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Augmentation of Spectral Efficiency using APSK in FBMC to Assess High Data Rate

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***Abstract**: There are various techniques which have been developed to improvise the modulation technique exploited in the system which were intended to enhance the data rate and bandwidth of the 5G network. Various researchers worked on OFDM modulation technique in order to enhance the efficiency as it is successfully working on 4G networks. Although utilization of OFDM in 5G networks will not provide the expected outcomes due to some flaws. This paper proposed a system that induced FBMC (Filter Bank Multi-Carrier) modulation technique which is capable of delivering higher spectral efficiency than OFDM. Proposed method employed APSK (Amplitude Phase Shift Modulation) for the modulation of sub carriers. The idea of implementing APSK in FBMC is to optimize the peak to average power ratio and also reduces bit error rate. The techniques proposed in the system, aimed to achieve high efficiency in terms of data rate and bandwidth with less power consumption. By using MATLAB all the simulations will be performed to analyze the results of spectral efficiency in terms of BER vs Eb/No (SNR) and power spectral density.*

***Index Terms**: 5G, FBMC, OFDM, APSK, QAM, Modulation, Cyclic Prefix, BER, SNR*

I. INTRODUCTION

Wireless is basically a term frequently used to elaborate computer networking where signals are transmitting by using waves whether a micro waves or radio waves. Instead of using wires, various specific equipment is used like NICs (Network Interface Card) and Routers. The consistent growth in the field of digital wireless communication in order to fulfill the growing need of digital applications and services developed 1G, 2G, 3G, 4G and now it's 5G. 5th Generation Mobile Network or simply 5G is the imminent revolution of mobile technology. The features and its usability are much beyond the prospect of a normal human being. With its ultra-high speed, it is potential enough to change the meaning of cell phone usability. Technique of multicarrier modulation basically processed by splitting the whole data stream into smaller parts i.e. from large to small. So, each lower data stream utilizes its individual carrier.

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There are various techniques which have been developed so far in order to enhance the efficiency of the 5G network system.

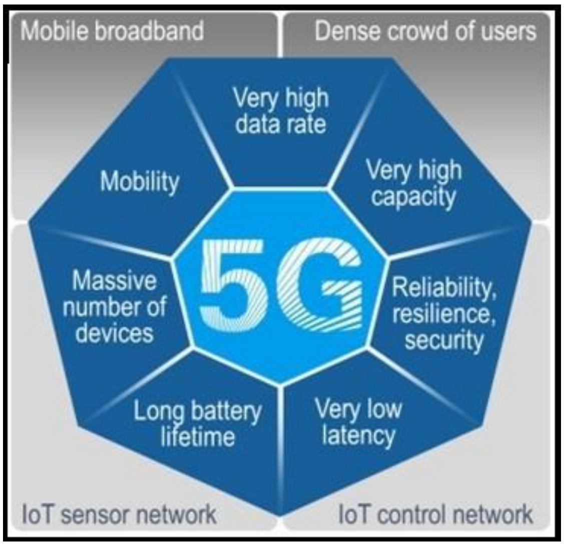

Fig. 1. 5G Networking Evolution [1]

OFDM- One of the known method used is OFDM (Orthogonal Frequency Division Multiplexing) which is a multicarrier signal modulation technique. It basically contains a group of modulated carriers which are nearly spaced. This scheme uses parallel transmission of data by utilisiong various subcarriers with orthogonality. In order to reduce the intersymbol interference, a guard band is inserted between successive OFDM symbols.

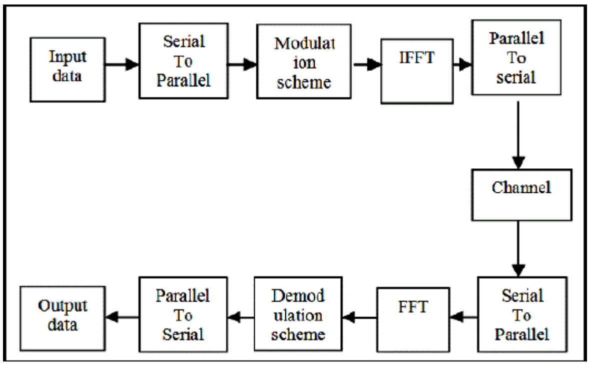

Fig. 2. OFDM Model [2]

There are various pros like the sturdiness in opposition to multipath fading, ease of execution, resistance to fading contains frequency, buoyancy to ISI, spectrum competence, simple equalization of channel. Despite these benefits of this technique, OFDM suffers from various drawbacks like high peak-to-average power ratio (PAPR), use of cyclic prefix (CP), out of band radiation (OOB), sensitivity towards the carrier offset and drift. So all these drawbacks give a setback to OFDM and thus not preferred for future 5G air interface.

