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Performance Analysis OFCDM with Different Modulation Schemes in LTE

Bungatavula Chandra Sekhar*, T. Ramya* and B. Ramachandran*

ABSTRACT

Next generation mobile communication systems involves transmission of several multimedia information, and hence need for increased data rate is inevitable. The OFDM technique which is widely used in 4G LTE standards suffers with problem of adjacent cell interference, which can be overcome by employing two dimensional spreading (Time and Frequency) to OFDM that facilitates single frequency reuse, frequency diversity and flexible transmission rates. In this work, an advanced multiple access scheme called OFCDM (Orthogonal Frequency Code Division Multiplexing) is taken for analysis which provides high data rate and at the same time combats issues of OFDM. The comparative analysis of BER as function of SNR between OFDM and OFCDM in Gaussian and Rayleigh fading channels is simulated with different signal mapping techniques and the results shows that OFCDM outperforms OFDM in terms of error rate.

Index Terms: OFDM, OFCDM, Two dimensional Spreading, LTE.

I. INTRODUCTION

The need for very high speed communication is increasing exponentially every year. To meet this demand, many solutions are to be considered in development of new methods in communication technologies. In general researchers to concentrate on data rate, latency, throughput, system capacity, spectral efficiency and power efficiency. In fact multiple access technique play important role in multi user environment. 3G wireless communication systems use wideband CDMA to achieve high data rates up to 2Mbps. However the need in real time multimedia applications through internet needs 4G communication which targets 50Mbps in uplink and 100Mbps in downlink providing maximum coverage area in full mobility and 1Gbps in low mobility environment. 4G is also referred to as Long Term Evolution (LTE) designed and developed by 3GPP as an air interface for cellular mobile communications. It is used to increase the capacity and data transfer rate of telephone networks used mainly for data rate communication.

Current LTE wireless technology uses OFDMA in downlink and SC-OFDMA in uplink. OFDMA is multi-user version of OFDM digital modulation scheme. This technique is widely used because of its greater advantages such as high spectrum efficiency, robustness against multipath fading and resistance to multi-user interference. In spite of having many advantages, it has few drawbacks such as phase noise, adjacent cell interference, Peak to average power ratio (PAPR) and also it doesn't provide coherent frequency diversity [1]. The problem of adjacent cell interference can be overcome by introducing spreading in OFDM to provide frequency diversity gain and facilitate single cell frequency reuse. So, introducing time and frequency domain spreading in OFDM achieves all the benefits of OFDM along with frequency diversity gain due to frequency spreading and flexible transmission rates due to time domain spreading. This two dimensional spreaded OFDM technique is called OFCDM which is proven to be advantageous than OFDM [1]. This paper shows the comparative BER analysis as a function of SNR between OFDM and OFCDM with different modulation techniques in Gaussian and Rayleigh fading channels.

* Department of ECE, SRM University, Chennai, India

BER performance of OFCDM increases with the signal-to-noise ratio (SNR). More over its performance can still be improved as the number of detection stages increases especially at high SNR [1]. Applying MIMO technique shows further improvement in BER performance. The error rate is low for higher symbol rate that enables high transmission rates but requires high bandwidth and also higher the bit rate the lower the error rate [2]. As the spreading factor increases, the BER performance increases along with the rejection of interference due to cancelation of correlation noise [2]. In slow moving environment where minimum Doppler frequency occurs, low time spreading factor is sufficient. Where as in case of high Doppler frequency, time spreading factor should be high for 16QAM modulation to ensure better performance [3]. The average peak power is reduced by 5dB by using a technique called Sub-Carrier Processing (SCP) due to which interference power of subcarrier decreases then BER decreases which cause increase in system throughput [4]. OFCDM with ZF equalizer had better performance than MC-CDMA MMSE at low values of SNR, but beyond some limit, MC-CDMA MMSE's BER fell drastically. However, OFCDM MMSE continuous to perform better than MC-CDMA MMSE [5]. When the detection stages at the receiver are less than 2, OFCDM has no frequency diversity to exploit and its performance is highly dependent on channel coding. However, it is observed that beyond Nf = 8, the performance becomes stable and does not improve further. It is due to the increase in MCI as the frequency domain spreading factor is increased [6-7].

