Multi-windowing Technique for 5G and Beyond

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Abstract—**Recently, the development of mobile technology has reached a point that requires a high data rate with high waveform aspects. So, traditional ways are no further tolerable. With the dawn of the fifth generation (5G), researchers have been investigating its waveforms and experimenting the methods to improve it. This research examines universal filter multi-carrier (UFMC) for a novel strategy by employing multi-windowing UFMC-based (MW-UFMC) to boost the power spectral density (PSD). This was accomplished by lowering out-of-band emission (OOBE), bit error rate (BER), and adjacent channel leakage ratio (ACLR). The 256quadrature amplitude modulation (256QAM) mapping modulation method was employed in this work. 256QAM is the maximum modulation level that is standard for the third-generation partnership project (3GPP). The proposed MW-UFMC is compared with the conventional UFMC and cyclic prefix orthogonal frequency division multiplexing (CP-OFDM). The proposed multi-windowing technique presents a multistage service that offer a diversity of options to the network operator, which exhibits several advantages over existing methods. These include a lower BER, improved PSD, enhanced spectral efficiency (SE), reduced OOBE that increases capacity for accommodating more bits, decreased ACLR, and lower latency.**

Keywords—**UFMC, 5G, multi-windowing, OOBE, BER, ACLR**

I. Introduction

Telecommunication nowadays has reached a peak in development that were not imaginable in its first phases. Where it started with the first generation (1G), where all analog then digital communication had been introduced in the second generation (2G), the digital evolution continued to produce the third generation (3G) that supports video calls and presents a global positioning system (GPS) in mobile. The fourth generation revolutionized by using the orthogonal frequency division multiplexing access (OFDMA) for the air interface. The fifth generation (5G) enhanced the OFDM waveform used in the 4G, where some parameters were used to measure the waveform performance [1]. These parameters are called key performance indicators (KPI), and these parameters are peak-to-average-power-ratio (PAPR), latency, computational complexity, filtering type, spectrum efficiency (SE), power spectral density (PSD), and Spectral coexistence. The new waveform is demanded due to IMT2020 for enhanced mobile broadband(eMBB) for applications requiring a high data rate and bandwidth, massive machine type communication (mMTC) for applications similar to the Internet of Things (IoT) applications, and ultra-reliable low latency communication (URLLC) for crucial applications like remote surgery and self-driving cars [2].

The modulation scheme used in 4G communication is orthogonal frequency division multiplexing (OFDM) which has low multipath interference but as a result of the orthogonality of the subcarriers that initiate what is called out-of-band emission (OOBE), because of the side lobes of the subcarriers. And this causes a rise in adjacent channel leakage (ACL). OFDM also suffers from inter-symbol interference (ISI) and inter-carrier interference (ICI). To reduce ICI and ISI, a cyclic prefix (CP) is introduced to the OFDM symbol; CP is a duplicate of the OFDM symbol's tail, which serves as a guard interval. Adding CP to OFDM results in the (CP-OFDM) scheme that is popular in 4G Long-Term Evolution (LTE) and Wi-Fi [3], but this scheme suffers from a high peak-to-average power ratio (PAPR).

On the other hand, there are several other types of multi-carrier modulation techniques, like filtered orthogonal frequency division multiplexing (F-OFDM), filter bank multi-carrier (FBMC), and universal filter multi-carrier (UFMC). F-OFDM has filtered the whole band, which makes the filter length very long, adding complexity to the system [1]. Moreover, FBMC has filtered each subcarrier with a separate filter to lower OOBE, ISI, and ICI, but it needs very complex hardware. Lastly, the whole band is split into subbands by UFMC, each including a number of subcarriers. Because UFMC uses shorter filters than FBMC, it is less complicated and considered for its robustness against ICI and lower latency scenarios [4]. Still, it has a bigger OOBE but is more relevant to multi-input multi output (MIMO) for maintaining the fundamentals of OFDM [1].

OFDM possesses numerous advantages in modulation and demodulation algorithms, enabling high efficiency in high-rate mobile communication and enhancing resilience against fading phenomena. However, its features are not

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compatible with the updated demands of the Internet of Things (IoT). OFDM leverages a rigorous synchronization procedure to maintain orthogonality, which opposes the energy conservation principle of the IoT [5].

