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Improving the Spectral Efficiency of OFDM System Using Raised Cosine Filter

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Abstract- **The current research trends towards mobile broadband communications highly focused on mitigating the power spectral analysis and frequency localization issues associated with Orthogonal Frequency Division Multiplexing namely OFDM signals. There are various existing research works have been found ensure less efficient communications strategies. Therefore to address various interference problems during transmission data filter, OFDM has been conceptualized and implemented. Most of the f-OFDM techniques have been designed without coding. The proposed study aims to develop a higher order modulations e.g. QAM/PSK based filtered OFDM system to mitigate the inter-symbol interference issues of channel properties. The proposed system has been configured and simulated in a real-time test bed (Matlab). The proposed system uses Root Raised Cosine (RRC) filter design specification and it also integrated the filter modules in the transmitter and the receiver side. The experimental outcomes of the proposed system show that it achieves very higher signal quality on less amount of bit error rates and the huge amount of power spectral density at the receiver end. It also achieves a high data transfer rate, well utilization of bandwidth as well as frequency localization factors as compared to the conventional OFDM models.**

Index Terms **- Filtered Orthogonal Frequency Dvision Multiplexing (f-OFDM); Root Raised Cosine (RRC)Filter , PSK(Phase Shift Keying) , Frequency Localization.**

I. Introduction

The mobile broad band communications services require a very efficient and fast data transfer technology therefore in order to enhance the broadband communications in terms of high speed, interoperable and secured access of microwave channels various existing state of art studies have been introduced[1].

The existing state of art studies towards wireless communication standards highlights that most of the current multicarrier modulation techniques use higher order orthogonal frequency division multiplexing (OFDM) scheme which widely used like a multi-carrier modulation. In the recent times, the concept of the filter based OFDM namely f-OFDM is gaining popularity, where a specific filter is designed considering higher order filter length to exceed the cyclic prefix such as Root-raised-cosine(RRC) based OFDM[2]. Filtered OFDM is conceptualized to enhance the broadband communications regarding high-speed, interoperable and secure access to microwave channels. In this project, an efficient filtered based OFDM System has been designed which imposes the RRC filter mechanism to improve the signal to noise ratio [3] [4]. The proposed method also ensures a better signal quality in the receiver end where the proposed f-OFDM achieves bandwidth utilization regarding frequency localization and considering inter-symbol interference and inters carrier inference within an acceptable limit. The proposed model also has been designed to establish a secure and efficient wireless communication to provide 30 to 40 megabits per sec data in a wireless medium [5][6]. In this pr5posed study an RRC filter oriented OFDM model has been designed and implemented where, the design specification of RRC filters highlights that it can be integrated with the OFDM system to limit the Inter symbol Interference (ISI). However, the proposed model also constructs a spectrally-localized multicarrier waveform which achieves very active signal to noise ratio and better spectral density of the signal at the receiver end. Therefore, the use of RRC filter in the proposed model minimizes the bit error rate and enhances the spectral density of the received signal. It can also be seen that the proposed model reduces the occurrence of Inter symbol interference and inter-carrier interference during the signal transmission through a channel. The performance evaluation of the proposed model has been evaluated considering the signal to noise ratio and the computation of bit error rate (BER).

The current research trends focused on minimizing the bit error rate and enhancing the spectral efficiency associated with an OFDM Signal. The proposed study aims to design a novel filtered OFDM namely f-OFDM system for channel interference avoidance. It also considers the concept of IFFT and FFT in the transmitter and receiver end for performing data encryption and decryption respectively. The proposed system achieves an efficient signal quality with very less amount of bit error rate and very less amount of computational cost.

The performance analysis of the proposed system shows the output signal spectrum contains more power spectral density as compare to conventional OFDM communications systems.

The paper is organized as follows Section II discusses about the recent studies towards efficient filtered OFDM communication systems which is followed by problem statement in Section III. Section IV discusses about proposed system followed by discussion of algorithm implementation in Section V. Section VI discusses about the result analysis followed by conclusion in Section VII.

