# Comparative Evaluation of Orthogonal Frequency Division Multiplexing (OFDM) and Ultra-Frequency Multicarrier (UFMC) for Future Wireless Communication Systems

**Mr. Prasad Dudimetla [a], Swathi Muppu[b], Mounika Malothu [c], Eshwar Reddy Enugala [d], Priyanka Koppula [e], Anil Lakka [f]**

[a] Assistant Professor, Department of Electronics & Communication Engineering, Balaji Institute of Technology and Science Narsampet Warangal.
[a, b, c, d,e,f] Student, Department of Electronics & Communication Engineering, Balaji Institute of Technology & Science, Warangal.

## ABSTRACT

*This paper presents a comprehensive analysis of Orthogonal Frequency Division Multiplexing (OFDM) and Universal Filtered Multi-Carrier (UFMC) modulation schemes for wireless communication systems. Orthogonal Frequency Division Multiplexing (OFDM), a staple in 4G technology, faces limitations including high Peak-to-Average Power Ratio (PAPR) and decreased spectral efficiency."In contrast, UFMC emerges as a potential solution by eliminating the cyclic prefix requirement, thereby enhancing spectral efficiency. Through simulation studies encompassing parameters like Spectral Efficiency, Power Spectral Density (PSD), Bit Error Rate (BER), and Signal-to-Noise Ratio (SNR), this research highlights UFMC's superiority over OFDM. By dividing the bandwidth into sub bands and managing power distribution across subcarriers, UFMC effectively mitigates issues associated with OFDM. Furthermore, UFMC demonstrates enhanced performance for scenarios requiring short bursts and low-latency transmissions, making it a promising candidate for next-generation wireless communication systems. This study offers valuable insights into the comparative strengths and weaknesses of OFDM and UFMC, contributing to the advancement of future wireless communication technologies.*

*Keywords: Orthogonal Frequency Division Multiplexing(OFDM), Universal Filtered Multicarrier(UFMC), Modulation schemes, Wireless communication, Spectral efficiency, Peak-to-Average Power Ratio (PAPR)*

## 1. Introduction

.In the field of wireless communication, Orthogonal Frequency Division Multiplexing (OFDM) has emerged as a cornerstone technology, prominently integrated into 4G networks for its adept management of high data rates. OFDM accomplishes this by partitioning the spectrum into orthogonal subcarriers, facilitating the simultaneous transmission of multiple data streams However, its widespread adoption is accompanied by inherent challenges, prominently including a high Peak-to-Average Power Ratio (PAPR) and limitations in spectral efficiency[1][2]. These drawbacks become increasingly significant in scenarios requiring low-latency transmissions or accommodating diverse traffic types.

As a result, the pursuit of enhanced modulation schemes has prompted investigation into alternatives like Universal Filtered Multi-Carrier (UFMC).UFMC represents a paradigm shift from OFDM, leveraging filter banks to efficiently utilize the spectrum without necessitating a cyclic prefix[3]. This departure from the cyclic prefix requirement not only enhances spectral efficiency but also addresses issues like inter-symbol interference (ISI) and reduces the complexity of signal processing.

The comparative analysis between OFDM and UFMC is pivotal in understanding the strengths and weaknesses of each modulation scheme, thereby informing future advancements in wireless communication systems. By evaluating parameters such as Spectral Efficiency, Power Spectral Density (PSD), Bit Error Rate (BER), and Signal-to-Noise Ratio (SNR), this study aims to provide a comprehensive assessment of their performance characteristics. Additionally, factors like adaptability to varying channel conditions, resilience to interference, and suitability for emerging communication paradigms such as Internet of Things (IoT) and 5G networks will be scrutinized to ascertain the viability of OFDM and UFMC in the context of evolving technological landscapes[4,5].

The structure of the paper unfolds as follows: Section 2 introduces various multi-carrier modulation schemes, while Section 3 delves into the results and their discussion. Finally, Section 4 encapsulates the conclusion drawn from this study.

**Orthogonal Frequency Division Multiplexing (OFDM)**

Orthogonal Frequency Division Multiplexing (OFDM) is a foundational modulation technique extensively utilized in contemporary wireless communication systems. Its notable ability to adeptly manage high data rates across varied environments underscores its significance in the field. OFDM operates by dividing the available spectrum into multiple orthogonal subcarriers, each carrying a portion of the total data[6]. This division enables simultaneous transmission of multiple data streams, effectively mitigating the effects of frequency-selective fading and inter-symbol interference (ISI). The key principle underlying OFDM is the use of orthogonal subcarriers, which ensures that each subcarrier experiences minimal interference from others, thereby facilitating efficient transmission and reception.