The emergence of 5G networks has emerged as a crucial inducer for developing the IoT due to its superior attributes, such as extended coverage, enhanced speed, and substantial bandwidth compared to alternative cellular network communication systems [6].

The next-generation smart grid represents a novel framework designed to address the increasing demands on network capacities. It distinguishes itself from previous generations of cellular networks by functioning as a distinct network slice within the 5G/6G networks [7]; the network slicing can adapt to the concept of our proposed work.

The subsequent sections of the paper are structured in the following manner. Section II provides a literature survey. UFMC transceiver structure is presented in Section III. Section IV presents the simulation results and discussion. Section V presents the work conclusions.

II. Literature Review

Previous researchers made several attempts to lower the OOBE; they used a variety of strategies to address this issue. The methodology utilized in [8] involves pairing and mapping the transmitted symbols of the input to expanded constellations. This pairing and mapping process ensures a 180-degree differentiation between subcarriers within each group. In contrast to OFDM, the sidelobes experience an average reduction of 10 dB with this methodology. Although the utilization of higher-order constellation symbols leads to a 1 dB enhancement in peak-to-average power ratio (PAPR), it also increases BER. However, it is important to note that the reduction in PAPR is constrained, and expected to be a deterioration in BER.

Kryszkiewicz and Bogucka [9] employed the optimized Cancellation Carriers selection (OCCS) method, which resulted in reduced out-of-band (OOB) power, decreased computing complexity, and lower PAPR compared to OFDM. The improvement in BER performance is only slightly superior to that of the conventional CCs method. On the other hand, Lasya [10] decreased PAPR and OOB power by combining selected mapping (SLM) and precoding or clipping and precoding. Moreover, Selim and Doyle [11] employed combining constellation expansion (CE) and advanced cancellation carriers (ACC) techniques, which results in an overall OOBE enhancement of about 8db compared to conventional OFDM. Furthermore, Tom *et al.* [12] used the procedure Suppressing alignment creates a suppressing signal to lower the OOB power leakage and PAPR of OFDM-based systems, resulting in a significant reduction in both the OOB power leakage and the PAPR but a trade-off between reducing OOB power leakage and lowering PAPR. Wu *et al.* [13] also used the Precoding method, and the OOB emission reduction performance is improved compared to OFDM.

In recent years windowing methods are one of the broadest strategies in use to decrease OOBE , as it employed in [14], which lowered the resource block (RB) length and reduced the OOB level compared to OFDM by using non-extended windowing; however, it is anticipated that windowing without extension of the window may worsen BER performance. Moreover, When the window length is extended in a windowing and restructuring (WR) for an OFDM-based system [15], The spectrum's OOB power is reduced even more, and BER performance may be regulated by modifying the window length. It's a trade-off between reduced OOB power and improved BER performance. Compared to Dolph-Chebyshev Filter, the Fractional Powered Binomial Filter (FPBF) for UFMC in [16] has lower side lobe levels and less adjacent channel interference, leading to greater bandwidth efficiency. Yarrabothu and Nelakuditi [17] employed UFMC with the Kaiser-Bessel window and provided slightly better sidelobe suppression than UFMC, according to the Dolph-Chebyshev window.

Moreover, a developed pulse shaping filter is employed [18] to lower the OOB radiation in the GFDM system; a maximum OOB radiation of –82.95 dB was attained, greatly outperforming the raised cosine (RC) and being more effective in decreasing the PAPR and BER of the GFDM transmitted signal than the RC pulse shaping filter. On the other hand, the windowing approach used the single sideband (SSB) CP-OFDM system [19], which had 63 dB OOB power at a window length of 32 with the usage of the Kaiser window, resulting in a decrease in BER. Another windowing employed in [20] is the Single Extension Windowing (SW) method, which increases the symbol length by increasing the windowing length and achieves an OOB 26 dB lower than CP-OFDM, although BER performance deterioration is proven.

