, multipath blackout (multipath propagation) results in inter-symbol interference (ISI) as well as inter-carrier interference (ICI) for OFDM signals, which severely degrade system performance. Thus, in practical OFDM systems, the CP transmitted during the guard period, consisting of the end of the OFDM symbol, is copied during the guard period, and the guard period is transmitted in accordance with the guard interval after the OFDM symbol. The reason of guard interval includes a copy of the end of the OFDM symbol is to allow the receiver to integrate an integer number of sinusoidal periods for each multipath while performing OFDM demodulation with FFT. [6] [7]

OFDM has excellent multipath durability, while CP maintains orthogonality between subcarriers. CP allows the receiver to more efficiently collect multipath energy. However, for a given total transmit power, the insertion of an uninformative CP reduces the effective energy per data bit. In general, the power loss is proportional to the relationship between CP length and symbol duration. If CP is too long, the power loss will be much higher. [8]

Recently, energy efficiency (EE) has become more and more important for the future of wireless due to limited battery resources in mobile devices [9]. Improving the EE can also reduce greenhouse gas emissions, which is considered to be one of the most serious threats to the global environment in human history. Many researches examine EE, spectral efficiency (SE) or the combination of the two in the context of wireless communication [10] [11].

Fig (1) illustrates the most concepts of an OFDM signal and therefore the inter-relationship between the frequency and time domains. Within the frequency domain, multiple adjacent tones or subcarriers are every severally modulated with complicated data. An Inverse FFT transform is performed on the frequency-domain subcarriers to provide the OFDM symbol in the time-domain. Then in the time domain, guard intervals between each of the symbols are inserted to forestall inter-symbol interference at the receiver caused by multi-path delay unfold in the radio channel. Multiple symbols may be concatenated to form the ultimate OFDM burst signal. At the receiver, an FFT is performed on the OFDM symbols to recover the initial information bits.

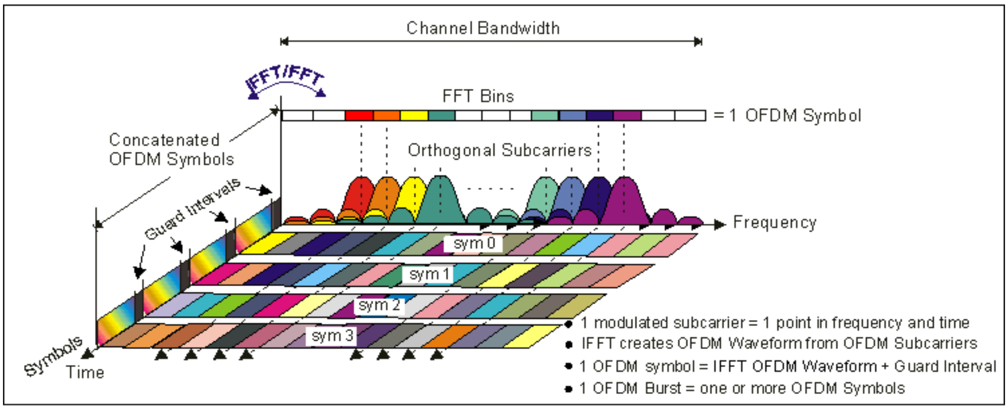

Fig (1) Frequency- Time Representative of an OFDM Signal [12].

BPSK modulation produces constant amplitude signal which reduce problems with amplitude fluctuation due to fading over different Communication Channels (AWGN & Rayleigh Channels) [13].

This paper proposes and simulates an easy, energy efficient transmission scheme that improves the EE for OFDM systems with BER as a function to SNR in OFDM Systems, use BPSK Modulation and compare system performance for different CP lengths of the OFDM System, which provides mobile communication with longer time through minimum power consumption

2. Method and Material

The system proposed in this paper requires equipment's and methods for implementing the OFDM transceiver based on BPSK modulation which may be classified as supplementary which must be provided and essential which must be satisfied as given.