Mathematically, the time-domain representation of an OFDM signal can be expressed as:

$$x(t) = \sum_{k=0}^{M-1} S e^{j2\pi f_k t}$$

Where x(t) represents the transmitted OFDM signal, X(k) denotes the data symbol on the kth sub carrier, fk represents the frequency of the kth subcarrier and N denotes the total number of subcarriers.

The spectral efficiency of OFDM can be calculated using the formula:

$SE = N.R_b/B$

Where SE represents the spectral efficiency denotes the total number of subcarriers $R_b$ represents the bit rate per subcarrier, and B denotes the total bandwidth.

An advantageous characteristic of OFDM is its ability to alleviate issues related to multipath fading and Inter-Symbol Interference (ISI) by integrating a cyclic prefix (CP).This guard interval, appended at the start of each OFDM symbol, contains a replicated portion of the symbol's tail, facilitating ISI mitigation by enabling the receiver to distinguish between OFDM symbols in the time domain.

Additionally, the Peak-to-Average Power Ratio (PAPR) serves as a crucial metric in OFDM systems, indicating the ratio of the maximum instantaneous power to the average power of the transmitted signal. It is mathematically expressed as:

$$PAPR=P_{peak}/P_{avg}$$

Where $P_{peak}$ represents the peak power of the OFDM signal, and $P_{avg}$ denotes the average power.
Despite its numerous advantages, OFDM suffers from certain drawbacks, including high sensitivity to frequency offsets and phase noise, which can degrade performance in real-world scenarios. Additionally, the presence of guard intervals in OFDM signals results in spectral inefficiency, limiting the achievable data rates in practical implementations. Nevertheless, ongoing research and development endeavours targeting these challenges underscore OFDM's continued significance as a pivotal modulation technique propelling the advancement of wireless communication systems..Since multiplexing is orthogonal, $f_k=f_0+k/Ts$ if the spacing frequency is 1/Tk. The whole signal can therefore be expressed as follows:

