

FBMC Modulation Schemes for 5G Mobile Communications

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Abstract— MCM (multicarrier Modulation) works on the concept of splitting a data stream into many bitstreams, each with a significantly low bit rate and modulating the several carriers with sub-streams. Multicarrier modulation schemes such as FBMC and OFDM are used. Spectral efficiency of the FBMC system is higher than the OFDM system. The simulation's results are used to examine the framework, argumentation, and evaluation of FBMC and its relation to OFDM. Furthermore, we obtain a higher throughput that is similar to the achievable rate, and the results of this study show that Filter bank multicarrier provides a satisfactory performance improvement.

Keywords- Multipath carrier, FBMC-OQAM, OFDM, Channel estimation.

1. Introduction

OFDM is the prevalent wireless communication strategy today, and it is expected to continue to be applicable in the future. The key flaw in OFDM system is that it involves the use of a CP. The main drawback of the OFDM method is that the subcarriers are not spectral localized, resulting in spectral leakage and interfering with the unsynchronized signal. FBMC seems to be a good strategy for overcoming OFDM shortcomings and meeting 5G specifications.

OFDM has increased demand and phased many problems in diverse networks as a result of the widespread use of MCM technique in many wireless standards. A further disadvantage of OFDM is its unsustainable out-of-band leakage, which prevents OFDM from coexisting with other communication networks.

Multicarrier is proposed for channel sensing and coexistence of primary and secondary users, and good separation or filtering for different subcarriers such as FBMC is needed to avoid interfering among them.

The aim of FBMC is to address the disadvantages of OFDM by improving spectral properties and channel utilization, as well as a higher data rates are possible within such a specified wireless communications bandwidth.

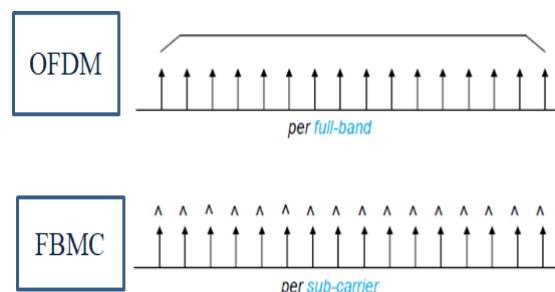


Fig.1. In OFDM all subcarriers have a single band whereas in FBMC each subcarrier has its own single band.

2. OFDM system

OFDM System:

OFDM is a digital signal modulation technique for reducing distortion and crosstalk by splitting a single data stream into many narrowband channels at different frequencies.

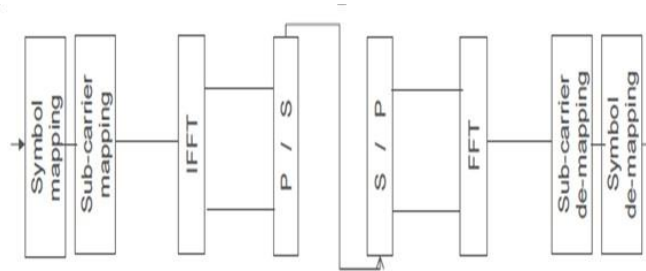


Fig. 2. OFDM Block Diagram

Subcarrier orthogonality provides robustness towards multipath effects and allows for a quick and easy implementation using FFT blocks, and the ability to use adaptive modulation and bit-loading strategies, and so on have all contributed to the popularity of OFDM and its variants. Traditional OFDM, on the other hand, has a range of flaws As a result, it's a low-cost solution for accommodating the complex and demands of 5G wireless networks.

OFDM uses a repetitive timeframe called cyclic prefix (CP) among two symbols to solve time distortion and facilitate per sub-carrier equalization.

The presence of a cyclic prefix causes inefficient use of available transmission time, causing the optimal latency condition to be violated, leading to poor spectral fidelity and reduced throughput. In OFDM, the transmitted and receiving filters are time-limited rectangular pulses with very high frequency side-lobes, causing spectral leakage to neighboring sub-carriers. Inter-carrier interference (ICI) is caused by these out-of-band emissions.

