Filter Bank Multicarrier Video communication for 5G Video Streaming applications

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ABSTRACT - Filter Bank Multicarrier (FBMC) transmission technique is highly applicable for upcoming wireless communication standard 5G video communications in design of physical layer protocol. It is compared to the existing 4G video communication such as Orthogonal Frequency Division Multiplexing (OFDM). In OFDM, there are drawbacks like high power consumption, low energy efficiency, high error rate and less number of users. In order to overcome these problems, main requirement of 5G video communication is to increase the data rate about 1000 times. Thus, FBMC is preferable physical layer prototype. FBMC uses one filter for a group of sub carriers. Filter bank multicarrier uses a different modulation technique known as multicarrier modulation. Multicarrier modulation is a form of signal waveform that uses multiple carriers normally closely spaced in a block to carry the information. These blocks of carriers are positioned in a bank known as a filter bank. The performance of each Filter bank multicarrier is considered by Throughput, Data rate, Bit error rate (BER), Mean square error (MSE), Peak to average power ratio (PAPR). The result of this study shows that Filter bank multicarrier depicts a satisfactory improvement in performance.

Keywords: PAPR, BER, MSE

I. INTRODUCTION

The current research interest on mobile communication systems is undergoing a paradigm shift from the widely established third and fourth generation technologies, to a much flexible future fifth generation (5G) networks [1-3]. 5G systems, which are expected to be deployed in 2020, aim at providing its users with giga-bit data-rate experience under increasing data-traffic-demand and high mobility, high throughput along with very low latency, efficient utilization of available spectrum etc., at reduced cost and with low power consumption. For the currently deployed fourth generation (4G)[4] long term evolution (LTE)[5] and other communication technologies like WiFi[6], WiMAX[7], digital audio[8], DVB-T (digital video broadcasting - terrestrial)[9], ADSL (asymmetric digital subscriber line) etc.[10], orthogonal frequency division multiplexing (OFDM) and its variants have been adopted, due to its advantages like fast and easy implementation by fast Fourier transform (FFT) blocks[11], robustness against multipath effects provided by the orthogonality of the sub-carriers, possibility of adaptive modulation and bit-loading strategies etc. However, traditional OFDM suffers from various drawbacks, which make it a limited choice to meet the diverse and challenging requirements of the future cellular systems. In order to combat time dispersion and to facilitate per sub-carrier equalization, OFDM uses a redundant time interval called cyclic prefix, between two symbols. The presence of cyclic prefix leads to inefficient use of the available transmission time there by disrupting the low latency requirement, leading to low spectral efficiency and ultimately, reduced throughput. The transmit and receive filter used in OFDM is time limited rectangular pulse, which has very high side-lobes in the frequency domain, that causes spectral leakage to adjacent sub-carriers. These out-of-band emissions ultimately lead to inter carrier interference (ICI). The presence of large side-lobes also limits its application to cognitive radio scenario. The orthogonality among the sub-carriers is distorted under fast fading mobile channels which also induce ICI [12]. Under doubly dispersive channels involving both time and frequency spreading, OFDM suffers from both inter symbol interference (ISI) and ICI, which demands stringent synchronization techniques, that increases the power consumption.

II. LITERATURE SUEVEY

OFDM [13] and FBMC known as the multicarrier techniques which is the data symbols will be transmitted simultaneously over the multiple frequency subcarriers. Their nature of multicarrier signals gives in-build support for frequency selective link/rank adoption. The main difference between

OFDM and FBMC is the pulse shaping applied at each subcarrier. Most of the wireless mobile communication video communication [14-15] that was developed today is based on OFDM. FBMC is an advancement of OFDM. The basic change in the FBMC system is the replacement of the CP in OFDM with the multicarrier system based on filter bank. Figure 1 shows the modulators for OFDM and FBMC.