FBMC (Filter Bank Multi Carrier) – FBMC is a type of multicarrier modulation method which utilizes some dedicated pulse shaping filters. This method is known for its fine properties of time and frequency localization through which ISI (inter-sumbol interference) and ICI (inter carrier interference) can be reduced up to a high extent as cyclic prefix is not needed. FBMC has the better utilization of the projected channel due to which spectrum efficiency got increases. In the model of FBMC, every specific sub channel is passes through a filter and get filtered on their own. System employed very narrow band filters that provides better control on the filter bank. In the proposed system, FBMC (filter bank multi-carrier) technique has been exploited. By using FBMC, the subcarriers are able to suppress the excessive side lobes by inducing filter bank which in turn enhance the spectral efficiency of the system. Filter bank multi carrier (FBMC) is one of the forms of multicarrier modulation. The major issue that OFDM technique faces is due to the utilization of cyclic prefix, it condenses the throughput of the system and also consumes power. Another issue with the OFDM system is its localization of spectral of the given subcarriers which is very poor and results in the leakage of spectrum and also produces interference and asynchronization among the transmitted signals. FBMC overcomes the issue comes up in OFDM technique by using narrow band filters. For the modulation of subcarriers, APSK is implemented. Due to its fewer utilization of amplitude, technique is capable to reduce peak to average power ratio (PAPR).

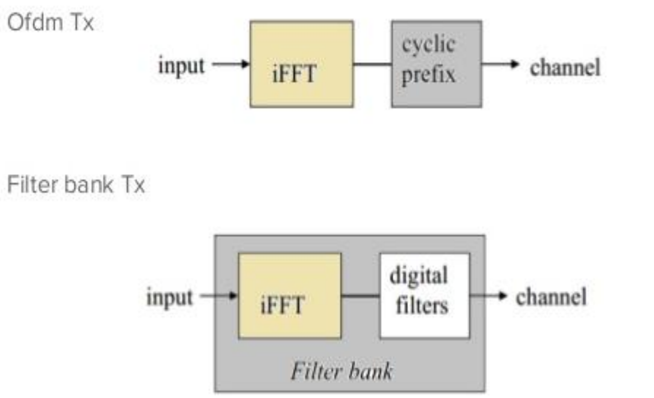

Fig. 3 Multi Carrier Modulation of OFDM and FBMC [3]

II. RELATED WORKS

A. *Literature Survey*

Onur Dursun Toren et al. [2009] proposed a system that employed the technique of H-OFDM i.e. hybrid orthogonal frequency division multiplexing in context with the waveform supposed to utilize in 5G technology. System exploited hybrid cyclic prefix (H-CP) instead of traditional cyclic prefix. Results compared in the terms of simulation which shows the enhanced performance of OFDM. Instead of CP, which is an indiscriminate progression in the CP-OFDM technique, a non-random sequence, unique-word (UW), is used in the UW OFDM method. Though it has been proved that, UW-OFDM and conventional CP-OFDM illustrates nearly the identical spectral efficiency. Even after using unique word cyclic prefix, channel leakage will be the consistent issue with system that also reduces the efficiency of overall system and enhances noise [4].

