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Computing Various Optimal Performance Trade-Offs Parameters for FBMC Based Modulation Scheme

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Abstract- Filter Bank Multicarrier compresses data more tightly for one reason? It bypasses the cyclic prefix step entirely. Still, that efficiency comes at a price - processors work harder even under strict constraints. based on the experiments runs the performance of develop FBMC configurations is assessed. Tracing signals from filter to delivery steps allows each trial to track BER, power spikes compared to typical baselines, and total data transported. Change things like pulse form or distance between subcarriers, performance moves in unambiguous ways. Because symbols spread out, they carry deeper detail and cut mistakes. If filtering occurs too frequently, blur begins to appear. However, the signal becomes blurry when filters are repeated too frequently. Sizing is crucial because peak power increases dramatically as symbol length increases. Choosing the proper filter repeat level is important because either extreme throws off performance. PAPR increases with sequence growth, particularly between 10,000 and 100,000 symbols. As interference decreases, speed rapidly increases; this is especially noticeable in large sets that are close to 20,000 units at maximum intensity.

Keywords— Wireless Communication, FBMC, OFDM, BER, PAPR, SNR, symbol length,

I. INTRODUCTION

Even without big gaps between channels or cyclic stuff, FBMC uses less transmission bandwidth compared to common OFDM setups. But the signal handling gets heavier at both receiver and sender ends. Sharp filter designs keep energy neatly packed into their assigned slots, so nearby interference drops way down. Just a little lag can sneak in thanks to the gentle slopes of those filters. Even as phones move and signals shift, it holds steady thanks to predictable patterns. A tiny drift in timing might drag performance down faster these days. Equalizers face tougher jobs since FBMC setups often bring distorted inputs, adding more strain. The real key lies in hitting that mix - precise but lean - especially when environments shift and paths split unpredictably.

Just looking at the previous research, it is noted the simulation may help check FBMC across different situations - key for better wireless setups. Researchers find out where FBMC works well since it calculates and displays key outcomes clearly. With tasks such as filtering, transmitting, receiving split into separate parts, adjusting settings or trying fresh ideas comes about easily.

Peeking at FBMC usually entails testing in environments where signals never remain stable, as jittery settings reveal how it genuinely behaves. Because interference flows quickly or configurations change, hidden characteristics emerge. When researching weak connections, busy airwaves, or altered frameworks, the insights go beyond simply examining data rates. Sharp changes throughout use highlight what holds up as speeds increase, yet soft operations like gradual sensor work expose minor drains that others overlook. Real-world testing separate concept from function, driving modifications long before anything is released. People continue to replay real-life experiences, and what is true gradually emerges. As hunches disintegrate into static, shapes emerge on their own. When make-believe loses its appeal, stark details take centre stage. Forward motion begins only when actions speak for themselves. Stats fall silent whenever life bursts in with a roar.

