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Research paper

Filter Optimizing and Maintaining Multi-Rate Processing Using an Optimized Universal Filtered Multi-Carrier (OUFMC) with Cascaded Integrator–Comb (CIC) Filter

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Abstract

Mobile tele-communication plays an important role for transmitting information such as data, images, videos and voice between places. For this purpose, a telecommunication process was introduced with different network generations. Among these various generations, the 5G-based information transmission process improves the overall communication process because it overcomes spectral efficiency issues by utilizing effective modulation techniques. This paper examines the optimized Universal Filtered Multi-Carrier (OUFMC) based modulation technique for improving the communication process. Along with the OUFMC technique, a cascaded integrator–comb (CIC) filter was utilized for maintaining multi-rate processing and computational efficiency. This optimized technique effectively reduces the signal over out-of-band leakage ratio and the distortion over out-of-band leakage ratio. Finally, this paper presents the excellence of the system as evaluated through experimental results.

Keywords: *5G, modulation techniques, optimized Universal Filtered Multi-Carrier (OUFMC), cascaded integrator–comb (CIC) filter, multi-rate processing, computational efficiency.*

1. Introduction

Today, communication technology plays a central role in effective information transformation from one place to another. During the information transmission process, the modulation technique of orthogonal frequency division multiplexing (OFDM) is used for effective transmission in 4G-based communication [1] processes to effectively handle different mobile handsets. Even though the 4G process successfully transmits data, it has difficulties processing multi-rate data and fails to follow computational efficiency. So, the 5G communication process [2] was introduced with relevant waveforms to overcome the above issues and also maintain the energy and signal interface rate. Additionally, modulation techniques were introduced to successfully handle different bandwidths, maintain low-latency transmission, switch between uplink to downlink and minimize low-rate devices successfully. Along with these characteristics, next level performance indicators such as universal filtered multi-carrier (UFMC) [3] are used to process each candidate waveform to attain the best communication results. This UFMC method successfully examines the sub bands and has maximum peak to average power ratio due to the overlap of signals at the time of transmission. So, the average power ratio is minimized by applying several modifications [4] using the modulation techniques introduced by different researchers.

Yunlong Cai et al. [5] analyzed various modulation techniques, such as the non-orthogonal multiple access (NOMA) and orthogonal multiple access (OMA) schemes, that include the code domain and power domain because they help transmit information in 5G networks effectively. In addition, they investigated the multiple access method for managing the changing demands of fifth-generation wireless networks. Frank Schaich et al. [6] discussed three different waveform candidates, Universal Filtered Multi-Carrier (UFMC), Filter Bank Multicarrier (FBMC) and filtered CPOFDM, in the 5G communication process for examining low latency waveform candidates. The introduced waveforms were examined in terms of upper link to downlink switching, flexibility of links, low latency transmission, energy efficiency, synchronization symbols, etc. The researchers examined the waveform candidates according to these features and interrelated them with the 5G communication process.

Ertugrul Basar et al. [7] integrated spatial modulation with the orthogonal frequency division multiplexing technique to improve the efficiency of energy in 5G wireless sensor networks. During this process, the network consists of a relaying process, filter bank, multi-carrier modulation and MIMO system for analyzing the strongest carrier in the physical layer.

From the above discussions, it can be concluded that the 5G communication process is enhanced by applying the Universal Filtered Multi-Carrier (UFMC), which is further optimized by the Cascaded Integrator–Comb (CIC) Filter. This paper presents an analysis of Filter Optimizing and Maintaining Multi-Rate Processing Using Optimized Universal Filtered Multi-Carrier (OUFMC) With Cascaded Integrator–Comb (CIC) Filter in section 2. Section 3 describes the experimental setup and evaluation results and Section 4 presents the conclusion.

2. Filter Optimizing and Maintaining Multi-Rate Processing Using Optimized Universal Filtered Multi-Carrier (OUFMC) with Cascaded Integrator–Comb (CIC) Filter

This section discusses using the Optimized Universal Filtered Multi-Carrier (OUFMC) With Cascaded Integrator–Comb (CIC) Filter as an optimizing filter and to maintain multi-rate processing. UFMC is an effective modulation technique that can be combined to work with the Filter Bank Multi-Carrier modulation process [8]. This process analyzes incoming data; every sub band and each specific subcarrier are filtered with the help of Filter Bank Multi-Carrier modulation process and the group of subcarriers is further filtered by UFMC [9]. This division of sub carrier processes can be used to transmit information effectively. Figure 1 shows the module of UFMC.

