

Study and Analysis of UFMC Technology in 5G Communications

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Abstract

Wireless communication technology plays a significant role in the development of mobile technology. Every user requires their own spectrum. However, spectrum bands are limited. Therefore, the communication system must be efficient. This paper discusses the Universal Filtered Multi-Carrier (UFMC) technology, a new promising technology intended to improve mobile networks in the future. This technology is less susceptible to estimate errors of time shifts and frequency shifts. 5G's major goals are speed, low latency, Quality of Service, and channel capacity. Physical layer waveform generation must be flexible in order to meet these requirements. Currently, 4G-LTE transmissions are not compatible with 5G technologies because of Out of Band radiation and high Peak to Average Power Ratio (PAPR). A future cellular network could benefit from UFMC. The performance of UFMC is evaluated using Power Spectral Density, PAPR, Signal-to-Noise Ratio, and Bit Error Ratio for 5G wireless communications. It is possible that UFMC will be more efficient and gives better solution.

Keywords: 4G, 5G, UFMC, PAPR, PSD, BER, SNR

1. Introduction

Recently, wireless communication has become highly dependent on high throughput and high speed. In contrast to high-speed wired communications, wireless communication is having greater popularity. As wireless applications demand increases and the number of connected users exponentially increases [1], the current Wireless Communication Systems (WCSs) are saturated. In order to facilitate the development of 5G wireless networks, solutions that use intelligent and efficient technologies must be used. An efficient, reliable, and secure 5G network faces many challenges [1]. The degradation of wireless communication occurs in a number of ways, including small scale fading, large scale fading,

distortion, and HPA nonlinearities. A multiple carrier transmission is used in the place of a single carrier transmission to meet these needs [2]. According to recent statistics, data usage is expected to rise by 30% in the next few years, which cannot be accommodated by the current technologies. Therefore, it is necessary to develop next generation WCSs. The 5G WCS is currently being rolled out around the world. Commercial availability of the system is expected in 2021. The medical field, the health sector, and the educational sector are also experiencing huge growth in demand [3]. 5G mobile technology promises faster wireless speeds, better security, and better accessibility.

The potential of 5G networks to offer an automated and immersive service have limitations [4]. Even though 5G systems outperform current systems in many ways, in 10 years these technologies won't be able to meet the demands of emerging intelligent and automated ideas. More features and better Quality of Service (QoS) are available on the 5G network than the 4G. Some of the highlights of 5G include the addition of new frequency bands, enhanced spectrum management techniques, and the combination of licensed and unlicensed channels [4-5]. Compared to current technology, 5G provides increasing power efficiency, lower overhead, and better signal synchronization. It also enables applications such as the IoT and machine-to-machine communication to succeed [6].

Over the past several decades, multicarrier modulation has been essential to the development of broadband communication systems [7]. Multicarrier modulation transmits parallel streams of information in the frequency domain at various center frequencies, which has proven to be fairly efficient at transmitting large amounts of data while offering higher robustness for communication against various impairments. Data is carried using a large number of closely spaced orthogonal subcarriers in the 4G technology LTE [8]. A guard band isn't necessary in order to separate different subcarriers. In Orthogonal Frequency-Division Multiplexing (OFDM), a Cyclic Prefix (CP) is added to each symbol as excess bits. The addition of the CP produces circular convolution by removing the interference between symbols [9]. There is a decrease in spectral efficiency due to the CP. There is also high Peak to Average Power Ratio (PAPR) with OFDM. The OFDM technique does not work well for 5G due to its major drawbacks. New techniques such as Universal Filtered Multi-Carrier (UFMC) are needed [10].

An UFMC filter reduces Out of Band (OoB) emissions by filtering a group of subcarriers. Due to the filter's wide bandwidth and its impulse response being short, it can reach high spectral efficiency in short bursts, since its bandwidth covers several subcarriers.

In UFMC, since there is no CP, the filters may be designed in a manner equivalent to CP-OFDM in terms of their total block length. In UFMC, there is no requirement for CP, so it is sensitive to small time misalignments [11]. The rest of the paper is organized as follows: Section 2 describes the UFMC technology for 5G. Section 3 analyzes the simulation results. Finally, the conclusion is presented in section 4.

