Performance Analysis of OFDM,FBMC,UFMC

(5G Physical Layer)

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Abstract: The purpose of this project is to compare the proposed 5G modulation techniques FBMC and UFMC against OFDM which is the modulation technique used in 4G communications. We compare key parameters of these modulation techniques to analyze the merits of each candidate. The parameters Power spectral density, spectral efficiency, Bit Error rate and Peak to average power ratio are considered for evaluation. The project is implemented using MATLAB.

I. Introduction:

The rise of mobile devices in today's world has led to a dramatic increase in load of existing communication networks. It has become a necessity for these networks to greatly improve their data rates and reliability to cope up with the ever increasing mobile traffic. The 4G technology brought a significant improvement in Data rate and reliability. The OFDM modulation technique used for 4G is capable of very high data rates. However, the use of cyclic prefixes and guard bands to avoid too big sidelobes, results in a loss of 16% of spectral efficiency compared to theoretical performance. Several modulation techniques have been proposed to solve the shortcomings of the OFDM technique. Although OFDM has been a great success and still has many advantages, there are many ideas for new 5G waveforms that could bring additional advantages to the new cellular system under certain conditions and circumstances. The potential requirement includes high speed data, provide low latency transmissions and energy efficient communications. No single waveform provides all the advantages and answers that are needed. This might result in 5G having an adaptive solution using optimal waveform for a given situation. There are several modulation techniques that are being considered for 5G. These include Filter Bank Multi-Carrier (FBMC), Universal Filtered Multi-Carrier (UFMC) and

Generalized Frequency Division Multiplexing (GFDM). Here, we compare FBMC and UFMC modulation techniques against the existing OFDM technique.

II. What is 5G?

There have been a lot of expectations and views about the ultimate form that 5G wireless technology should take. In order to meet the industry and user needs, it is necessary to accommodate all requirements within the definition process, ensuring that the final definition meets the majority of users' needs without becoming so demanding that any system cannot succeed. The following set of requirements have been widely accepted as a set of requirements for 5g technology

- 1-10Gbps connections
- 1 millisecond end-to-end latency
- 1000x BW per unit area
- Reduced network energy usage
- High battery life for low power devices
- 10-100x number of connected devices
- 99.999% availability
- 100% coverage

The requirements listed above cover a wide range and many believe cannot be satisfied through a single technique. The new scheme should be designed in a way to enable a number of different radio access networks to work simultaneously meeting its own needs.

III. UFMC

UFMC is seen as a generalization of Filtered OFDM and FBMC (Filter Bank Multi-carrier) modulations. The entire band is filtered in filtered OFDM and individual subcarriers are filtered in FBMC, while groups of subcarriers (subbands) are filtered in UFMC.

This subcarrier grouping allows one to reduce the filter length (when compared with FBMC). Also, UFMC can still use QAM, which works with existing MIMO schemes.

The full band of subcarriers (*N*) is divided into subbands. Each subband has a fixed number of subcarriers and not all subbands need to be employed for a given transmission. An *N*-pt IFFT for each subband is computed, inserting zeros for the unallocated carriers. Each subband is filtered by a filter of length *L*, and the responses from the different subbands are summed. The filtering is done to reduce the out-of-band spectral emissions. Different filters per subband can be designed, however, in this example, the same filter is used for each subband. A Chebyshev window with parameterized sidelobe attenuation is employed to filter the IFFT output per subband.

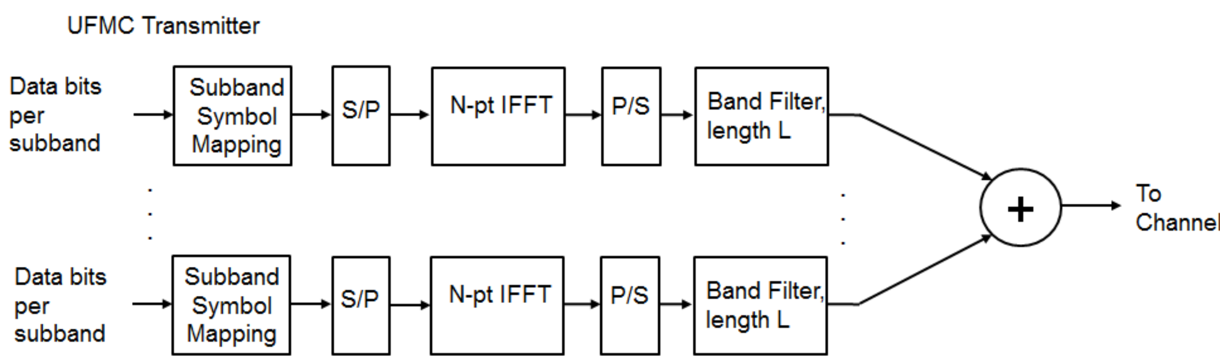

Fig1. UFMC Transmitter

The example next highlights the basic UFMC receive processing, which is FFT-based, as is OFDM. The subband filtering extends the receive time window to the next power-of-two length for the FFT operation. Every alternate frequency value corresponds to a subcarrier main lobe. In typical scenarios, per-subcarrier equalization is used for equalizing the joint effect of the channel and the subband filtering. In this example, only the subband filter is equalized because no channel effects are modeled.