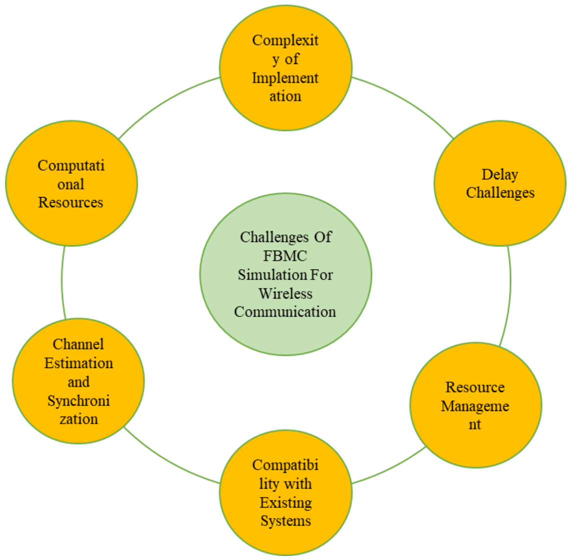

Fig. 1 Challenges of FBMC simulation for Wireless communication

Running system performance tests with FBMC modulation isn't as simple as it sounds. There are a bunch of hurdles that can mess with accuracy—starting with the FBMC structure itself. With overlapping subcarriers and all those filter banks, simulating FBMC eats up way more computing power than something like OFDM. That means longer simulation times and a bigger drain on resources, especially when you're dealing with complex scenarios like multipath fading or multiple antennas. Keeping the bit error rate low at the receiver is another headache. High Peak-to-Average Power Ratio (PAPR) in FBMC that can really wreck your signal if you don't nail the nonlinear effects from power amplifiers and the distortion they bring. You need to pin those down or your results won't mean much. On top of that, handling inter-symbol interference demands sharp equalization strategies. But those strategies can get complicated fast, and tuning them just right in a simulation isn't easy. Let us not forget that the real world is not static; channel circumstances vary, and individuals move around. If your simulations fail to reflect that messiness, you are missing the purpose. If you want meaningful outcomes, you must design and calibrate correctly.
Strangely, FBMC's system has a tendency for bringing researchers together, even from disparate labs. People can change signal pathways, test out new codes, or experiment with better filters, and the system will simply roll with it. This adaptability fosters new ideas and keeps everyone going forward, step by step. When compared to other methodologies, FBMC yields results that are more than simply a guess. Sure, you'll meet stumbling blocks—changing speeds, signal interference, you name it—but each modification is an opportunity to learn. At the end of the day, updating FBMC requires more than just changing code; it is about understanding the entire system as new difficulties arise.

The rest of the paper is organized as follows; the section II has presented the extended review of various relevant researches associated to the simulation of FBMC modulation. Section is summarized in tabular form at the end. The section III has described the various design parameters affecting the performance of the FBMC modulation. Section IV have presented the proposed simulation and muddling system for the FBMC investigation. The flow chart and the design methodology are discussed. The section V followed the various results and investigations performed to investigate the impacts of BER, and PAPER on the FBMC system p[performance. Finally, conclusions and prospective study scopes are offered in the Section VI.

II. LITERATURE REVIEW

Table 1 sum up a bunch of studies on FBMC. You get a quick look at what each study focused on—their methods, what mattered, where they fell short, and which parameters they tested. Honestly, most research on communication systems keeps running into the same walls: things don't always translate well to the real world, plenty of work is just simulations, and the tech can be pretty complex to put into practice. Plus, some studies stick to only one type of modulation, which doesn't really cover the variety you see out there. All this makes it tough to prove these ideas work outside the lab. That's why it's so important to dig into how tweaking things like Signal-to-Noise Ratio (SNR) and Peak-to-Average Power Ratio (PAPR) actually boosts the reliability and quality of communication links. And it's not just about those two—modulation order, subcarrier spacing, filter design, and channel conditions all play a big part. This paper zeroes in on these factors and aims to see how optimizing they can make a real difference.

Comparison of Existing Methods

Authors	Methodology	Significance	Limitations	Parameters Used
Shalaby et al. [1]	Performance evaluation of 5G modulation techniques	Provides comparative performance metrics for various 5G modulation schemes	Limited to specific SNR levels and conditions	SNR levels, modulation types
Kundrapu et al. [2]	Characteristic analysis of modulation schemes	Analyses OFDM, FBMC, and UFMC for next-gen networks, aiding in network design	May not cover all practical scenarios	Modulation schemes, performance metrics
Jang et al. [3]	Comprehensive performance comparison	Highlights performance differences between OFDM and FBMC uplink systems	Focuses only on uplink systems	Uplink configurations, performance indicators
Guneser et al. [4]	Performance analysis of modulation techniques	Evaluates the effectiveness of different modulation techniques in 5G systems	Limited generalizability beyond 5G	Different modulation techniques, performance metrics
Kumar et al. [5]	Enhancement of signal efficiency and PAPR performance	Improves understanding of FBMC performance in optical communication	Focuses on optical communication, limits wireless context	Signal efficiency, PAPR metrics
Vaigandla and Benita [6]	Study and analysis of multi-carrier modulation	Compares FBMC and OFDM, contributing to the understanding of their applicability	May not address all design aspects	Multi-carrier configurations
Mokara et al. [7]	Performance evaluation of modulation schemes	Evaluates OFDM, FBMC, and UFMC for wireless communication	Limited to simulation results	Modulation schemes, performance metrics
Song [8]	Evaluation of prototype filter-based FBMC/OQAM system	Enhances understanding of filter design in FBMC systems	Limited to specific filter designs	Prototype filter parameters
Hadjer and Abdelhafid [9]	Comparison of MIMO-FBMC and MIMO-UFMC	Analyzes equalization techniques for improved performance	Focused on specific equalization methods	MIMO configurations, equalization techniques
Shrivastava et al. [10]	Design of optimal FBMC subcarrier index modulation	Optimizes subcarrier index modulation for better performance	May require complex filter designs	Subcarrier indices, prototype filter parameters
Shaik et al. [11]	Holistic evaluation of UFMC, FBMC, and F-OFDM	Enhances spectral efficiency in 5G networks	May not account for all operational environments	Modulation schemes, performance metrics