2.1 Requirement:-

The system in Fig (2) represents the component of the proposed system which contains: -

1 - Binary input which represent the data entry to the system

2 - BPSK modulation: are a dual modulation schemes, wherever the 0's and 1's during a binary message are pictured by both completely different part states within the carrier signal. In digital modulation techniques, a collection of basis functions are chosen for a specific modulation scheme. Generally, the idea functions are orthogonal to every other. Basis functions may be derived victimization Gram solon orthogonalization procedure. Once the basics functions are chosen, any vector in the signal area can be represented as a linear combination of them. In BPSK, just one sinusoid is taken because the basis function. Modulation is

achieved by varied the part of the sinusoid counting on the message bits. The 2 completely different phase states of the carrier signal are:-

$$S_1(t) = A_c \cos(2\pi f_c t), \quad 0 \leq t \leq T_b \text{ for binary 1}$$
$$S_0(t) = A_c \cos(2\pi f_c t + \pi), \quad 0 \leq t \leq T_b \text{ for binary 0}$$

3 - S/P conversion: the Serial to Parallel converter takes the serial stream of input bits and outputs N parallel streams (indexed from 0 to N-1).

4- IFFT: The IFFT takes frequency-domain input data (complex numbers representing the modulated subcarriers) and converts it to the time-domain output data (analog OFDM symbol waveform).

5- Guard Interval/Cyclic Prefix: Is a periodic addition of the final part of an OFDM symbol that is added to the front of the symbol in the transmitter, and at the receiver the CP is removed before demodulation. Usually adding (CP) has as 2 functions that are eliminate the bury image interference (ISI) and inter-channel interference (ICI)

6 - DAC: converts a digital signal from the computer into an electrical voltage which can be used to drive electrical equipment

7- Channel Models: Between transmitter and receiver, environments can be defined as channel. On channel transmission system are influenced by reflection, refraction and scatter. In theoretical model, there are some methods. In this paper, AWGN and Rayleigh Fading were used to model the communication channel.

- AWGN: This channel is one of the simplest mathematical models for various physical communication channels, including fixed lines and some radio channels. It is noise that affects the transmitted signal as it passes through the channel.
- Rayleigh fading: It has been observed that when there is no line of sight, the path between transmitter and receiver,

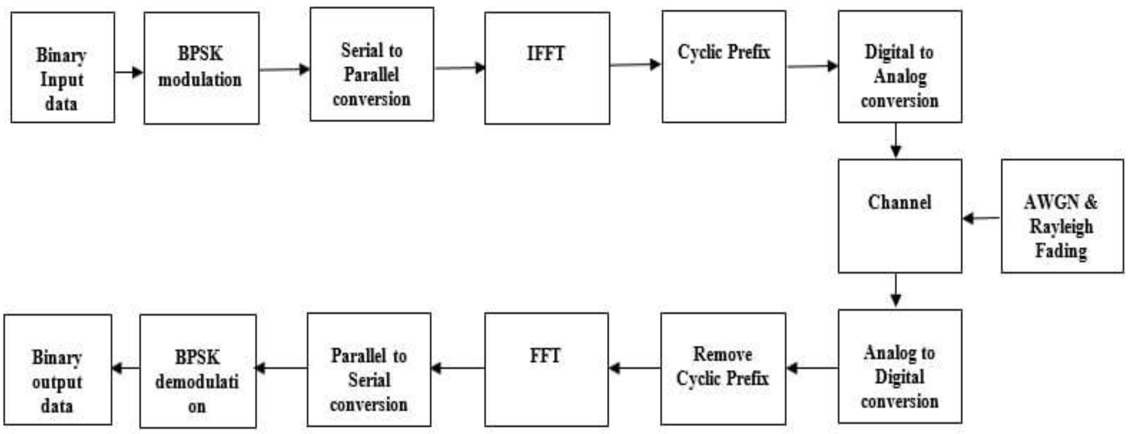

Fig (2) OFDM Transceiver

which has only one indirect path, the received signal at the receiver will be the sum of all reflected and scattered waves. For different paths they have a distribution of, called the Rayleigh distribution, this is called the Rayleigh fading distribution.

8- FFT: Is able to convert a signal from the time domain to the frequency domain. The FFT of a non-periodic signal will cause the resulting frequency spectrum to suffer from leakage.

9-P/S conversion: is used for summing all subcarriers and combining them into one signal. Input word is split into N time-multiplexed output words where N is the ratio of number of input bits to output bits. The order of the output can be either least significant bit first or most significant bit first (depends on application).

2.2 OFDM System Performance

OFDM performance was estimated with these channels according to a BER of, and the SNR was calculated on AWGN and Rayleigh fading channel.