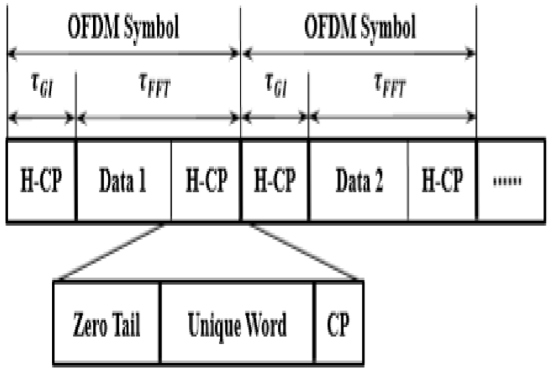

Fig. 4. H-OFDM System Symbol Structure [4]

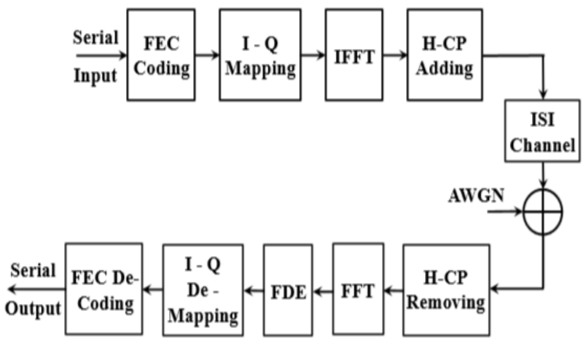

Fig.5. H-OFDM system- transmitter and receiver structure [4]

Jovana Mrkic et al. IEEE proposed an OFDM system for 5G technology by implementing Index modulation technique in which it has been stated that transmission of information is also possible by using indices of the selected sub carrier as traditionally symbols were used.

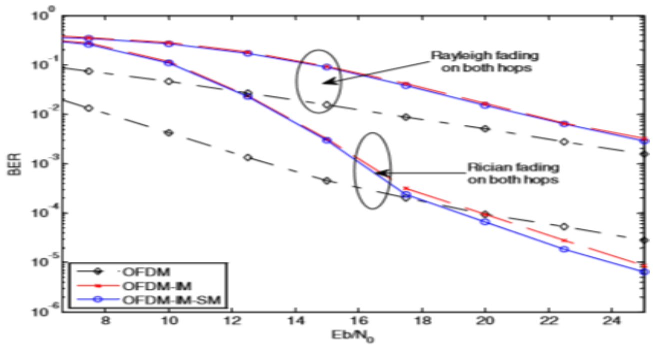

Fig.6. BER Performances of Dual-Hop OFDM, OFDM-IM and OFDM-IM- SM Relay Systems [5]

The system which has been proposed utilized the parameter BER (bit error rate) to analyze the performance of dual hop OFDM relay system in terms of active subcarriers.[5]

Parnika Kansal et al. IJCA developed a system to reduce the PAPR by employing DSLM (Dispersive Selective Mapping) technique which is considered as a comprehensive adaptation of Overlapped Selective Mapping (OSLM) in FBMC i.e. filter bank multi carrier modulation technique which is one of the chief drawbacks of OFDM technique. Though the usage of filters in FBMC, also helps to lessen the value of PAPR (peak to average power ratio) as compare to OFDM. The method deals with the time dispersive nature of the FBMC-OQAM signals and hence termed as Dispersive SLM. System which has been proposed in this paper simulated the result by implementing the technique in MATLAB. The drawback of the DSLM is that the PAPR shows no reduction if it is calculated in the current symbol period duration as most of the symbol energy lies in the two successive symbol periods [6].

Yunlong CAI et al. have presented the study of various techniques of modulation and multiple access (MA) which has been employed to meet the standards required for 5G networks. Various modulation techniques that has shown their capability for the techniques like orthogonal multiple access (OMA) has been analyzed and also their result of execution in terms of out-of-band leakage, spectral efficiency, and bit-error rate has been discussed in the paper. It also includes the study of various types of non-orthogonal multiple access (NOMA) candidates, including power-domain NOMA, code-domain NOMA and NOMA multiplexing in multiple domains. Study explained in the paper stated that to tackle the new confronts that 5G networks are expected to resolve, various modulation schemes have been projected, like filtering, shaping of calculated pulse, and pre-coding to lessen the out-of-band (OOB) leakage of signals obtained through OFDM. [7]

Qazi Nuaman et al., IJRASET provided an analysis of technique which is suitable for the requirement of 5G Networks. Discussion which has been proposed in the paper stated that OFDM technique could not considered as an adequate method for 5g wireless networks due to some limitations like PAPR, OOB, and use of cyclic prefix (CP) which created the need for new waveforms candidates like UFMC, FBMC, and GFDM to get exploited in 5G air interfaces.