2. Universal Filtered Multi-Carrier

Figure 1 shows the block diagram of the UFMC transmitter. The total bandwidth B is divided into K sub-bands according to the block diagram. There are N subcarriers in each sub-band. N subcarriers are modulated with QPSK, 4QAM, 16QAM, or 256QAM. FBMC does not require OQAM modulation, but rather demonstrates the principle of orthogonal subcarriers by passing complex QAM modulated symbols through IDFT instead [12]. Dolph-Chebyshev filtering is used for each sub-band. According to the number of FFT points used, the length of the filter is selected. In OFDM, CP is almost the same length as the IFFT. With UFMC, the OoB radiation is reduced, and the ICI is minimized as a result of filtering. The UFMC signal is generated by summing the filtered signals from each sub-band. In [14], UFMC uses the zero prefix to avoid ISI. When filter length is equal to or less than ZP, the filter should be suitable. In multipath environments, performance will improve as a result of adding ZP. UFMC utilizes sub-band filtering to improve frequency coverage, so the filter length is reduced, hence short burst transmission is well-suited to it. There is less complexity associated with UFMC implementation compared with OFDM [13]. Figure 1 also shows the UFMC receiver. The transmitter of UFMC uses filters. In UFMC, the received symbol has length $N+L_f-1$. The $2N$ point FFT recovery of data symbols from the UFMC is achieved at the receiver by adding $N-L_f-1$ zeros. The data is recovered only when the even bits of $2N$ point FFT are considered, since all odd sub carriers contain ISI.

UFMC base band signal is represented as,

$$x(n) = \sum_{p=0}^{K_{sb}-1} \sum_{q=0}^{L_f-1} \sum_{r=0}^{N-1} D_r^p g[q] e^{\frac{j2\pi n(r-1)}{N}}$$

Here, K_{sb} is the number of sub bands, Filter length is L_f , and FFT points are N .

In order to calculate FIR filters with specified parameters, a sequence of weights of finite length is used; these weights are called weight windows, which limit an ideal filter's infinite impulse response [15]. Using a weight window to specify a digital filter's

characteristics, the weighting method is used to determine its characteristics. The mathematical equation of finding time-limited functions can be used to determine a good weight window. This can be approximated with a Fourier transform, which is frequency limited. Within the frequency range, their energy share is minimal. An important factor that affects the characteristics of the systems using the UFMC technology is the length of the weighting window of the filter [16]. In order to reduce OoBR of UFMC signals, it is necessary to use long-length weighting sequences. As a result, the filter expands its impulse response.