Qi et al. [12]	Efficient channel equalization and performance analysis	Focuses on massive MIMO systems, enhancing understanding of uplink performance	Complexity in channel equalization	Massive MIMO configurations, equalization metrics
Zheng et al. [13]	Deep learning-aided FBMC system design	Explores innovative approaches to enhance FBMC performance using deep learning	Requires significant computational resources	Deep learning models, system parameters
Butenko et al. [14]	Modeling the physical layer with FBMC technology	Advances understanding of FBMC in advanced radio access systems	May not cover all physical layer scenarios	Modelling parameters, spectral efficiency
Kanapala and Hussain [15]	Performance analysis of FBMC/OQAM system	Evaluates the effectiveness of prototype filters in FBMC/OQAM systems	Limited to specific filter designs	Prototype filter configurations

Factors and Parametrers Impacting the FBMC Perfromance

FBMC systems come with a handful of trade-offs. You have to weigh things like delay, computing power, how well the system handles rough channels, spectral efficiency, and how much signal leaks outside its band. By dropping cyclic prefixes and shrinking guard bands, FBMC squeezes out more spectral efficiency than OFDM. The prototype filters in FBMC do a good job keeping out-of-band emissions low, which helps the system get along with neighbouring channels, but these filters can add some extra delay. FBMC handles Doppler shifts and frequency offsets pretty well, so it works in high-mobility situations. Still, it can be more sensitive to timing errors. Since FBMC naturally brings some interference, you need more advanced equalization, which bumps up the system's complexity. So, getting the best out of FBMC means juggling all these factors, depending on where and how you use it. Also, as you can see in Figure 2, a bunch of different things can influence how FBMC performs in simulations.

Number of Subcarriers (N): In the simulation, we use 64 subcarriers. This setting controls how finely we split up the frequency range, which shapes both spectral efficiency and how well the system stands up to frequency-selective fading.

Filter Order (M): We set the filter order to 4 in the code. That means the filter has four taps. This choice matters because it shapes how well the signal stays localized in both time and frequency — a big deal for FBMC performance.

Sampling Frequency (Fs): The sampling frequency is 512 Hz. This value sets the system's total bandwidth and determines how far apart the subcarriers are.

Signal-to-Noise Ratio (SNR): The simulation checks performance across SNR values from 0 up to 30 dB. SNR plays a huge role in performance, especially when it comes to Bit Error Rate (BER).

We set the number of symbols (Num Symbols) to 10,000. That number matters because it affects how reliable our simulation results are, especially when calculating BER.

For the filter design, we're using a root-raised cosine filter with a roll-off factor of 0.5 as the prototype filter in the FBMC system. The specific filter and its parameters play a big role in how well the system performs.

Honestly, all these reasons—just like you see in the Figure 2—are at the heart of why we're doing this research.

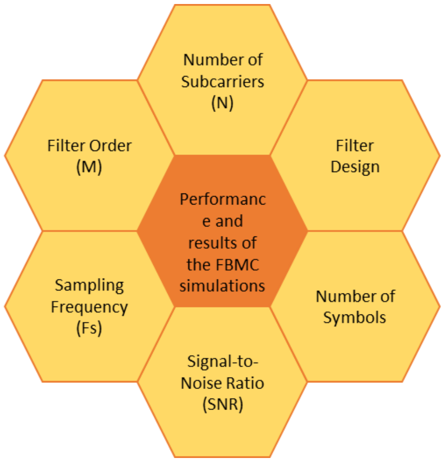

Fig. 2 Impacts of various design faction for FBMC

III. PROPOSED FBMC COMMULICATION SYSTEM SIMULATION METHODOLOGIES

This approach covers all the main parts of FBMC modulation: filter design, modulation, and demodulation. It also calculates key performance metrics for the FBMC system, like BER, throughput, and PAPR.