Moreover, compared to orthogonal time frequency space (OTFS) and OFDM systems, the WR-OTFS system was employed [21], the system can lower the OOB power level by more than 66 dB, and the WR-OTFS method can achieve a gain of 10 dB over OFDM at BER of 10^{-3} . The addition of decomposed selective mapping (Dcomp-SLM) to the UFMC system utilized in [22] resulted in a 5 dBW/Hz improvement in PSD performance over the traditional UFMC. The utilization of Kaiser windowing has been studied in [23, 24], resulting in a noteworthy reduction in OOBE and a considerable enhancement of the PSD. This improvement in PSD has significantly enhanced the BER for high Signal to Noise Ratio (SNR) values. In another study [25], researchers investigated the use of Quantized massive MIMO-UFMC with a piecewise linear companding (PLC) scheme for OOB reduction; results showed that this approach exhibited lower sidelobe levels compared to other companding techniques and demonstrated superior bit error rate (BER) characteristics when compared to de-companding systems. Universal Windowing multi-carrier (UWMC) was employed by [26], which resulted in a decrease in OOBE, higher spectral efficiency, and BER equivalent to traditional windowed OFDM (W-OFDM). The improved partial transmits sequence (PTS) technique employed in [27] reduces the high PAPR and OOB radiation that improves PSD.

Hammoodi *et al.* [28] employed pulse windowing techniques utilizing a modified Kaiser-Bessel filter instead of the conventional Dolph-Chebyshev filter for UFMC-based waveforms; results indicated that the approach yielded superior sidelobe suppression compared to UFMC-based waveforms utilizing a standard Dolph-Chebyshev and Kaiser window. On the other hand, Sam *et al.* [29] employed windowing and filtering techniques. Utilizing both windowing and filtering techniques results in a highly confined spectrum, leading to substantial suppression levels in the adjacent channels. Moreover, Liu *et al.* [30] tried the linearized alternative direction method of multipliers (LADMM). The findings indicate that the LADMM algorithm performs better in mitigating PAPR and OOB radiation than existing methods. Additionally, the LADMM algorithm demonstrates superior BER performance relative to alternative methods.

In this paper, we propose a new technique for UFMC, which is multi-windowing UFMC based (MW-UFMC); with this technique, there is no need for only one window might be sharp and complicated or shallow with light complexity to comprehend all the data. Multi-windowing gathers parts of different windows, constructing one window with different windowing aspects, making sending different types of data over one window easy, maintaining acceptable complexity, latency, BER, and good PSD.

UFMC suffers from OOBE and ACL, and the most common approach to deal with these problems is by applying a windowing technique on UFMC. Because of the diversity of using the data, some users need high data rates with high quality, like video chat, and others might not need that high-performance application like emailing or voice call; a modulation scheme is required to decide how to deliver the service to the users, all above make the Multi Windowing necessary to manage the band adequately.

III. UFMC Transceiver Structure

To effectively address a wide range of demands, it is imperative to employ alternative data transmission methodologies apart from Orthogonal Frequency Division Multiplexing (OFDM). One of the primary methods employed to address the challenges of high PAPR and high OOB emissions is the utilization of filter-based waveforms, such as the Universal Filtered Multi-Carrier (UFMC) scheme [31], which is split the band into a number of subbands and each one includes a number of subcarriers.

Using a simple one-to-one data transmission to describe our UFMC system. Supposed that are N allotted subcarriers for transmission to the K_{th} users. N is the whole number of subcarriers split into B sub-bands. Assume that the i_{th} sub-band has M_i Subcarriers. Consequently, the following formula resulted:

$$\sum_{i=1}^{B} M_i = N \tag{1}$$

For each subband, N-length IFFT and L-length filtering is used. Hence, the data vector $x_{i,k}$ will have length $N + L - 1$.

Finally, the time-domain broadcast vector x_k to the K_{th} user would be a superposition of filtered components from the B sub-bands:

$$x_k = \sum_{i=0}^{B} (x_{i,k} * f_{i,k}) \tag{2}$$

where $f_{i,k}$ is the filtering for the i_{th}sub-band and $x_{i,k}$ is the i_{th} sub-band data vector after applying N point IFFT. Eq. (2) might be expressed in vectorial form by utilizing the Toeplitz matrix for filtering and the IDFT matrix for IFFT. Finally, the K_{th} user's UFMC signal may be expressed as:

$$x_k = \sum_{i=1}^{B} F_{i,k} V_{i,k} S_{i,k} \tag{3}$$

where $F_{i,k}$ denotes to the Toeplitz matrix; it holds the filter impulse responses used to execute the linear convolution and $V_{i,k}$ is the IDFT matrix that assigns complex symbols S_i to the assigned subcarriers [32].

