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Study and Comparative Analysis of OFDM and UFMC Modulation Schemes

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Abstract: In various areas, wireless systems are used. In order to allocate the available time and frequency resources, these wireless systems require flexible mechanisms. With 5G, transmission rates will be higher, latency will be lower and quality of service and channel capacity will be higher. The physical layer must be able to generate flexible waveforms to meet the above requirements. Currently, Orthogonal Frequency Division Multiplexing (OFDM) transmission does not support 5G communication. In the case of 4G/OFDM, there are many problems in terms of out of band emission, spectral efficiency, and peak to average power ratio (PAPR). An alternative transmission scheme Universal Filtered Multicarrier (UFMC) is introduced to address this problem. The paper compares OFDM with UFMC. The purpose of this paper is to discuss Spectral Density, Spectral Efficiency, Signal to Noise Ratio (SNR) and Bit Error Rate (BER). In comparison to OFDM, UFMC provides better performance.

Keywords : Bit Error Rate (BER), Universal Filtered Multicarrier (UFMC), Orthogonal Frequency Division Multiplexing (OFDM), Power Spectral Density (PSD), Multi Carrier Modulation (MCM),) Signal to Noise Ratio (SNR).

1. INTRODUCTION

The OFDM modulation technique is the most desirable for 4G systems. A major advantage of OFDM is that it is robust to channel delays, contains single-tap frequency equalization, and is technically straightforward to use [1]. The system must be highly synchronized in order to support high data rates. The OFDM modulation system has a high efficiency for bandwidth utilization [2]. There is no inter-symbolic interference(ISI).

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In 4G technology LTE [3], data is transmitted by a large number of orthogonal subcarriers, which are closely spaced. It is still possible to receive the sidebands from both carriers without interference even though they overlap [4]. This is due to their orthogonal alignment. Separating subcarriers does not require guard bands. An OFDM symbol with a cyclic prefix(CP) includes repeated bits [5]. In order to eliminate inter-symbol interference, CPs are added to end up with circular convolutions. This decreases spectral efficiency, increases BER and increases PAPR due to the use of CP. Therefore, 5G communication[6-7] cannot be efficiently achieved with this technique. A new technique such as UFMC is necessary [8].

UFMC makes QAM transmission and multiuser systems as well as simple, limited frame-length out-of-band transmission. Multiple users can link UFMC most effectively [9-10]. This modulation method involves the use of multiple carriers for filtered OFDM. UFMC provides filtering as part of its supply chain. UFMC filter capacity rises with grouping suppliers. UFMC preserves dynamic orthogonality by integrating QAM with current MIMO [11-12]. In this paper we compare the performance of UFMC modulation with OFDM modulation.
The paper follows the following: In Section 2, we present multi carrier modulation schemes; results are discussed in section 3 and the conclusion of this work is presented in Section 4.

Orthogonal Frequency Division Multiplexing (OFDM)
Modern wireless communication systems use OFDM modulation to transmit data. QAM and FDM are combined in OFDM to produce a system that offers high data rates [13]. Different types of modulation are referred to as QAM. By delegating a slice of the frequency spectrum to each channel, FDM basically allows multiple communication channels to coexist. R.W.Chang proposed the original concept of OFDM [14]. A range of subcarriers can be created using OFDM in order to transmit data over a wide range of frequencies. 4G LTE[6-7] is currently using OFDM. The data rate of LTE devices is 1 Gpbs and bandwidth lies between 1.4 – 20 MHz. A packet switch is used in LTE [15]. An OFDM method is a more efficient and less time consuming way to model 5G networks. High PAPR is one of the main disadvantages of OFDM [16].

OFDM split the whole spectrum into subbands and transmits those employing cyclic prefixes (CP), time, and frequency synchronization. A CP frame is added between OFDM symbols before transmission in order to prevent interference between symbols on the receiver, such that the CP time duration exceeds the channel delays time [17].