The MATLAB simulation's FBMC implementation starts with parameter initialization, where the system framework is established by defining important communication system parameters like the total number of sub carriers (N=64), filter taps (M=4), sampling rate (Fs=512 Hz), the modulation order (64-PSK), amount of transmitted symbols, as well as SNR range. Then, using 64-PSK with a phase offset, random data symbols are created and modulated to produce complex-valued signals for every subcarrier. The foundation of FBMC modulation is a root raised cosine proto-type filter using roll-off factor β=0.5 that shapes the subcarrier signals and minimizes spectral leakage by convolution using the transmitted symbols. The final FBMC transmit waveforms is produced by concatenating the filtered symbols.

An Additional White Gaussian noisy (AWGN) channel is used to study channel development. Realistic transmitting conditions are simulated by controlling noise levels that correlate to various SNR values. Demodulation is used to reconstitute transmitted data after the receiver applies the same prototype filter to retrieve symbol components. In order to provide a thorough evaluation of FBMC communication efficiency under various channel conditions, system performance is assessed using BER, PAPR, spectral effectiveness, as well as throughput analysis. The parameters used for FBMC simulation are shown on Table 2.

Simulation Parameter table

Parameter	Symbol	Value	Description
Number of Subcarriers	N	64	Total number of subcarriers used in the FBMC system
Filter Taps	M	4	Order of the prototype filter
Sampling Frequency	Fs	512 Hz	Sampling frequency of the communication system
SNR Range	SNR_dB	0–30 dB (step size = 3 dB)	Range of Signal-to-Noise Ratio values used for simulation
Number of Symbols	numSymbols	10,000	Total number of transmitted symbols
Modulation Order	modOrder	64	Modulation order used in the system (64-PSK)
Bandwidth per Subcarrier	B	Fs/N = 8 Hz	Bandwidth allocated to each individual subcarrier
Roll-off Factor	β	0.5	Roll-off factor of the root raised cosine filter

Bit Error Rate (BER): These metrics show how accurately the system transmits data at different Signal-to-Noise Ratio (SNR) levels. BER stands for bit error rate, which is defined as

$$BER \approx Q\left(\sqrt{\frac{2\cdot SNR}{M}}\right) \quad (1)$$

where; The tail probability of the typical normal distribution is represented by the Q-function's is order of modulation.

Peak-to-Average Power Ratio (PAPR):It calculates the ratio of the signal's average power to its peak power. This is crucial for assessing the power efficiency of the modulation scheme.

$$PAPR=\frac{P_{peak}}{P_{avg}} \quad (2)$$

Throughput: This measures the effective data transmission rate of the system. Figure 3 shows the block diagram for the FBMC-based simulation setup. Here's how it works: First, the system sets up the design parameters and creates random disassembles. We use QPSK modulation, and for testing FBMC performance, we try out both 4-filter and 8-filter configurations.

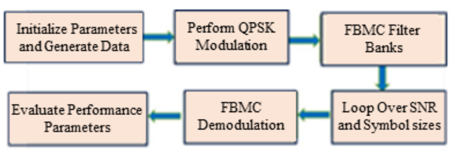

Fig. 3 block diagram of FBMC System Simulation

The sequential flow chart of the proposed method is shown in the Figure 4. it is the expansion of Fig 3 and makes it clear the method loops over the SNR and number if transmitted symbols to investigate the impact of BER and PAPER and throughput. The implementation allows for comprehensive analysis of FBMC performance under various conditions, which is crucial for optimizing wireless communication systems.