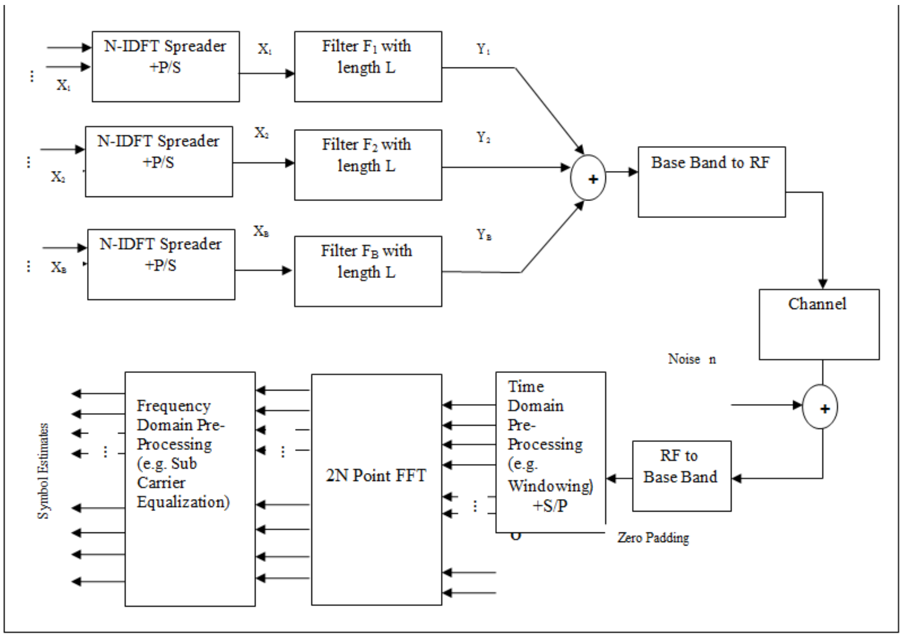

Figure 1 depicts the OUFMC system model that divides the overall bandwidth into different sub-bands B. Each sub band has been allocated to different subcarriers that are related to the Physical Resource Block (PRB) with LTE. The system consists of N number of carriers in which the frequency signal is changed into the time domain signal. The converted signal is filtered with the help of a Cascaded Integrator–Comb (CIC) Filter [10] with a length of L. The CIC filter optimizes the process by combining finite impulse responses with the interpolator process, which analyzes the transmitted signal by using more cascaded integrators and more comb sections to optimize the filtering process. Figure 2 shows the general architecture of CIC multi-rate processing.

