# Implementation Of 5G using OFDM and FBMC (Filter Bank Multicarrier) /OQAM (Offset Quadrature Amplitude Modulation)

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**Abstract**

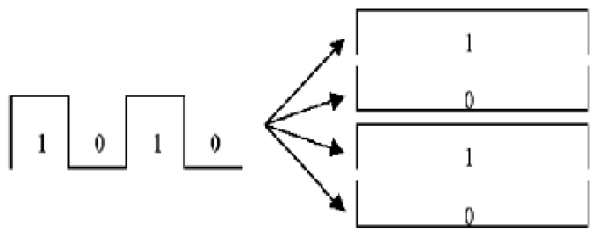
Now a day's demand of broadband speed has increased due to digital multimedia applications. The needs for technicality for implementation are very difficult but also we have to make it very easy & robust to implement it for efficient results. Orthogonal Frequency Division Multiplexing (OFDM) is an important multicarrier technique that makes it possible to transmit high speed data over the distant channel with less complexity and faster data rate as compared to traditional single carrier techniques. This paper proposes OFDM & FBMC/OQAM model prototyping for hardware implementation using MATLAB software and observe the result performances from GUI in MATLAB. Also we observe reduction of intersymbol interference (ISI) in OFDM plot & ICI (intercarrier interference) reduction in FBMC/OQAM with 20dB noise improvement suppressing closely placed subcarriers that lead to noise in OFDM. Hence increment in efficiency and reduced peak to average ratio(PAPR). Every sub-carrier is modulated with a particular modulation technique like O-QAM (orthogonal quadrature amplitude modulation) or phase shift keying at a low symbol rate, persisting total data rates same as to conventional single-carrier modulation technique in the same bandwidth. OFDM is specially suitable for high-speed data rate due to its avoidance of intersymbol interference (ISI). FBMC can be considered as an evolved CP-OFDM. Instead of filtering whole band as in the case of OFDM, fbmc filters each subcarrier individually ***Keywords:*** *AWGN, ISI, DFT OFDM, FBMC, PAPR,QAM.*

## 1. Introduction

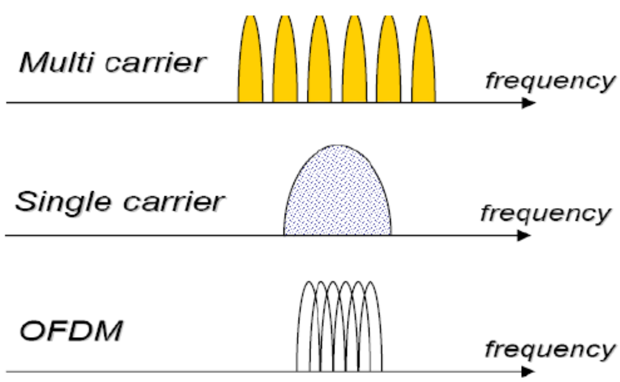
Orthogonal frequency division multiplexing (OFDM) has became one of the most modulation technique for wireless communication. Orthogonal Frequency Division Multiplexing (OFDM) can be defined as an alternative wireless modulation technique to CDMA. Orthogonal frequency division multiplexing has capacity to surpass the capacity of CDMA system & represent the wireless transmission method for 4G technology. OFDM is used worldwide for various applications while there is a problem identified in higher data transmission rate communication is intersymbol interference (ISI). ISI appears when there is interference at transmission side and the receiver cannot decode the transmission precisely. For example, in a wireless communication system, the same transmission is sent in all directions. In multipath distant transmission the transmitted information signal is reflected from middle objects for example hills, mountains or residential area, the receiver recieves many replicas of signal. In communication system, this phenomenon is called multipath. Because the reflected multipaths consume much time to reach the receiver, the delayed replicas of the original signal intersect with the linear signal, resulting into an ISI ( Intersymbol Interference).

### 1.1 Need for multicarrier system

OFDM is applicable for high data transfer rates due to its capability to counteract resistance ISI. OFDM avoids the multipath effects dividing the direct signal into numbers of many carriers having narrow bandwidth. This leads to reduced symbol rate decreasing the amount of ISI. Also, a guard period is inserted to the initial of every symbol, avoiding the consequences of ISI for multipath signals taking time less than the guard period. A. It also decreases the time required for each transmission as a result of which data transfer rate of entire communication system increases. In high data speed transmission delay time is constant for each multipath so intersymbol interference can be a limitation OFDM avoids ISI transmitting many low speed transmissions at a time. For example, the figure shows two ways to transmit the binary data..