In time varying cell networks, its orthogonality among many of the sub-carriers is distorted, which results in ICI. Inter symbol interference (ISI) and inter modulation interference (ICI) affects OFDM, a required stringent synchronization procedures and increasing power usage. The OFDM scheme has a high PAPR, some spectral efficiency loss due to Cyclic Prefix incorporation, and imperfect synchronization induces orthogonality loss. The current development work would concentrate on the application of FBMC to address these shortcomings.

3. Fbmc system

4.

FBMC System

The majority of today's wireless mobile networking technology is built on an extension of the OFDM scheme called OFDM with FBMC. Multicarrier processes, such as OFDM and FBMC, are multicarrier approaches in which data symbols are sent over several frequency subcarriers at the same time. According to the multicarrier nature of both signals, they have built-in support for frequency selective reference adoption, and the main difference across OFDM and FBMC is the pulse shaping introduced on every subcarrier. The most significant improvement in the FBMC system is the replacement of the CP in OFDM with a multicarrier system that used a filter bank.

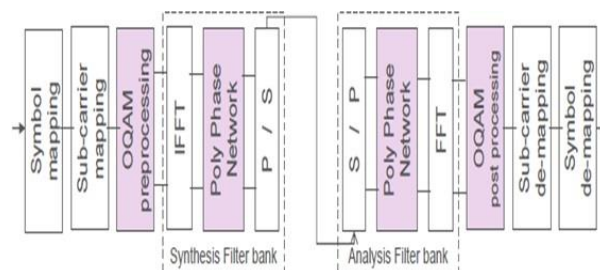


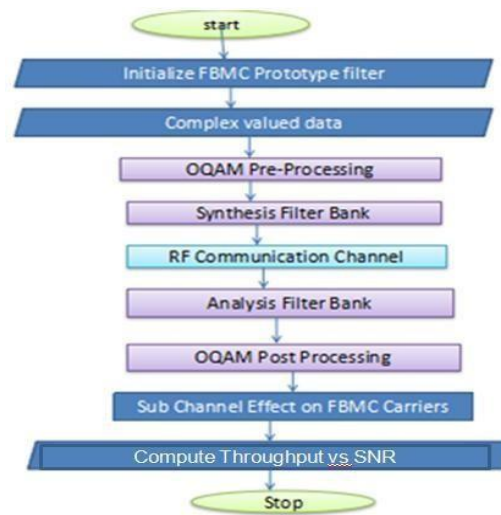
Fig.3. Reconstruct the modulators for FBMC by using different prototype filters and OQAM processing.

Symbol Mapping: This block's main function is to translate binary data into symbols and then map such symbols as frames to subcarrier mapping as input.

Subcarrier Mapping: It's important for making FBMC frames. Every frame of framed data has a preamble configuration that is used for fast carrier frequency tuning and timing synchronization, and the frequency of each subcarrier is chosen from an orthogonal signal range, and those frequencies are known at the receiver to recover the signal.

IFFT: It transforms a region or signal to the frequency domain and is also known as the backward Fourier transform.

FFT: It represents the frequency domain by converting a signal from its original domain.



The prototype filter has been the first filter throughout the filter bank attached to the zero frequency carriers can deliver excellent functionality, and it uses the Offset Construction Quadrature Amplitude Modulation (OQAM) technique.

OQAM Pre-Processing: It has two operations

1. Complex –to-real conversion
2. Multiplication by sequence

OQAM Post-Processing: It also has the two operations

1. Multiplication by sequence
2. Real-to-complex conversion

FBMC Methodology

The prototype filter for the zero frequency carrier is the FBMC solution, and it serves as the foundation for the other subcarrier filters. Filter banks will split a signal into sub-bands of different frequencies, allowing the spectrum to be partitioned equally. Filters are defined using a number of multicarrier symbols which really coincide with in time domain is known as the overlapping factor K. The order of the prototype filters can be modified as the length of the filter is $P = M \cdot K - 1$ where $K = 2, 3$, or 4.