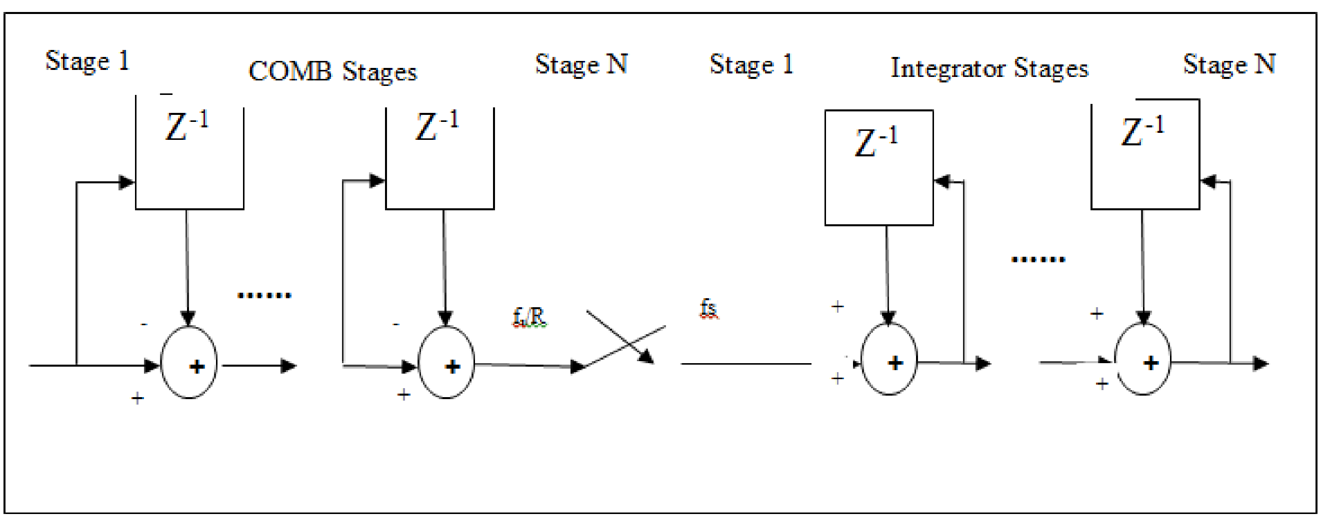

Figure 2:. CIC Interpolator Filtering process

The RRC (Root Raised Cosine) filter generates a serial input signal and produces an output square in each single clock cycle. The RRC filter decreases the computational complexity. So, the CIC filter can be used for all process applications when compared to RRC filters. Then, the CIC function of each signal filtering process is done by applying the following function.

$$H(z) = [\sum_{k=0}^{RM-1} z^{-k}]^N \quad (1)$$

$$\left(\frac{1-z^{-RM}}{1-z^{-1}}\right)^N \quad (2)$$

In the above equations (1 and 2), R represents the interpolation ratio of signal, M is the number of samples at every stage and N denotes the number of stages of each filter. Along with the sampling rate function, the CIC filter utilizes different characteristics, such as linear phase response, delay and addition and subtraction processes [11] while examining the signal. According to the above process, the filtered signals are grouped together and transmitted to the transmitter. Then, the receiver obtains the transmitted signal, which is converted from a time domain into a frequency domain signal. During this transaction, the OUFMC has length N+L-1, in which 0 is added as padding and for 2N-point FFT. Then, the Delta-Dirac function is applied to the signal as follows:

$$Y_m(k) = \sum_{i=1}^{B} \widehat{X_{1,m}}(k) F_{i,m}(k) \quad k = 0, \ldots .2N-1 \quad (3)$$

In the above equation (3), $\grave{x_i}$ and F_i represent the 2N-point FFT based time domain signal. According to the above process, subcarrier data is analyzed and an odd number of data is dropped. The remaining information is considered while transmitting data effectively. Then, the OUFMC is further optimized by maximizing the Signal to Interference Ratio (SIR) using two different stages, such as maximizing the Signal to in-band Distortion plus out-of-band Leakage Ratio (SDLR) and maximizing the Signal to out-of-band Leakage Ratio (SLR). The process represented as follows:

$$SLR(\Delta n, \in) = \frac{\sum_{k'/2\epsilon S_i} f^H S_m^{k'}(\Delta n, \in) f}{\sum_{k'/2\beta \notin S_i} f^H \left(I_{m,ICI}^{k'}(\Delta n, \epsilon) + \left(I_{m,ICI}^{k'}(\Delta n, \epsilon)\right) f\right.} \quad (4)$$

In the above equation (4), the SLR process normalizes the signal and manages the energy of each sub band while transmitting data from the transmitter to receiver. The duration of Δn is $-0.5 \leq \Delta n \leq 0.5$. In addition, the SLR process minimizes [12] the interference between the sub bands and the total

energy of the process is further minimized. The Signal to in-band Distortion plus out-of-band Leakage Ratio (SDLR) is computed as follows.

$$SDLR = \frac{f^H\left(\sum_{k'/2\epsilon S_i} \sum_{\Delta n} \sum_{\in} S_m^{k'}(\Delta n, \in) p\Delta n(\Delta n) p_{\in}(\in)\right) f}{f^H\left(\sum_{k'=0}^{2N-2} \sum_{\Delta n} \sum_{\in} I^{k'}(\Delta n, \in) p\Delta n(\Delta n) p_{\in}(\in)\right) f} \quad (5)$$

The above estimated SLR and SDLR in the above equation (5), measures effectively ensure the signal SIR of each sub carrier. In addition, the optimized UFMC with CIC manages the 5G communication process by optimizing the energy. The

Dolph-Chebyshev filter has a high Bit Error Rate (BER) and low SIR, SLR and SDLR metrics compared with the CIC filter. The following section presents the evaluation of this system's excellence using a simulation.

