

Comparative Analysis Of FBMC and OFDM For 5G Communication

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Abstract — This paper presents a comparative study between Filter Bank Multi-Carrier (FBMC) and Orthogonal Frequency Division Multiplexing (OFDM) techniques for 5G wireless communication. Both are multicarrier modulation methods used for high-data-rate transmission. However, FBMC offers better spectral efficiency, reduced interference, and improved frequency localization compared to OFDM. This paper summarizes the working principles, system architecture, and performance comparisons based on spectral density, computational complexity, and prototype filters.

Keywords: Filter Bank Multi-Carrier (FBMC), Orthogonal Frequency Division Multiplexing (OFDM), 5G Wireless Communication, Multicarrier Modulation, Spectral Efficiency, Interference Reduction, Frequency Localization, Prototype Filters, Power Spectral Density, Computational Complexity, High Data Rate Transmission

I INTRODUCTION

The rapid growth of wireless communication technologies has led to the emergence of the fifth generation (5G) communication system, which aims to provide high data rates, low latency, improved spectral efficiency, and massive connectivity. Traditional multicarrier modulation techniques like Orthogonal Frequency Division Multiplexing (OFDM) have been widely adopted in 4G and LTE systems due to their robustness against multipath fading and efficient implementation using Fast Fourier Transform (FFT). However, OFDM suffers from limitations such as high out-of-band (OOB) emissions, sensitivity to synchronization errors, and reduced spectral efficiency due to the cyclic prefix.

Filter Bank Multi-Carrier (FBMC) is a promising alternative that addresses some of the limitations of OFDM. By using well-designed prototype filters for each subcarrier,

FBMC offers improved spectral containment, better resilience to frequency and time offsets, and higher bandwidth efficiency. Unlike OFDM, FBMC does not require a cyclic prefix, which increases the effective data rate and reduces energy consumption.

This project focuses on the comparative analysis of FBMC and OFDM for 5G wireless communication systems. The study aims to evaluate the performance of both modulation techniques under various channel conditions, including flat fading and frequency-selective fading. Key performance metrics such as Bit Error Rate (BER), spectral efficiency, and resilience to interference are considered. Understanding the advantages and limitations of these modulation schemes is crucial for optimizing 5G system design and enhancing overall network performance.

II PROBLEM STATEMENT

With the exponential increase in mobile data traffic and the proliferation of connected devices, 5G communication systems require modulation techniques that can efficiently support high data rates, low latency, and reliable connectivity. While OFDM has been the standard for 4G and LTE networks due to its simplicity and robustness against multipath fading, it faces significant challenges in 5G applications. Its major limitations include high out-of-band (OOB) emissions, sensitivity to frequency and timing offsets, and reduced spectral efficiency due to the cyclic prefix.

FBMC has emerged as a potential alternative that promises better spectral efficiency, reduced interference, and elimination of the cyclic prefix. However, its implementation is more complex, and its performance under various channel conditions is not as extensively studied as OFDM.

The problem addressed in this study is to determine the relative performance of FBMC and OFDM in 5G wireless

communication systems, particularly in terms of Bit Error Rate (BER), spectral efficiency, and resilience to multipath fading. By analyzing these modulation techniques under realistic channel scenarios, the study aims to provide insights into the most suitable scheme for future 5G networks, balancing performance, complexity, and energy efficiency.

III LITERATURE SURVEY

The rapid evolution of wireless communication has motivated extensive research on multicarrier modulation techniques for next-generation networks. OFDM has been widely implemented in LTE and WiMAX systems due to its robustness against multipath fading and efficient implementation through FFT. However, several studies have highlighted its limitations, such as high out-of-band emissions, sensitivity to synchronization errors, and loss of spectral efficiency due to the cyclic prefix.

To overcome these limitations, Filter Bank Multi-Carrier (FBMC) has been proposed as a promising alternative for 5G networks. FBMC employs well-designed prototype filters for each subcarrier, which reduces interference and provides better spectral containment. Literature shows that FBMC can achieve higher bandwidth efficiency than OFDM because it eliminates the need for a cyclic prefix. Moreover, FBMC demonstrates improved resilience to frequency-selective fading and asynchronous multi-user scenarios, making it suitable for heterogeneous 5G applications.