2.2.1 Bit Error Rate

Performance analytics for modern digital communication systems. With end-to-end performance metrics. This performance metric is usually bit error rate (BER), which quantifies the reliability of the entire system from "input bits" to "output bits," including electronics, antennas, and signal paths in the middle. BER can be mathematically defined as.

$$\textbf{BER} = \frac{\textit{No. Of Errors}}{\textit{Total Bits Recevied}} \qquad \textbf{, BER (dB) = 20 } \log_{10}(BER)$$

There are several factors that affect BER. If the bit rate and transmission medium are good at a certain time, but the signal-to-noise ratio (SNR) is high, the BER will be very low.

2.2.2 Signal to Noise Ratio

SNR is the ratio of the received signal to the noise in the frequency domain. SNR can be mathematically defined as, SNR is an indicator often used to assess the quality of a communications link. A higher value of SNR means a better quality of the communication link.

$$\textbf{SNR} = 10 \log_{10} \frac{Signal\ power}{Noise\ power} dB$$

SNR is an indicator often used to assess the quality of a communications link. A higher value of SNR means a better quality of the communication link.

3. OFDM Programming In Matlab

The system proposed in this paper is simulated using Matlab, because it supports a toolkit called Communication System Toolbox, which contains a large group of classes that represent channels, modifications and communication tools. These tools allow using these classes and specifying their parameters instead of complex mathematical modeling.

3.1 Simulations

The OFDM performance analysis was performed in terms of different cases of subcarriers number are simulated with various CP length over different communication fading channels (AWGN, Rayleigh Fading) according to BER over SNR where the number of subcarriers starts from 128 to 2048 subcarriers with FFT points for 1000 OFDM frames (symbol) transmitted and 6 line numbers for the multipath Rayleigh channel, since each OFDM symbol folds with 6 line Rayleigh fading channel.

3.2 System Parameters

The system parameters used for adjusting the system to obtain best performance for the proposed system are illustrated in table (2).

Table (2): System Parameters.

Parameter	Values
Avg. Path Gains	[0 -0.9 -4.9 -8 -7.8 -23.9] , (dB)
Doppler Spread (FD)	50 Hz
Frequency Selective (FS)	3.84 MHz
No of Cyclic Prefix (CP)	4, 8, 16, 32
No of Frames	1000
No of Subcarriers (N)	128, 256, 512, 1024, 2048
Path Delays	[0 200 800 1200 2300 3700]*1e-9 , (sec)
Time Sample (TS)	1/FS

Table(3) illustrated these cases where the highlighted cases represents the optimum cases where they considered the best for each type of fading since CP is minimum and the No. of subcarriers is maximum and hence represents the best and most efficient combination scheme for the system power.

For 128 number of subcarriers with 2 various CP lengths over different communication channels, the system on Rayleigh fading channel shows a better response when the length of CP is 8 symbols than the length of CP is 4 symbols, while the system on AWGN fading channel shows nearly same response for CP is 4 or 8, but the overall system response in AWGN is better than the overall system response in Rayleigh fading channel.

Table (3): Different cases of subcarriers number 128 to 2048.

Case No.	No. of Subcarriers	Simulated Results	
1	128	CP Length 4 - 8	
		Rayleigh fading	8 symbols show better performance than 4 symbols.
		AWGN	Nearly compatible response up to SNR =9dB & BER= 10^{-5}
		Rayleigh fading & AWGN(8)	AWGN show better performance than Rayleigh fading
2	256	CP Length 4 - 8	
		Rayleigh fading	8 symbols show better performance than 4 symbols.
		AWGN	Nearly Compatible as in 128 up to SNR=8dB & BER=10^{-5}
		Rayleigh fading & AWGN(8)	AWGN show better performance than Rayleigh fading
		CP Length 8 - 16	
		Rayleigh fading	8 symbols show better performance than 16 symbols.
		AWGN	Nearly 8 &16 Symbol responses are Compatible to each other
		Rayleigh fading & AWGN(16)	AWGN show better performance than Rayleigh fading
		CP Length 4 - 8	
		Rayleigh fading	8 symbols show better performance than 4 symbols.
		AWGN	Nearly 4 & 8 Symbol responses are Compatible to each other