3. Simulation Results

Table 1 presents the simulation parameters for testing the efficiency of the Optimized Universal Filtered Multi-Carrier (OUFMC) With Cascaded Integrator–Comb (CIC) Filter.

Table 1:. Simulation Parameters

Parameter	Value
Modulation	QPSK
number of total subcarrier	64
number of used subcarrier	32
number of null subcarrier	32
Filter of UFMC	CIC filter Attenuation=60dB, length=10
number of sub band in UFMC	64/8
number of sub band in UFMC	4

By using the above parameters, efficiency of the system was evaluated in terms of the bit error rate (BER) and the SIR, SLR and SDLR metrics. Table 2 shows the obtained values.

Table 2: Performance Values

Modulation Techniques	BER	SIR	SLR	SDLR
OFDM	0.98	17.56	17.32	18.65
UFMC-CW	0.84	29.10	28.46	31.89
UFCM-Opt	0.68	32.71	31.78	34.24
OUFMC-CIC	0.54	48.25	49.32	56.77

Table 2 indicates the efficiency of the OUFMC-CIC method compared with traditional methods such as Orthogonal Frequency Division Multiplexing (OFDM), Universal Filtered Multi-Carrier with Dolph-Chebyshev filter and Universal Filtered Multi-Carrier with optimized. Figure 3 shows a graphical representation of the obtained values. As the name infers, bit error rate is the rate at which errors happen in a transmission framework. This can be straightforwardly converted into the quantity of errors that happen in a string of an expressed number of bits. The meaning of bit error rate can be converted into a basic equation: BER= No. of Errors/Total number of bits sent. [13] The Series Load Resonant converter (SLR) is a DC/DC converter in light of a full circuit which permits delicate exchanging activity. In a delicate exchanging converter, exchanging happens when voltage and additional current esteems are zero, thus enhancing a converter's effectiveness. A change is said to have zero-voltage exchanging (ZVS) and zero-current exchanging (ZCS) when the voltage/current is zero as the switch changes state. The converter comprises of a full-connect MOSFET connect, a thunderous tank spoke to by the Lr inductor and Cr capacitor hinder, a full-connect rectifier and a yield channel (Co). The thunderous recurrence of the tank is given by:

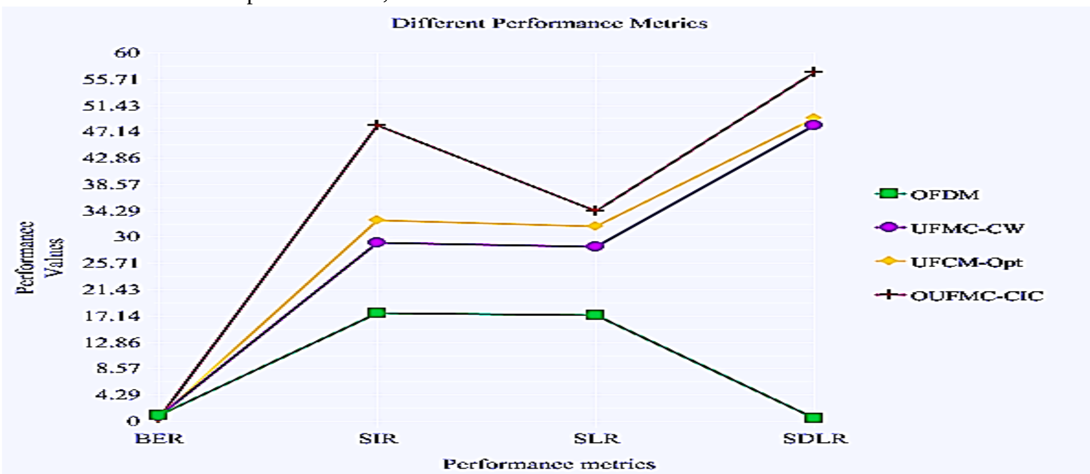

Figure 3: Different Performance Metrics with total subcarrier 64

Figure 3 clearly indicates that the proposed OUFMC with CIC method ensures the minimum bit error rate that improves the Signal to Interference Ratio (SIR) while transmitting data in a 5G communication process. In addition, this method maximizes the SLR and SDLR processes effectively.