Table 1. Comparison Between 4G and 5G Technology [8]

Specification	4G	5G
Full form	Fourth generation	Fifth generation
Data bandwidth	2Mbps to 1Gbps	1Gbps and higher as per need
Frequency Band	2 to 8 GHz	3 to 300 GHz
Standards	All access convergence including OFDMA, MC-CDMA, network-LMPS	CDMA and BDMA
Technologies	Unified IP, seamless integration of broadband LAN/WAN/PAN and WLAN	Unified IP, seamless integration of broadband LAN/WAN/PAN/WLAN and new advance technologies based on OFDM modulation used in 5G
Service	Dynamic information access wearable devices, HD streaming, global roaming.	Dynamic information access wearable devices, HD streaming, and any demand of the user.
Multiple Access	CDMA	CDMA, BDMA
Core network	All IP network	Flatter IP network, 5G network interfacing (5G-NI)
Handoff	Horizontal and vertical	Horizontal and vertical
Initiation from	Year 2010	Year 2015

This paper has concluded the usage of these technologies in context of 5G networks. This paper has analyzed the existing technique used for current 4G systems and previews different techniques proposed for future 5G networks [8].

K. Nagarajan et al. IEEE proposed a technique that employed discrete wavelet transform to analyze the channel estimation and partial time sequence to reduce the PAPR in 16QAM OFDM system. Because of multipath propagation & noise the performance of OFDM system is affected by channel leakage. OFDM channel is analyzed to estimate the channel leakage, MSE – Mean Square Error and SNR – Signal to Noise Ratio using DWT - Discrete Wavelet Transforms Techniques. The output obtained in the system concluded that the peak to average power ratio is minimized by increasing the sub divided blocks that was increased in partial transmit scheme. It has been analyzed in the system that, OFDM utilized high power amplifier to obtain sufficient power for the transmission. But utilization of QAM enhances the consumption of power, as QAM uses amplitude component of signal to represent binary data, linearity needs to be maintained and hence linear amplifier is needed which consumes more power [9].

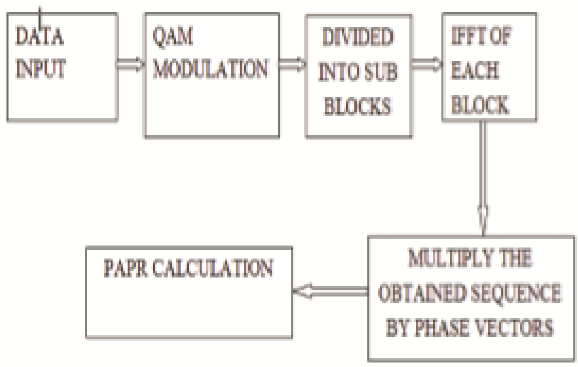

Fig.7. PTS (Partial Transmit Sequence) System [9]

Iram Maisarah Mokhtar et al. Indonesian Journal-EECS proposed Generalized Inverse Discrete Fourier Transform Non- Orthogonal Frequency Division Multiplexing (GIDFT n-OFDM) system in order to accomplish the need of 5G network system for higher data rate. Three types of usual PAPR reduction techniques were applied in GIDFT n-OFDM system which are Clipping, Partial transmit Transform (PTS) and Selective Mapping (SLM). The system performance is compared and evaluated using Complementary Cumulative Distribution Function (CCDF) plot. SLM has given the best PAPR value of compared to other PAPR reduction techniques that have been performed in this paper. Simulation results show that SLM technique give significant reduction of PAPR 9 dB of the original performance. It is also concluded that the overlapping frequency increase, the PAPR reduction also decreased in great values. In addition, even though the overlapping percentage is increase, only PTS and SLM still manage to reduce the PAPR despite of large input data. But reduction in PAPR doesn't prove the consistency of BER. [10]

