Orthogonal Frequency Division Multiplexing for Enhanced Spectral Efficiency

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***Abstract*— Orthogonal Frequency Division Multiplexing (OFDM), a special form of multicarrier modulation (MCM) with heavily spaced subcarriers as well as overlapping spectra was patented in the United States of America in 70s. Orthogonal Frequency Division Multiplexing has been popularly utilized in modern days due to its ability for spectral efficiency and robustness to noise and fading. It provides flexibility and agile spectrum allocation in case of cognitive radios. This paper will focus on Orthogonal Frequency Division Multiplexing (OFDM) research and simulation for enhancement of spectral efficiency. OFDM is especially compatible for high-speed wireless communication due to its resistance to Inter symbol Interference. As in modern days communication systems has increased their data transfer speed, the required time for each transmission has become very short. As delay time due to multipath remains constant, Inter symbol interference became limitation in high-data-rate communication. OFDM avoids this difficulty by transmitting numerous low speed transmissions simultaneously.**

Keywords*— *Orthogonal Frequency Division Multiplexing (OFDM),Spectral Efficiency,Inter symbol Interference(ISI),Inter channel Interference(ICI),

I. INTRODUCTION

In a fundamental communication system, the information is modulated for a single carrier frequency. This information in the form of symbol occupies total available bandwidth. In such a situation, there are maximum chances of creating inter-symbol-interference (ISI). It happens especially at frequency selective channel. The grass root idea of orthogonal frequency division multiplexing is to divide total spectrum into number of orthogonal sub channels to have narrowband

Most probably Sub channel faces flat fading. It is possible in OFDM, that sub channels may have overlapping sub in the frequency domain; Due to such arrangement transmission rate gets increased. In recent years orthogonal frequency division multiplexing has increased its interest. European digital broadcast radio system has also used OFDM, ADSL known as asymmetric digital subscriber line in wired environment also using OFDM.XDSL known as digital subscriber lines uses OFDM to provide higher transmission bit rate over twisted wires. OFDM has been majorly used in numerous higher data rate wireless communication network systems due to number of advantages it has. It provides Immunity at selective fading. OFDM appears highly resistant to frequency selective fading as compared to single carrier system. It does happen as overall channel gets divided in to number of segmented narrowband signals , these narrowband signals gets affected as a flat fading channel. OFDM is also characterized with resilience to interference. These characteristics limit the interference over a channel. So it will not affect sub channels. As OFDM utilizes closely spaced overlapping sub carriers, it enables highly increase in spectrum efficiency. Another property of OFDM which leads to spectral efficiency is resilient to inter symbol interference and inter frame interference. It happens due to low data rate at each sub channel. OFDM is resilient to narrowband effects. Channel coding and interleaving at OFDM enables symbol lost recovery to avoid narrowband effects. Channel equalization at OFDM is much simpler leading toward increased spectral efficiency.

II. LITERATURE REVIEW

The paper named as “Spectral Efficiency Analysis in OFDM and OFDM/OQAM based Cognitive Radio Networks” authored by Haijian Zhang, published in IEEE 2009. It states that “The future wireless communication is expected to be able to improve the efficiency of spectrum usage. To solve the challenge of spectrum shortage, an innovative opportunistic spectrum access strategy, called Cognitive Radio (CR) has been proposed. Conventional Orthogonal Frequency Division Multiplexing (OFDM) has already been suggested as a physical layer candidate for CR system. Herein another potential candidate for CR, OFDM Offset Quadrature Amplitude Modulation (OFDM/OQAM) is introduced, and its spectral efficiency for coded multicarrier transmission is compared with Cyclic Prefix based OFDM (CP-OFDM) and Raised Cosine windowed OFDM (RC-OFDM) in CR context. Simulated results of Spectral Efficiency Comparison (SEC) for different multicarrier systems are interpreted by theoretically analysing the out-of-band radiation of their prototype pulses shaping. Both theoretic analysis and experimental results can show that OFDM/OQAM is a more natural candidate than CP-OFDM and RC-OFDM for CR networks application”. [1]

The paper named as “Considerations regarding the spectral efficiency of orthogonal frequency division multiplexing” authored by Alina Elena, published in international conference on development and application systems, suceava, romania, may 17-19, 2012. States that “This paper presents briefly the fundamental mechanisms underlying the generation and demodulation of the OFDM signal, starting with the reasons that required the implementation of multi-carrier systems in the first place – i.e. the mitigation of Inter Symbol Interference (ISI) - and ending with the analytical and functional description

of the main blocks in the OFDM transmitter and receiver. The role of IFFT and FFT in the generation and demodulation of OFDM signal is also described to some detail, as this is too often not fully understood by students and engineers. Eventually, the paper presents a simple and realistic method to calculate the spectral efficiency of OFDM systems, with an example for the practical implementation of IEEE 802.11a systems. The spectral efficiency of OFDM systems is characterized by the maximum data rate for a given bandwidth, and by the minimal requirements for SNR and C/I, for a given modulation type and data rate."[2]