The receive-end processing is shown in the following diagram.

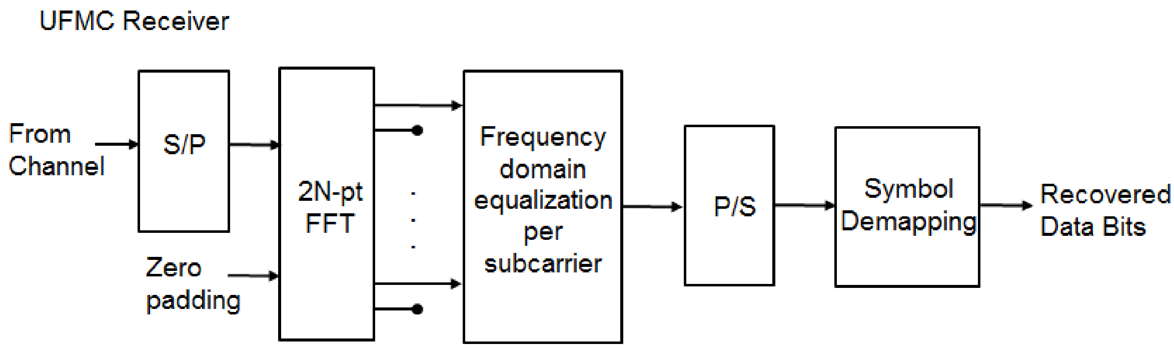

Fig2. UFMC Receiver

UFMC is considered advantageous in comparison to OFDM by offering higher spectral efficiency. Subband filtering has the benefit of reducing the guards between subbands and also reducing the filter length, which makes this scheme attractive for short bursts. The latter property also makes it attractive in comparison to FBMC, which suffers from much longer filter length.

IV. FBMC

FBMC filters each subcarrier modulated signal in a multicarrier system. The prototype filter is the one used for the zero frequency carrier and is the basis for the other subcarrier filters. The filters are characterized by the overlapping factor, *K* which is the number of multicarrier symbols that overlap in the time domain. The prototype filter order can be chosen by user.

The current FBMC implementation uses frequency spreading. It uses an *N*K* length IFFT with symbols overlapped with a delay of *N/2*, where *N* is the number of subcarriers. This design choice makes it easy to analyze FBMC and compare with other modulation methods.

To achieve full capacity, offset quadrature amplitude modulation (OQAM) processing is employed. The real and imaginary parts of a complex data symbol are not transmitted simultaneously, as the imaginary part is delayed by half the symbol duration.

The transmit-end processing is shown in the following diagram.

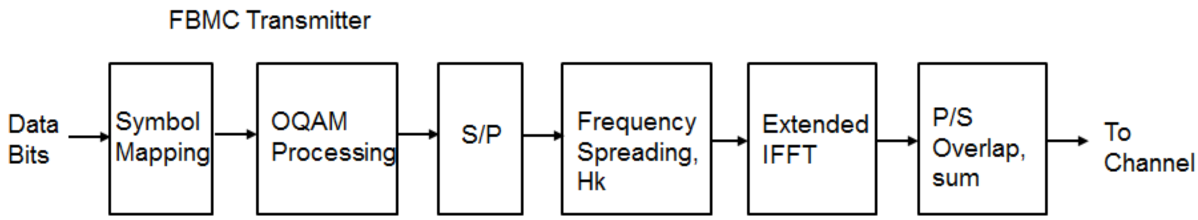

Fig3. FBMC Transmitter

The example implements a basic FBMC demodulator and measures the BER for the chosen configuration in the absence of a channel. The processing includes matched filtering followed by OQAM separation to form the received data symbols. These are demapped to bits and the resultant bit error rate is determined. In the presence of a channel, linear multi-tap equalizers may be used to mitigate the effects of frequency-selective fading.

The receive-end processing is shown in the following diagram.

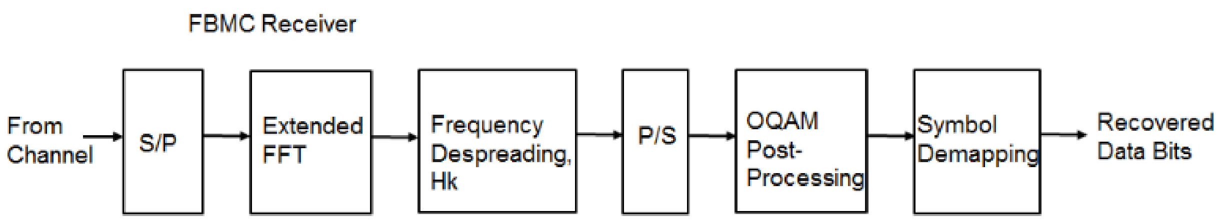

Fig4. FBMC Receiver

FBMC is considered advantageous in comparison to OFDM by offering higher spectral efficiency. Due to the per subcarrier filtering, it incurs a larger filter delay (in comparison to UFMC) and also requires OQAM processing, which requires modifications for MIMO processing.

V. OFDM

OFDM is a multi-carrier transmission technology in which the frequency band is discrete into a number of subchannels. Usual multiplexing techniques involve a number of filters to prevent interference among the sub-carriers and the non – overlapping must be preserved with a minimum frequency separation. On the other hand, OFDM uses signal processing techniques which thus eliminates this issue moreover, the sub- carriers are orthogonal in nature eliminating the need of many filters.