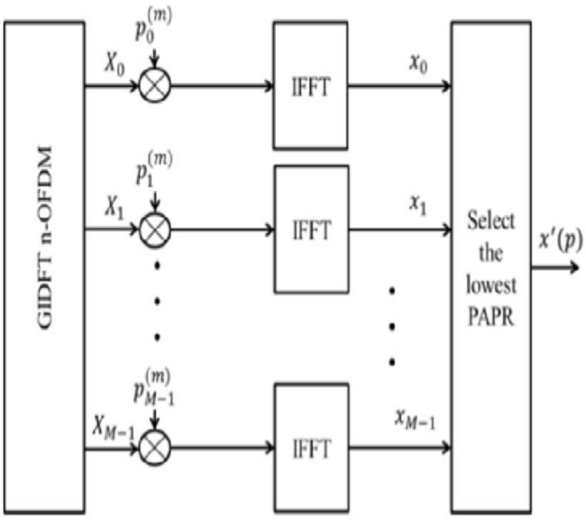

Fig.8. Block diagram of GIDFT n-OFDM for SLM technique [10]

Martha C. Paredes et al., IEEE, offered an analysis of the OFDM modulation technique for signal transmission by considering various models of High-Power Amplifiers (HPA) in different scenarios with high PAPR (Peak to average Power). The overall analysis of the system is simulated in terms of BER (Bit error rate) and PSD (Power spectral density). Number of subcarriers utilized in the system is 64 bits with the implementation of QPSK modulation technique for subcarriers. The analysis concluded that RAPP Model of HPA outpaces among the others. But the inclusion of high PAPR develops a serious degradation in the transmission especially when it passes through a non-linear HPA. Although to improve the efficiency of HPA and to lessen the non-linear distortion, various techniques were introduced but they are not competent enough, if OFDM is implementing in 5G Technology. [11]

III. PROBLEM IDENTIFICATION

It has been observed in the prior developed systems that to enhance the data rate efficiency of wireless network technology, the most served and effective available technique so far for communication purpose is Orthogonal frequency division multiplexing (OFDM), which employs a square window in time domain thereby allowing a very efficient implementation and thus has been adopted in several broadband wired and wireless communication systems. There are various modifications proposed by various researchers in order to reduce the PAPR value of the system. There are various researches took place in order to enhance the data rates and efficiency in the 5G network system. OFDM is efficient enough to provide expected speed and efficiency but in 4G technology. A method is still required which can provide enhanced data rate with reduced PAPR and power consumption. The major flaws encountered in OFDM is due to the utilization of cyclic prefix which in turn diminishes the throughput of the channel. Localization of subcarriers in the channel is weak due to which out of band emission occurs which develops spectral leakage and interference during transmission. In the base paper, Martha C. Paredes et al. [11] used various HPA technique in order to obtain the improved results of BER and PSD. The system which has been proposed, analyzes the performance of OFDM technique under various HPA models by taking the operating point of Input Back-Off (IBO) at 2 dB and 12 dB. It has been stated in the paper that, at IBO= 2dB, maximum distortion was 4.9 dB by Saleh model HPA and minimum was 1.1 dB by Ghorbani Model whereas by taking IBO= 12 dB, RAPP model outperforms among the others. In the base paper, high power amplifier (HPA) has employed at the output of transmitter to obtain sufficient transmits power for large area coverage. To enhance the power efficiency, HPA requires to operate around the region of saturation. Signals that consists of high peak power passes through the high-power amplifier, peaks of the signal get clipped in a non-linear manner and this induces the inter modulation distortion at the receiver. This distortion enhances the bit error rate in the signal. Although, the interference can be lessened, if the operation of high-power amplifier can be done in linear region. But the available linear amplifier has poor efficiency and cost is too high. Another issue occurs in HPA is the coverage of operational area which will also reduce. It has been observed in the paper, for power spectral density (PSD), the operating frequency ranges from 0 to 18 MHz with a span of 2 MHz, and the obtained at IBO of 2db and 12 db.

IV. PROPOSED WORK & METHODOLOGY

A system is proposed which exploited the FBMC (Filter bank multi-carrier) technique. By using FBMC, the subcarriers are subjected to side-lobe suppression by passing them through a filter bank, which makes them capable of delivering higher spectral efficiency than OFDM. FBMC is robust to intrinsic a-synchronicity between a transmitter and a receiver. Instead of standard utilization of QAM in almost every technique, this paper employed the technique of APSK for the modulation of sub carriers. Since, APSK considerably outperforms QAM in terms of mutual information. Mutual information provides the maximum transmission rate (in bits per channel use) at which error-free transmission is possible with a given signal set. Therefore, maximization of the channel mutual information is a very effective criterion to optimize the APSK constellation for any signal-to-noise ratio (SNR) operating point.