This paper is organized is as follows: section II presents the general OFDM system. In section III, implementation of OFCDM system along with 2D spreading used in this work is explained. In section IV, the BER analysis from simulation results are discussed and finally conclusion and future scope are given in section V.

II. OFDM

Information in the digital communication is expressed in the form of bits. Group of bits are combined to form symbols. Symbols format may vary in size from system to system. To achieve the higher efficiency, the available spectrum is divided in to the several orthogonal subcarriers. Symbols in spectral space are taken to form OFDM data by using modulation technique and convert them to time domain by taking Inverse Discrete Fourier Transform (IDFT). IDFT is usually used because of its simplicity in implementation. After modulating OFDM symbols, the carriers transmitted in parallel occupies the fully available frequency bandwidth. For the received signal to be synchronized at receiver, the OFDM symbols are modulated on frame basis, which is done by dividing symbols into frames. Probability of Inter Symbol Interference (ISI) may be less for longer symbol durations, but could not be eliminated. To make almost eliminated, a Cyclic Prefix (CP) is added to each symbol. CP is typically 25% of cycle from the end of symbol added to the front of symbol. Addition of CP allows to capture the symbol with uncertainty of CP length and still able to obtain correct information on full symbol length. These cyclically extended symbols are mapped over continuous signal and transmitted over communication channel. This is clearly shown in Fig.1. At the receiver section the exact reverse process is done for each OFDM symbol [8].

III. OFCDM

The major difference between OFDM and OFCDM is 2D spreading. OFCDM uses 2D spreading utilizing both time and frequency domain spreading. In this technique, every symbol is initially spread in time domain with spreading factor Nt and later with frequency domain spreading factor Nf. By spreading in both time and frequency domain, it achieves greater advantages of frequency diversity [1]. The total spreading factor is Nt x Nf. The Fig-2 shows OFCDM system model with 2D spreading of Nt=4 and Nf=2. Here single cell reuse is possible because of Nf >1 [1].

The data bits generated are passed through the serial to parallel converter which allows data bits to be transmitted in parallel for processing on multiple channels. Parallel converted data on channels is encoded using channel encoder and modulated. 2D spreader spreads the modulated data in time and frequency. At