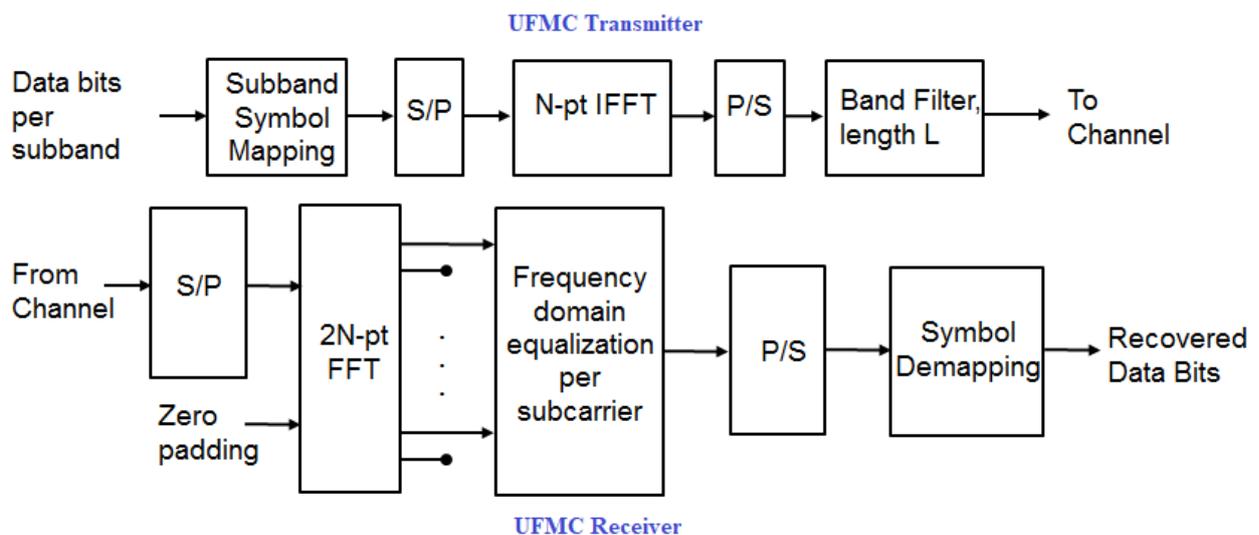


Figure 1. UFMC Transceiver and Receiver

3. Simulation Results

Performance evaluations of UFMC are discussed in this section. MATLAB has been used to evaluate the performance of UFMC. The simulation parameters are listed in Table 1. Figure 2 shows the Power Spectral Density (PSD) of UFMC. The spectrum represents the superimposition of 10 UFMC sub bands, each of which contains 20 subcarriers carrying 16QAM data symbols. Table 2 and Fig.3 illustrate a comparison between the Signal-to-Noise Ratio (SNR) and the Bit Error Ratio (BER) of the UFMC for the 16QAM scheme on an AWGN channel. Figure 4 displays the spectral efficiency of UFMC.

Table 1. Simulation Parameters

Simulation Parameter	Value
Simulation tool	MAT Lab
No. of FFT points	512, 1024
No. of Sub-bands	10

Sub-band Offset	156
Filter Length	43
Modulation	4,16, 64, 256 QAM
Filter	Dolph-Chebyshev filter
Sub-band Size	20

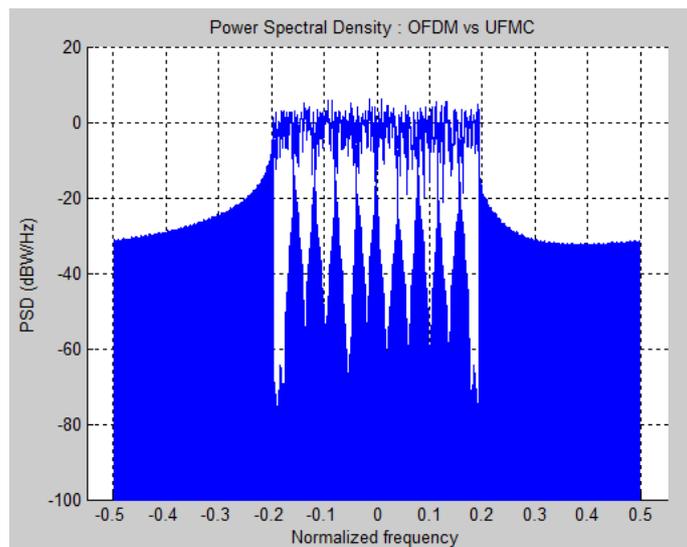


Figure 2. PSD of UFMC

Table 2. UFMC: SNR vs BER

SNR (dB)	BER
1	0.1737
2	0.1437
3	0.1325
4	0.10875
5	0.0875
6	0.06625
7	0.045
8	0.035
9	0.0225
10	0.01125
11	0.005
12	0.0025
13	0.0025
14	0.00125
15	0