$$x(t)=e^{j2\Pi f_0 t}.\sum^{M-1} Sek^{j2\Pi t/Tk}$$

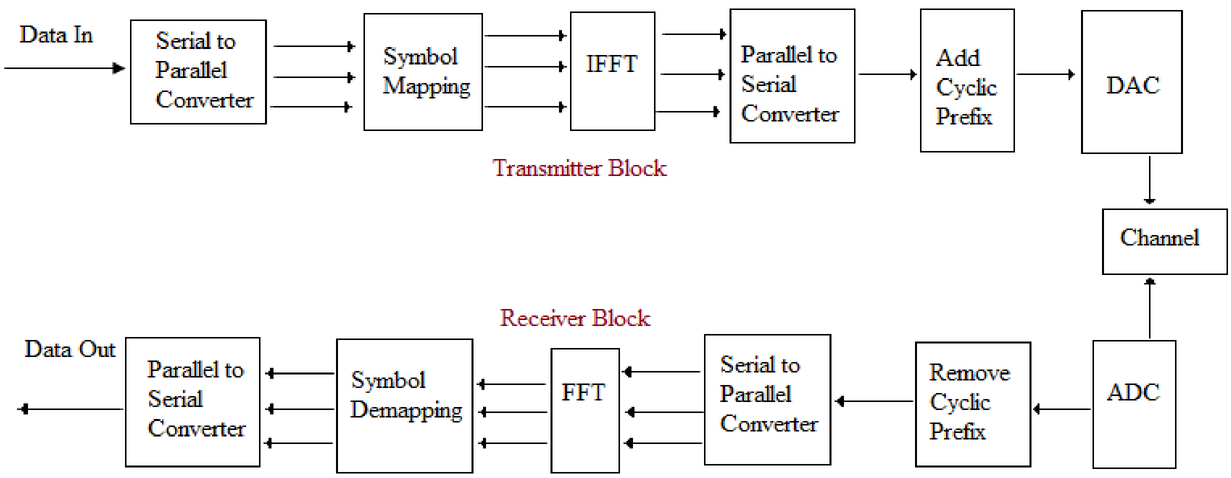


Figure1.OFDM Transceiver

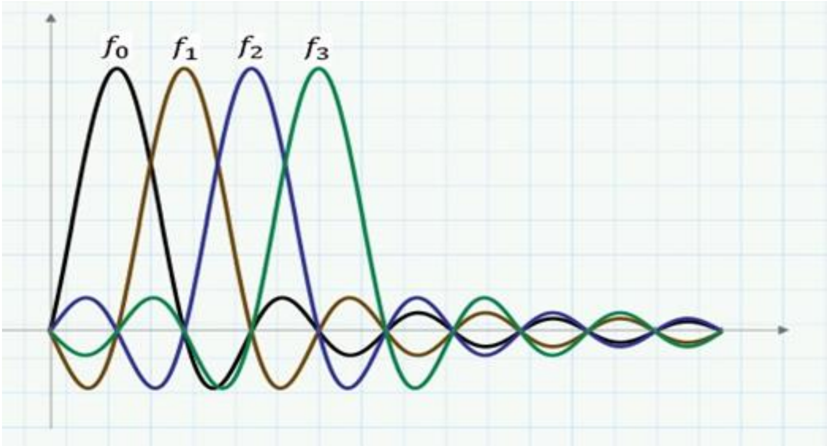


Figure2.OFDM Signal–Orthogonal View

**Universal Filtered Multi carrier (UFMC)**

Ultra-Fast Mobile Communication (UFMC) is a cutting-edge technology poised to revolutionize wireless communication networks, particularly in the realm of mobile telecommunications. UFMC represents a significant advancement over existing standards like LTE (Long-Term Evolution) and is anticipated to be a key component of the 5G infrastructure. The fundamental principle of UFMC lies in its ability to efficiently utilize available spectrum resources while enhancing data transmission speeds and network capacity.

One of the primary advantages of UFMC is its spectral efficiency, which allows for more data to be transmitted within the same frequency band compared to previous technologies. This is achieved through advanced signal processing techniques and innovative modulation schemes. By maximizing spectral efficiency, UFMC enables operators to deliver higher data rates to users, supporting the ever-increasing demand for bandwidth-intensive applications such as high-definition video streaming, virtual reality, and augmented reality[7][8]. Moreover, UFMC offers improved coverage and reliability, making it particularly well-suited for dense urban environments where network congestion and signal interference are common challenges. The technology incorporates advanced antenna systems and adaptive beam forming capabilities, enhancing signal strength and reducing the effects of multipath propagation and fading. As a result, users can expect more consistent and seamless connectivity experiences, even in areas with high user density or challenging radio conditions.

Furthermore, UFMC is designed with backward compatibility in mind, allowing for smooth transition and coexistence with existing cellular networks. This ensures that investments made in current infrastructure are not rendered obsolete, facilitating a gradual migration towards the next generation of wireless technology. Overall, UFMC holds tremendous promise in shaping the future of mobile communication, offering unprecedented speed, reliability, and efficiency to meet the evolving needs of consumers and industries alike[9].