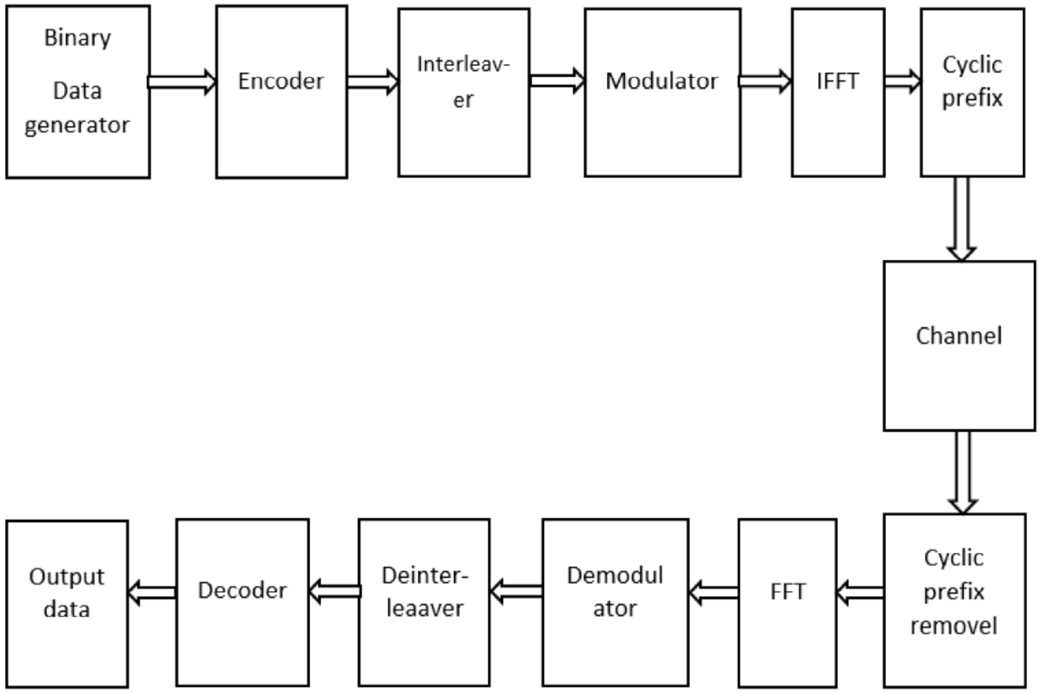

Figure 1: OFDM Block Diagram

the multiplexer, the parallel processed data streams are multiplexed to form serial output. Serial output of parallel to serial converter is scrambled using scrambler for data recovery during burst errors. IFFT realizes the up conversion and OFDCM symbols are obtained at its output and interleaved by inserting guard interval between the symbols using guard interleaver to prevent ISI. OFCDM symbols are fed to pulse shaping filter where the processed data is mapped on to a waveform for transmission and transmitted to channel using high gain antenna.

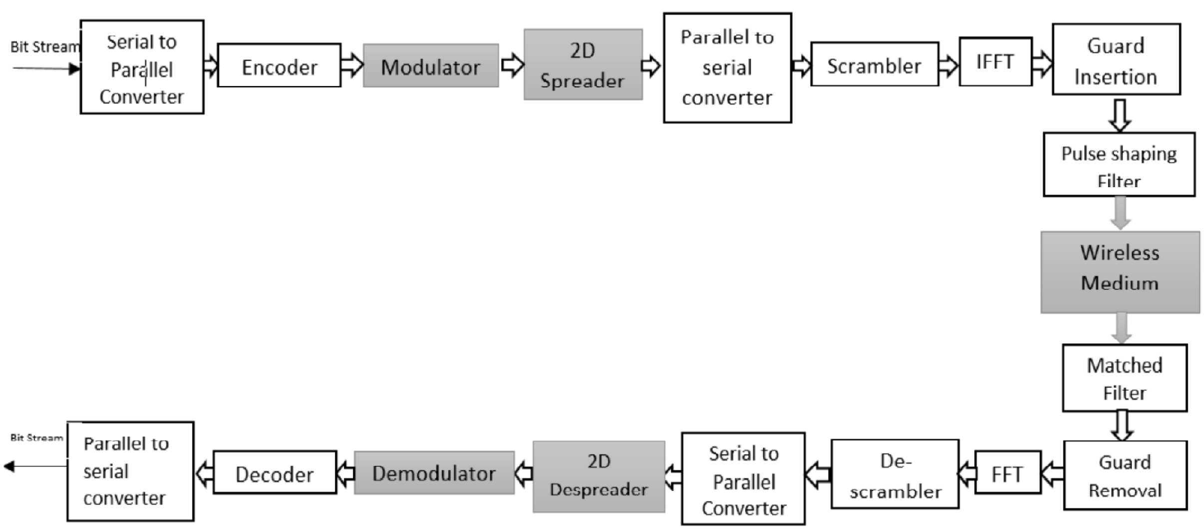

Figure 2: OFCDM Block Diagram

At the receiver, the exact reverse operation of transmitter section is performed. Received waveform at antenna is detected and de-mapped using matched filter, removed guard interval. FFT realizes down conversion of OFCDM symbols and converted to its respective frequency domain. Descrambler rearranges the symbols and despreaded using 2D despreader. Finally demodulated and decoded to extract the data bits on each interleaved channel.

(A) Two dimensional spreading and despreading

The process of 2D spreading and despreading involves the processing of symbols in both time and frequency domain. Here we use spreading factors of Nt = 4, Nf=2 (SF=8). Each OFDM symbol is initially spread in time domain with time spreading factor of Nt = 4 where the symbol is multiplied with orthogonal code whose dimension is equal to Nt {+1, -1, +1, -1}. This time spreaded symbols are copied over interleaved subcarriers for spreading in frequency domain with frequency spreading factor of Nf=2 with code {+1, -1} whose dimension equal to Nf. Symbols over interleaved subcarrier is multiplied with frequency spreading code. This gives the 2D spreaded symbols over the subcarriers. The same process of spreading is done for every OFDM symbol [3].

At the receiver section 2D despreader does the exact reverse operation of 2D spreader at transmitter. Each interleaved subcarrier is initially despread in time domain where signals are multiplied with time spreading code {+1, -1, +1, -1} and then added over all the time domain. After the time domain despreading, subcarriers over the frequency domain are despreaded by multiplying with frequency spreading code {+1, -1} and added over all frequency domain.