3	512	Rayleigh fading & AWGN(8)	AWGN show better performance than Rayleigh fading
		CP Length 8 - 16	
		Rayleigh fading	8 symbols show better performance than 16 symbols.
		AWGN	Nearly 8 &16 Symbol responses are Compatible to each other
		Rayleigh fading & AWGN(8)	AWGN show better performance than Rayleigh fading
4	1024	CP Length 8 - 16	
		Rayleigh fading	8 symbols show better performance than 16 symbols.
		AWGN	Nearly Compatible up to SNR=10dB &BER= 10^{-6}
		Rayleigh fading & AWGN(16)	AWGN show better performance than Rayleigh fading
		CP Length 8 - 32	
		Rayleigh fading	Nearly 8 &32 Symbols response are Compatible to each other
		AWGN	Nearly 8 &32 Symbol responses are Compatible to each other
		Rayleigh fading & AWGN(32)	AWGN show better performance than Rayleigh fading
5	2048	CP Length 8 - 32	
		Rayleigh fading	32 symbols show better performance than 8 symbols.
		AWGN	Nearly 8& 32 Symbol responses are Compatible to each other
		Rayleigh fading & AWGN(32)	AWGN show better performance than Rayleigh fading

4. Results

The results of this work were compared with the results of some previous works as demonstrated in table(4), the results achieved in this work where nearly the same like the previous ones, unlike the others Rayleigh fading were simulated, tested and evaluated. Table(3) illustrates all the cases scenarios simulated, where the system responded exceptionally for some cases that are highlighted in table (3). Fig (3) & Fig (4) shows the system responses for Rayleigh fading channel, where the CP is 8 and 16 for 256 and 512 number of sub-carrier respectively, both responses shows no huge differences on system performance while an energy saving is achieved due to the reduction of the CP of the frames, while maintaining the BER with the SNR. Fig (5) & Fig (6) shows the system responses for AWGN fading channel where the CP is 8 and 32 for 1024 & 2048 number of sub-carrier respectively, both responses shows no differences on system performance while higher energy saving is achieved based on Rayleigh fading channel due to the reduction of the CP of the frames, while maintaining the BER with the SNR better than the one in Rayleigh fading channel. This leads to transmit the largest data volume with the smallest CP size, the lowest transmission power consumption, the highest SNR and the lowest BER which rises system reliability in transmission.

Table (4): Some of previous results compared to the achieved results

Research Papers	**Parameters**		
	CP	**Power Saving**	**BER**
This work	4→32	AWGN 2.6% to4.9% Rayleigh Fading 1.6% to 3.5%	AWGN No change or negligible Rayleigh Fading Improve to 10^{-5} with SNR increase up to 9dB
Reference (5)	128	AWGN (only) by 5%	AWGN No Change
Reference (14)	256	AWGN (only) by 4%	AWGN Improved by 4dB

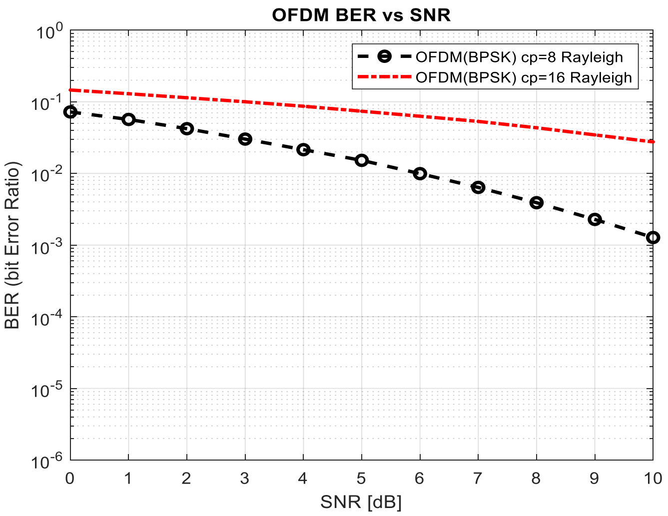

Fig (3) case 256: Rayleigh fading with CP (8, 16)