An OFDM system consists of a transmitter and a receiver. The signal is mapped into a suitable constellation by the different modulation techniques. This serial data is then converted into parallel data stream, to which ofdm is performed. It consists of N sub carriers which carries the symbols. An OFDM transmitter involves an IFFT block.

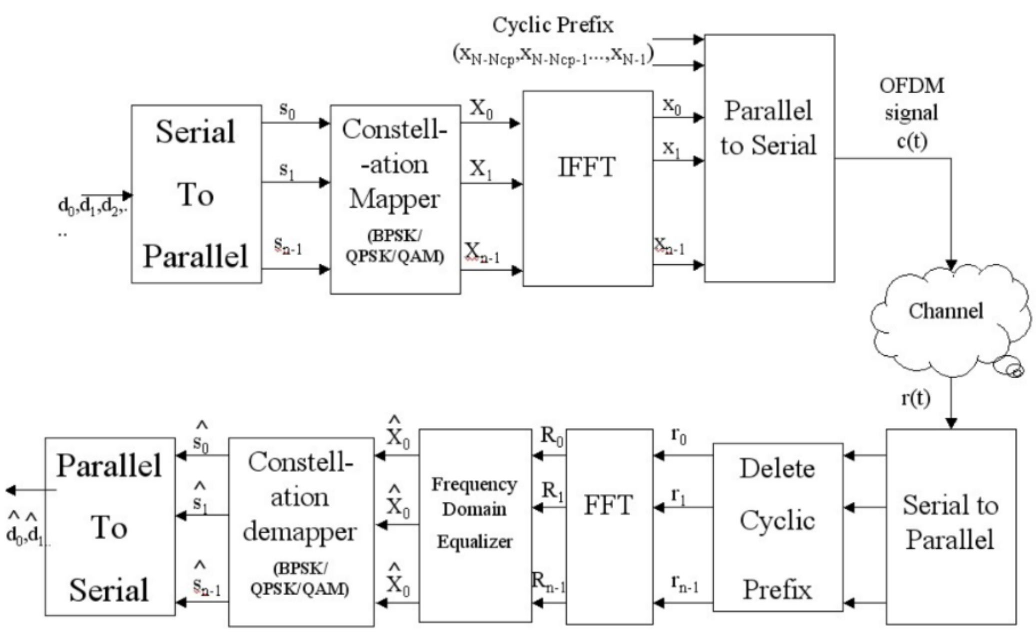

Fig5. OFDM MODEL

$$f(n) = \sum_{k=0}^{N-1} F(k) exp(\frac{j2\pi kn}{N})$$

Cyclic prefix is added to the output to reduce ISI. This is then processed to a serial output which is passed through the corresponding channel.

At the receiver the data is converted into parallel input and the cyclic prefix is removed. This is then subjected to FFT. The frequency domain signal in kth receiving subcarrier is expressed as

$$F(K) = \sum_{n=0}^{N-1} f(n) exp(\frac{-j2\pi kn}{N})$$

VI. CHANNELS

Wireless environments provides a challenging platform for maintaining good communication. The performance is mostly affected by fading (Multipath fading and motion induced fading).In a wireless communication channel, the signal can travel in more than one path in between the transmitter and receiver. The presence of multipath components in a transmission may have variant causes including atmospheric reflection or refraction, or due to reflections from other Interfering Objects (IO) like buildings, sub channels, etc. Generally, the multipath propagation, which involves a radio channel with several IOs and a moving receiver need to resort to statistical methods rather than a deterministic description of the radio channel which is proven to be less efficient. The statistical description of the radio channels is essential for wireless communication applications. The project uses AWGN.

a. AWGN CHANNEL

Additive white Gaussian noise (AWGN) channel is widely used in analysis of different modulation schemes. The channel adds a white noise to the signal passing through it. The advantage of using this channel is the absence of Fading.

The received signal is expressed as:

$$R(t) = s(t) + n(t)$$

Where s (t) is transmitted signal and n (t) is additive white Gaussian noise.

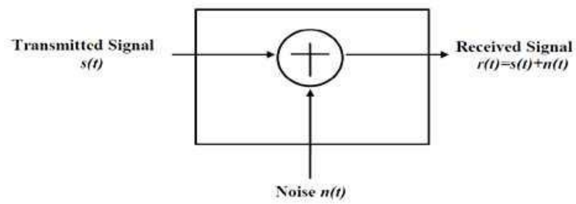

Fig6. AWGN CHANNEL

VII. MEASUREMENTS

a) Spectral Density

The spectral density represents the strength of the signal over a time period (i.e) the possible bandwidth over which the bits can be sent successfully.

b) Spectral Efficiency

Spectral efficiency/ spectrum efficiency or bandwidth efficiency refers to the no. of bit that can be transmitted over a bandwidth. It is the information rate that can be transmitted over a given bandwidth in a specific communication system.

$$\eta_{OFDM} = \frac{m \times N_{FFT}}{N_{FFT} + N_{CP}}$$

$$\eta_{UFMC} = \frac{m \times N_{FFT}}{N_{FFT} + L - 1}$$

$$\eta_{FBMC} = \frac{m \times S}{S + K - \frac{1}{2}}$$

c) PAPR

The peak-to-average power ratio is the peak amplitude squared divided by the RMS value squared power. It plays a vital role in signal processing applications. The system is more efficient if the PAPR is less. However, the modulation techniques with multiple inputs have higher PAPR , whereas those with single input has lower PAPR.

d) BER

It is the number of bit errors per unit time. It is unitless and the performance measure is usually in percentage.