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II. Related Work

This section introduces various states of art studies towards efficient higher order multi-carrier f-OFDM-based modulation schemes for achieving high data transfer rate and greater spectral efficiency of the received signal. The followings are the existing research trends in wireless communication and multicarrier modulation.

The study of **Li et al. [7]** introduced a novel DSP-based SSBI alleviation strategy, with lower intricacy than already proposed policies, is proposed and surveyed through mathematical recreations surprisingly. The execution change is measured by reproductions of 9 × 112 Gb/s 16-QAM SSB-OFDM signal with a net optical ISD of 2.1 (b/s)/Hz. The execution is appeared to be like that of the more mind-boggling collector based iterative SSBI pay procedure. Recreations foresee an 8.7 dB decrease in the required OSNR at the 7% overhead HD-FEC edge, and increments up to 100% in greatest scope over uncompensated standard single-mode fiber utilizing the proposed rearranged SSBI pay strategy.

Lee and Yoo [8] presented a polyphase sifted orthogonal recurrence division multiplexing (PF-OFDM) The proposed structure uses a changed discrete Fourier change trans-multiplexer to accomplish more prominent phantom productivity than an OFDM framework while saving in reverse similarity with it. The model PF-OFDM channel has phenomenal time and recurrence restriction properties, which make it conceivable to kill a gatekeeper interim and effortlessly smother interchannel obstruction.

In the study of **Gutman et al. [9]** introduced three noteworthy execution criteria of the framework: (i) power productivity of the PA, (ii) otherworldly virtue of the transmitted sign communicated by neighboring channel obstruction, and (iii) transmission execution demonstrated by shared data or image blunder rate. So as to satisfy the initial two criteria, it is proposed to utilize iterative cutting and sifting (ICF) at the transmitter together with low contribution back-off while the third rule is acquired by an adjusted iterative recipient (MIR). The proposed MIR depends on the evidently understood iterative beneficiary, yet with ICF in the input way. They got results and demonstrated that the proposed framework is superior to anything its rivals while considering the three execution criteria together. The investigation and results are centered on OFDM; be that as it may happen that, the proposed methodology might be connected to a single carrier.

In the study of **Wang et al. [10]** a radio-over-fiber(ROF) system has been demonstrated to the best contender for the remote access innovation, and the orthogonal recurrence division multiplexing (OFDM) procedure has been acknowledged as the center transmitting change, so the OFDM-ROF system is the intriguing issue in the worldwide the educated community. An OFDM-ROF framework reenactment model basing on IEEE 802.16a physical layer convention had been developed. Extraordinary consideration had been paid on the high top to-normal force proportion (PAPR) of the OFDM signal which incredibly obliged the execution of the OFDM-ROF framework. A cut-out and sifting innovation had been explored and simulated over a real-time test bed. The proposed system also compared with the experimental outcomes of Nyquist sampled, the two over inspected signal had a superior execution in diminishing PAPR. The bit blunder rate (BER) mistake stream research had been finished with transmitting the cut sign in nonlinear twisted ROF join. Also, the QAM had been affirmed for the favored procedure in OFDM-ROF links.

Kim et al. [11] designed a channel and-forward (FF) hand-off for orthogonal recurrence division multiplexing (OFDM) transmission frameworks is considered for enhancing context execution over straightforward increase and-forward (AF) handing-off. Not at all like customary OFDM have transfers performing OFDM demodulation and modulation, to lessen preparing multifaceted nature, the proposed FF hand-off correctly channeled the approaching sign in the time area with a limited drive reaction (FIR) and advances the separated sign to the destination. Three configuration criteria are considered for improving the hand-off channel. The primary model is the minimization of the transfer transmits power subject to per-subcarrier sign to-clamor proportion (SNR) requirements, the second rule is the expansion of the most exceedingly bad subcarrier channel SNR subject to source and hand-off transmits power limitations, and the third paradigm is the amplification of the information rate subject to source and hand-off transmits power imperatives.