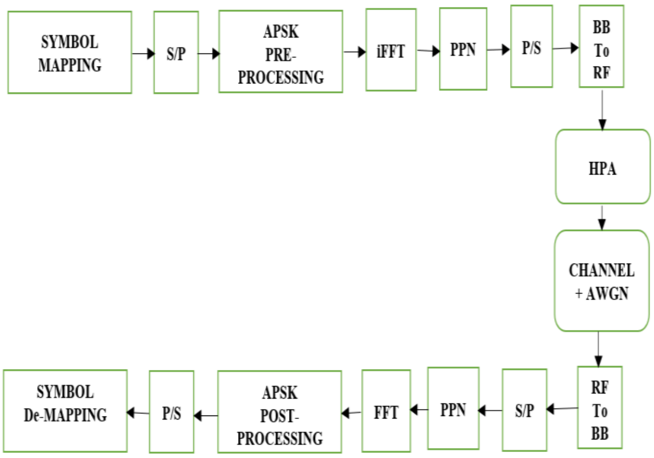

Fig. 8 Block Diagram of Filter Bank Multi Carrier (FBMC) Using APSK

In the proposed system, APSK has been employed in FBMC in the pre and post processing stage. Initially, group of signals $x_n(t)$ passes through filters with an impulse response of h(n), the output of mapped signal is stated as

$$S(t)= \sum_{n=1}^{N} h_n(t) * x_n(t) \qquad (1)$$

where S(t) stands for composite signal; ∗ means linear convolution. It has been known that a synthesis filter bank (SFB) contains an array of filters $h_n(t)$, n = 1, ..., N. The conversion of signal from serial to parallel can be accomplished by recovering the data samples as

$$d_i(mM)=\frac{1}{M}\sum_{i=0}^{M-1} x(n-M+i)\, e^{-j2\pi k i/M} \qquad (2)$$

Where M is number of data samples, m is considered as a symbol index. Here, the supposed sampling frequency is unity. As the number of carriers are M, its carrier frequency spacing is 1/M and T will be the period of transmission. Since, T=M (carrier frequency spacing is inverse of carrier time spacing). Since, x(n) is considered as a sine wave in time duration T. Likewise $d_i(mM)$ is transmitted by i periods in the period T. So, the complete signal is a bunch of sine waves which fulfills the condition of orthogonality. In order to implement the 64-bit APSK processing, MATLAB functions of "*apskmod*" and "*apskdemod*" is implemented by considering N as a number of constellation points. In the system, the utilized vector of modulation is defined as

$$N = [8\ 12\ 20\ 24] \qquad (3)$$

It generates 4 Phase shift keying circles with least amplitude circles which will lessen the encountered noise in the channel. The further modulation will be processed by declaring the variables and functions and

$$\text{bitsPerSym} = \log_2(\text{sum}(N)) \qquad (4)$$

$$\text{radii} = [0.8\ 1.2\ 2\ 2.5] \qquad (5)$$

$$z = \text{randi}\ ([0\ 1], 1000 * \text{bitsPerSym}, 1) \qquad (6)$$

In Eq. (5), radii are used to define the radius between the constellations. Now the implementation of APSK modulation on the extracted parallel data stream:

$$y(n) = \text{apskmod}(z, N, d_i(mM), \text{'bit'}, S(t)); \qquad (7)$$

The obtained data in Eq. (6) is further processed to the iFFT (inverse Fast Fourier transform) which is used to reduce the mathematical complications in the data processing.