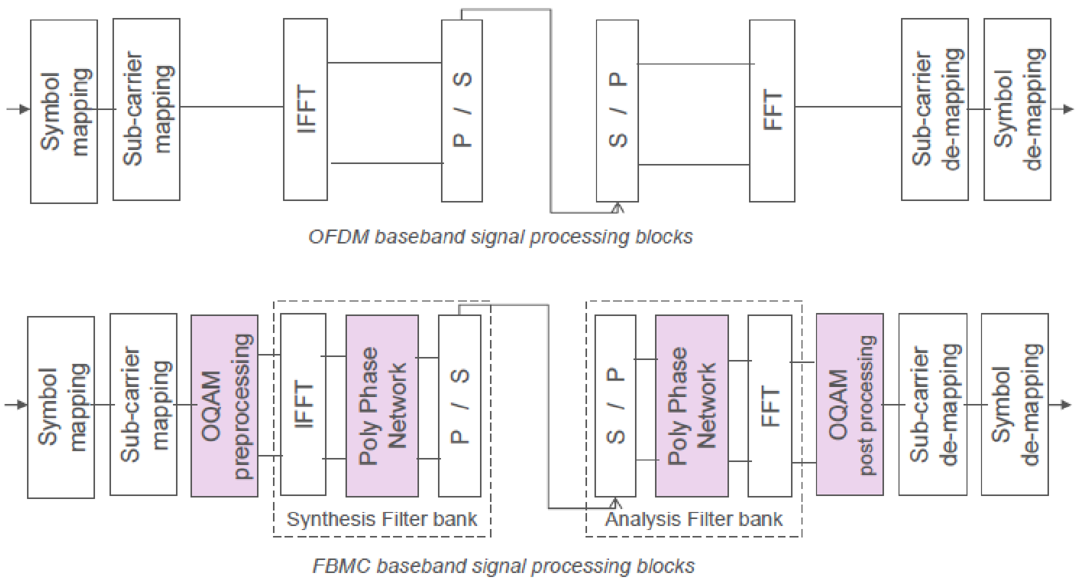

Figure 1. Reconstruct the difference in modulators for OFDM and FBMC.

Based on Fig. 1, the inverse fast fourier transform (IFFT) [16] and the input of the Cyclic Prefix (CPin) was replaced by the synthesis filter-bank (SFB) [17]. Meanwhile for the output of the Cyclic Prefix (CPout) [18] and fast fourier transform (FFT) was replaced by the analysis filter-bank (AFB). The frequency spectrums of the subcarriers in the OFDM system are overlapped with the minimum frequency spacing. Besides that, the orthogonality was reached between the different of the subcarriers. The input stream was split into parallel data streams using the serial to parallel data converter (S/P). Subsequently, to generate time sequence of the streams, it will be passed into an IFFT block. The symbol time sequences of the OFDM system will be extended by adding CP. The digital signal produced and converted into analog form before it has been transmitted over the channel. FBMC overcomes the weakness of the OFDM system. In the FBMC system, it produced a well localized sub-channel [19] in both frequency and time domain by adding a generalized pulse shaping filters. There is no CP needed in the FBMC system, so it provided more effective use of the radio resources and have more spectral containment signals. Filter-bank can be defined as an array of the N filters that will be processed the N input signals to generate N outputs. There are two types of the filter-bank in this system which is analysis filter-bank (AFB) and synthesis filter-bank (SFB). In the AFB, the input of N filter is connected together. Besides that, the system in analogous manner that can be assumed as an analyzer to the input signal based on each filter characteristics. Meanwhile in the SFB, the outputs of the filter array will be added and a new signal will be synthesized [20]. The synthesized analysis configuration known as transmultiplexer and will be applied in the multicarrier communication systems. Mathematically, each carrier can be described as a complex wave:

$$s_c(t) = A_c(t)e^{j[\omega_c t+\phi_c(t)]} \quad (1)$$

The real signal is the real part of $s_c(t)$. Both $A_c(t)$ and f $_c(t)$, the amplitude and phase of the carrier, can vary on a symbol by symbol basis. The values of the parameters are constant over the symbol duration period t . OFDM consists of many carriers. Thus the complex signals $s_s(t)$ (Fig. 4) is represented by:

$$s_s(t) = \frac{1}{N}\sum_{n=0}^{N-1} A_n(t)e^{j[\omega_n t+\phi_n(t)]} \quad (2)$$