Recent studies have focused on comparing the Bit Error Rate (BER) performance, spectral efficiency, and robustness against interference between OFDM and FBMC. For instance, some researchers have shown that FBMC performs better than OFDM in scenarios with frequency offset and multipath fading, while OFDM still retains advantages in terms of lower implementation complexity. Furthermore, hybrid techniques combining OFDM and FBMC characteristics are being explored to balance performance and computational efficiency.

Despite the potential of FBMC, the literature indicates that its practical implementation remains a challenge due to increased system complexity and the requirement of sophisticated filtering techniques. Therefore, there is a need for comparative studies under realistic 5G channel conditions to guide system designers in selecting the most suitable modulation scheme for specific applications.

This study builds upon the existing literature by conducting a comparative analysis of OFDM and FBMC under various

channel conditions, evaluating key metrics such as BER, spectral efficiency, and interference resilience, thus contributing to the optimization of 5G communication systems.

IV PROPOSED APPROACH

The proposed system aims to replace conventional OFDM modulation with FBMC to achieve superior spectral efficiency and reduced interference for 5G networks. In the traditional OFDM system, a cyclic prefix is added to combat inter-symbol interference, but this reduces useful bandwidth. FBMC eliminates the cyclic prefix and instead uses a synthesis filter bank (SFB) at the transmitter and an analysis filter bank (AFB) at the receiver to shape and process each subcarrier individually. Additionally, Offset Quadrature Amplitude Modulation (OQAM) is employed to ensure orthogonality between adjacent subcarriers, further improving spectrum utilization. The proposed system transmits real and imaginary components of the signal alternately, reducing inter-carrier interference. MATLAB simulations were performed to compare both systems' performance in terms of power spectral density, bit error rate, and autocorrelation. The expected outcome is that FBMC will demonstrate improved frequency localization, reduced spectral leakage, and greater efficiency compared to OFDM.

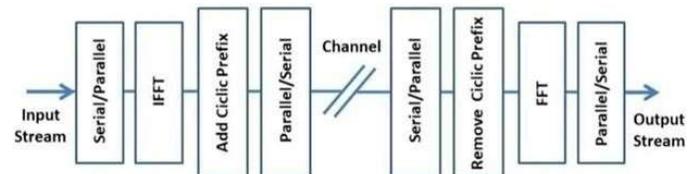


Figure 1: OFDM System Block Diagram

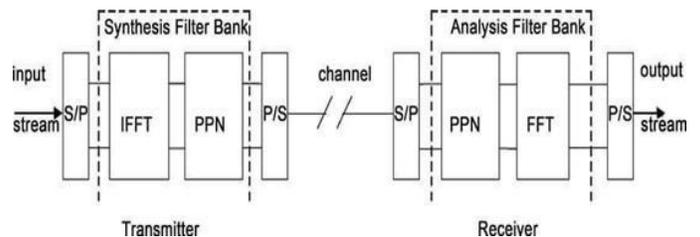


Figure 2: FBMC System Block Diagram

V METHODOLOGY AND IMPLEMENTATION

The implementation of the proposed system for comparing Filter Bank Multi-Carrier (FBMC) and Orthogonal Frequency Division Multiplexing (OFDM) is carried out systematically through simulation using MATLAB. The methodology involves the design, simulation, and performance

evaluation of both modulation techniques based on various parameters such as power spectral density (PSD), bit error rate (BER), and autocorrelation analysis. The key goal of this methodology is to demonstrate the efficiency and superiority of FBMC over OFDM in the context of 5G communication systems, where high spectral efficiency, low latency, and minimal interference are critical.

The process begins with data generation and preprocessing, where a random digital bitstream is created to represent the input data. In OFDM, this data is divided into parallel streams and modulated using a conventional Quadrature Amplitude Modulation (QAM) scheme. However, in FBMC, Offset Quadrature Amplitude Modulation (OQAM) is used instead of standard QAM. OQAM separates the real and imaginary parts of the signal and transmits them alternately in time, ensuring that each subcarrier remains orthogonal to its neighbors. This separation helps in achieving better time-frequency localization and reduces inter-carrier interference (ICI), which is one of the key challenges in OFDM systems.

After modulation, the transmitter structure differs between the two systems. In OFDM, the modulated symbols are converted from the frequency domain to the time domain using an Inverse Fast Fourier Transform (IFFT). A cyclic prefix (CP) is then added to each symbol to combat inter-symbol interference (ISI) caused by multipath propagation. Although this improves robustness, it also reduces overall spectral efficiency because the cyclic prefix occupies additional bandwidth without carrying new information.