$$x(n) = \sum_{i=0}^{M-1} y(n) e^{j2\pi \frac{i(n-mM)}{M}} \qquad (8)$$

In order to obtained the orthogonality of the system, the frequency spacing of the subcarriers should be integer multiple of the time spacing, $\nabla f = \frac{c}{T}$, c= 1, 2,…n-1. Now the individual filter used for each transmitted signal are based on specially design prototype filter $p_T(t)$ shown in Eq. (9)

$$h_n(t) = P_T(t) e^{2\pi j n \Delta f t + j\emptyset_n} \qquad (9)$$

$\emptyset_n$ is used for the phase, the final baseband signal is obtained by

$$S(t) = \sum_{m=-\infty}^{\infty}\sum_{n=1}^{N} y_n p_T(t-mT) e^{2\pi j n\Delta f t + j\emptyset} \qquad (10)$$

The time-based prototype filter is achieved by sampling of the continuous signal of time used in Eq. (8) i.e.

$$p_T[l] = p_T l T_S,\ l=0,1,\ \ldots.\ L-1 \qquad (11)$$

Where L is the length of prototype filter. Suppose the overlapping factor is K, which means the length of the prototype filter is K times of the symbol period i.e.

$$L = KN \qquad (12)$$

When the value of overlapping factor, k=4, the predefined values of frequency response is given as

$$p = [1, 0.97196, 0.707, 0.235147] \qquad (13)$$

$$P(f) = \sum_{k=-k+1}^{k-1} p_k \frac{\sin(\pi NK(f-\frac{k}{NK}))}{NK\sin(\pi(f-\frac{k}{NK}))} \qquad (14)$$

where N is the total number of subcarriers, K is the overlapping factor and p_k is mapped from the aforementioned coefficients, where p0 = 1, p±1 = 0.97196, p±2 = 0.707 and p±3 = 0.235147. Then, its impulse response pT (t) can be obtained by an inverse Fourier transform, as follows:

$$p_T(t) = 1 + \sum_{k=1}^{k-1} p_k \cos 2\pi \frac{kt}{KT} \qquad (15)$$

The above algorithm is used to implement the preprocessing unit of FBMC by utilizing the APSK modulation technique for the subcarriers. Similarly, the postprocessing has been inversely executed to obtain the transmitted signal.

V. STIMULATION RESULTS

The stimulation of FBMC technique with the implementation of APSK modulation method has been analyzed in terms of power spectral density, BER and prototype filter responses.

Basic implementation of OFDM technique has also been included to obtain the real time comparison. Figure 9, shows the power spectral density of the implemented FBMC technique and the standard OFDM model.