Table 3 presents the simulation parameters for testing the efficiency of the Optimized Universal Filtered Multi-Carrier (OUFMC) With Cascaded Integrator–Comb (CIC) Filter for the total sub carrier of 128.

Table 3: Simulation Parameters

Parameter	Value
Modulation	QPSK
number of total subcarrier	128
number of used subcarrier	32
number of null subcarrier	32
Filter of UFMC	CIC filter Attenuation =60dB, length=10
number of sub band in UFMC	128/8
number of sub band in UFMC	4

By using the above parameters, the efficiency of the system was evaluated in terms of bit error rate (BER) and the SIR, SLR and SDLR metrics. Table 4 shows the obtained values.

Table 4: Performance Values

Modulation Techniques	BER	SIR	SLR	SDLR
OFDM	1.38	21.57	24.46	1.00
UFMC-CW	1.85	33.10	28.46	55.25
UFCM-Opt	1.68	35.71	33.76	53.22
OUFMC-CIC	0.54	54.67	39.40	66.78

Table 4 indicates the efficiency of OUFMC-CIC method compared with traditional methods, such as Orthogonal Frequency Division Multiplexing (OFDM), Universal Filtered Multi-Carrier with Dolph-Chebyshev filter and Universal Filtered Multi-Carrier with optimized, for the total subcarrier length of 128. Figure 4 shows a graphical representation of the obtained values.