It is important to note that if the filter order is 1, the UFMC is constructed to the ZP-OFDM. The UFMC transceiver block diagram is illustrated in Fig .1 [33].

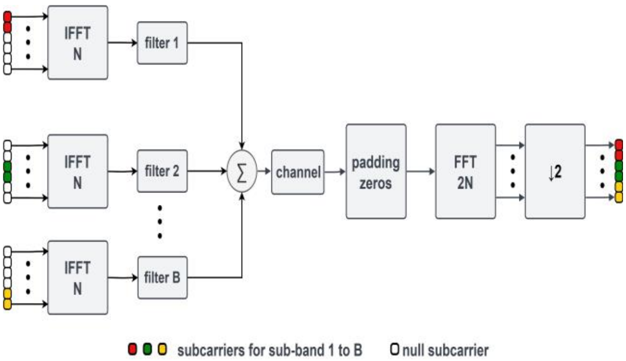


Figure 1. UFMC system block diagram.

For complexity reasons, the received signal zero-padded and passed the next power of 2 FFT at the receiver side, and this is because it is usually applied FFT or IFFT with a power of two points since it takes less time. The signal needed post-processing, such as equalization and downsampling by a factor of 2. Like in F-OFDM, the filtering operation is the core of this technique. Therefore, it should be applied and appropriately built [1].

The multi-windowing intended to lower BER by using windows precisely according to the data quality and what part of the window should be chosen. The window function plays a crucial role in shaping the PSD of the windowed signal, and different window functions can be used to achieve different spectral properties. The time-frequency domain relationship is expressed below.

$$X_W(f) = X(f) * W(f) \tag{4}$$

where $X\ (f)$ is the original signal, $W(f)$ is the window function, $X_W\ (f)$ the signal after windowing.

The power spectral density of the windowed signal can be computed as follows:

$$P_{X_{W(f)}} = P_{X(f)} \times |W(f)|^2 \quad (5)$$

where $P_{X(f)}$ is the power spectral density of the original signal, $|W(f)|^2$ is the squared magnitude of the Fourier transform of the window function, and $P_{X_{W(f)}}$ is the power spectral density of the windowed signal [34].

The window function can be chosen based on the desired shape of the power spectral density of the windowed signal, to reduce the out-of-band emissions caused by the filter bank, a window function $w(n)$ is applied to each subcarrier signal $x(n)$. The windowed signal is given by:

$$x_w(n) = x(n).w(n) \quad (6)$$

where $x_w(n)$ is the windowed subcarrier signal [35].

The window function $w(n)$ is designed to minimize the out-of-band emissions of the windowed signal while maintaining good spectral containment of the signal in the passband. The choice of windowing function and the OOBE level can significantly impact the system's Adjacent channel leakage ratio (ACLR) performance. It is the ratio of power between the main channel and those channels around the main channel. Better ACLR leads to better usage of the spectrum and less interference with neighboring bands. We can express this ratio in decibels using this formula:

$$ACPR_{dB} = \left(P_{adj}\right)_{dB} - \left(P_{ch}\right)_{dB} \quad (7)$$

where *Pch* is the main channel power, and *Padj* is the power in the adjacent channel [26].

The windowing technique can be used to improve a communication system's bit error rate (BER) performance. The BER is the ratio of the number of bits in error to the total number of bits transmitted, and it is a key performance metric for any communication system. The mathematical model for the windowing related to the BER can be described as follows [36]:

$$BER = \frac{1}{2}\, erfc\left(\sqrt{\frac{E_b}{N_0}}\right) \quad (8)$$

where erfc is the complementary error function, E_b is the energy per bit, and N_0 is the power spectral density of the noise. The BER equation shows that the BER decreases with increasing $\frac{E_b}{N_0}$, which measures the signal-to-noise ratio (SNR).