Consider that transmission consumes four seconds time duration. Then, bit of data in the left side of the figure will have the duration of one second. Besides OFDM will transmit the four bits parallelly like the right side of the figure shows. In this scenario, every binary bit of data requires a time of four seconds. This duration improvement helps to minimize the ISI. In addition to this traditional single carrier has more complexity compared to the OFDM which shows low complexity for the implementation of high speed system. The filters used for subcarriers require longer time constants for filtration and are narrow. Specially time constants have length is four times of symbol length of basic multicarrier signal & at the end result single symbols overlap in time. To get orthogonality O-QAM (Orthogonal quadrature amplitude modulation ) is used as the modulation technique, so FBMC is not orthogonal with respect to complex plane.




## 2. Orthogonality

If the signals are not dependent on each other mutually they are called orthogonal signals. Whenever dot product of two signals is equal to zero they are called as orthogonal signals. Let's assume m & n are integers. When you take a sine wave of frequency m and multiply it by & sinusoid of a frequency n, and multiply them. The integral of the product is given by:

$f(t) = \sin m wt \times \sin n wt,$

Using trigonometric formulae ,we can rewrite the equation as,

$f(t) = 0.5(n-m) + 0.5(n+m)$

As two signal components are sinusoidal in nature , so by the time of one period integral would be zero. Orthogonality is a property by which multiple information signals can be transmitted over a common channel accurately & received, without interference is called as orthogonality. Qualtity of communication system is degraded when there is no orthogonality between subcarriers which also causes blurring of signals. In an OFDM signal, subcarriers are spaced very much closed to each other to maintain orthogonality among subcarriers. Orthogonality is achieved in in the frequency domain with the help of OFDM by the process in which different subcarriers are allocated with various information signals. OFDM signals are composed of addition of sinusoids, regarding with related subcarrier. Every subcarrier is selected with baseband frequency as an integer multiple of the symbol duration inverse, as a result all subcarriers constitute an integer number of cycles each symbol. At the end we get the orthogonality in which subcarriers are orthogonal to each other. Transmission is orthogonal so the peak of a subcarrier is regarded to each of nulls of all other subcarriers. Discrete Fourier Transform (DFT) detects each signal to determine that signal is not continuous but discrete sampling. transceiver section of OFDM transceiver part shows the dicrete sampling of the signal . There is no need of introducing guard bands. Raised efficiency of spectrum is offered by the orthogonality. Transciever design becomes simple due to this and also cross talk is eliminated

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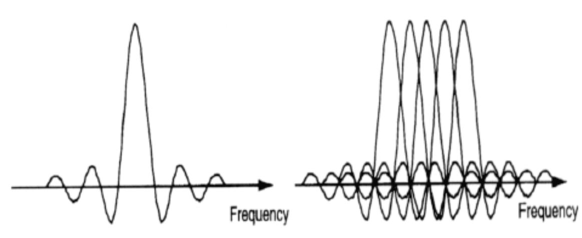

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## 3. Peak to average power ratio

High peak to average power ratio (PAPR) is the main limitation of OFDM. Saturation in power amplifiers is caused by the higher PAPR(peak to average power ratio), It results into modulation products between the sub carriers and band energy gets fluctuated. Hence, it is PAPR should be reduced to increase efficiency. Definition of PAPR is given as,

$$PAPR = \frac{\text{Peak Amplitude of the Signal}}{\text{Average value of the Signal}}$$

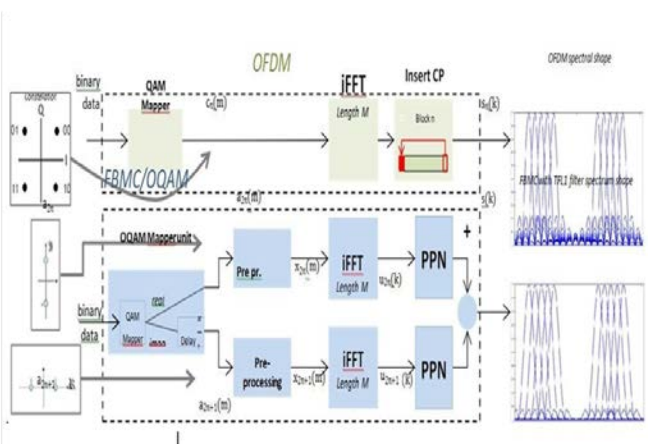
An OFDM signal comprises of many sub carriers which are independent in nature, and their coherent addition is done,we get the large peak-to-average power ratio (PAPR). N times the average power that is peak power is generated when N signals with same phases are added. Hence over wide dynamic range, requires a linear behavior of the system and the amplifier output has the reduced efficiency. Transmitter amplifier saturation is avoided by keeping the average power low.