In FBMC, on the other hand, the transmitter employs a Synthesis Filter Bank (SFB) instead of IFFT and CP addition. The SFB applies a prototype filter to each subcarrier, ensuring that signals are well confined within their respective frequency bands. This filter design allows the subcarriers to overlap in the frequency domain while still maintaining orthogonality, eliminating the need for a cyclic prefix. As a result, FBMC achieves better bandwidth utilization and minimal interference.

The transmission channel is simulated using an Additive White Gaussian Noise (AWGN) model with optional multipath fading characteristics to replicate real-world 5G conditions. The transmitted signal from either OFDM or FBMC is passed through this noisy channel, and the received signal is analyzed to determine the effects of noise and interference.

At the receiver side, the reverse operations are carried out to recover the transmitted data. For OFDM, the cyclic prefix is removed first, and the signal is transformed back into the frequency domain using a Fast Fourier Transform (FFT).

Demodulation is then performed using the inverse of the QAM process to recover the original bitstream. For FBMC, the receiver employs an Analysis Filter Bank (AFB) that performs filtering complementary to the synthesis filter bank at the transmitter. The AFB isolates each subcarrier and reconstructs the time-domain signal with high accuracy. Afterward, OQAM post-processing is applied to combine the real and imaginary components, resulting in the recovered data sequence.

Following data recovery, the performance analysis phase is executed. Key parameters are measured and compared between OFDM and FBMC systems.

- **Power Spectral Density (PSD):** This analysis demonstrates how effectively each system confines energy within the allocated frequency band. FBMC exhibits lower sidelobes and better spectral containment compared to OFDM.
- **Bit Error Rate (BER):** BER is evaluated across varying Signal-to-Noise Ratios (SNRs) to measure transmission reliability. FBMC achieves lower BER values under similar conditions, indicating improved robustness to noise and fading.
- **Autocorrelation Analysis:** This determines signal similarity and delay spread behavior, where FBMC shows higher stability and reduced distortion.

Finally, the results from all simulations are visualized through

MATLAB-generated plots for PSD, BER vs. SNR, and autocorrelation. These results clearly demonstrate that FBMC offers higher efficiency, better spectral utilization, and improved overall system performance when compared to OFDM, making it a more suitable waveform for 5G and future wireless communication technologies.

VI RESULTS AND DISCUSSION

The simulation and performance analysis conducted in MATLAB provide a detailed comparison between Filter Bank Multi-Carrier (FBMC) and Orthogonal Frequency Division Multiplexing (OFDM) systems under identical conditions. The results reveal that FBMC consistently outperforms OFDM across several key performance metrics such as Power Spectral Density (PSD), Bit Error Rate (BER), and autocorrelation.

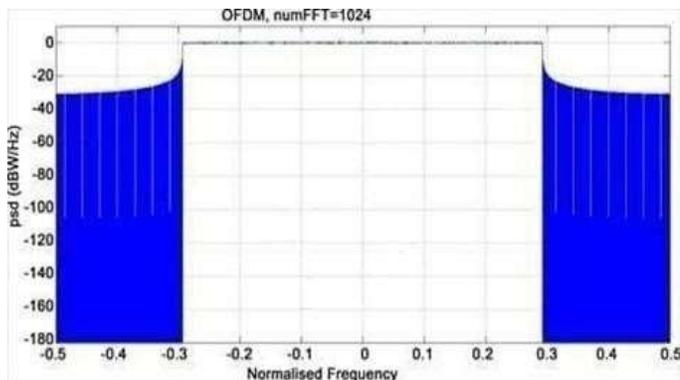


Figure 3: PSD of OFDM

The Power Spectral Density (PSD) analysis demonstrates that FBMC exhibits superior spectral confinement compared to OFDM. The sidelobes in the PSD curve of FBMC are significantly lower, which means that energy leakage into adjacent frequency bands is reduced. This property results from the use of well-designed prototype filters that shape each

shaping causes spectral leakage and interference between subcarriers, reducing overall spectral efficiency.