Multi-carrier OFDM is a widely used waveform for RF systems and LTE downlink communications [18]. It allows for high spectral efficiency in channels with limited bandwidth and significantly boosts data rates. OFDM's robustness to both phase noise and time selective channels can be determined by the spacing between its subcarriers [19]. By using multiplexing, data is grouped in packages of M for frequency multiplexing, which is known as OFDM symbol, a different carrying is modulated simultaneously on each data [14]. M data points are considered (S_0, S_1, …., S_{M-1}), M data is divided into two sequences by time T_s. A signal at the frequency f_k is present in each data through the S_k module. A complex form $S_k\ e^{2j\pi f_k t}$ is used to represent each signal. The signal x(t) for all M symbols can be calculated as follows:

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

Multiplexing is orthogonal, if the spacing frequency is $1/T_k$, then $f_k = f_0 + k/T_s$. Then, we can write the overall signal as:

$$x(t) = e^{j2\Pi f_o t} . \sum_{k=0}^{M-1} S_k e^{\frac{j2\Pi t}{T_k}}$$

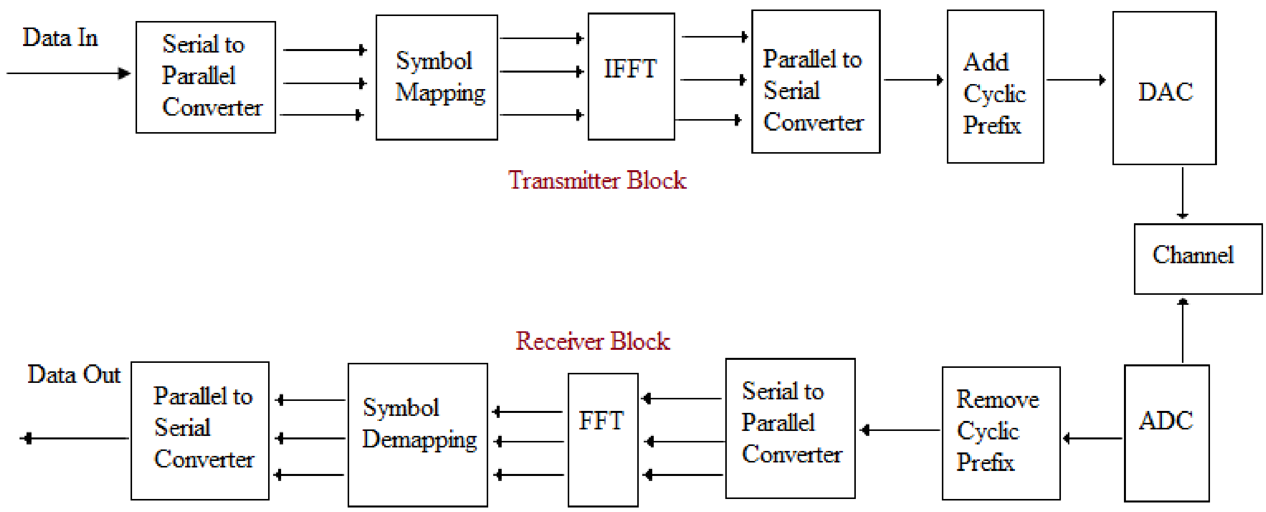

Figure 1. OFDM Transreciver

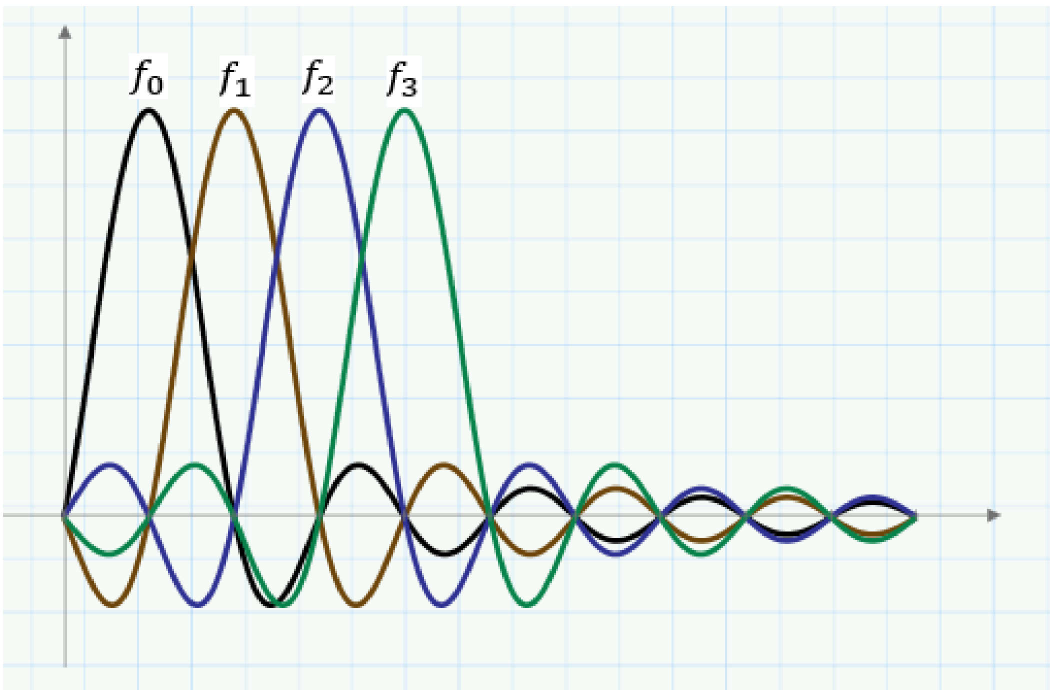

Figure 2. OFDM Signal – Orthogonal View

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Universal Filtered Multicarrier (UFMC)

We should develop some new waveforms in the 5G physical layer to overcome the disadvantages of OFDM [22]. A new waveform candidate for future wireless systems, the UFMC, was introduced, to get improved spectral efficiency, minimized out-of-band emissions and reduced latency. A version of the