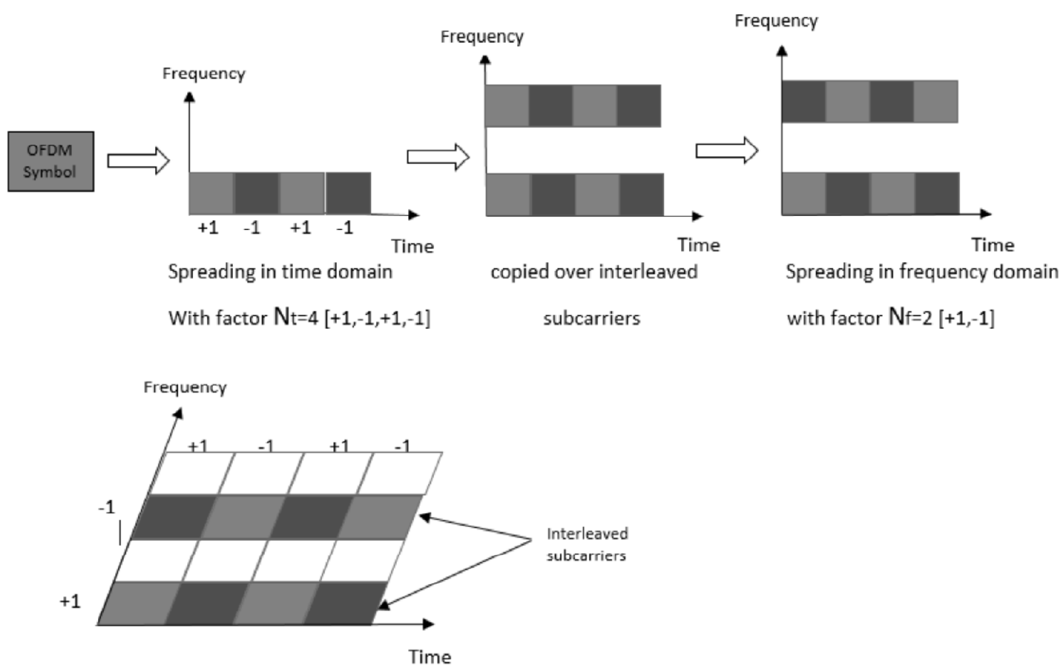

Figure 3: Two Dimensional Spreading

IV. SIMULATION

Simulation of OFCDM system is carried out using MATLAB software having each block in OFCDM system with appropriate parameters and below shown Table.1 gives parameters of the system. Simulation is done assuming single user in single cell environment with no multi-user interference. Downlink transmission with Perfect channel estimation is assumed at receiver so that BER performance of multiple access technique alone can be observed. Constant spreading factor of SF=8 is used throughout the simulation for OFCDM system.

(A) Simulation Results

Simulation plots from Fig: 4 to Fig: 7 show BER Vs SNR (dB) analysis, each graph for a particular modulation technique BPSK, 4QAM, 16QAM and 64QAM comparing both OFDM and OFCDM in Gaussian and Rayleigh channels. From the simulation results we interpret that the error rate in OFCDM has greater

Table I
simulation parameters

FFT Size	64
Modulation	BPSK, 4QAM, 16QAM, 64QAM
Number of subcarriers	1024
Number of symbols	10^4
Bits per symbol	52
Spreading	Two Dimensional
Nt	4
Nf	2
Channel Bandwidth	100 MHz
Environment	Single cell
Channel	Gaussian, Rayleigh

exponential fall compared to OFDM and it is also observed that, at higher signal to noise ratio the BER is extremely low for Gaussian channel in case of OFCDM. It is seen that OFCDM outperforms the OFDM on basis of error rate.