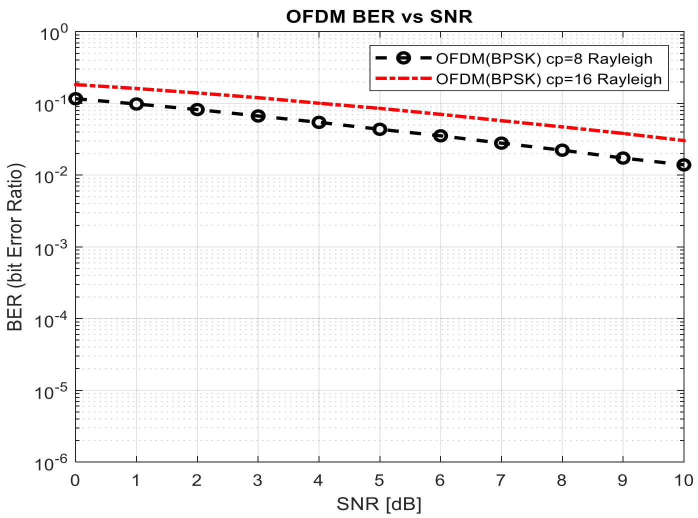

Fig (4) case 512: Rayleigh fading with CP (8, 16)

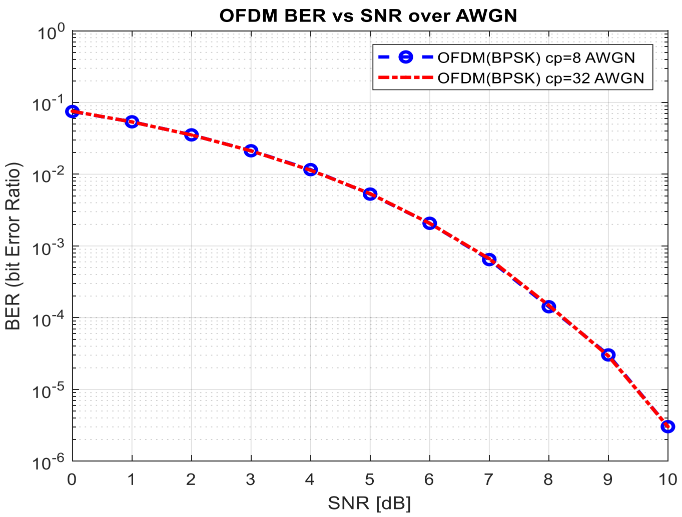

Fig (5) case 1024: AWGN with CP (8, 32)

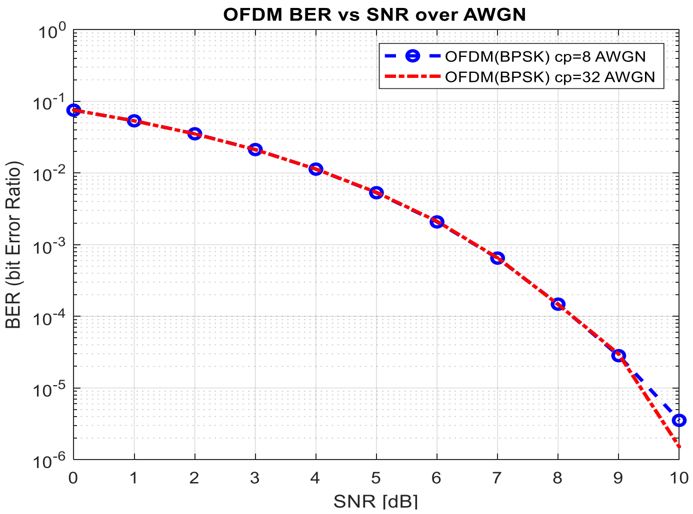

Fig (6) case2048: AWGN with CP (8, 32)

5. Conclusion

The simulation of the system proposed in this paper shows an EE transmission scheme for OFDM systems with LTE. The system scan the CP length size range of (4→32) with sub-carrier frame size range of (128→2048) on both different fading channel (AWGN, Rayleigh fading). An appropriate length of CP with convenient number of subcarriers guarantee maximum SNR with lowest BER which allows minimum BW with minimum power consumption.

The proposed system may provide mobile communication a longer battery time through minimum power consumption, where minimum bandwidth provides multiple communication, also maximum SNR means better communication and lowest BER means high quality of mobile communication with lower battery power usage.

The proposed system nearly maintains the same bit error rate (BER) about 10^{-6} in an AWGN channel with SNR about 10dB with (2.6% to 4.9%) energy saving. While the BER improves in Rayleigh fading channel up to 10^{-5} with SNR increases up to 9dB with (1.6% to 3.5%) energy saving where this improvement increases the wireless communication time.

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