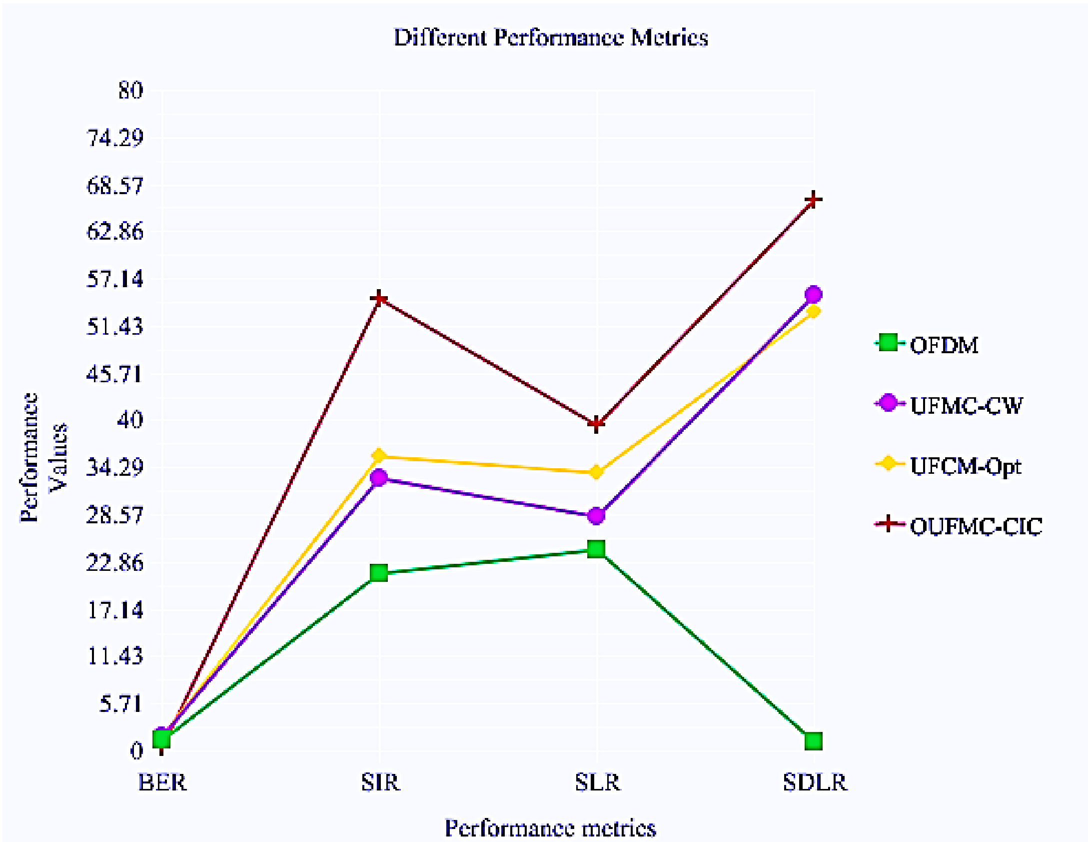

Figure 4:. Different Performance Metrics with total subcarrier 128

Figure 4 clearly indicates that the proposed OUFMC with CIC method ensures the minimum bit error rate that improves the Signal to Interference Ratio (SIR) while transmitting data in a 5G communication process. In addition, this method effectively maximizes the SLR and SDLR processes for the subcarrier length of 128.

Table 5 presents the simulation parameters for testing the efficiency of the Optimized Universal Filtered Multi-Carrier (OUFMC) With Cascaded Integrator–Comb (CIC) Filter for a total sub carrier of 512.

Table 5:. Simulation Parameters

Parameter	Value
Modulation	QPSK
number of total subcarrier	512
number of used subcarrier	32
number of null subcarrier	32
Filter of UFMC	CIC filter Attenuation =60dB, length=10
number of sub band in UFMC	512/8
number of sub band in UFMC	4

By using the above parameters, the efficiency of the system was evaluated in terms of bit error rate (BER) and the SIR, SLR and SDLR metrics. Table 6 shows the obtained values.

Table 6: Performance Values

Modulation Techniques	BER	SIR	SLR	SDLR
OFDM	1.38	21.57	24.46	1.00
UFMC-CW	1.85	33.10	28.46	55.25
UFCM-Opt	1.68	35.71	33.76	53.22
OUFMC-CIC	0.54	54.67	39.40	66.78

Table 6 indicates the efficiency of the OUFMC-CIC method compared with traditional methods such as Orthogonal Frequency Division Multiplexing (OFDM), Universal Filtered Multi-Carrier with Dolph-Chebyshev filter and Universal Filtered Multi-Carrier with optimized. Figure 5 shows the graphical representation of the obtained values. [14]

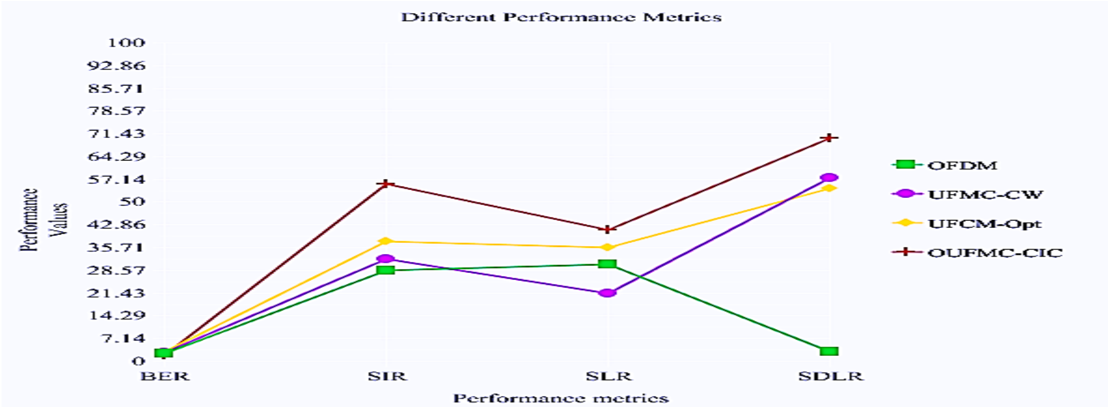

Figure 5: Different Performance Metrics

Figure 5 clearly indicates that the proposed OUFMC with CIC method ensures the minimum bit error rate that improves the Signal to Interference Ratio (SIR) while transmitting data in a 5G communication process. In addition, this method effectively maximizes the SLR and SDLR processes. The signal-to-noise proportion (SNR) is expressed in decibels of a flag by registering the proportion of its summed squared magnitude to that of noise. These values increased in all cases. From this discussion, it is concluded that the BER rate of the proposed method is reduced, compared to other methods.