To improve the BER performance, a window function is applied to the transmitted signal before it is transmitted, which is designed to reduce the spectral leakage and out-of-band emissions of the transmitted signal, which can reduce the noise and interference at the receiver and improve the BER performance.

IV. Result and Discussion

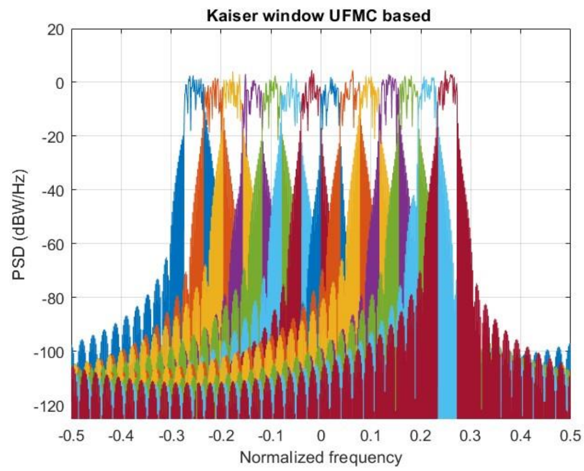
This work evaluated MW-UFMC waveforms performance compared with conventional UFMC, which similarly treats all the sub bands concerning sidelobe suppression. The parameters employed in this simulation are shown in Table I. The work uses 256QAM, which is the limit of 5G 3GPP standardization, UFMC band split into 14 sub bands chosen according to 3GPP [37]. It operates a network with 1000 iterations of input data that behave like a thousand users in the networks with the standard numerology of 15KHz; to match the numerology that is employed with the legacy system and through Additive white Gaussian noise (AWGN) channel; the study focused on AWGN channel to keep track with changes in results of employing different windowing parts.

TABLE I. Parameters Used in the Matlab Simulation

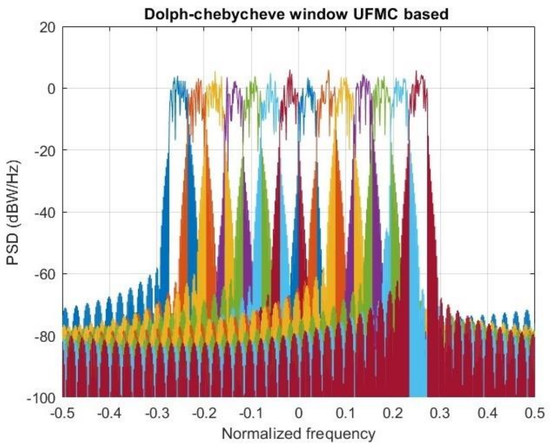
parameter	value
Window	Kaiser, Dolph-Chebyshev, Hanning, and Bohman
β	6
IFFT/FFT	512
Number of subcarriers for each band	20
Number of subbands	14
Subcarriers spacing	15 KHz
QAM	256
Filter length	43
Sidelobe attenuation	40
Channel	AWGN
Monte-carlo iterations	1000

The simulation investigated four different windowed UFMC waveforms, i.e., Dolph-Chebyshev, Kaiser, Hanning, and Bohman; these windowing is proposed to form the parts of the multi-Widowing technique; these parts had different levels of OOBE as illustrated in Fig. 2.

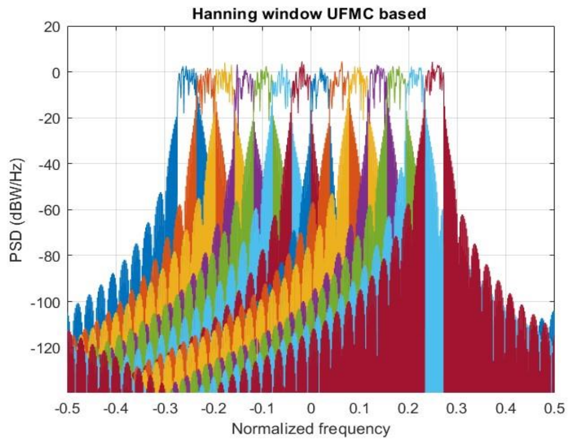
As illustrated in Table II, the preceding figures demonstrate that utilizing different window parts to form multi-windowing resulted in broad OBBE reduction levels compared to conventional UFMC the Dolph-Chebyshev windowed.