A clipping and filtering technology for OFDM systems has been studied and simulated in the work **of Wang et al [12]** where the radio over fiber system has been demonstrated to the best contender for the remote access innovation, and the orthogonal recurrence division multiplexing (OFDM) strategy has been acknowledged as the center transmitting innovation, so the OFDM-ROF system is the interesting issue in the global the educated community. An OFDM-ROF framework reenactment model basing on IEEE 802.16a physical layer convention had been developed. Unique consideration had been paid on the high peak-to-average power proportion (PAPR) of the OFDM signal which significantly compelled the execution of the OFDM-ROF framework.

Chini et al. [13] presented a use of a sifted choice condemnation channel estimator for OFDM-based DTV frameworks utilizing big request QAM tweaks. The execution and the execution of the channel estimator are examined. PC reproductions were directed to assess the implementation of the channel estimator. The channel estimation misfortune is around 1.2 dB from the perfect situation where the channel is thought to be known by the recipient. For a given multipath spread, the misfortune can be further diminished by expanding the FFT size. The FFT size is, however, subject to the furthest point of confinement forced by the Doppler spread.

Li et al. [14] investigated, through broad PC recreations, the impacts of section and sifting on the execution of OFDM, including the force unearthly thickness, the peak variable, and the bit-mistake rate. Our outcomes demonstrate that cut-out and separating is a promising strategy for the transmission of OFDM signs utilizing practical straight enhancers.

III. Problem Statement

The previous section introduced various existing studies towards efficient broadband communication techniques using higher order sub carrier modulation techniques.

Accuracy, in order to compute Bit Error Rate and denoising the OFDM, transmitted Signal in receiver end has become one of the recent issues in the field of Signal Processing and Communications. Lack of proper analysis associated with various higher order modulations schemes such as (QAM/PSK) creates a very problematic scenario during the computation of bit error rates and Signal to Noise Ratio (SNR) regarding various channel condition scenarios and channel correlation factors. It has a great impact on the spectral estimation of Digital Signals. The high-speed data access in a multi-user model for transmitting data simultaneously over different subcarriers using different types of modulation techniques (QAM/PSK) results in allocative inefficiency, handover latency, frequency selective fading, and frequency flat fading, etc.

IV. Proposed System

This section highlights the core design principal associated with the proposed f-OFDM model. The proposed system utilizes Orthogonal Frequency Division Multiple Access (OFDMA) in order to provide a very fast data transmission rate and channel access over a wireless medium. The proposed system consists of four different types of modules, the respective description associated with each module are given as follows.

A. f-OFDM Transmitter (Tx) Module:

In OFDMA transmitter module an input image is taken which is needed to be transmitted over a wireless channel. After that, the input image is converted into binary/ digital bits representation to perform the convolution encoding. The SNR value is also calculated using the image information.

The binary image represented with a single column. After performing the convolution encoding, the binary data is processed through QAM [M= 4] Modulation. Where the signal is further analyzed in its frequency domain Orthogonal Frequency Division Multiplexing (OFDM) is performed on the QAM modulated a signal, where IFFT is also performed for data encryption process and before transmitting the signal over the Gaussian Channel the message, will be addressed through an RRC filter to enhance the spectral efficiency and minimize bit error rate.

RRC filter Design: The RRC filter has been designed considering various components of an OFDM signal such as 1. Filter roll off, 2. Filter span 3. Samples per symbol 4. The size of the signal constellation and 5. Some bits per symbol.

The proposed system also computes the impulse response associated with the f-OFDM spectrum and it also filters the modulated data for maximizing the SNR and to minimize the BER.

B. f-OFDM Signal Transmission Module:

In this module, it has been shown that when a modulated signal is transmitting through channel thus noise is bound to come for the purpose of this project the Gaussian noise has been computed and added to the signal during the transmission phase over a wireless channel.