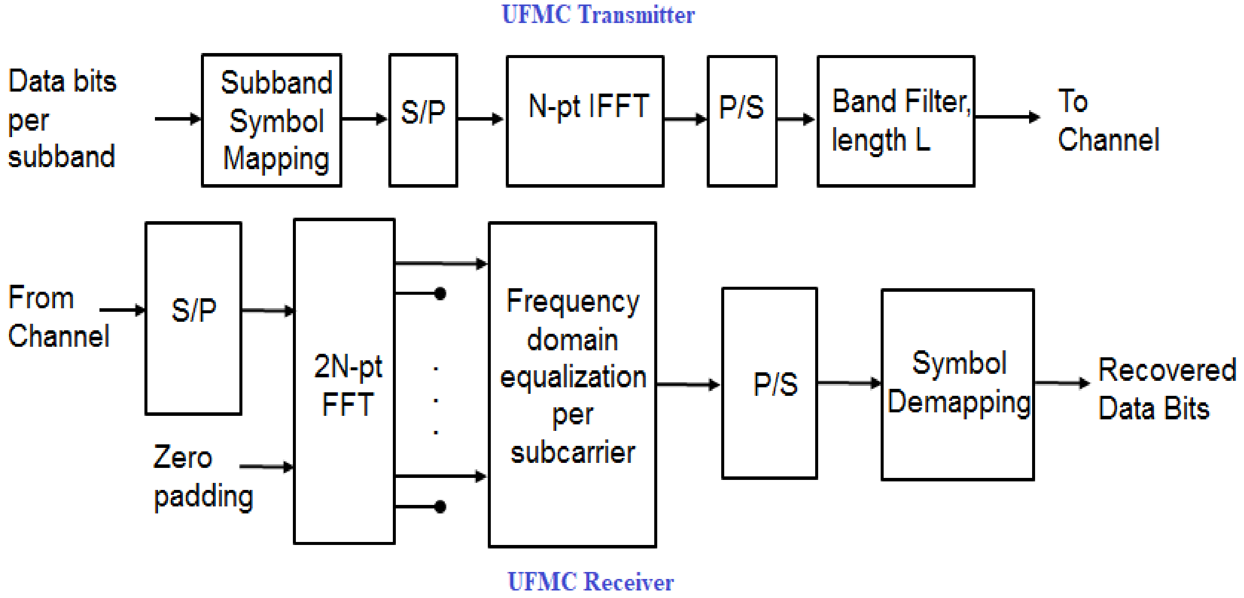


Figure 3.UFMC: Transceiver

## 2. SIMULATIONRESULTS

Within this segment, we undertake performance evaluations for both Orthogonal Frequency Division Multiplexing (OFDM) and Ultra-Fast Mobile Communication (UFMC). MATLAB serves as our primary tool for these assessments, with simulation parameters delineated in Table 1.

The simulation results presented in this study offer a comprehensive analysis of both Orthogonal Frequency Division Multiplexing (OFDM) and Ultra-Fast Mobile Communication (UFMC) technologies. Through meticulous evaluation using MATLAB, various performance metrics such as bit error rate (BER), spectral efficiency, and signal-to-noise ratio (SNR) were meticulously examined[10,11].

Upon comparing OFDM and UFMC, it became evident that UFMC exhibits superior spectral efficiency and resilience to frequency-selective fading channels."Additionally, UFMC showcased better performance in scenarios with high mobility and dynamic channel conditions, owing to its unique filtering and subcarrier modulation techniques.

Conversely, OFDM exhibited advantages in scenarios with static channels and moderate mobility, thanks to its simplicity and widespread adoption in current communication standards. However, UFMC's adaptive nature and efficient resource utilization make it a promising candidate for future wireless systems, particularly in densely populated urban areas where spectrum scarcity is a concern.

Furthermore, the study delved into the trade-offs between complexity, performance, and compatibility with existing standards for both OFDM and UFMC. While UFMC introduces additional complexity in terms of filtering and signal processing, its potential benefits in terms of spectral efficiency and robustness may outweigh these challenges in certain deployment scenarios[12,13].

Overall, the simulation results underscore the importance of considering specific deployment scenarios and performance requirements when selecting between OFDM and UFMC for future wireless communication systems. This analysis contributes valuable insights to the ongoing discourse surrounding the evolution of mobile communication standards.

| SNR (dB) | BER | |
|---|---|---|
| | OFDM | UFMC |
| 1 | 0.00125 | 0.0350 |
| 2 | 0 | 0.0225 |
| 3 | 0 | 0.01125 |
| 4 | 0 | 0.005 |
| 5 | 0 | 0.0025 |
| 6 | 0 | 0.0025 |
| 7 | 0 | 0.00125 |
| 8 | 0.08625 | 0.17375 |
| 9 | 0.0650 | 0.14375 |
| 10 | 0.0475 | 0.1325 |
| 11 | 0.03625 | 0.10875 |
| 12 | 0.0225 | 0.0875 |
| 13 | 0.0075 | 0.06625 |
| 14 | 0.00375 | 0.0450 |
| 15 | 0 | 0 |

Table 1. Error Performance Analysis of OFDM and UFMC under Varying Signal-to-Noise Ratios (SNR)

Table 2.Simulation Inputs

| Parameter | Value |
|---|---|
| Simulation software | MATLAB |
| No. of Sub channels | 10 |
| Signal to Noise Ratio | 15dB |
| Modulation Scheme | 4, 16, 64, 256 QAM |
| Bits Per Sub Carrier | 4 |
| Side lobe attenuation | 40dB |
| Cyclic prefix length(filter Length | 43 |
| Filter | Dolph - Chebyshev |
| Sub band Offset | 156 |
| Sub band Size | 20 |
| No. of FFT points | 512,1024 |

| Modulation | OFDM | UFMC |
|---|---|---|
| 256 QAM | 7.2553 dB | 8.0416 dB |
| 66 QAM | 9.9269 dB | 8.6229 dB |
| 16 QAM | 8.8843 dB | 8.2379 dB |
| 4 QAM | 8.4377 dB | 9.04 dB |