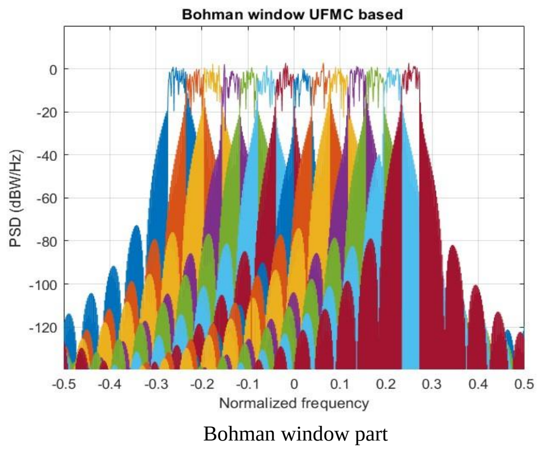
(a) kaiser window part



(b) Dolph-chebyshev windowing part.



(c) Hanning window part.



(d)

Bohman window part

Figure 2. Multi windowing for 5G and beyond.

TABLE II. OOBE LEVEL OF THE MULTI-WINDOWING PARTS

Windowing type	Kaiser	Dolph-chebysheve	Hanning	Bohman
OOBE level (dBW/Hz)	–102.34	–78.65	–109.19	–120.48

Multi-windowing provides an intermediate representation of the employed windowing parts for the entire system. Therefore, it employs a mixture of various features. Placing windows with lower OOBE at the edges can improve spectral efficiency due to reduced OOBE, leading to less ACLR and more throughput. When using windowing parts on the following formation, such as putting three Kaiser windowed subbands on the front edge of the band to enhance the spectral efficiency because of Kaiser OOBE reduction, in the middle of the band four subbands are windowed using Dolph-Chebyshev windowing, other four subbands in the middle are windowed using hanning windowing, as for the tail the band; three subbands are windowed using bohman windowing that has good side lobe suppression even though it suffers from spectral regrowth. Fig. 3 illustrates how the subband windowing is distributed over the band.

This multi-windowing technique provides better spectral usage due to the sharp subbands on the edges, which offer better OOBE. Not all data require high Power Spectral Density (PSD) performance. Therefore, it is necessary to balance the data stream and the windowing utilized. The algorithm depicted below determines the appropriate window segment for processing user data.

Algorithm 1. Window Selection

1- **Begin**

2- choosing the windows part as follows:

- **If** (OOBE < –72 dBW/Hz) ⇒ use the Dolph-Chebyshev Windowing part.
- **Else if** (OOBE < –98 dBW/Hz) ⇒ use Kaiser Windowing part.
- **Else if** (OOBE < –107 dBW/Hz) ⇒ use Hanning Windowing part.
- **Else** ⇒ use Bohman windowing part

3- **End**

Previous algorithm could help us better control the OOBE when using multiple windowing waveforms; less OOBE leads to more throughput through the channel, and the network operator sets subbands according to the data quality. Fig.4 shows BER performance for the UFMC Kaiser window part, UFMC Doloh-chebychev window part, UFMC Hanning window part, UFMC Bohman window part, and CP-OFDM waveforms, and comparing it with multi-windowing for Fig. 3 scenario. To be fair, the BER of CP-OFDM is multiplied by a factor of approximately 2.999 when compared to UFMC since UFMC used several subbands through the band [23, 38]. Still, CP-OFDM uses the entire band, indicating that UFMC demonstrates superior BER performance compared to CP-OFDM under specific conditions and assumptions. CP-OFDM achieved poor performance, which requires more transmission power, whereas UFMC Doloh-chebychev had accepted performance. On the other hand, Kaiser and Hanning windows had better BER that nearly to be alike. Still, the Bohman window UFMC based exhibited a significant improvement in performance when compared to its predecessor, as it demonstrated the lowest BER among the alternative methods, even though it suffered from spectral regrowth; it is a trade-off. Furthermore, the MW-UFMC waveform has shown an advantage when using various Windowing with distinct bands on the receiver; consequently, the data is more secret.