C. f-OFDM Receiver (Rx) Module:

In the f-OFDM receiver module the modulated signal is received and unfiltered the modulated data after that the reverse process which has been performed in the transmitter as mentioned above module has been evaluated to reshape and retrieve the original image. Here the received modulated and a noisy signal is first processing through ODFM and QAM demodulation respectively after that it passes through a vertibri decoder for reshaping. The original image is received at the receiver side.

D. Computation of Bit Error Rate:

After the successful retrieval of the original image the performance analysis of the proposed system is done to evaluate the system performance. This module computes the bit error rate of the modulated signal on the increment of Signal to Noise (SNR) ratio and plots them into a graph.

This chapter introduces the overall system design concept associated with the proposed f-OFDM system which includes the system requirements, operating environment, system and subsystem architecture, etc. This chapter also highlights the design specification related to the proposed system where each and every module integrated with the proposed filtered Orthogonal Frequency Division Multiplexing (f-OFDM) has been discussed. The proposed model has been designed considering the properties of conventional OFDM model. It has been configured and simulated in a test bed where performance analysis of the proposed model shows that it achieves a very high data transfers rate and spectral efficiency in the receiver end.

Therefore, the proposed f-OFDM system has been designed considering the concept of OFDMA modulation to utilize the bandwidth, and it is also capable of enhancing the channel access in a parallel computation regarding fast and reliable data transfer rate.

V. SYSTEM ARCHITECTURE

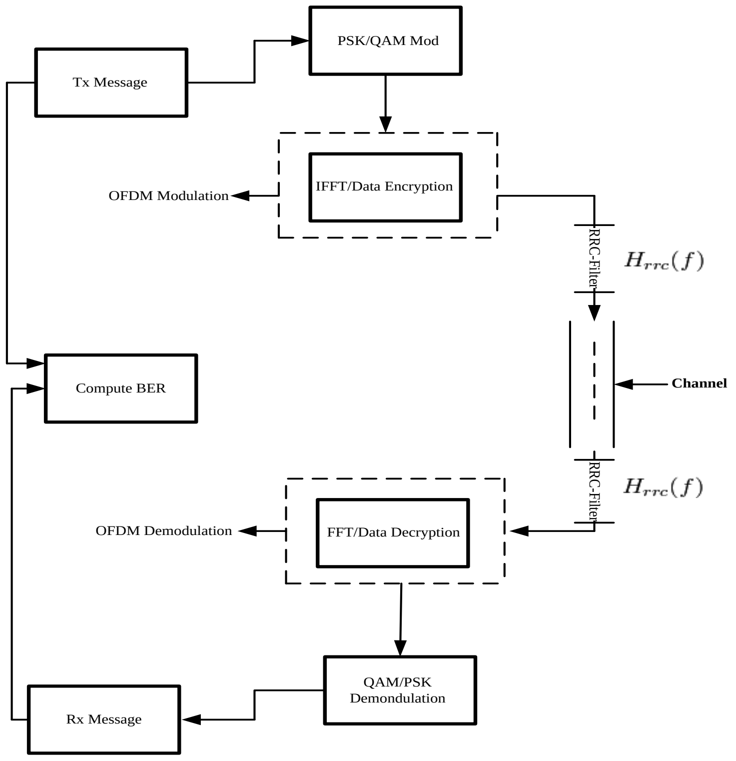

Figure 1 System Architecture of the Proposed Model

The stated figure 1 shows the system architecture of the proposed f-OFDM model to perform an efficient and fast wireless broadband communication. The proposed model has been designed with four different types of sub modules 1. f-OFDM Transmitter Module 2. f-OFDM receiver module 3. Signal transmission through channel and 4. Computation of Bit Error Rate. The above-stated figure also shows how an image has been transmitted through a wireless medium using OFDM/QAM Modulation and Demodulation. The proposed system also computes the Signal to noise ratio (SNR) and BER in order to evaluate the performance graph. The input image is converted into binary data representation and process through convolution encoding. However, before performing the convolution encoding parallel to serial conversion of the binary data is evaluated. Quadrature Amplitude Modulation (QAM) is conducted on the binary data, and it generates another bits representation of the signal which is again further processed through the OFDM modulation, after that the signal is dealt with by an RRC filtered for filtering modulated data.