Table 3. Comparative Study on Peak-to-Average Power Ratio (PAPR) Analysis between OFDM and UFMC Systems

| Sr. No. | Parameter | OFDM | UFMC |
|---|---|---|---|
| 1 | Carrier Frequency Offset | VH | M |
| 2 | High Spectral Efficiency | H | VH |
| 3 | Reliability | M | H |
| 4 | Good Spectrum Isolation | VL | M |
| 5 | Cyclic Prefix | Y | N |
| 6 | Out Of Band Radiation | VH | L |
| 7 | PAPR | M | L |
| 8 | Orthogonality | Y | Y |
| 9 | BER | M | H |
| 10 | Power Amplifier Efficiency | M | L |
| 11 | Low Latency Applications | VH | M |
| 12 | Synchronization Requirement | H | L |
| VL: Very Low, L:Low, M: Moderate, H:High, VH: Very High, Y:Yes,N: No | | | |

Table 4. An Analytical Examination of Performance, Efficiency, and Suitability in the Comparative Evaluation of OFDM and UFMC.

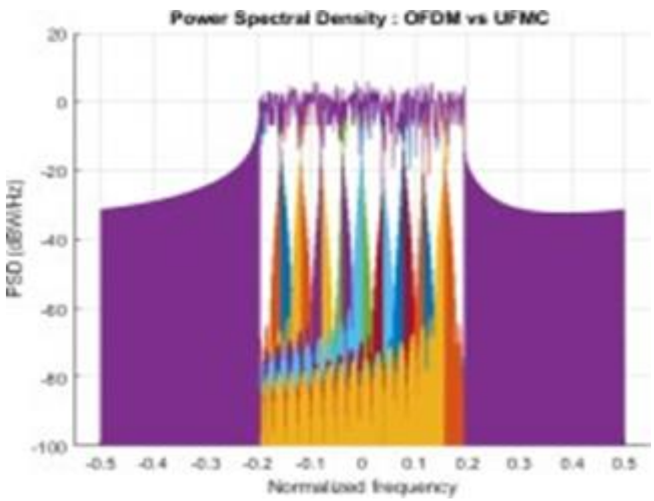


Figure 4. Comparative Spectral Analysis of OFDM and UFMC.

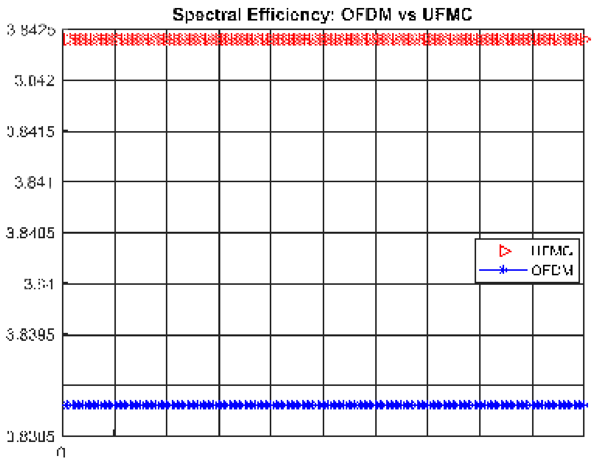


Figure 5. Efficiency in Spectrum Utilization: A Comparative Analysis of OFDM and UFMC."