The paper named as "Spectral Efficiency and BER of OFDM Systems with Carrier Frequency Offset (CFO)" authored by Rashi Sharma published in International Journal of Current Engineering and Technology,2015 states that "Orthogonal frequency division multiplexing (OFDM) is a parallel transmission method, where single data stream is separated into a number of lower rate subcarriers, and each carrier is orthogonal to all other carriers. One of the main problems for OFDM system is Carrier frequency offset (CFO). OFDM is sensitive to CFO, which spoils the orthogonality between the sub-carriers, and cause Inter-carrier interference (ICI) in the OFDM, which corrupts the overall performance of OFDM and creates the frequency difference between the local oscillators of the transmitter and receiver, and the signals transmitted on each carrier are not independent of each other. In this paper, we introduce the analysis for calculating the Spectral Efficiency of OFDM systems with CFO. We further present the bit error rate (BER) performance of OFDM system with various CFOs under additive white gaussian noise (AWGN). This paper presents, the CFO in OFDM and the analysis for calculating the effect of the various CFOs on the performance of the OFDM system in term of BER under AWGN. Finally, in this paper, the results are sufficient to prove the Spectral Efficiency analysis and BER performance of OFDM system with various CFOs in AWGN channel."[3]

The paper named as "Spectral Efficiency Comparison of OFDM/FBMC for Uplink Cognitive Radio Networks" authored by H. Zhang published in EURASIP Journal on Advances in Signal Processing, Volume 2010, states that "Cognitive radio (CR) is proposed to automatically detect and exploit unused spectrum while avoiding harmful interference to the incumbent system. In this paper, we emphasize the channel capacity comparison of a CR network using two types of multicarrier communications: conventional Orthogonal Frequency Division Multiplexing (OFDM) with Cyclic Prefix (CP) and Filter Bank based Multi Carrier (FBMC) modulations. We use a resource allocation algorithm in which subcarrier assignment and power allocation are carried out sequentially. By taking the impact of Inter-Cell Interference (ICI) resulting from timing offset into account, the maximization of total information rates is formulated under an uplink scenario with path loss and Rayleigh fading, subject to maximum power constraint as well as mutual interference constraint between primary user (PU) and secondary user (SU). Final simulation results show that FBMC can achieve higher channel capacity than OFDM because of the low spectral leakage of its prototype filter."[4]

The paper named as "Spectral Efficiency Comparison of OFDM and MC-CDMA with Carrier Frequency Offset" authored by Junaid Ahmed published in radio engineering, vol. 26, no. 1, April 2017 states that "Inter-carrier interference and multiple access interference due to carrier frequency offset (CFO) are two major factors that deteriorate the performance of orthogonal frequency division multiple access (OFDMA) and multicarrier code division multiple access (MC-CDMA) in wireless communication. This paper presents a new mathematical analysis for spectral efficiency of OFDMA communication systems over a frequency selective Rayleigh fading environment in the presence of multiple users. It also compares the spectral efficiency performance of OFDMA and MC-CDMA at different load, signal-to-noise ratio, CFO and delay spread conditions. MC-CDMA is found to be more resilient to CFO in general, however, OFDMA performs better at high load."[5]

III. SYSTEM DEVELOPMENT

A. Block Diagram

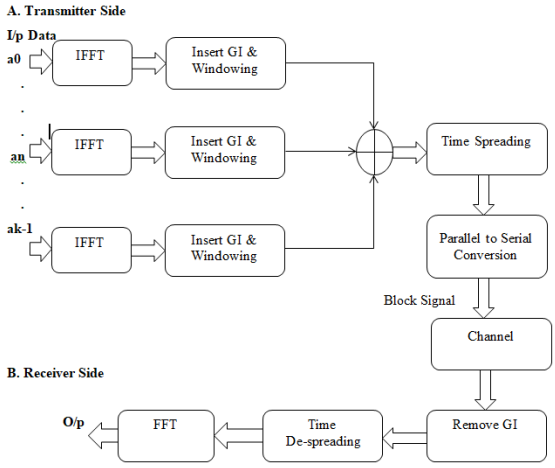

Figure.1

As shown in figure.1 functional block works as below

1. Inverse fast Fourier transform (IFFT) :

As shown in block diagram a0, an & a k-1 is frequency domain signals. These signals are converted in to time domain signal using IFFT block. The proposed system is based on time spreading hence it become essential to convert signal in to time domain signal first.