4. Conclusion:

In this paper, we introduced different multi-rate filter structures using various optimization techniques which resulted in high speed, high throughput and high computation rate. Multi-rate filter structures were implemented for decimation using the MATLAB modeling tool and the best decimation optimized Universal Filtered Multi-Carrier (OUFMC) based modulation technique to improve the communication process. Along with the OUFMC technique, a cascaded integrator–comb (CIC) filter was utilized to maintain the multi-rate processing and computational efficiency. The optimized structure also yielded higher throughput and computation rate compared to other structures, as well as better signal over out-of-band leakage ratio and distortion plus out of band leakage ratio. This optimized technique, which helps in 5G-based information transmission procedures, improves the overall communication process because it overcomes spectral efficiency issues by utilizing effective modulation techniques. The excellence of this system was evaluated with the help of experimental results.

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References

[1] V. Vakilian, T. Wild, F. Schaich, S. t. Brink, and J.-F. Frigon, “Universal Filtered Multi-Carrier Technique for Wireless Systems Beyond LTE”, Proceedings of 9th International Workshop on Broadband Wireless Access, IEEE Globecom'13, Atlanta, GA, USA, Dec. 2013.

[2] G. Wunder, M. Kasparick, T. Wild, F. Schaich, Y. Chen, S. t. Brink, et al., “5GNOW: Application Challenges and Initial Waveform Results,” Proceedings of Future Network & Mobile Summit 2013, Lisbon, July 2013.

[3] C. Lin and G. Y. Li, “Terahertz communications: an array-of-subarrays solution,” IEEE Commun. Mag., vol. 54, no. 12, pp. 124–131, Dec. 2016.

[4] M. Al-Imari, P. Xiao, M. A. Imran, and R. Tafazolli, “Uplink non-orthogonal multiple access for 5G wireless networks,” in Proc. Int. Symp. Wireless Commun. Syst. (ISWCS), Barcelona, Spain, pp. 781–785, Aug. 2014.

[5] Y. Cai, Z. Qin, F. Cui, G. Y. Li, and J. A. McCann, “Modulation and Multiple Access for 5G Networks”, https://arxiv.org/pdf/1702.07673.pdf.

[6] F. Schaich, T. Wild, and Y. Chen, “Waveform contenders for 5G – suitability for short packet and low latency transmissions”, http://www.ece.tufts.edu/ee/108/Reading6.pdf.

[7] E. Basar, “Index modulation techniques for 5G wireless networks”, IEEE Communications Magazine Vol. 54, no. 7, July 2016.

[8] C.-X. Wang, "Cellular Architecture and Key Technologies for 5G Wireless Communication Networks", IEEE Commun. Mag., vol. 52, no. 2, pp. 122-30, Feb. 2014.

[9] B. Farhang-Boroujeny, “Ofdm versus filter bank multicarrier,” Signal Processing Magazine, IEEE, vol. 28, no. 3, pp. 92–112, May 2011.

[10] M. A. A. Hasan, F. Nabita, A. Khandakar, I. Ahmed, and F. Ahmed, “Analytical Evaluation of Timing Offset Error in OFDM System,” Communication Software and Networks, vol.3, no.7, pp.26-28, Feb. 2010.

[11] C.-C. Cheng, "Enhanced Spatial Modulation with Multiple Signal Constellations", IEEE Trans. Commun., vol. 63, no. 6, pp. 2237-48, June 2015.

[12] D. Basnayaka, M. Di Renzo, and H. Haas, "Massive but Few Active MIMO", IEEE Trans. Vehic. Tech., no. 99, pp. 1-17, Oct. 2015.

[13] D. A. Basnayaka, M. Di Renzo, and H. Haas, Massive but few active MIMO. IEEE Transactions on Vehicular Technology, vol. 65, no. 9, 6861-6877. 2016.

[14] E. G. Larsson, O. Edfors, F. Tufvesson, and T. L. Marzetta, Massive MIMO for next generation wireless systems. IEEE communications magazine, vol. 52, no. 2, 186-195. 2014.