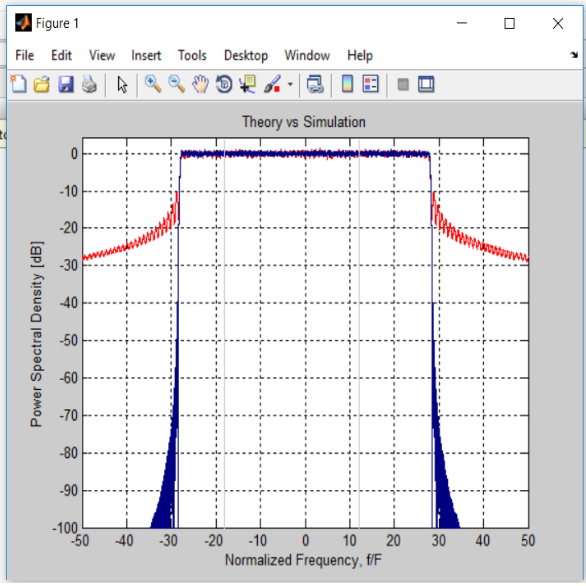

Fig. 9 Power Spectral Density of FBMC and OFDM

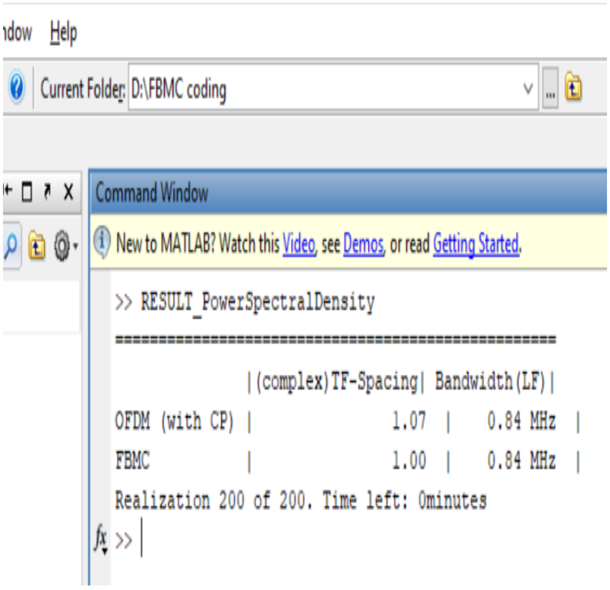

Fig. 10 Spacing and Bandwidth of FBMC & OFDM for PSD

In the above fig.10, the time and frequency spacing and bandwidth has been realized for FBMC and OFDM to obtain the power spectral density of FBMC and OFDM. Fig. 11 shows the Bit Error Rate realization of FBMC and OFDM. It is the implementation of FBMC using APSK. For FBMC, number of symbols considered is 2048 bits while for OFDM, it is considered as 1024 bits. Overlapping factor is 4 for both the simulation. The value of SNR (Signal to Noise Ratio) is taken from 0 to 20 db. It has been observed that the value of BER is 0.06 for FBMC and 0.15 for OFDM if the value of SNR is 0. When SNR = 5 dB, the value of BER is almost reduced to 0 for FBMC. It has been concluded in the figure that the BER of FBMC is reduced up to a high extent when compares to OFDM.

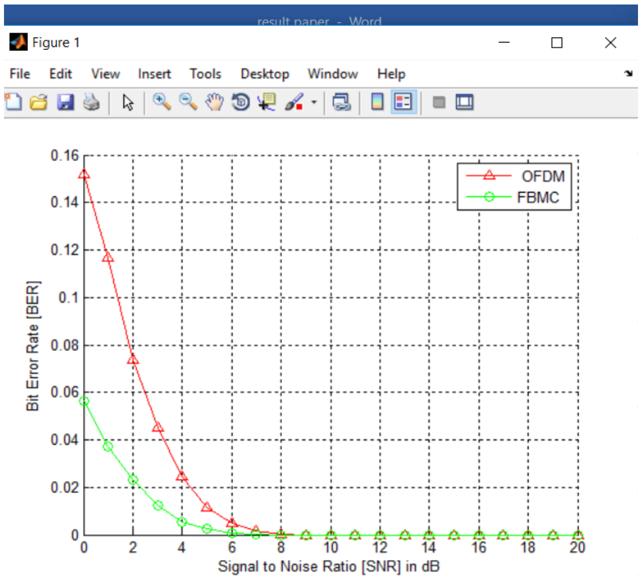

Fig. 11 BER response of FBMC and OFDM

Table 1. Result Comparison

CONCLUDED RESULT		
Technique Used	**FBMC**	**OFDM**
Modulation Scheme	64 APSK	16 QAM
No. of Symbols	2048	1024
Overlapping Factor	4	4
Filter	PHYDAS	Not used
Taken SNR Value	0 to 20 DB	0 to 20 DB
BER value at 0 DB	0.06	0.15

VI. CONCLUSION & FUTURE SCOPE

Proposed technique implemented FBMC that uses 64 Bit of APSK for subcarrier modulation.

As per the previous work which has been studied during survey in order to improvise the efficiency of OFDM, it can be concluded that OFDM technique has various flaws summarized in the Section of Literature Survey, due to which rate of transmission has been affected. In proposed system, Bit Error Rate has been analyzed for both the techniques of FBMC and OFDM. The value of Signal to Noise Ratio is considered from 0 to 20 Db. It has been observed from the outcome, FBMC performs better than OFDM in terms of Power Spectral Density and Bit Error Rate. As per the concluded Result taken from the Simulation of implemented technique, BER of FBMC is 0.06 whereas for OFDM, it is 0.15 at SNR = 0 db. It has also been observed in the result that Error Rate has reduced to zero at SNR= 5 Db for FBMC. Since reduction of in-band and out-of-band emissions will in turn reduces the interference among users within allocated band and also reduces the interference among neighbor operators.

Further study in future can concern about the implementation of some prevention technique in the system to reduce the EM wave radiation due to the enhancement of antennas and radio circuits as mm waves will be used for the 5G technology.

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