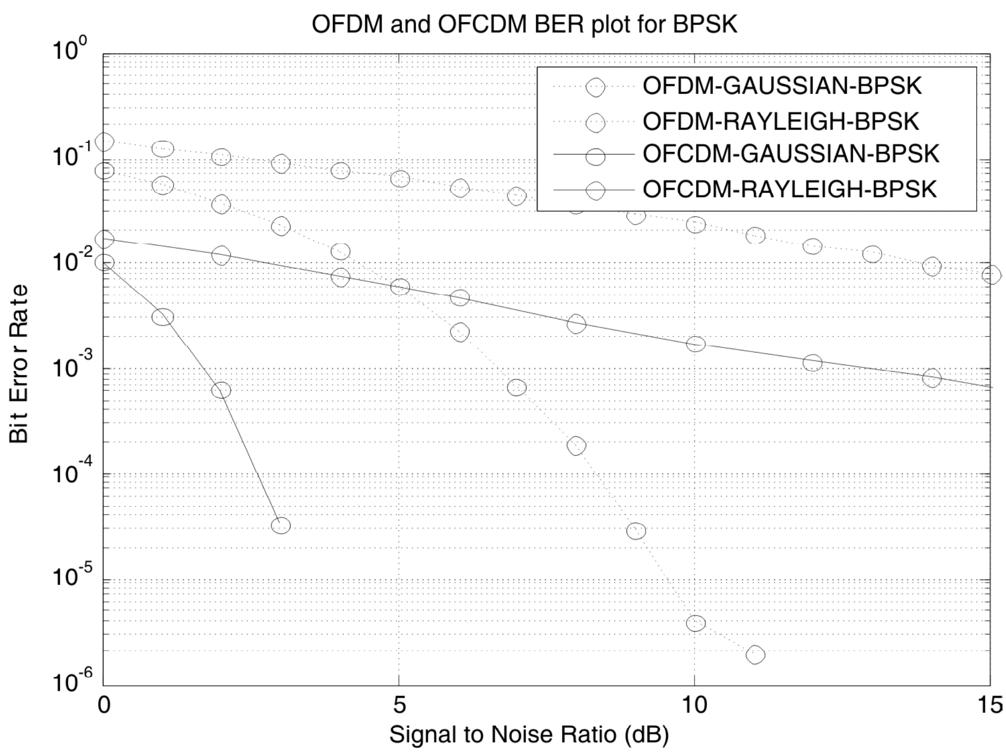

Figure 4: BER Vs SNR of OFDM and OFCDM in Gaussian and Rayleigh using BPSK modulation

Above plot in Fig: 4 is plotted for OFDM and OFCDM in Gaussian and Rayleigh using BPSK modulation. It is observed that the error rate is very low even at low SNR of 5dB in case of OFCDM compared to OFDM in both the channels. OFCDM achieves gain in SNR of 5dB in case of Gaussian channel and 10dB in case of Rayleigh channel.

The above Fig 5 shows the BER comparison of OFDM and OFCDM in Gaussian and Rayleigh using 4QAM modulation. The graphs depicts that OFCDM with its lower error rates achieves gain in SNR of 5dB in case of Gaussian channel and 11dB in case of Rayleigh channel.