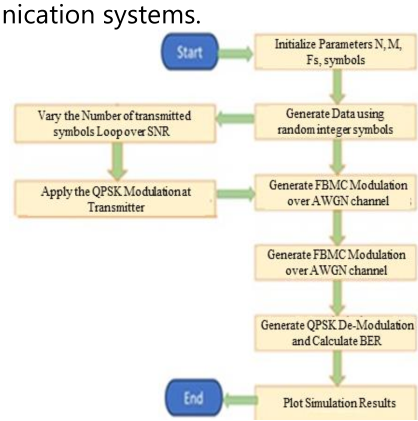

Fig. 4 flow chart of FBMC BER analysis and Simulation

By calculating and visualizing multiple performance metrics, researchers can make informed decisions about the suitability of FBMC for specific applications. The modular structure of the code (with separate functions for filter design, modulation, and demodulation) allows for easy modification and experimentation with different parameters or techniques within the FBMC framework.

IV. RESULTS AND DISCUSSION

This section has presented the sequential simulation results and evaluation of the FBMC based modulation system also validated the basic code. The performance evaluation parameters for FBMC systems For BER, spectral efficiency (SE) and throughput of the system,

Spectral Efficiency (SE): It is defined as the number of bits transmitted per second per Hertz of bandwidth. For a modulation scheme with MM bits per symbol and RR symbols per second, the spectral efficiency can be calculated as:

$$SE = (\log2(Mo)*R)/ B \quad (3)$$

where B is the bandwidth Mo is modulation order and R is rate of transmission.

Throughput: It is the actual rate at which data is successfully transmitted over the channel, measured in bits per second (bps). It can be calculated as:

Throughput=Data Rate×(1-BER)Throughput= Data Rate×(1-BER) (4)

Experiment 1 Results of Effect of Repartitions

The Figure 5 displays the performance of a FBMC modulation scheme in a wireless communication. the performance of Bit Error Rate (BER), is compared for 4 and 8 repetitions (Rep) system against the different Signal-to-Noise Ratio (SNR) in decibels (dB).

Higher SNR generally leads to better performance and lower error rates. Furthermore, using 8 repetitions consistently results in a higher BER compared to using only 4 repetitions across all SNR levels. This suggests that increasing the number of repetitions may have adverse effect on the wireless commutation and thus it is required to determine the optimal number of filters repetitions (Rap) determine the optical number if repetitions. The number or order or reputation of FBMC filter plays an important role to mitigate the BER and also to increase the system capacity.

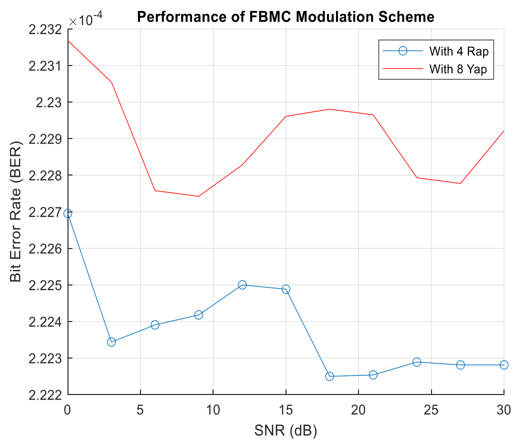

Fig. 5 BER of FBMC for different Filter Taps (Rap)

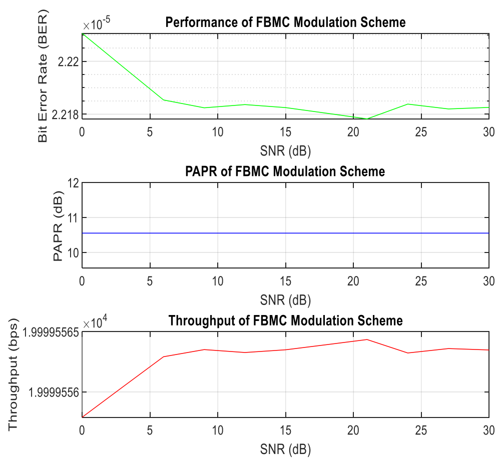

Fig. 6 PAPR and Throughput Evaluation for FBMC

The Figure 6 have compared and evaluated the performance of an FBMC modulation scheme under varying SNR conditions. The PAPR is initially validated as 10.5 dB while the throughput, which increases rapidly with SNR until about 1.999x104, in near future the higher throughput is desired to achieve. The numbers of FBMC sub carriers are kept constant during the simulation to 64 as standard.