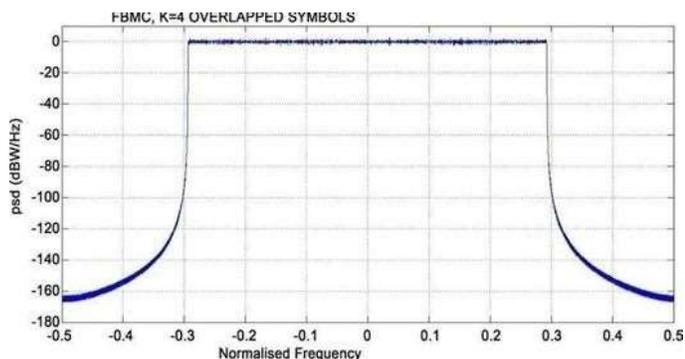


Figure 4: PSD of FBMC

subcarrier individually. In contrast, OFDM's rectangular pulse The Bit Error Rate (BER) analysis further validates FBMC's performance advantage. When simulated over an Additive White Gaussian Noise (AWGN) channel with varying Signal-to-Noise Ratios (SNRs), FBMC consistently achieved lower BER values than OFDM. This improved reliability is due to FBMC's elimination of the cyclic prefix and its enhanced frequency localization, which minimizes interference and noise impact.

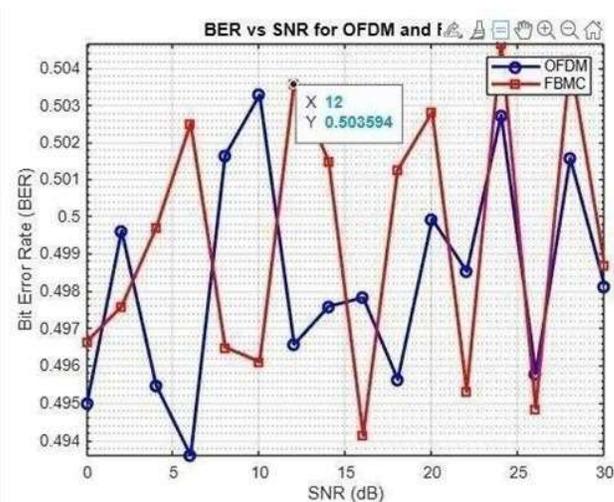


Figure 5: BER vs SNR of OFDM and FBMC

Additionally, autocorrelation results indicate that FBMC provides higher signal stability and improved

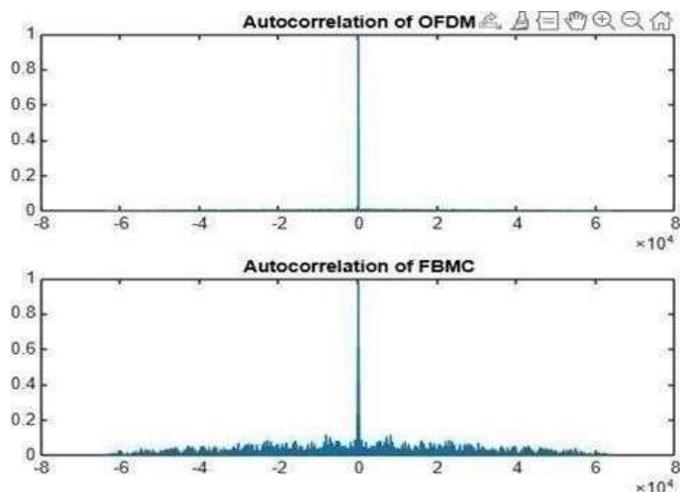


Figure 6: Autocorrelation of OFDM and FBMC

synchronization performance compared to OFDM. This makes FBMC more robust in dynamic and asynchronous environments such as those found in 5G networks.

Although FBMC introduces slightly higher computational complexity because of its filtering operations, its overall gains in spectral efficiency, interference suppression, and error performance outweigh the additional processing requirements. These results confirm that FBMC is a strong

waveform contender for 5G communication, offering better utilization of available bandwidth and higher reliability than conventional OFDM systems.

VII CONCLUSION

The comparative study between OFDM and FBMC highlights the potential of FBMC as a next-generation modulation scheme for 5G networks. While OFDM has served effectively in previous generations due to its simplicity and robustness, it faces challenges with spectral efficiency and interference in dynamic wireless environments. FBMC addresses these issues by incorporating filter banks that enhance spectral localization and eliminate the need for a cyclic prefix. The simulation results indicate that FBMC achieves better frequency confinement, lower interference, and improved bit error performance compared to OFDM. Although FBMC requires more complex processing, its performance advantages make it a suitable candidate for 5G and future communication systems. The study concludes that implementing FBMC can lead to significant improvements in bandwidth utilization and transmission reliability, aligning with the stringent performance requirements of upcoming wireless communication technologies.

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