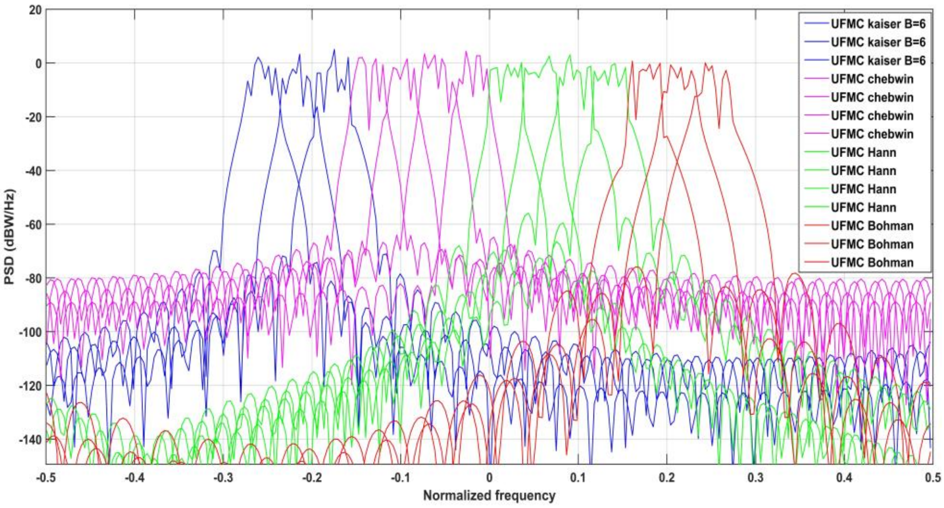


Figure 3. PSD of the Multi-Windowing technique with 256QAM using four window parts.

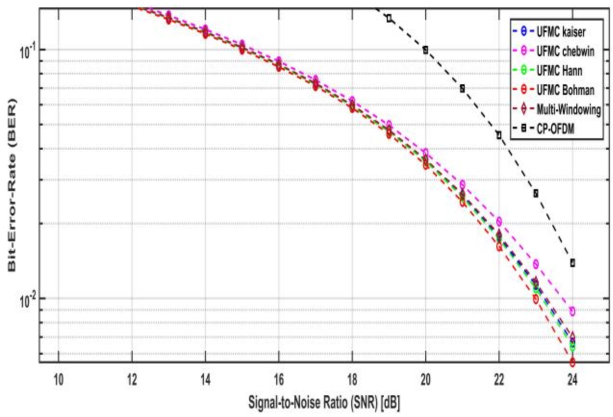


Figure 4. BER performance of different windowing.

This paper focused on some 5G network key parameters PSD, OOBE, ACLR, and BER, but enhancing some parameters might negatively affect others. For example, improving OOBE Could cause an increase in computational complexity or BER rising and vice versa. Multi Windowing tried to be an effective strategy for 5G technology. Since it has reduced latency and improved BER and OOBE than CP-OFDM and provided different parts in the band that can be used differently for different kinds of data weight.

TABLE III. ACLR OF MULTI-WINDOWING TECHNIQUE COMPARED TO CP-OFDM

Technique		**ACLR(dBW/Hz)**
CP-OFDM		–31.3
Conventional UFMC		–77.15
Multi windowing UFMC based	Kaiser window part	–101.93
	Dolph-Chebyshev window part	–77.15
	Hanning window part	–110.7
	Bohman window part	–120.52

To explicate the prevalence of PSD in UFMC relative to CP-OFDM, it is imperative to underscore key performance indicators, specifically the Adjacent Channel Leakage Ratio (ACLR). The definition is clear and lacks ambiguity. The subject matter in question refers to the ratio of power between the primary channel and its adjacent channels. Improved ACLR leads to less interference with the neighboring bands, which results in enhanced efficiency in the utilization of the spectrum. Table III presented the enhancement observed in the ACLR of the Windows component employed in the given investigation.

A comparison between the proposed technique and previous techniques for the same parameters regarding ACLR and BER when SNR is 15dB, as illustrated in Fig. 5.