Finally, the OFDM modulated signal is transmitted over the wireless communication medium, during the transmission through the channel the signal gets affected by the presence of Gaussian noise. The proposed model can detect and compute the presence of Gaussian noise in an OFDM signal whereas at the receiver end the modulated signal is again preprocessed with the filter and demodulation (QAM and OFDM) then a decoder is used to perform the decoding of the received information which is further reshaped to retrieve the noisy image at the receiver end. The proposed system utilizes a concept of reducing the bit error rates at the receiver end while increasing the SNR values. The performance metrics shows the effectiveness of the proposed system.

VI. IMPLEMENTATION

The implementation of the proposed system has been carried out using MATLAB,

This project aims to develop a scalable and faster higher order subcarrier modulation and RRC filter based OFDM system for achieving high spectral efficiency and high data transmission rate in the wireless communication medium. In this project, a higher order modulation such as QAM/PSK, OFDM, and RRC filter based communication system is prototyped and simulated considering MATLAB test bed environment. The proposed model is designed using three different types of modules which are

1. f-OFDM transmitter module
2. f-OFDM Channel and
3. f-OFDM receiver module

The modules as mentioned above are simulated over a real-time test bed where the Matlab tool has been considered for integrating different modules. The design specifications and the implementation strategies associated with each and every module components are discussed below.

f-OFDM Transmitter (Tx) Module

The proposed f-OFDM model enables the concept of Orthogonal Frequency Division Multiplexing as well as Orthogonal Frequency Division Multiple Access mechanism. In the transmission module Message of the OFDM signal to be transmitted over a wireless channel is considered which is further converted into the binary representation in order to perform vertibri encoding scheme for error detection and correction. The resultant signal is further preprocessed through modulation block where PSK and QAM=4 are performed. The proposed system performs Inverse First Fourier Transform (IFFT) and OFDM as multicarrier modulation strategy. It also can be seen the proposed model ensures high data transfer rate and bandwidth utilization as OFDM systems utilizes parallel multicarrier frequencies. The advantage of using OFDMA modulation is it can support more subcarriers using more sub-channelization as compared to the conventional OFDM. The transmitter model also computes Signal to Noise ratio before transmitting the carrier signal over the wireless medium. In the transmitter module, RRC impulse response oriented filter is configured. The design specification and the mathematical modeling's associated with the RRC filter are highlighted below.

Raised Cosine Filter:

Higher frequency spectral components in OFDM signals sometimes results from high peak to average power ratio. Therefore, the high PAPR ration in signal components increases the probability of noise in the transmitted signal while transmitting through a bandwidth-limited channel. It can also be seen that during the transmission of the signal Inter symbol interference can occur which degrades the transmitted signal quality. In the existing state of art studies various low pass, filters have been integrated where the use of raised-cosine filter gained most of the attention. Usually, The raised cosine filters satisfy the Nyquist equation and minimize the spectral distortion very efficiently. In this project two roots raised cosine filters have been integrated with the transmitter and receiver modules which suppress the unnecessary signal components from the modulated signal and enhance the signal to a ratio (SNR) with respect to BER very fast. In the transmitter module, the QAM/PSK modulated message is encrypted using IFFT. Thus, the proposed system also ensures the security also.

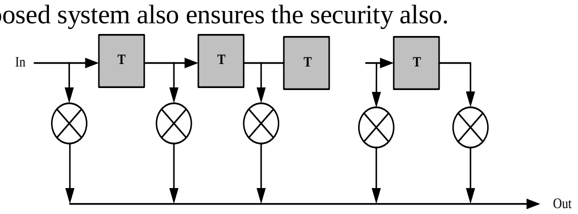

Fig 2 An FIR based RRC filter Structure

The above figure 2 shows that RRC filter can be derived from the concept of Finite Impulse Response Paradigm (FIR). The filter as mentioned above design also demonstrates that it can cause a delay of half of its length.