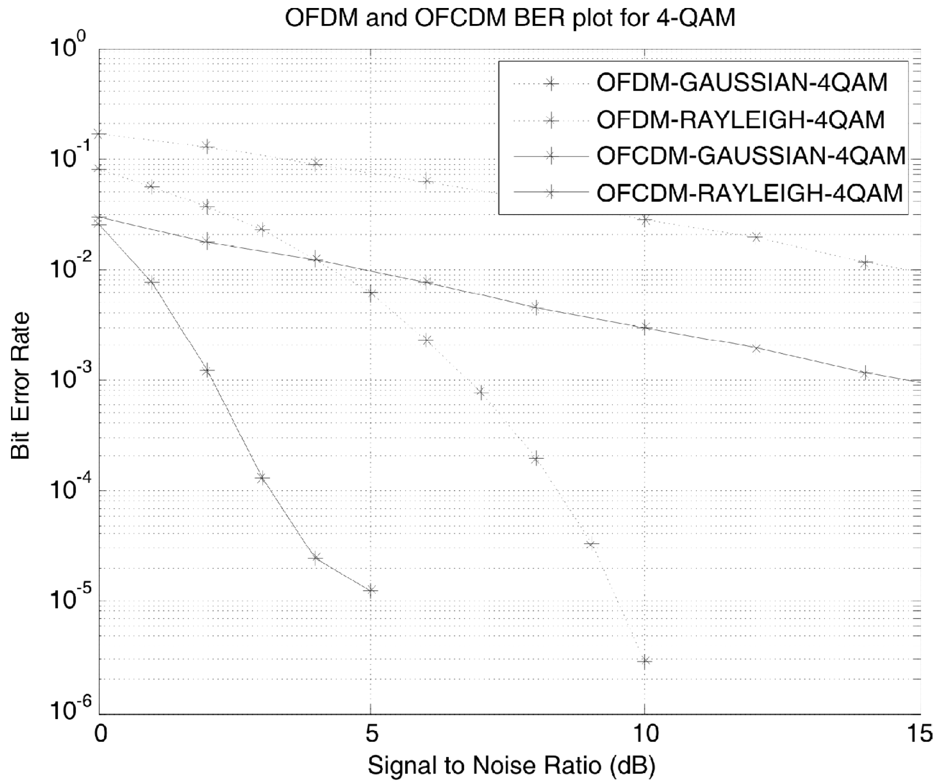

Figure 5: BER Vs SNR of OFDM and OFCDM in Gaussian and Rayleigh using 4QAM modulation

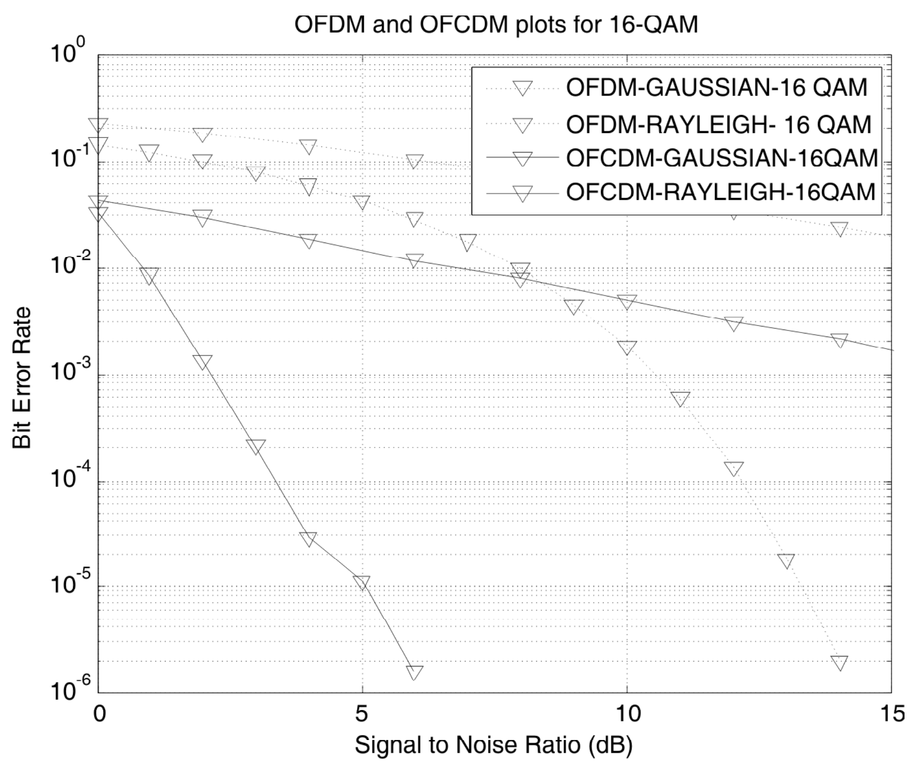

Figure 6: BER Vs SNR of OFDM and OFCDM in Gaussian and Rayleigh using 16QAM modulation

The above Fig. 6 show BER analysis for OFDM and OFCDM in Gaussian and Rayleigh using 16QAM modulation, it is observed that OFCDM gains SNR of 10dB in case of Gaussian channel and 12dB in case of Rayleigh channel.