VIII. PROPOSED WORK

The implemented project involves comparison of physical layer candidates to 5G. 5G standard is not completely established and thus uses a number of modulation techniques. Here, we compare modulation techniques such as OFDM, FBMC, UFMC. The comparison involves simulating these modulations over different set of parameters. The results obtained includes measurements such as spectral efficiency, BER vs SNR, PAPR and power spectral density. The implementation is performed using MATLAB.

Parameters

Properties	Values
FFTLength	512
Bits per Sub carrier	4
OFDM	
CyclicPrefixLength	43
UFMC	
Length of Filter	43
Stop Band Attenuation	40
FBMC	
Spreading Factor	4

a. Comparison of Spectral Density

The spectral density of FBMC and UFMC over OFDM is compared. The simulation plots two graphs with reference to the same respectively. The spectral density represents the strength of the signal over a time period (i.e) the possible bandwidth over which the bits can be sent successfully. A modulation's spectal density is efficient if the strength is closer to the normalized frequency.

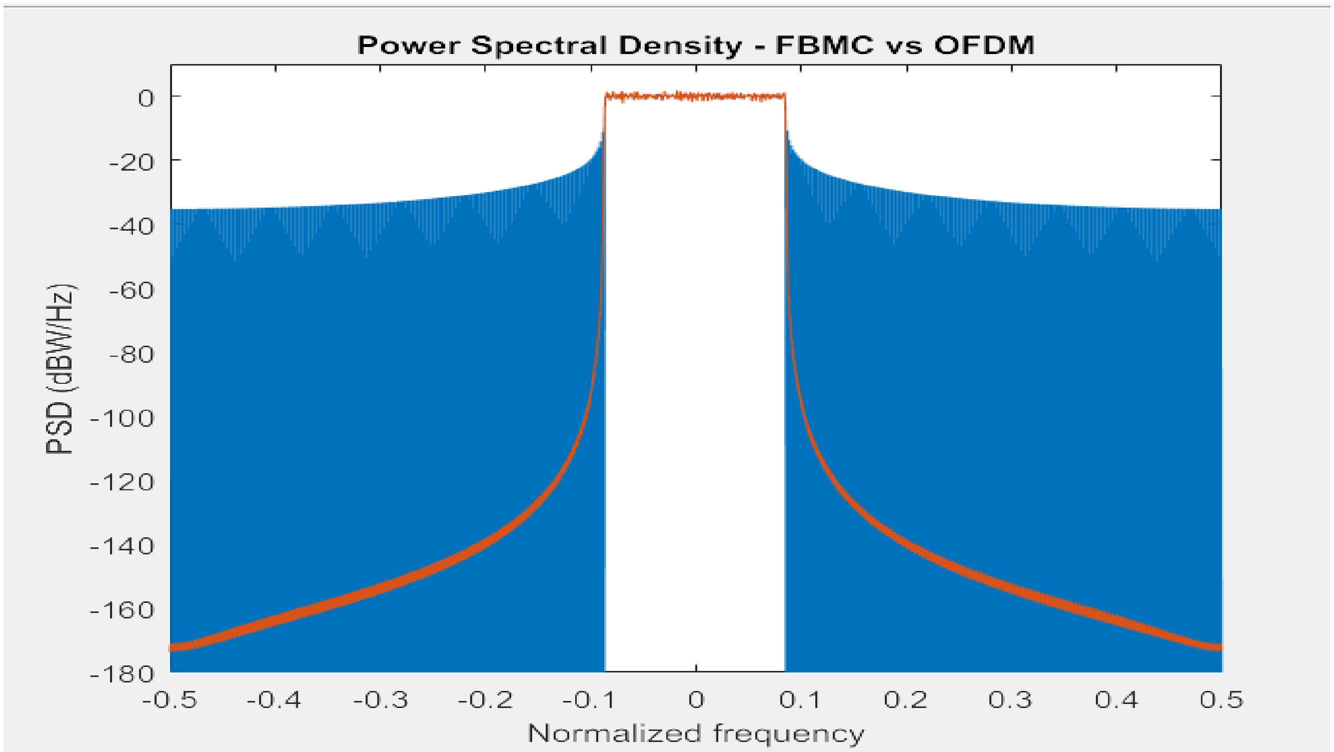

Fig7. Power spectral Density FBMC vs OFDM

The red shaded region represent the spectral density of FBMC while blue that of the OFDM. It can be seen from the above graph that the spectral density of FBMC is greater than that of the OFDM. The FBMC has the spectral density closest to the normalized frequency when compared to all other 5G modulation techniques such as OFDM,UFMC.