2. Insertion of GI and windowing:

In OFDM, the beginning of each symbol is preceded by a guard interval. As long as the echoes fall within this interval, they will not affect the receiver's ability to safely decode the actual data, as data is only interpreted outside the guard interval. Windowing method is used for efficient spectral shaping in orthogonal frequency division multiplexing (OFDM) based systems.

3. Time spreading

Time spreading and windowing both used to reduce both the frequency and time overhead. Time spreading converts signal

in to block structured signals. These block structured signals helps to improve spectral efficiency.

4. Parallel to serial conversion

All these converted block structures are converted in to serial data before transmission over communication channel.

5. Removal of Guard Interval

To get original data at receiver side first step is to remove guard intervals inserted at transmitter between the signals. Once it is removed signal is fed to time spreading block.

6. Fast Fourier transform

The output of time de spreading block is in time domain format. To get signal in its original for that means in frequency domain format. The proposed system applies fast Fourier transform.

IV. RESULTS AND CONCLUSION

In proposed system Signal to noise ratio vs spectral efficiency with and without channel coding is plotted and compared against F-OFDM. The proposed system is implemented over MATLAB platform. Implemented system clearly shows that signal to noise ratio is inversely proportional to bit error rate. As well as signal to noise ratio is analyzed against spectral efficiency also. With increased signal to noise ratio, spectral efficiency is also increasing.

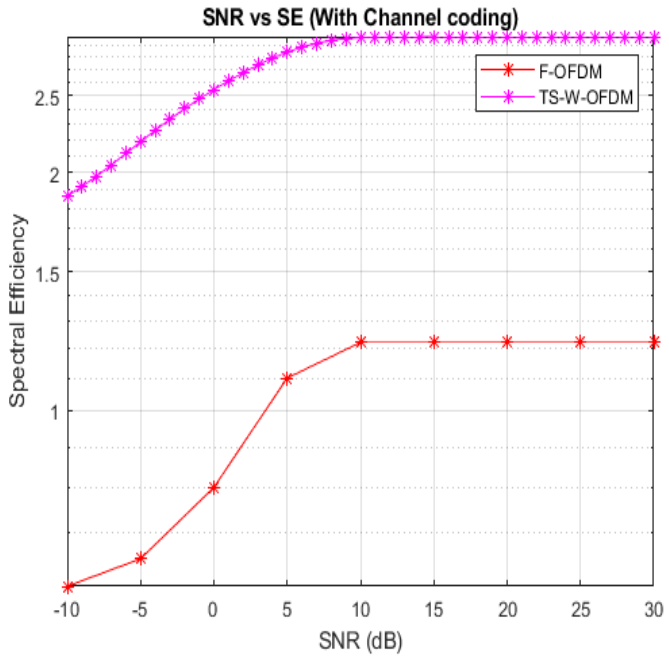

Figure. 2

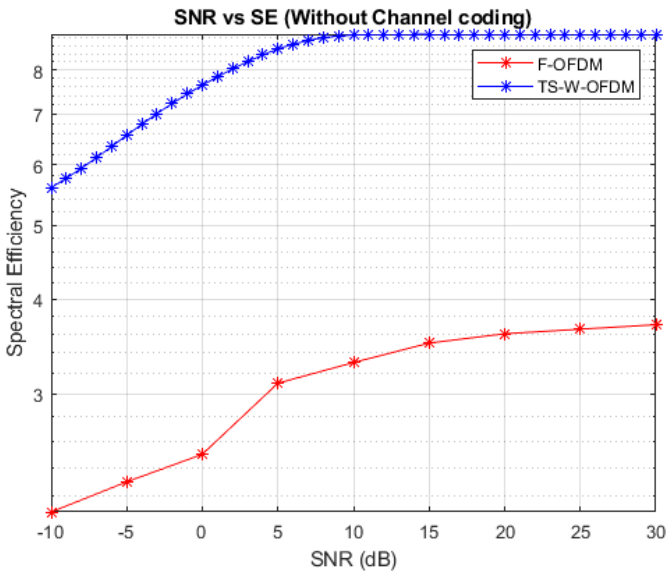

Figure.3

Overall at last it is found that in proposed system spectral efficiency has been enhanced. It gives edge over inter symbol interference; inter channel interference with increased bit data rate.

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