The implemented transfer functions and their respective equations of designed RRC filter are shown below.

$$H_{RRC}(w) = \begin{cases} \sqrt{T_C} & \text{Where } |W| \leq |W1|, \\ \sqrt{\frac{T_c}{\sqrt{2}}}\sqrt{1+\cos(\pi\frac{w-w_1}{rw_c})}(1) & \text{for } |W1| \leq |W| \leq |W2|, \\ 0 & \text{for } |W| \geq |W2| \end{cases}$$

The proposed model also computes the impulse response factor from the equation as mentioned above 1.

The following equation shows the impulse responses computed after evaluating the RRC filter model into the proposed f-OFDM system. It is assumed that the transfer as mentioned above function derives the impulse response fRRC (t) = fRRC (-t)

The impulse function of the RRC filter is given below.

$$f_{RRC}(t) = \frac{B}{t\pi}\sin(wt) + \frac{1}{\pi}\int_{w1}^{w2} H_{RRC}(w)\cos(wt)dw(2)$$

The above-mentioned equation 1 shows that the signal components are derived superposition of three other different components where the first element is the constant spectrum, the second component is a sinc parameter implemented in the time domain which has also been derived from the RRC function, and the third element is the (at the higher frequency) is zero.

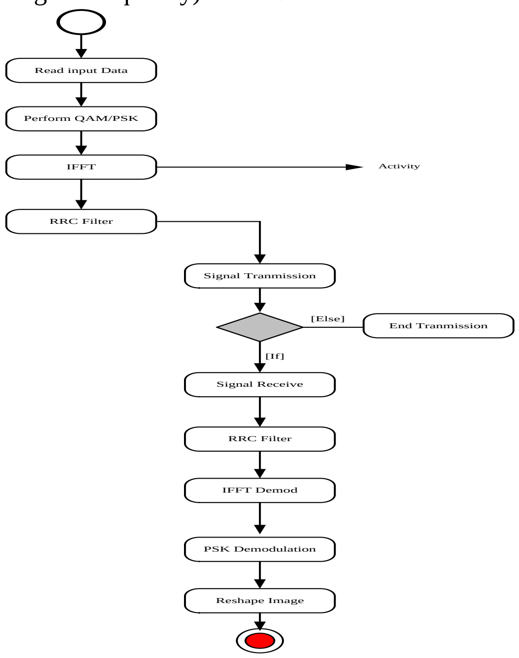

Figure 3 Activity Diagram of the proposed Model

The Pseudo code of the transmitter model is described below with its input, variable initializations, computational statements, and functions.

Start

Input: Image file

Output: Modulated Image

Initialize I

1. Read ← Input Image (I)
2. Image file ← Write(I)
3. Initialize the SNR range for the signal
4. for range(1←length(SNR))
5. Plot and show the input image
6. Store input image into Iorg
7. Convert the image into binary format.
8. Convert into single column
9. Perform convolution encoding
10. Perform → QAM (M=4)

11. Perform OFDMA Modulation
12. End for
13. Save the image info into a net mat variable
14. Compute ← SNR
15. Define Filter Roll off ←0.1; // Filter Design
16. Define span ←6;
17. Define samples per symbol ← 100;
18. Signal Constellation (M) ← 256;
19. Compute K ← log2(*M);
20. Import rcosdesignFilter (modsignal;rrcfilter,sps);
21. Filter ← Modulated Data
22. Compute Impulse response of the RRC filter
23. Transmit the modulated signal.

End

The algorithm as mentioned earlier shows how a signal is modulated using OFDM and QAM in the transmitter side using the concept of IFFT.