M = symbol size, K = values of $P_0 P_1 P_2 \dots$, P = length of prototype filter and the transmitted signal $s(t)$ of Throughout the time domain, a multicarrier device is specified as :

$$S(t) = \sum_{k=0}^{K-1} \sum_{l=0}^{M-1} g_{l,k}(t) X_{l,k}$$

Where $s(t)$ is a transmitted signal of a multicarrier system $x_{l,k}$ denotes the transmitted symbol at subcarrier position l , and time position k . The transmitted basis pulse, $g_{l,k}(t)$ in $s(t)$ is defined as:

$$g_{l,k}(t) = p(t - kT) e^{j2\pi l F(t - kT)} e^{j\theta_{l,k}}$$

Thus $p(t)$ is a time and frequency shifting variant of prototype filter, including T denoting time sampling and F symbolizing frequency spacing, whereas $g_{l,k}(t)$ is pulse basis (basis pulse and orthogonal) (subcarrier spacing), $\theta_{l,k}$ is phase shift which becomes relevant in FBMC-OQAM. The FBMC provides good side lobe attenuation while using this prototype filter, but enhances spectral performance and perhaps a superior prototype filter is constructed only with overlapping factor K , and indeed the FBMC gives excellent side lobe attenuation while using this prototype filter, therefore boosts spectral efficiency.

A synthesis analysis configuration is called Transmultiplexer, and a digital filter bank is a series of filters with a standard input or output (TMUX).

Synthesis filter bank: M upsamplers and M synthesis filters accommodate the synthesis filter bank shown at the converter. $M/2$ upsamples its input signals, which can then be filtered using synthesis filters.

Analysis filter bank: M analysis filters & M down samplers compensate the analytical filter bank used for the receiver. To generate the output signal, each input signal will be first filtered with only an analytical filter upon being downsampled by such a factor of M/2.

A theory with basis pulses $g_{l,k}(t)$ is based upon this received signal $r(t)$.

$$Y_{l,k} = \langle r(t), g_{l,k}(t) \rangle = \int_{-\infty}^{\infty} r(t) g_{l,k}(t) dt$$

the received signal $r(t)$, $y_{l,k}$ is noisy received signal, $g_{l,k}$ conjugative which is inverse function of basis pulse and with the filter frequency samples l,k denotes length of subcarriers and no of samples.

Hermite polynomials $H_n(\bullet)$ are used to build a prototype filter with FBMC-QAM.

$$P(t) = \frac{1}{\sqrt{T_0}} e^{-2\pi(\frac{t}{T_0})^2} \sum_{i=\{0.4, 8, 12, 16, 20\}}^{\infty} a_i H_i(2\sqrt{\pi} \frac{t}{T_0})$$

Whereas the time and frequency shifted version of prototype filter is $p(t)$ and with T denotes the orthogonal, $i=\{0,4,8..\}$ coefficients and $TF=2$ of time frequency spacing.

The complex-orthogonality status is balanced by the real-orthogonality property when R is added for FBMC-QAM, and it has the same symbol density as the OFDM without CP.

For one time-frequency location, the ergodic potential is

$$C = E_h \{ \log_2 (1 + |h|^2 SNR) \}$$

E_h denotes an ergodic indicator, which is the maximum reciprocal knowledge between the input and output of channel power C , and h denotes the channel's impulse response with signal to noise ratio SNR.