Where $\omega_n = \omega_0 + n\Delta\omega$

If the signal is sampled using a sampling frequency of 1/T, then the resulting signal is represented by:

$$s_s(kT) = \frac{1}{N}\sum_{n=0}^{N-1} A_n e^{j[(\omega_0+n\Delta\omega)kT+\phi_n]} \quad (3)$$

III. PROBLEM STATEMENT

In OFDM, Orthogonality between subcarriers allows controlling ICI by ensuring time and frequency synchronization at the receiver. OFDM has very large side lobes, rectangular pulse shaping exhibit poor stop band attenuation and requires guard band at spectrum in order to control out-of-band emissions. OFDM uses cyclic prefix to reduce ISI, which limits the spectral efficiency. These problems are overcome by FBMC/OQAM which adopts Zadoff-chu sequence based preamble to reduce the carrier frequency and timing synchronization. The proposed method does not transmit a cyclic prefix or guard band and shapes subcarriers using well frequency-localized waveforms that suppress signals side lobes, thus providing larger spectral efficiencies. The system complexity has been reduced by preamble based (or pilot based) synchronization. Zadoff-Chu sequence based preamble is proposed to reduce the CFO and STO estimation that avoids intrinsic interference and has been used for channel estimation. In this paper, a periodic Zadoff–Chu sequence preamble is considered; both STO and CFO estimators are designed based on a least-square approach. This is a time domain approach which exhibits a stable performance independently of the actual TO. This method also provides good robustness against multipath channels but has rather moderate complexity. By using Zadoff–Chu sequence preamble, accurate CFO has been obtained to see the reduced PAPR results and improved BER performance.

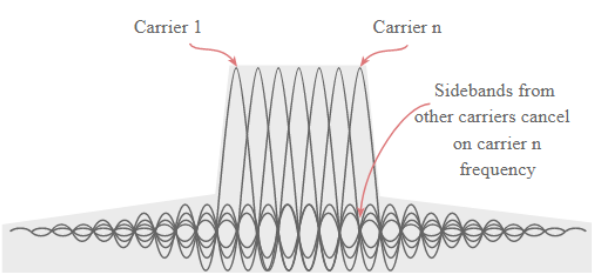

Fig: subcarrier synchronization issues in OFDM

IV. PROPOSED SYSTEM ARCHITECTURE

The focus of the proposed architecture is to obtain better spectral efficiency using Zadoff-chu sequence based preamble design with FBMC/OQAM to minimize the BER. The proposed system architecture is shown in the Figure 2.

Figure 2 presents a set of magnitude responses of the modulated versions of the pulse-shape (t) for the data symbols transmitted at t=0 and t=T. The colors used for the plots follow those in Figure 2 to reflect the respective phase shifts. Let $n = \ldots, -2, -1, 0, 1, 2, \ldots$, denote symbol time index, let $k = 0, 1, 2, \ldots$, denote symbol frequency index, let $sk[n]$ denote the (n, k) data symbol in the time-frequency lattice, and let $\theta k[n] = (k - n)(\pi/2)$ be the phase shift that is added to the carrier of $sk[n]$. Accordingly, a CMT waveform that is constructed based on the pulse-shape/prototype filter (t) is expressed as