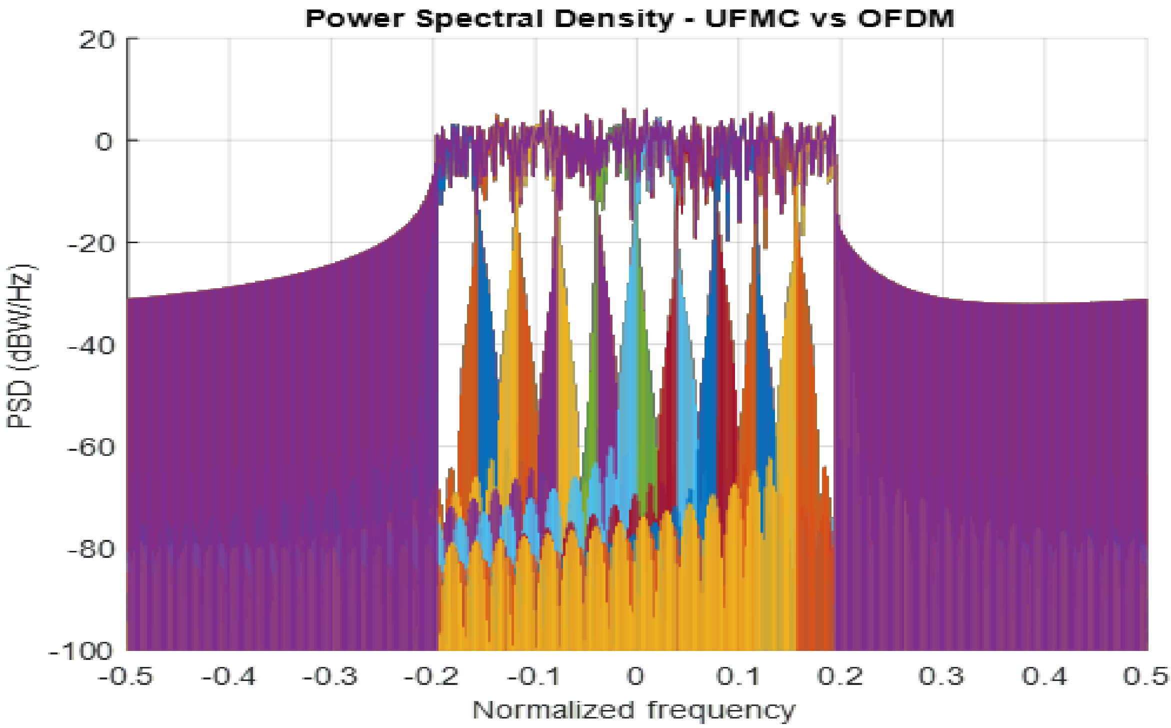

Fig8. Power spectral Density UFMC vs OFDM

The middle shaded region represent the spectral density of UFMC while blue that of the OFDM. It can be seen from the above graph that the spectral density of UFMC is greater than that of the OFDM. Thus it is seen that the FBMC and UFMC are a better option when compared to that of the OFDM. Thus making one of the two a wiser option for 5G.