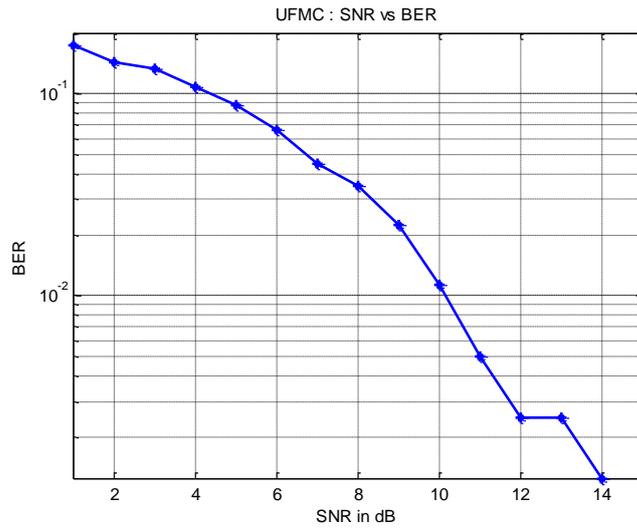


Figure 3. UFMC: SNR vs BER

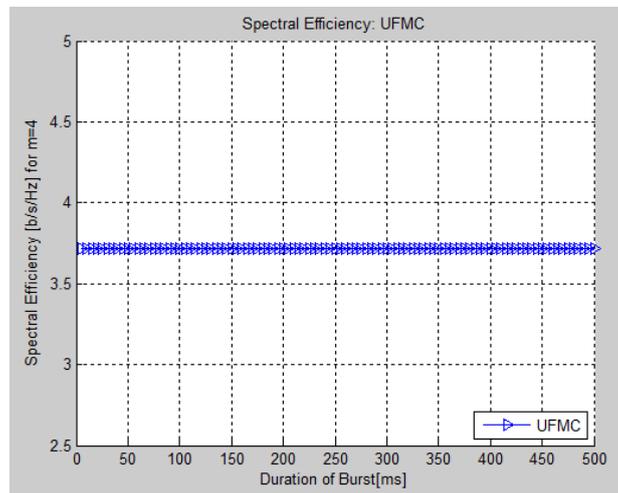


Figure 4. UFMC: Spectral Efficiency

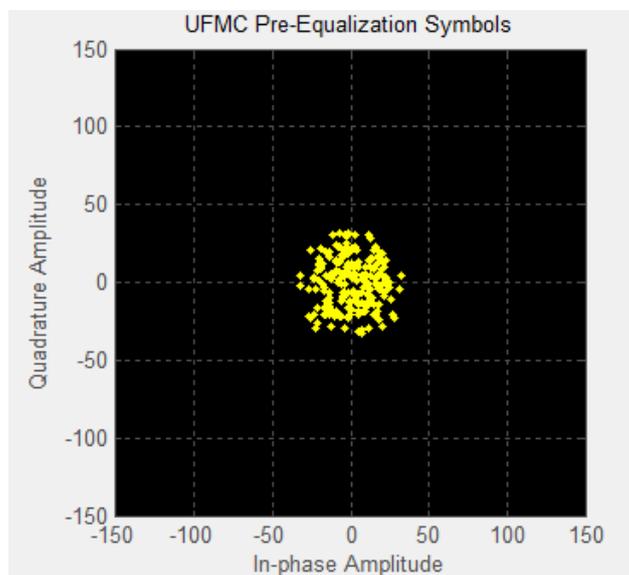


Figure 5. UFMC: Pre-equalization Symbols

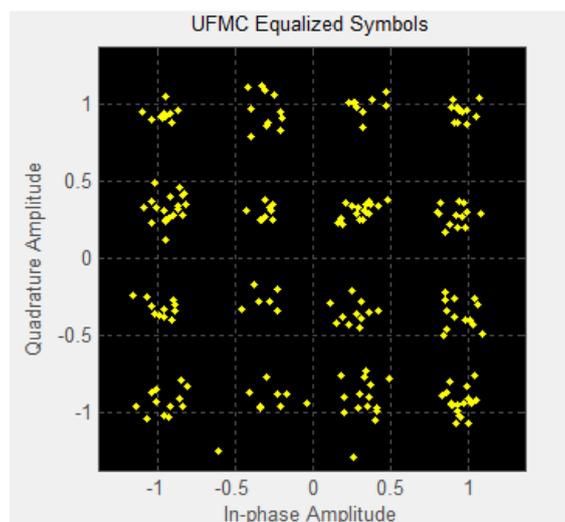


Figure 6. UFMC: Equalized Symbols

Table 3. UFMC: PAPR Analysis

No. of FFT points	Modulation	PAPR (dB)
512	4QAM	9.0473
512	16QAM	8.2379
512	64QAM	8.6229
512	256QAM	8.0416
1024	4QAM	7.7732
1024	16QAM	8.2967
1024	64QAM	9.6202
1024	256QAM	7.5373

4. Conclusion

Orthogonal Frequency-Division Multiplexing (OFDM) is a technique used in 4G technology that has some disadvantages, such as high Peak to Average Power Ratio (PAPR) and low spectral efficiency. The Universal Filtered Multi-Carrier (UFMC) provides solutions to these drawbacks. In contrast to LTE-Advanced networks using OFDM technology, UFMC provides greater spectral efficiency for 5G networks. UFMC does not require a Cyclic Prefix; UFMC leads to greater data transmission rates, which means increased protection against inter-symbol interference. In this paper, the Power Spectral Density, Spectral Efficiency, PAPR, Bit Error Ratio and Signal-to-Noise Ratio of UFMC are analyzed. The UFMC waveform has better spectral efficiency, and therefore is a better candidate for 5G communication. With UFMC, the Out of Band Emission is reduced by using sub-band

filtering. A UFMC transmission can be made MIMO compatible by using QAM modulation. 5G cellular networks employ the UFMC waveform for asynchronous transmissions.

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