In certain circumstances, a data symbols being chosen from the fixed signal constellation which is used in the BICM capacity:

$$C_B = E_h \left\{ \max_{x \in \{A_1 A_2 \dots\}} \left(M - \sum_{i=1}^m E_{b, \frac{y}{h}} \left[\log_2 \frac{\sum_{x \in X} pdf_h \left(\frac{y}{x} \right)}{\sum_{x \in X_b^i} \left(\frac{y}{x} \right)} \right] \right) \right\}$$

Where C_B is the BICM capacity, which also includes the adaptive symbol alphabets $\{A_1 A_2 \dots\}$ and at once the subcarrier spacing (pulse shape) matches the channel statistics, a one-tap equalizer is sufficient for the FBMC receiver. Assuming that each subcarrier has a limited bandwidth subcarrier band, an equalization strategy is applied at the output of the analysis filter banks. The primary aim of FBMC is to equalize the segment prior to taking the actual portion in order to prevent unreal (imaginary) interference.

As a consequence, channel estimation should be performed in the dynamic domain, which takes into account imaginary interference and complicates the estimation process.

Based on Block-Type Pilot Arrangement Channel Estimation

If indeed the channel is stable mostly during block when the pilots are sent to each carriers and now all the data subcarriers are transmitted via the channel, there may be no frequency calculation error, but there will also be random errors to noise sources. A (Least Square) LS estimator is used to achieve perfect channel estimation. The channel estimate at pilot sub-carriers confirmed the LS estimation given by:

$$H_p(k) = \frac{Y_p(k)}{X_p(k)}$$

Where $Y_p(k)$ and $X_p(k)$ are errors output and received output at the Kth pilot sub-carriers respectively.

Cognitive radios, Digital subscriber lines, power line communications, and doubly dispersive networks, among other applications, can benefit from FBMC. The key advantage of FBMC is that it can provide spectrum performance, and the cyclic prefix, CP, necessary for OFDM is not required, freeing up more space for real data.

5. Results

Simulation Results of FBMC-OQAM and OFDM

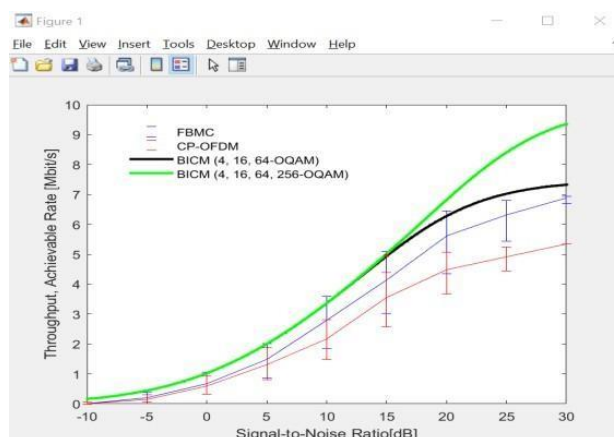


Fig.5. Simulation outcome of throughput vs SNR by the measurements of various techniques like FBMC, CP-OFDM, and BICM with QAM.

The results obtained were compared to information theory and measurements of CP-OFDM, BICM with FBMC-OQAM, and Matlab software was used to incorporate OFDM and FBMC systems. Since FBMC has a higher output than the OFDM system due to the higher available information measures and lack of CP overhead, channel calculation in FBMC uses the information spreading process, while in BICM, Using such a symbol alphabet up to 256-QAM increases the achievable rate, where 64 and 256 are QAM modulation index stages. The calculated throughput is similar to the feasible values when the SNR is large, but the throughput benefit is lower, and the power and hardware costs are far higher. As a result, SNR often operates in the middle of the spectrum.

6. Conclusion

The FBMC physical layer version is the one to use. For a group of sub-carriers, FBMC employs a single filter. Filter bank multicarrier employs a unique modulation method known as multicarrier modulation. A multicarrier modulation is a signal waveform in which several carriers are closely spaced in an extremely large block to carry data. The calculated throughput is similar to the feasible values when the SNR is high, but with a limited throughput gain and much power and hardware costs are higher. As a consequence, SNR often operates in the middle of the spectrum. Owing to more available bandwidth and no CP overhead, FBMC has a higher throughput than the OFDM system.

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