b. Comparison in Spectral Efficiency

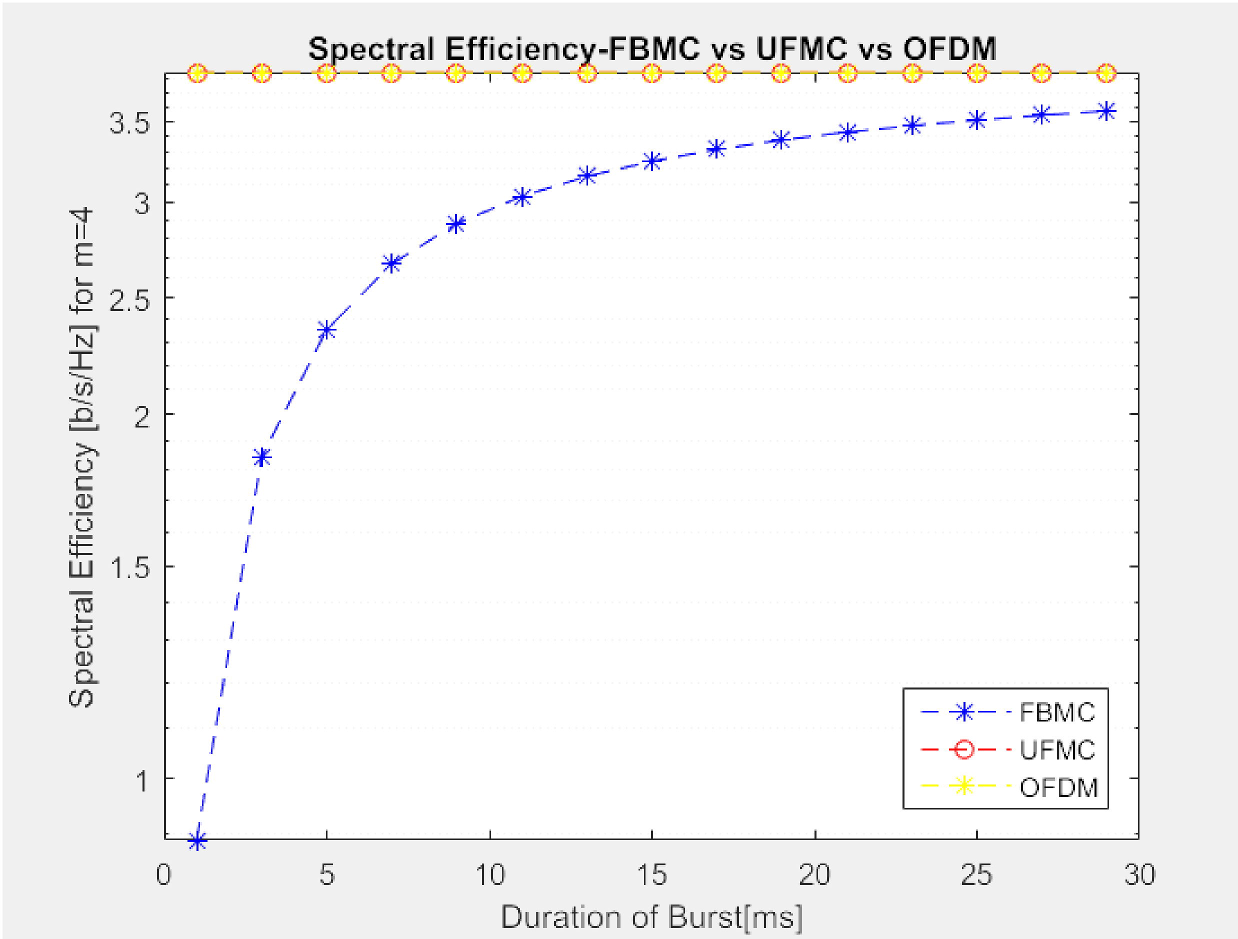

Fig9.Spectral Efficiency UFMC vs FBMC vs OFDM

The graph denotes the spectral efficiency of the three, OFDM, UFMC and FBMC. The graph is generated by varying the duration of burst from 0 to 30. Since the no. of cyclic prefix and the filter length are equal the OFDM and the UFMC overlap each other over the given bursts. It's observed that the FBMC 's spectral efficiency increases with the increase in duration of bursts. It is greater than other two if duration of bursts is larger.

c. Comparison of PAPR

All of the three have high PAPR which is a drawback in these. Among these FBMC has the highest PAPR followed by OFDM and UFMC.

OFDM- 8.8843 dB

FBMC- 10.1178 dB

UFMC- 8.2379 dB

d. Comparison of BER vs SNR

Variation in the SNR affects the quality of the constellation.The simulation of BER vs SNR was generated for SNR from 0 to 15 dB. FBC has the best performance compared to the other techniques.It is is closer to zero from 5 dB.