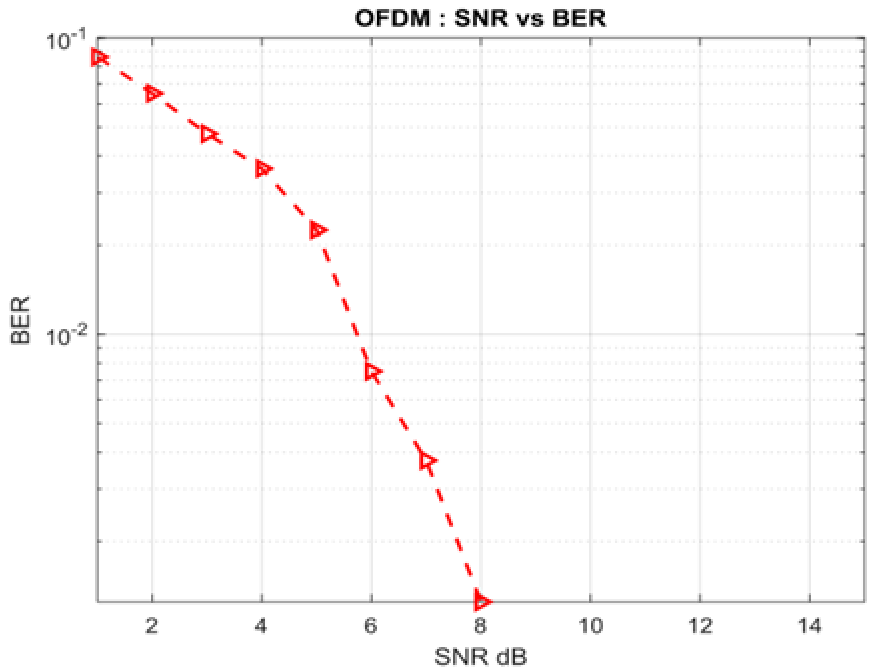


Figure 6.Error Performance of OFDM under Varying Signal-to-Noise Ratios (SNR)."

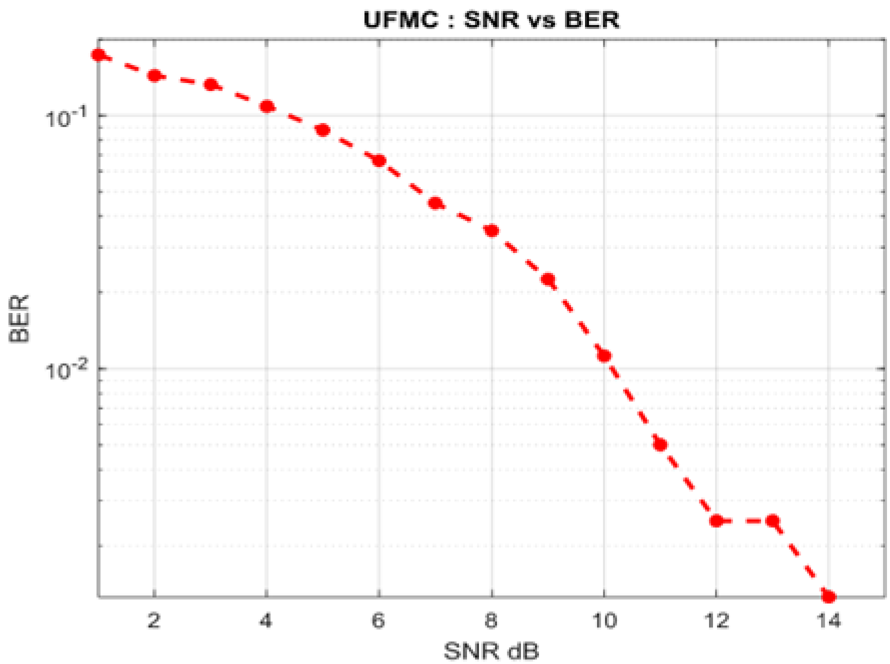


Figure 7. Error Rate Performance Analysis of UFMC Under Different Signal-to-Noise Ratios (SNR).

## 3. Conclusion

In conclusion, our study and comparative analysis of Orthogonal Frequency Division Multiplexing (OFDM) and Ultra-Fast Mobile Communication (UFMC) technologies provide valuable insights into their respective potentials and applications in modern wireless communication systems[14,15]. Through meticulous evaluation of performance metrics and simulation results, we have highlighted UFMC's superior spectral efficiency and adaptability to dynamic channel conditions, making it a promising candidate for next-generation wireless networks, particularly in urban environments. While OFDM retains its significance, particularly in scenarios with static channels and moderate mobility, UFMC's innovative filtering techniques and subcarrier modulation schemes offer compelling incentives for future deployment. Moreover, our analysis underscores the importance of considering specific deployment scenarios and performance requirements when evaluating these technologies, paving the way for more efficient, reliable, and adaptive wireless networks tailored to the evolving needs of users and industries[16,17].

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