VII. Result Discussion

This section discusses about the important findings of the proposed study. It also highlights experimental outcomes of the proposed f-OFDM model. The following figure 4 highlights the experimental outcomes of the proposed system where the bit error rate s for the transmitted f-OFDMA signal has been evaluated considering different types of higher order sub carrier modulation techniques.

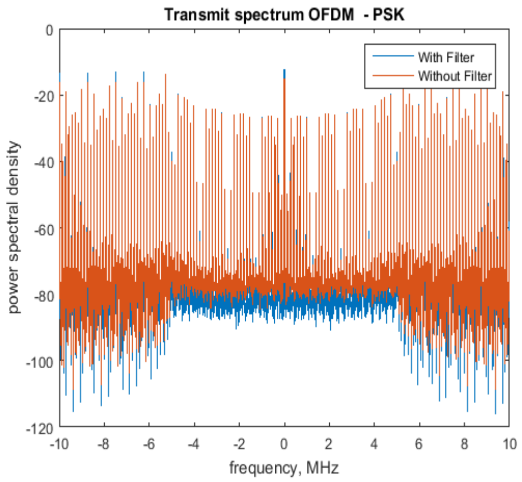

Figure.4 Transit Spectrum of f-OFDM

The proposed filtered OFDM system indicates that using the filter in the transmitter and receiver side of the communication system ensures better signal quality regarding spectral efficiency, signal to noise ratio as well as bit error computation rate as compared to the existing conventional WiMAX or 3G OFDM mobile broadband communication technologies. An Experimental test bed to evaluate the proposed model has been created using MATLAB Tool. The following figures show the effectiveness of the proposed model considering various performance parameters such as SNR V/s BER. It also shows the transmit spectrum of the OFDM signal using PSK modulation.

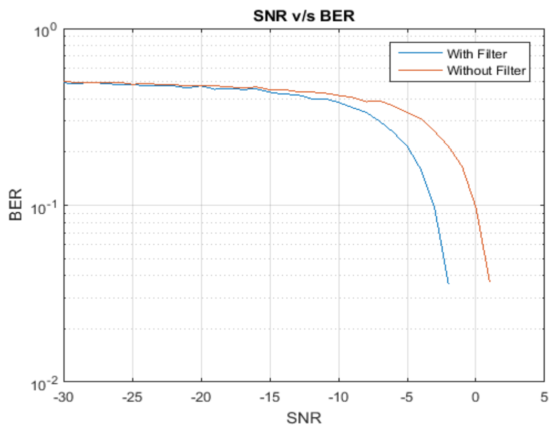

Figure.5 Comparative analysis of SNR V/s BER computation

The above-shown figure shows that the proposed higher order modulation based f-OFDM achieves better spectral efficiency in the output signal as compared to the conventional OFDM model without considering any kind of filters. It shows the effectiveness of the proposed system as compared to the conventional OFDM systems.

VIII. Conclusion

Achieving spectral efficiency and less error in the output OFDM signal for receiver end has become more challenging these days. Therefore, this proposed study introduces a spectrally localized and efficient higher order multicarrier modulation based f-OFDM system for efficient data transmission in mobile broadband communication services. The proposed system achieves very fast data transfer rates (30 to 40 Mbps) in multiple channel access. It can also be seen that during the transmission of the filtered OFDM signal the frequencies have been efficiently localized as compare to the conventional OFDMA and UF-OFDM systems. The proposed study uses RRC filter components to avoid interference and enhance the output signal spectral efficiency at the receiver end. The proposed filter has been designed considering a large filter length to exceed the CP length of OFDM. IFFT has been performed at the transmitter end for performing encryption on the data. The proposed filter is a spectrum shaping filter for interference (ISI) avoidance. It also uses the bank of filters at the receiver side (BS) to for interference rejection. The performance analysis of the proposed system has been done considering the integration of filter in the transmitter and the receiver side which shows that the proposed scheme achieves more flexible dynamic spectrum as compared to the conventional mobile broadband communication systems.

IX. ACKNOWLEDGMENT

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