technology is also called Universal Filtered OFDM [10,20]. It offers much more efficient usage of radio resources since the UFMC system is equipped with a spectral containment signal. This eliminates the need for CP [21]. UFMC offers several advantages over OFDM. The bandwidth is separated into many sub-bands, according to UFMC. There are several subcarriers for each subband. The subbands are filtered. During transmission, binary data streams are divided into substreams based on their data speeds. A base band modulator generates the complex symbols for user K in the UFMC system. A block of streams is formed by converting the parallel signals to serial signals using the IFFT spreader. It will then be passed on to the filter[10]. Each block's output is filtered and then added together and sent to the baseband and RF sections. The signal will be processed by the domain pre-processing window in the receiver section after it has been routed through the RF to baseband link. There is no interference through this window. A 2N point stream is generated as a result of this process. There are N sub-carriers in those streams, which are parallel streams. Symbol demappers are also known as frequency domain symbol processers. De-mapping of symbols occurs here. Symbols are demodulated using a QPSK demodulator, which uses the bits of data in the symbols to retrieve them[10].

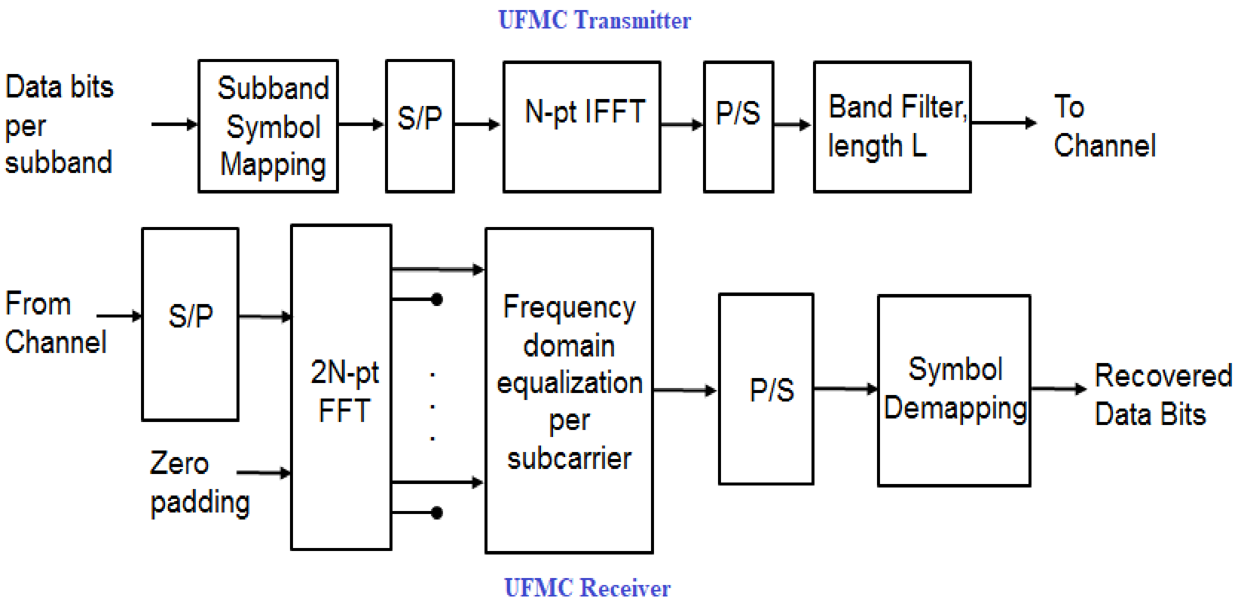

Figure 3. UFMC: Transceiver

2. SIMULATION RESULTS

In this chapter, performance assessments of OFDM and UFMC are addressed. OFDM and UFMC are evaluated using MATAB. Table 1 provides a list of the simulation parameters.