Results of Different Symbol sizes

An extra experiment is performed to investigate the impact of increasing the symbol size for FBMC considering higher traffic of future. The Figure 7 represented the BER against the different symbol sizes. It can be observed that BER is nearly costate with SNR for FBMC and decreases with increasing symbol sizes. Doting all experiments the modulation order is kept costate to minimum. Using the intelligent Machine learning based prediction of these parameters may significantly improve performance in future.

Similarly, the Figure 8 represented the validated and evaluated results for the Throughput against the different symbol sizes. It can be observed that Throughput also increases as the data size increases. And remains nearly costate with SNR for FBMC with 2x105

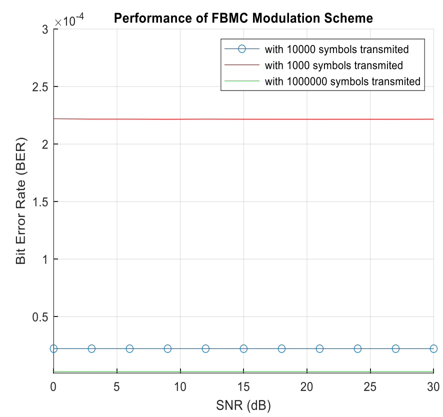

Fig. 7 Parametric result of SSE for regression fitting

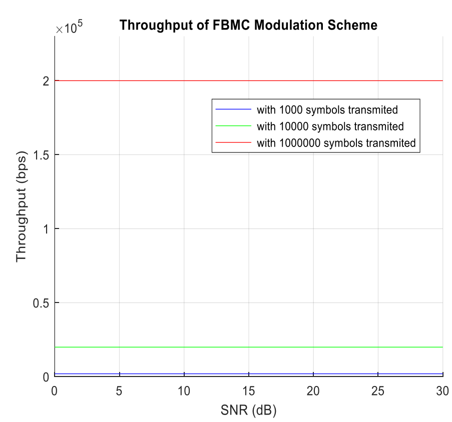

Fig. 8 Throughput evaluation for transmission length at 512 Hz sampling g frequency

Results of PAPR Comparsion for FBMC

The Figure 9 illustrates comparative results for the PAPR simulation for the Different symbol lengths or size

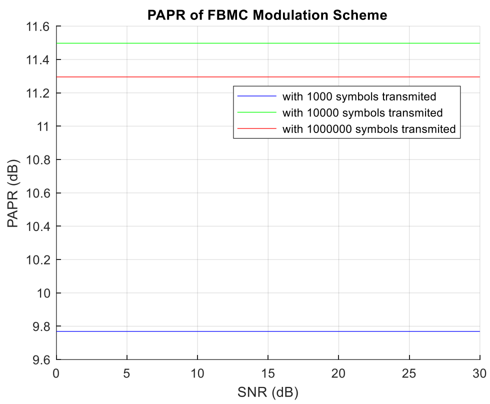

Fig. 9 Result of the PAPR comparison for

transmission length at 512 Hz sampling g frequency
Conclusiosn and Future Scopses

The study highlights several critical conclusions regarding the performance of FBMC modulation in communication systems. When we used eight filter repetitions instead of four, the Bit Error Rate (BER) always went up, no matter the Signal-to-Noise Ratio (SNR). So, there's a clear trade-off—more repetitions mean more errors. On the other hand, bigger symbol sizes actually dropped the BER, so larger symbols seem to make the system more reliable.

For Peak-to-Average Power Ratio (PAPR), we started at 10.5 dB. As the symbol length grew, PAPR shot up too. For example, with 100,000 symbols, PAPR was about 1.8 times higher than with only 10,000. Throughput jumped quickly as SNR increased until it hit around 1.999 x 10^4, and it also improved with bigger data sizes. After a certain point—about 2 x 10^5 SNR—the throughput just levelled off. Throughout all these tests, we stuck to 64 subcarriers and the lowest modulation order to keep things consistent. It's worth mentioning: using symbol lengths under 10,000 just slowed everything down too much, so they're not really useful.

This all highlights how important it is to pick the right number of FBMC filter repetitions. Get it right, and you can cut down on errors and boost capacity. There's still plenty to explore—like designing a smart, machine learning-based solution to push performance even further. It'd also be interesting to see how fading channels affect FBMC, or what happens when you tweak the modulation order. There's a lot of room for new ideas here.

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