$$\mathbf{PAPR} = \frac{\text{Peak Amplitude of the Signal}}{\text{Average value of the Signal}}$$

**PAPR = ((xk)^2)max / E{(xk)^2**     1<=k<=N

Where E{(xk)^2 stands for the expected value or average value of the time domain signal.

## 4. Proposed Method



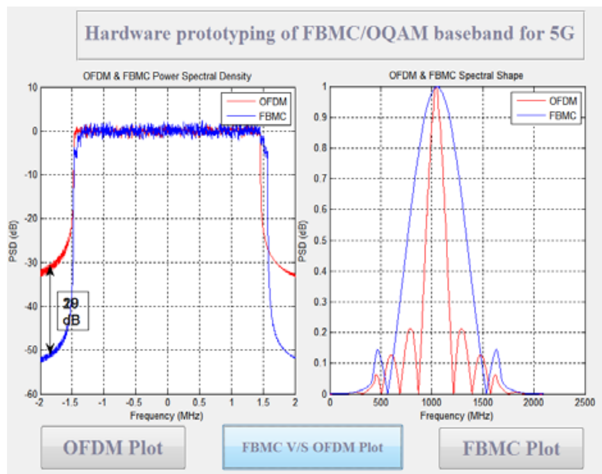

OFDM modulator architecture: QAM mapper is the first section of proposed OFDM architecture which is implemented through simple constellation table that is Look-Up Table (LUT) helps us to implement the OFDM architecture. To support up to 16-QAM, as per the LTE standard, 16 QAM requires the LUT having 16 locations. The second section of OFDM modulator architecture is the IFFT (Inverse Fast Fourier Transform) that is said to be main element of this OFDM architecture. The exploration of an architecture and optimization of an algorithm helps us to select the best solution. This OFDM & FBMC solution with pipelined architecture & less complex gets us the best solution with reduced memory usage. This architecture gives the solution that an M-point IFFT can be divided into 4 IFFTs having M length M 4 , and this is given by the formula log4(M) i.e. stages in IFFT (where M can be said as power of 4), It is called as radix-4 butterfly. Pipelined architecture allows to calculate all butterflies together instead of calculating it stage by stage. Radix-4butterfly having log4(M) stages is attached with feedback buffer in order to do calculation. At each stage only 1 sample is processed every clock cycle, after that its inserted into the buffer or sent to the next stage. The R22SDF also optimizes the radix-4 by decomposing it into two pipelined radix-2 butterflies (hence the name R22), each having two adders and one buffer. With such a decomposition, the hardware complexity of this architecture counts for log4(M) 1 multipliers, 4log4(M) adders, and memory proportional to M 1. The devised architecture for the IFFT uses the Decimation In Frequency (DIF) decomposition which results in output samples in bit reversal order. Thus, to avoid additional memory usage and latency overhead, both the insertion of the cyclic prefix and the reordering operation are done jointly. IFFT output samples are alternatively read and written in a memory unit of depth M, in bit reversed and normal order, with the LCP last samples read first to generate the the cyclic prefix between subsequent blocks. The resulted OFDM modulator architecture is fully pipelined enabling continuous stream processing of one complex sample in baseband discrete time domain per clock cycle.