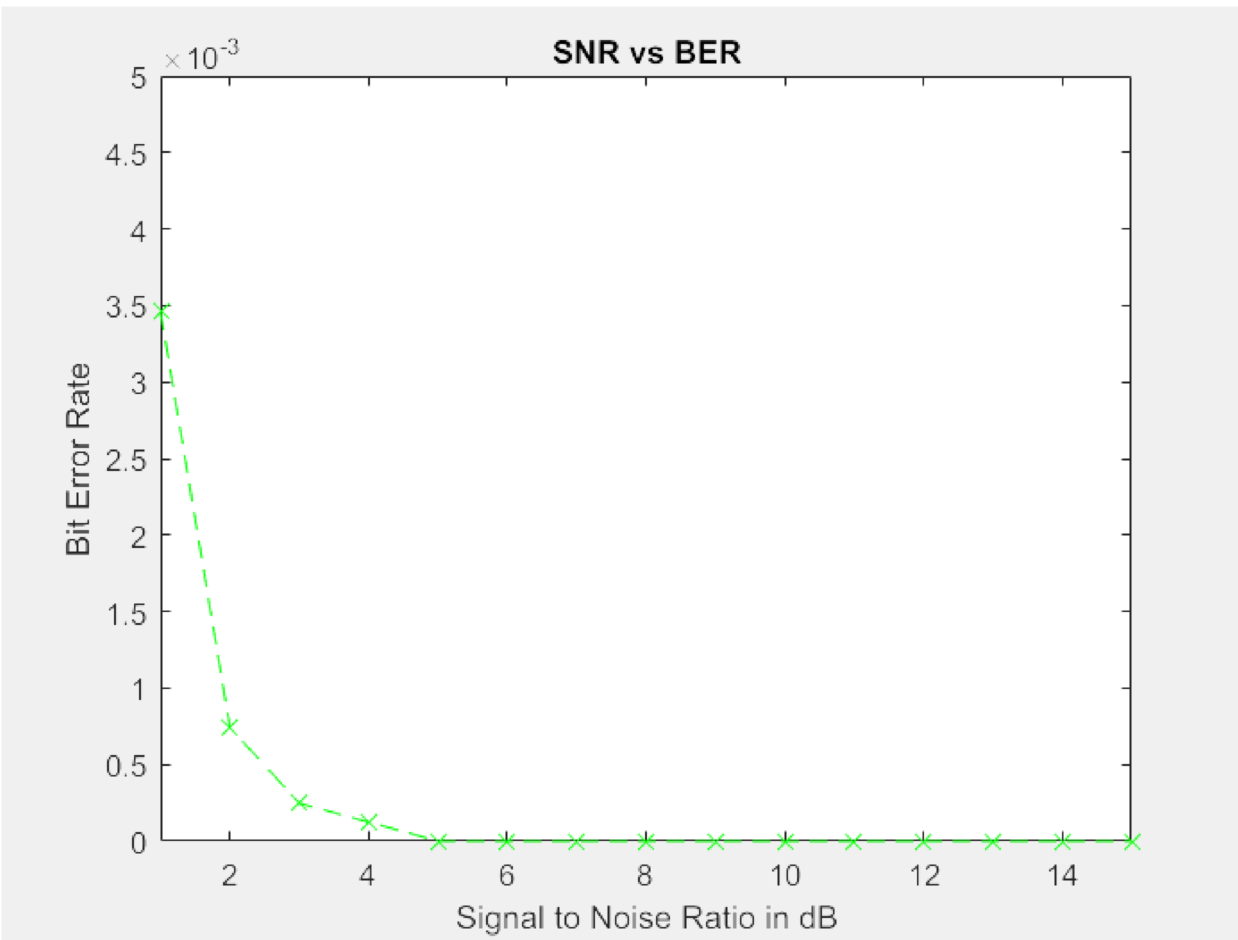

Fig10. SNR vs BER-FBMC

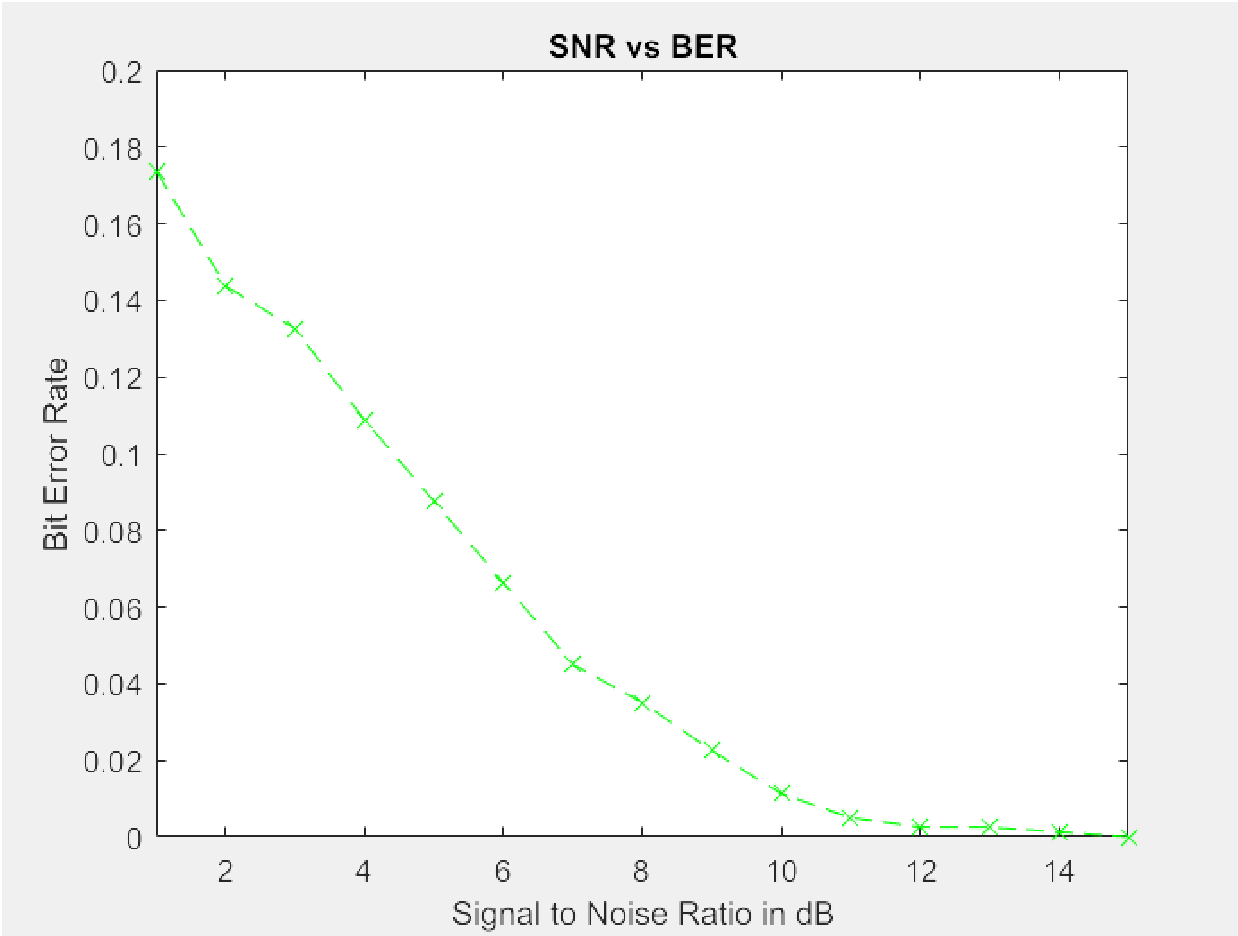

Fig11. SNR vs BER-UFMC

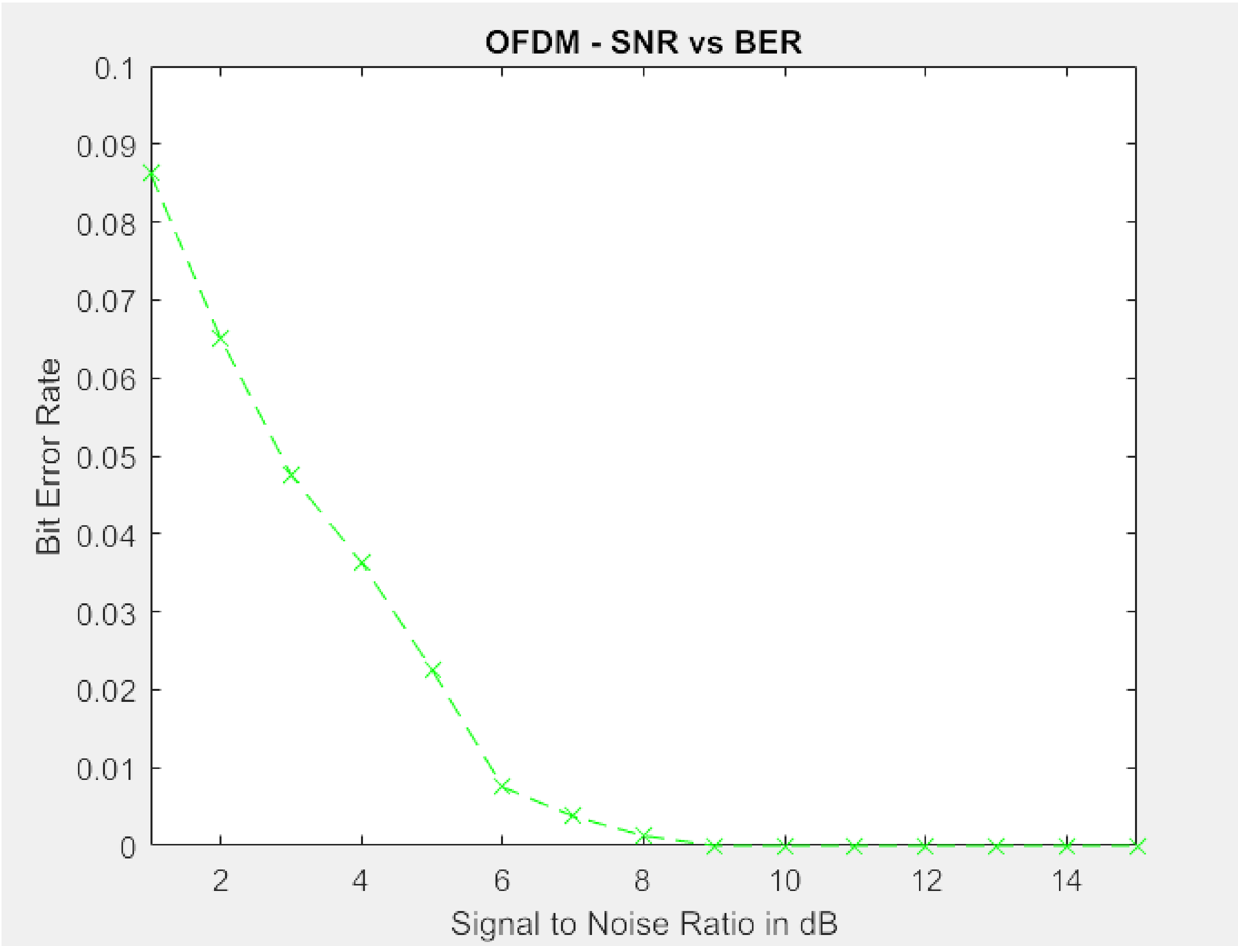

Fig12. SNR vs BER-OFDM

IX. CONCLUSION

The goal of the project to obtain a performance analysis of different modulation schemes FBMC,UFMC,OFDM implemented in 5G communications. This helped in obtaining the efficiency of the modulation techniques considering parameters like PAPR,BER,Spectral Density and Spectral Efficiency. This could further be enhanced by applying the modulation schemes across different wireless communication channels. MIMO feature could be added to test the capability of the system for multiple users.

X. REFERENCES

(1) F. Schaich and T. Wild, "Waveform contenders for 5G — OFDM vs. FBMC vs. UFMC," *Communications, Control and Signal Processing (ISCCSP), 2014 6th International Symposium on*, Athens, 2014, pp. 457-460.

(2) M. Bellanger. FS-FBMC : An alternative scheme for filter bank based multicarrier transmission. In 5th International Symposium on Communications Control and Signal Processing (ISCCSP), pages 1–4, May 2012

(3) Mirnia, S.E.; Zarei, A.; Emami, S.D.; Harun, S.W.; Arof, H.; Ahmad, H.; Shalaby, H.M.H., "Proposal and performance evaluation of an efficient RZ-DQPSK modulation scheme in all-optical OFDM transmission systems," in *Optical Communications and Networking, IEEE/OSA Journal of* , vol.5, no.9, pp.932-944, Sept. 2013

(4) http://www.mathworks.com/help/comm/ref/comm.awgnchannel-class.html

(5) https://www.mathworks.com/help/comm/examples.html