$$x(t) = \sum_n \sum_k s_k[n]\, a_{n,k}(t),$$

where

$$a_{n,k}(t) = e^{j\theta_k[n]} p_{n,k}(t),$$

$$p_{n,k}(t) = p(t - nT)\, e^{j((2k+1)\pi/2T)t}.$$

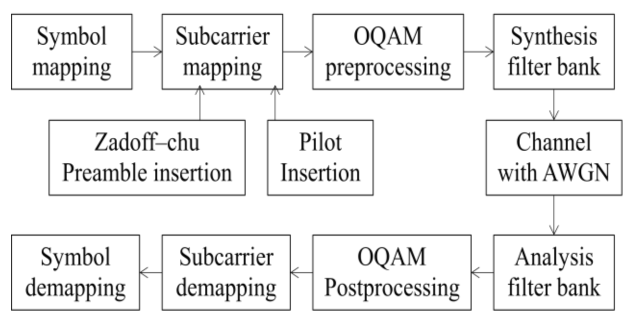

Figure 2 Proposed block diagram for FBMC

The block diagram consist of transmitter, receiver and channel with additive white Gaussian noise (AWGN). The Transmitter consists of Symbol mapping, where the digital data is modulated using the any one of digital technique namely QPSK, 4-QAM or 64-QAM and BER of the system mainly depends on this block. The need of subcarrier mapping would be useful for the FBMC frame creation that consists of preambles, data pilots and data subcarriers. Each FBMC frame is equipped with a preamble that is specially designed for fast tuning of carrier frequency and timing synchronization at the receiver, upon the receipt of each packet. Pilots are used for the efficient channel estimation and equalization that is needed in order to realize spectral efficiency, spectrum sharing approaches or high mobility scenarios. OQAM processing scheme simultaneously employs an improved pulse shaping, and interpolation by factor 2 for transmit at the Nyquist rate. The additional filtering, together with the IFFT/FFT operation and serial to parallel conversion forms a synthesis filter-bank structure, where the prototype filter is designed to significantly suppress ISI.

The ideal receiver performs the exact opposite operation to that of transmitter. The parameters (time, frequency and phase) of transmitted FBMC signal must be observed exactly across the receiver. They are timing and frequency synchronization, channel estimation, channel equalization and phase tracking. In FBMC, Timing Offset (TO) and Carrier Frequency Offset (CFO) results in ISI (Inter-Symbol Interference) and ICI (Inter-Carrier Interference). Pilot aided and blind synchronization methods are used to provide the synchronization. FBMC only satisfies the Orthogonality in the real domain, which causes it suffering from intrinsic interference even if perfect Timing and frequency synchronization is achieved. However, to avoid the intrinsic interference originated from neighboring symbols in the time domain, more than a couple of FBMC symbols either pilots or preambles must be allocated only for channel estimation purpose. Generally the pilots are used to cancel the interference. By doing so, the received main pilots become interference-free, and channel estimation can be performed.

preamble design

the short preamble that consists 10 cycles of a periodic signal with a summation of multiple tones of subcarrier with wider separation than the subcarrier spacing to allow detection of large CFO values. It is used to find a coarse estimation of CFO, so that the CFO will be within the range of half symbol spacing. The payload contains information such as the length of the frame, the data rate and the channel code. As in OFDM, the long preamble does not start with a guard interval. By the end of long preamble, all synchronization steps have to be completed and the receiver should be ready to correctly detect payload part of the packet. The long preamble in FBMC frame is positioned such that the underlying filters do not overlap with the short preamble and the payload part of the frame.

The design consideration is made in the proposed work to achieve this, the length of the long training should be at least equal to the length of the prototype filter (K) plus by a factor 2. Hence, efficient prototype filter leads to a shorter preamble and thus bandwidth efficient system is more. This is analyzed by using wider subcarrier that increases the bandwidth of each subcarrier, accordingly reduce the symbol period and the length of the corresponding prototype filter. The proposed preamble makes an attempt to control the length of the preamble that improves the bandwidth efficiency. This results in improvement of BER and reduction in PAPR values. A longer preamble allows a more accurate estimate of CFO and the key parameter for preamble design is FBMC that satisfies both conditions.

The proposed Zadoff–Chu (ZC) sequence is efficiently utilized for generating a long preamble that achieves superimposed ZC sequences used for preamble symbols.Zadoff–Chu sequences are used in the 3GPP LTE Long Term Evolution air interface in the Primary Synchronization Signal, uplink control channel, uplink traffic channel and sounding reference signals. Thus the proposed ZC sequences will be useful for random accessing of preamble in 5G evaluation. The proposed Zadoff–Chu sequences are an improvement over the Walsh Hadamard precoding used in universal mobile telecommunication because they result in a constant-amplitude output signal, reducing the cost and complexity of the radio's power amplifier.