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The PSD for OFDM and UFMC modulations is shown in figure 4. OFDM suffers from a lot of out-of-band power leakage. In UFMC, the lobed side is smaller. Transmission of the UFMC signal consumes less power than that of OFDM. OFDM and UFMC spectral efficiencies are shown in figure 5. Variations of burst duration from 0 to 100 result in the graph shown. As burst duration increases, the spectral efficiency remains constant. For OFDM spectral efficiency is 3.8388 and for UFMC, it is 3.8424. The PAPR of UFMC (8.2379 dB) is the lowest compared to that of OFDM (8.8843dB). Constellation quality is affected by SNR variation. Based on SNR of 0 to 15 dB, the simulation of BER vs. SNR was performed. Bit error rate of OFDM is better compared to UFMC.

Table 1. Simulation Parameters

Parameter	**Value**
Simulation software	MATLAB
No. of FFT points	512, 1024
Sub band Size	20
Sub band Offset	156
Filter	Dolph-Chebyshev
Cyclic prefix length (filter Length)	43
Sidelobe attenuation	40dB
Bits Per SubCarrier	4
Modulation	4, 16, 64, 256 QAM
SNR	15dB
No. of Sub bands	10

Table 2. BER vs SNR comparison between OFDM and UFMC

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

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Table 3. PAPR comparison between OFDM and UFMC

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

Table 4. Comparisons of OFDM and UFMC

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

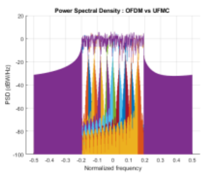

Figure 4. PSD: OFDM vs UFMC

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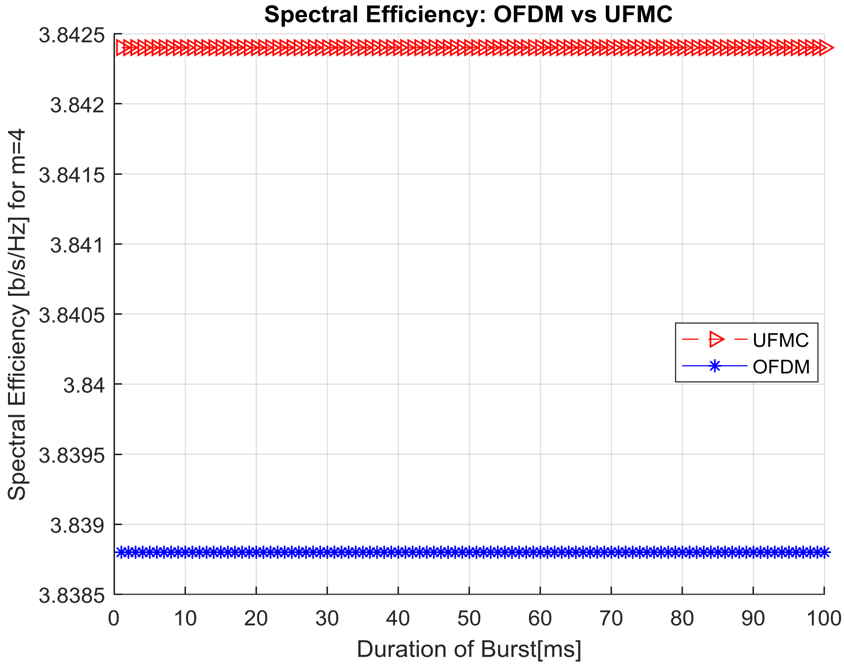