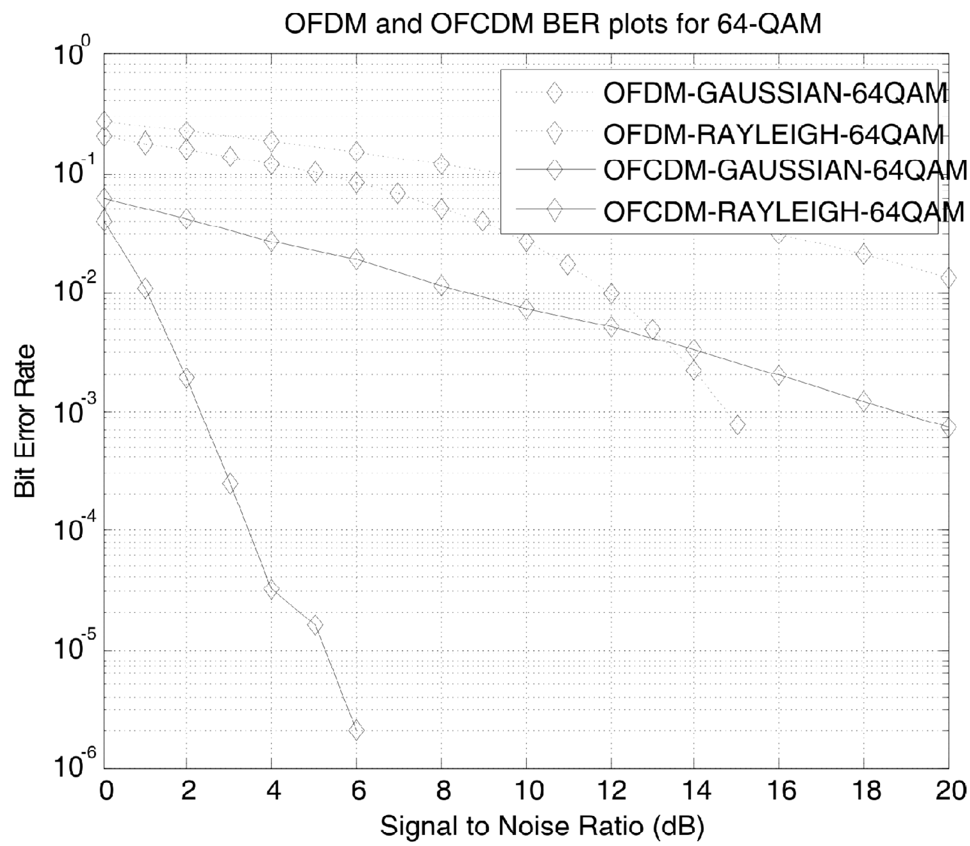

Figure 7: BER Vs SNR of OFDM and OFCDM in Gaussian and Rayleigh using 64QAM modulation

From the above fig. 7 the BER analysis for OFDM and OFCDM in Gaussian and Rayleigh using 64QAM modulation, it is observed that there is high fall in error rate compared BPSK, 4QAM and 16QAM. Though 64QAM is showing greater performance in error rate and also gain in SNR of 12dB, the gain in SNR is approximately same in case of both the Gaussian and Rayleigh channels.

From this analysis, the error rate performance of OFCDM technique is comparatively less than the OFDM and below shown Table-II gives the analysis of gain in SNR achieved by using OFCDM with respect to OFDM.

Table II
Gain in signal to noise ratio

Modulation	*Gain (dB)*	
	Gaussian	*Rayleigh*
BPSK	5dB	10dB
4QAM	5dB	11dB
16QAM	10dB	12dB
64QAM	12dB	12dB

V. CONCLUSIONS

In this work ,the implementation of OFDM and OFCDM models is done using simulation and investigated for BER Vs SNR performance of OFDM and OFCDM in Gaussian and Rayleigh channels for BPSK, 4QAM, 16QAM and 64QAM modulation techniques. BER performance of OFCDM in comparison with OFDM is analyzed for both channels for a particular modulation and the results show that the OFCDM technique has lower error rates even at low SNR, achieving high gain in SNR, which is proven to be greater importance in future generation communication systems in high data rate applications. Hence, the work concludes that OFCDM outperforms OFDM technique in its error rate performance.

The work analysis is made with constant spreading factor of Sf=8, which has an effect on error rate and this work can be extended with varying spreading factors in future. But some of the researches have shown that increase in spreading factor causes increase in system complexity due to increase in number of detection stages. There are also few other parameters that affect the error rate like symbol size, number of carriers and the inclusion of MIMO technique in the system model which can be taken as a challenge for future research work.

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