ZC sequence is generated by

$$x_u(k) = e^{-\frac{j\pi uk(k+N\text{mod}2)}{N}}, k = 0,1,\ldots.N-1.$$

where u is the root index, there are two root indexes considered in this paper “ZC_RootIndex1” and “ZC_RootIndex2”. The two root indexes are used to generate two different sets of preamble that generates a repeated structure of preamble. The repeated structure of preamble are also useful for carrier frequency, timing synchronization and channel estimation. N is the length of the sequence that is obtained by the number of subcarriers used in the FBMC. The preamble is generated and FBMC frame is created by using the ZC sequence preamble. Now, this frame is transmitted over the channel with AWGN. The parameters of frame gets affected due to the noise, the receiver must be able to detect the noise and generate the accurate results. Thus, the ZC preamble is useful in receiver section.

The data symbols $[n]$ can be extracted from (t) straightforwardly if $an,(t)$ are a set of orthogonal basis functions. The orthogonality for a pair of functions is defined as

$$\langle a_{n,k}(t), a_{m,l}(t)\rangle_R = \begin{cases} 1, & n=m,\ k=l \\ 0, & \text{otherwise} \end{cases}$$

and, hence, for any pair of n and k,

$$s_k[n] = \langle x(t), a_{n,k}(t)\rangle_R .$$

The above equations may be combined to arrive at the CMT transmitter and receiver structures that are presented in Figure 2. As shown a synthesis filter bank (SFB) is used to construct the transmit signal, and the received signal is passed through an analysis filter bank (AFB) to separate the data streams of different subcarrier bands. Here, it is assumed that there are N subcarrier streams and the data stream of the kth subcarrier at the input to the SFB is represented by the impulse train:

$$s_k(t) = \sum_n s_k[n]\,\delta(t-nT) .$$

Carrier frequency offset and Timing offset synchronization

The carrier frequency offset is achieved by angle of the correlation peak and the timing offset synchronization is achieved by the cross-correlation between local proposed ZC sequences and received preamble sequences. The searching range is one frame length, so the maximum delay of the input signal should not exceed one frame length. The peaks selected for estimation is chosen by filter coefficients and the number of preamble symbols per frame and the interval between two filter tap is the time that a preamble symbol last.

Channel estimation

The proposed preamble symbol is chosen to do channel estimation as it can be used to generate pilot sequence. The value of preamble symbols in transmitter is known and the repeated structure formed cyclic prefix in preamble that make it robust to multipath. The least-squares channel response estimate at subcarrier i can be obtained as: Hi=Yi/Xi, where Yi is the received symbol and Xi is the transmitted preamble symbol on the i^{th} subcarrier.

Phase Tracking

The compensated phase is estimated by pairs of pilots and zc sequence preambles in frame. The tracking aims at computing a channel estimate by using transmitter and receiver data on the pilots at two different time instants. The phase is calculated as mean value of the angles of pilots and preambles.

V. SIMULATION RESULTS

The proposed work uses the following simulation parameters for the performance metrics such as Complementary Cumulative Distribution Curve (CCDF) for FBMC signal with different multicarrier to analyse the Peak to Average Power Ratio (PAPR) and BER, MSE for spectral analysis. The frequency offset and timing offset with respect to MSE is also considered.

The performance of Frequency over Spectrum power is shown in Fig.2. The OFDM utilizes the frequency spectrum of 10MHz bandwidth out of which 9MHz is utilized for subcarrier transmission and remaining 1MHz is utilized for guard band which wastes the spectrum. To overcome this issue, different multi carrier techniques such as F-OFDM, GFDM, OFDM and FBMC for 5G spectrum is analyzed. The observation shows that the FBMC technique is much better than the other multi carrier techniques due to the efficient usage of spectrum. The proposed FBMC method efficiently suppresses the side lobes and reduces out – of – band emission. It is observed that FBMC with well-designed preambles and prototype filters helps to improve the spectrum of each sub carriers within limited bandwidth.