Figure 5. Spectral Efficiency: OFDM vs UFMC

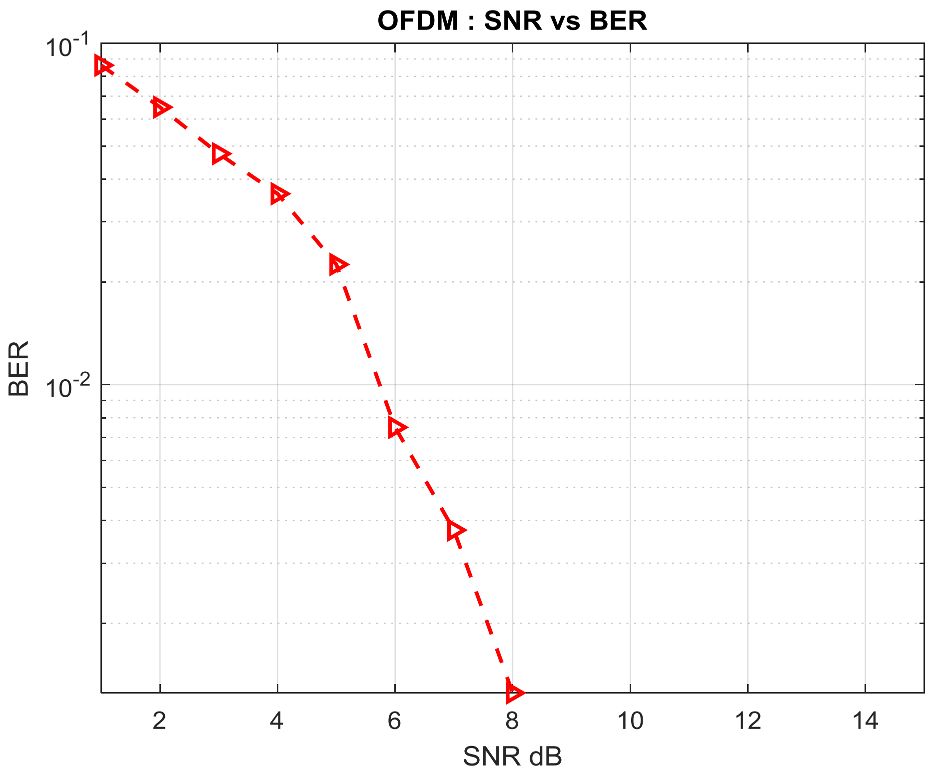

Figure 6. OFDM: BER vs SNR

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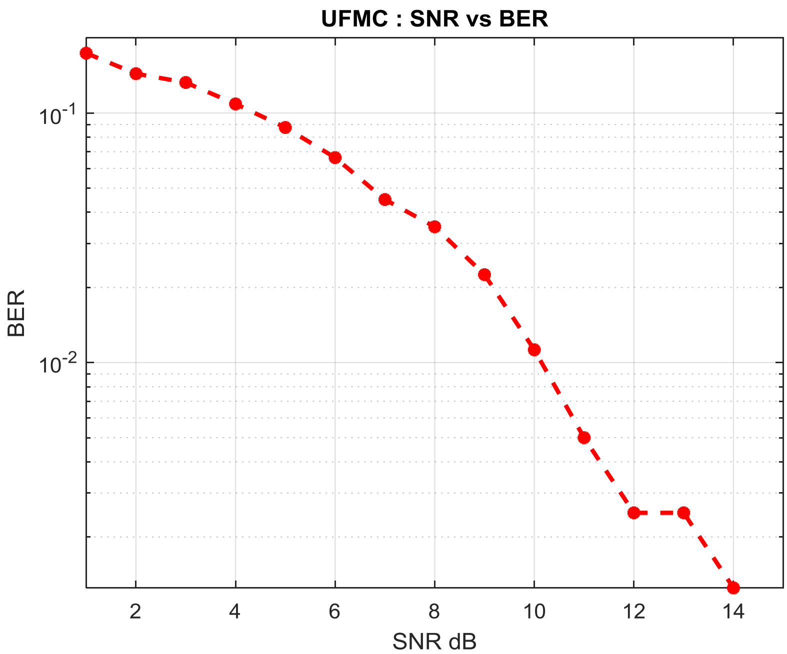

Figure 7. UFMC: BER vs SNR

3. CONCLUSION

A comparison of OFDM and UFMC modulation schemes was carried out in this paper. There were better features with UFMC than with OFDM. The Spectral Efficiency, PSD, BER and SNR parameters have been simulated. OFDM technique used in 4G technology has some drawbacks such as high PAPR and low spectral efficiency. UFMC offers solutions to these problems. UFMC does not use cyclic prefix, so it increases spectral efficiency. UFMC uses subbands to split the total bandwidth. In UFMC, the maximum power decreases as the number of subcarriers add up in phase. Because of this, the PAPR for UFMC is lower. When compared to OFDM, UFMC offers greater performance for short bursts/low latency transmissions. Wireless next generation communication can work quite well with UFMC.

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