**FBMC modulator architecture:** FBMC/OQAM differ with OFDM by 3 components firstly it consists of QAM mapper with real and imaginary component I (a2n(m))and the Q (a2n+1(m)) with an offset of M/2 samples that are in time domain as shown in Fig. OQAM has an advantage over the OFDM that it efficiently reduces the ICI that is inter carrier interference and also ISI that is Inter Symbol Interference (ISI) after a filter having suitable design is applied. Secondly, PolyPhase Network (PPN)is used for filtering operation after iFFT. The main advantage of this polyphase network (PPN) is frequency & time localization for better noise improvment, in which the length & shape of the used prototype filter plays an important role. Betterment in time localization reduces ISI (intersymbol interference) while betterment in frequency localization reduces ICI (intercarrier interference). Time and frequency localization uses IOTA (Isotropic Orthogonal Transform Algorithm) a prototype based filter function. Raised Cosine Filter is another possible prototype filter where its shape and its time-frequency localization can be adjusted through a roll-off factor, but theoretically requires an infinite filter length. Note that OFDM is a special case of FBMC: the rectangular waveform defined in expression is a prototype filter of length M. In our study, we use TFL1 prototype filter because of its compromise between time and frequency localization. Furthermore, it is filter of length M, which greatly reduces the computational complexity at the transmitter and the receiver side (simpler equalization). Two IFFT and PPN units are required for the FBMC/OQAM modulator. Afterwards, the two corresponding outputs are added together to provide the signal to be transmitted through the channel. Third, thanks to the filter time and frequency localization and the application of the OQAM modulation, pulse-shape orthogonality can be achieved without the need for a cyclic prefix.(mathematical term. )The spectrum shapes of the two considered modulation schemes are presented in Fig. 1, where the TFL1 prototype filter was used for FBMC/OQAM. The cardinal sine of OFDM sub-carriers has secondary lobes with higher amplitude than FBMC/OQAM with the TFL1 filter. Since each sub-carrier contributes to the global spectrum shape, OFDM has a higher out-of band leakage. ICI is caused in the case of OFDM because absence of synchronization causes intercarrier interference of secondary lobe of adjacent subcarriers. The first unit in the proposed FBMC/OQAM architecture has 1st section Offset QAM (O-QAM) mapper. LUT that is look up table is used in this architecture. Offset is introduced due to insertion of FIFO of size M/2 in imaginary (Q) output part of component. Xn(m) samples are calculated by pre-processing units from the samples of An(m). The proposed architecture shows that output of preprocessing unit X2n(m) the sub-sequence. jm is the exponential term is computed prior to the phase term which is compared with real valued input and it reduces the number of multipliers. Sine and cosine coefficients are stored in look up table & related addresses are generated with the help of counter. Additional Multiplier is not required for (1)n+mqjm which is simplified form, because it can simply be got by interchanging the real part I and imaginary section Q by the use of multiplexers, besides 2's complement is used for sign inversion. IFFT unit has the same function as in the case of the OFDM modulator architecture. 2 M points of IFFT section are applicable for the processing the 2 real offset streams values mapped symbols of the OQAM. Clipping ratio, can defined as

Clipping ratio= S/σ

Where S can be said as the room mean square power of the OFDM signal and it can be shown that, for an OFDM signal having N subchannels, $S = N$ for a baseband signal and $S = N/2$ for a bandpass signal.

## 4. Results




When program is runned on the MATLAB software it shows improvement of 20 dB in FBMC (filterbank multicarrier or offset quadrature amplitude modulation in terms of PSD i.e. power spectral density with respect to OFDM i.e. orthogonal frequency division multiplexing . There is suppression in the side lobes of spectrum of FBMC as compared to OFDM as shown in graphics user interface (GUI ). Hence there is increase in signal to noise ratio. That means decrese in noise can improve the data transmission rate . As a result fidelity in impelementing hardware prototype of 5G technology in communication system also increases.

## 5. Conclusion

5G communication system efficiency can be defined from the factors like capacity, efficiency of spectrum, flexibility energy consumption and reduction of cost. Secondly very high band width is required for this network so as to complete requirement of high efficiency. MIMO technology is used in 5G. It is required for the great user experience in CDMA multiplexing system. FBMC/OQAM modulation based architecture for advanced communication system is presented in this paper . The prototyped new wave- form is considered as a key feature of the future flexible 5G air interface. This paper illustrates

(1) Algorithm Simplification and Optimization,
(2) Architecture Exploration,
(3) Prototyping and Demonstration.

This proposed architecture serves as a key for instant architecture exploration and performance analysis and comparison OFDM-based systems with FBMC/OQAM. Both OFDM and FBMC/OQAM based modulators are illustrated in this paper, with the help of different algorithm/architecture and system parameters execution and purpose. Fully pipelined architecture of FBMC/OQAM pipelined architecture reduces complexity at both sides i.e. transmitter and receiver. At the resulting output we get improvement in latency and signal to noise ratio

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