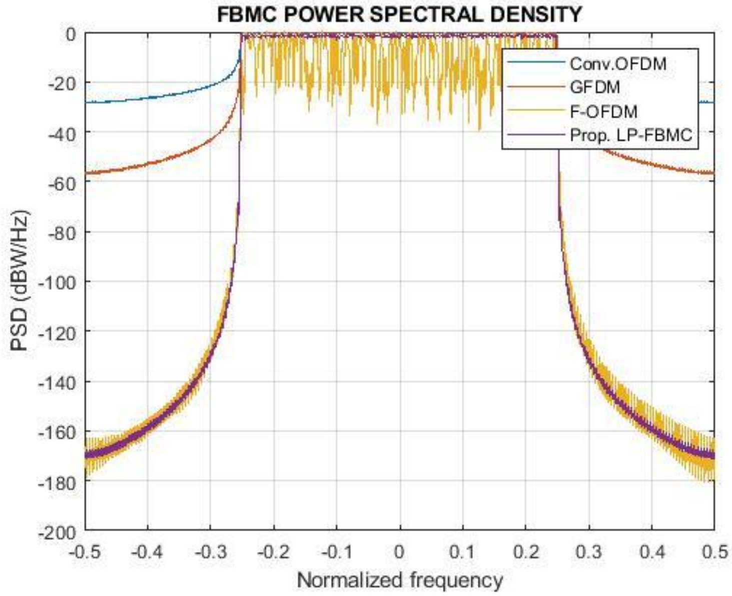

Fig 2. Power Spectral densities

The performance of PAPR over CCDF is shown in Fig.3. PAPR is the common metric to characterize the amplitude fluctuations of the signal. These amplitude fluctuations results in out of band emissions, spectrum re-growth, causing ICI and ISI. The CCDF curve shows how much time the signal spends at or above a given power level. The PAPR value of FBMC is reduced to 2dB while compared with other access techniques of 5G.