CP-OFDM and UFMC are afflicted with OOBE, but UFMC is less harmed. Our method can simultaneously enhance OOBE, BER, and ACLR. Moreover, the proposed multi-windowing had low latency due to the diversity of the windowing in this system to handle different kinds of data, heavy or light. The comparison between multi-windowing and the Benchmark reveals the superiority of the Multi Windowed UFMC over the predecessors, as presented in Table IV.

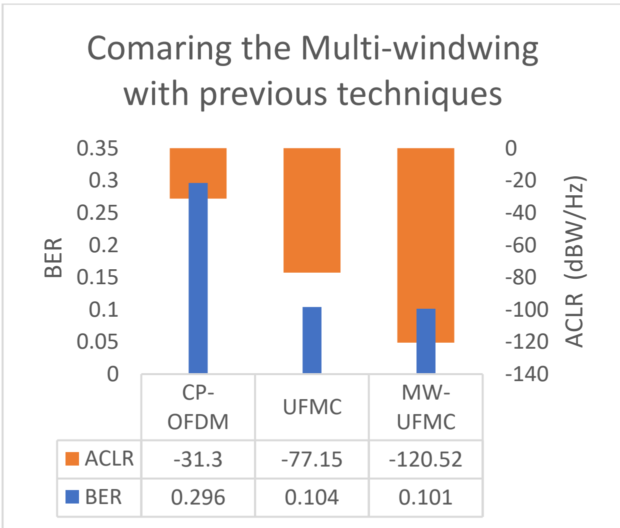


Figure 5. Comparing the Multi-windowing with previous techniques.

TABLE IV. COMPARING OUR MULTI-WINDOWING TECHNIQUE COMPARED BENCHMARK

Ref.	Method	Targeted KPI	The enhancement
Yarrabothu and Nelakuditi [17]	Kaiser Bessel Windowing (UFMC/5G)	PSD BER ACPR complexity	OOBE reduction without BER reduction ACPR enhancement Neglected complexity
Hammoodi *et al.* [26]	Universal Windowing (UFMC/5G)	PSD ACPR	Reduce OOBE no reduction in BER ACPR enhancement
Hammoodi *et al.* [28]	Kaiser-Hankel Windowing(CP-OFDM ,UFMC / 4G, 5G,6G)	PSD BER ACL Complexity	OOBE reduction Enhances BER Enhances ACPR Low complexity
Our proposed MW-UFMC	Multi-Windowing (UFMC/5G and beyond)	PSD BER ACLR Complexity Latency Security Numerology	OOBE reduction BER reduced as SNR increases ACLR enhancement Lower complexity than Kaiser only Lower latency than Kaiser only Better security because of the different windowing parts Different numerologies can be used due to different windowing parts

V. CONCLUSION

This study introduces a novel air interface approach for 5G and future communications, employing the Multi-windowing technique MW-UFMC with 256QAM modulation. This modulation scheme represents the uppermost limit defined by the 3GPP standards. The proposed method is subsequently compared with CP-OFDM and standard UFMC techniques. The results demonstrate that the new approach significantly improves the overall system performance, as evidenced by enhanced BER, improved PSD, reduced OOBE, increased data capacity, lower ACLR, improved spectral SE, decreased latency, and manageable computational complexity. Multi-windowing techniques provide flexibility with windowing utilization depending on the sort of data; the proposed window included different parts of subband groups that employed various windows, which led to realizing a window with multi aspects depending on the window part. The data is organized for transmission by categorizing the sub bands into window parts based on their data type. Results in enhanced flexibility in data transmission and facilitates an appropriate balance between the transmission of large and small datasets. The multi-windowing methodology introduces a multistage service that offers network operators a wide range of options. This technology demonstrates numerous advantages when compared to current systems. That might make MW-UFMC a significant contributor to the next generation of wireless communication.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

This was a teamwork of the participants. Mustafa Mohammed Heil conducted the work and wrote the results. Ahmed Talaat Hammoodi analyzed the data and provided guidance in addition to Jamal Mohammed Rasool, who reviewed the work, and all authors had approved the final version.

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