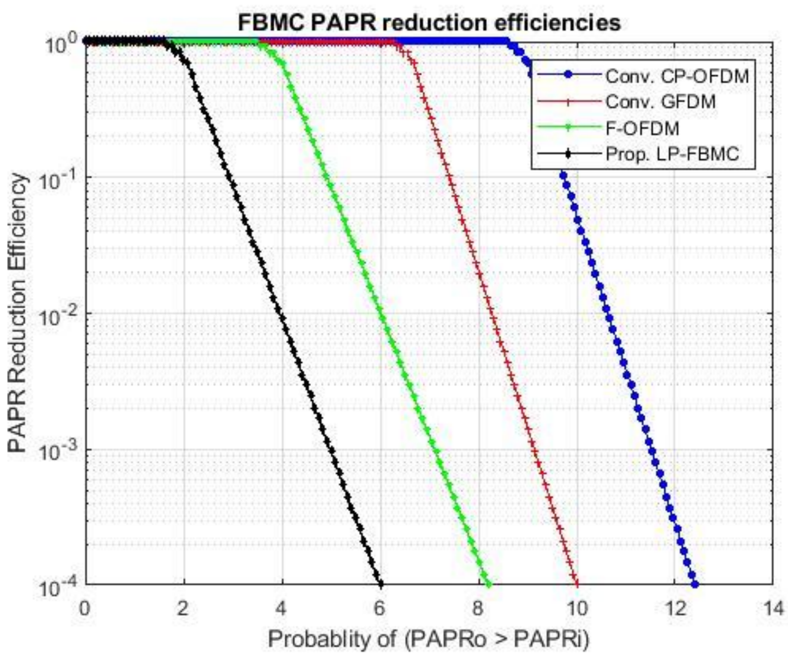

Fig 3. PAPR Vs CCDF

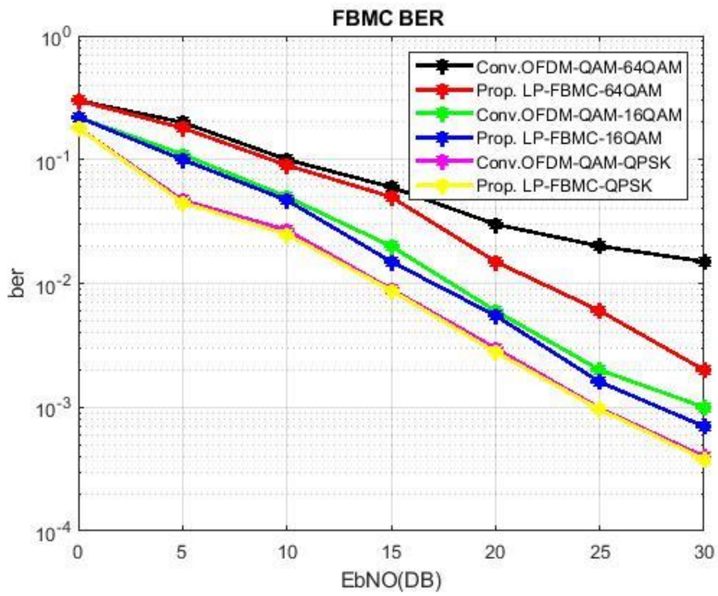

Fig 4. SNR Vs BER

The performance of SNR over BER is shown in Fig.4. The BER response of FBMC is much better than OFDM.

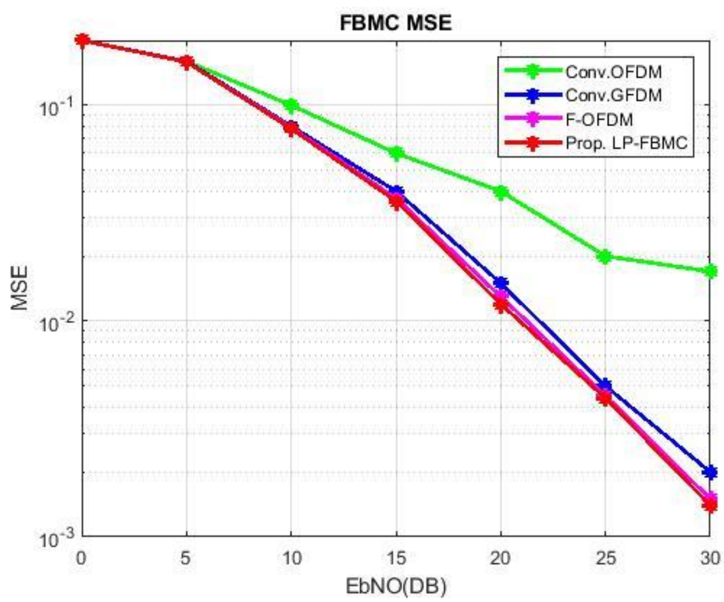

Fig 5. SNR Vs MSE

The performance of SNR over MSE is shown in Fig.5. The intrinsic interference originated from neighboring symbols in time domain severely damages the pilot signal in the channel estimation stage leads to poor estimation accuracy. So to analyze the channel estimation, the Mean Square Error (MSE) as a function of SNR founds to be useful. The FBMC scheme has almost no loss in most SNR ranges while OFDM scheme has a very big loss at all SNR points.

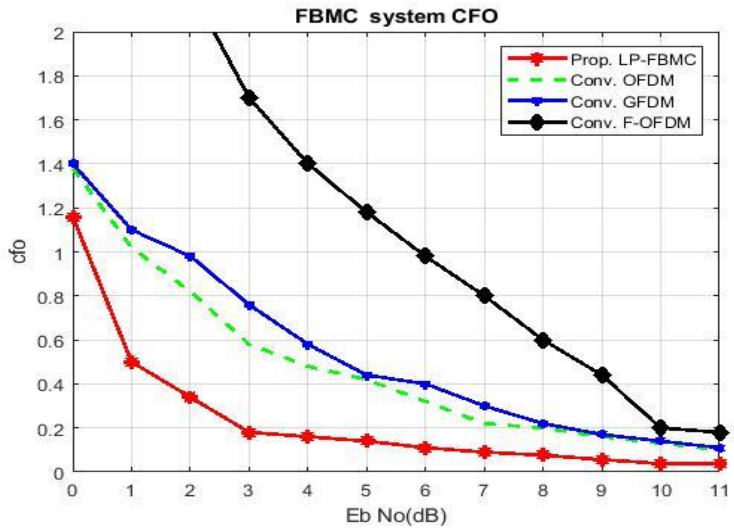

Fig 6. SNR vs Frequency offset

The performance of Frequency offset over MSE is shown in Fig.6. In OFDM, imperfect frequency domain synchronization among different uplink users leads to MSE caused by inter-carrier interference (ICI). In FBMC, even a small CFO causes loss of Orthogonality among the different subcarriers and thus introduces ICI. Furthermore, carrier frequency offset (CFO) results in ISI in a multi carrier OQAM system. The graph presents mean square error (MSE) or distortion in terms of ICI, ISI at the receiver. As a result, if a system requires high SNR, FBMC outperforms than OFDM in terms of CFO immunity. This indeed is an important gain in a system with high data rate when higher order modulations are required.

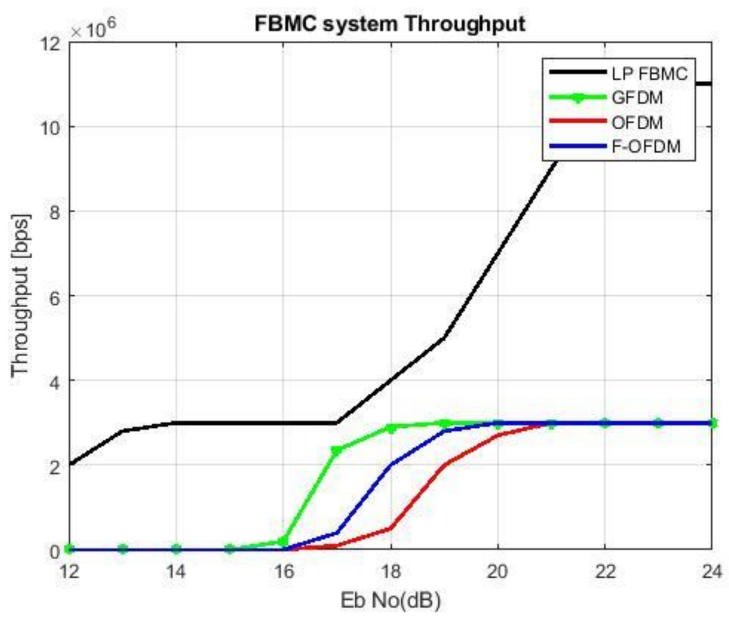

Fig 7. SNR vs Throughput

The performance of Throughput data rate is shown in Fig.7.The throughput of the proposed FBMC shows much better performance than the other existing techniques.

From Table 1, it is observed that the proposed FBMC method is well suited for 5G based video communications compared to the state of art approaches OFDM [3], F-OFDM [5] and GFDM [7] respectively.

Table I. COMPARISON SUMMARY

Parameters	OFDM[3]	F-OFDM[5]	GFDM[7]	FBMC
Computational complexity	2048	2048	1024	512
PAPR EFFECIANCY	0.01	0.05	0.009	0.002
MIMO Compatibility	YES	YES	YES	HIGHLY EFFECTIVE
CFO OFFSETS	1.8	0.6	0.5	0.2
BER	0.09	0.009	0.007	0.001
MSE	0.0055	0.0035	0.003	0.002
THROUGHPUT	2.1 MBPS	2.3 MBPS	2.5 MBPS	11 MBPS

VI. CONCLUSION

This paper proposes a new preamble design and corresponding channel estimation algorithm for FBMC/OQAM system. The Zadoff-chu sequence used to generate the long preamble structure for the frame. The performance results show that the proposed preamble based method performs well than the conventional preamble structure in the following attributes of spectral efficiency, and reduced PAPR values. Moreover, the proposed algorithm has low complexity which makes efficient BER performance with respect to SNR and MSE for corresponding frequency offset and timing offset. Hence it can be directly applied to advanced mobile systems like 5G. This work can be extended to MIMO FBMC in future because it offers many exciting problems for research.

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