Performance Analysis of OFDMA, UFMC, and FBMC for Optical Wireless Communication

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***Abstract*—Optical Wireless Communications have become an essential research topic due to their potential spectrum efficiency. Nowadays, OWC evaluates many applications such as internet of things (IoT), visible light communication (VLC), and light fidelity (Li-Fi). OFDMA, FBMC, UFMC, recently used in 4G and 5G. This work is concentrated on providing a detailed study for the new modulation schemes. This article compared between BER, PAPR, spectral Density, and spectral efficiency of FBMC, UFMC, and OFDM modulation techniques to analyze the merits of them. The simulation results show that OFDMA has a higher BER, lower PAPR, compared to FBMC while FBMC has greater spectral efficiency and better performance of spectral density which makes it the optimum modulation schema among the rest. Furthermore, UFMC produces better results than OFDM and eliminates the complexity of FBMC.**

Keywords*— *OFDMA, UFMC, FBMC, OWC, LiFi, VLC, BER, PAPR.

I. Introduction

Due to increasing demands of wireless technology, the need of more spectrums has become a great and major aspect. Currently, optical wireless communication (OWC) starts to become the major topic in most current studies that aim to develop a new technique to generate more reliable communication and efficient frequency spectrum. The main objective of upcoming optical wireless communication is to obtain transmission with high data rates, minimum latency, best quality of service and maximum channel capacity [1].

To achieve the above objectives, newer techniques have been developed. In our paper, a comparison study among Orthogonal Frequency Division Multiplexing (OFDM), Filter Bank Multi Carrier (FBMC), and Filter Bank Multi Carrier (FBMC) in OWC has been accomplished. The article also aims to propose the best modulation schema to be used in optical wireless technologies such as light fidelity (Li-Fi) and visible light communication (VLC).

This paper is categorized as follows: The main topic of this article and its main objectives were introduced in the first section. A brief literature review of OFDMA, FBMC, and UFMC in optical wireless communication, is covered in the second section. Simulation procedures & results as well as their observation are explained in sections three and four. Finally, the paper conclusion to sum up the study and set the proposed schema that suits Li-Fi and VLC technologies.

II. Litrature Review

Optical wireless communications become a major topic with the start of fifth generation mobile communication (5G). Visible light communication (VLC) and light fidelity (LiFi) are two applications of OWC that we want to improve in our study. While VLC, one example of OWC that uses LEDs, is being used as point-to-point transmission, LiFi is being used widely for multiple user access in a coherent and non-coherent channel. LiFi is an efficient and reliable approach that uses LEDs to transfer data with high speed OWC and low spectrum interference. It is the optical representation of Wi-Fi communication that first introduced in 2011, by Harald Hass [2]. Li-Fi is currently being developed to integrate with new 5G techniques and works in hybrid systems. A three essential modulation schemas are being tested with optical wireless communication and 5G, which are Orthogonal Frequency Division Multiplexing (OFDM), Filter Bank Multi Carrier (FBMC), and Universal Filtered Multi-carrier (UFMC).

A. OFDMA

Orthogonal Frequency Division Multiplexing (OFDM) network was implemented with oorthogonality techniques which used in 4G LTE/LTE-A. OFDMA modulation and demodulation process are operated with IFFT and FFT principles due to its simplicity and efficiency [1]. In OFDM, multiplexing is done by dividing the total spectrum into sub-bands and each band is transmitted with set of conditions like Cyclic Prefix (CP), time and frequency synchronization [3].

While OFDMA presents and adopts perfectly in 4G due to its built-in orthogonality, receiver circuit integrity, better spatial diversity, and multiplexing competence, it doesn't support 5G because of its major drawbacks such as Out Of Band Radiation (OOBR), subcarriers orthogonality, high Peak to Average Power Ratio (PAPR), Inter Symbol Interference (ISI), and Inter Carrier Interference (ICI) [4, 5]. Therefore, OFDM was modified and improved which leads to a Filter Bank Multi Carrier (FBMC), Universal Filtered Multi-carrier (UFMC).

B. FBMC

Filter Bank Multi Carrier (FBMC) was implemented to mitigate OFDMA disadvantage in 5G mobile communication. FBMC success to provide a better spectral efficiency, and optimum spectral inclusion compared to OFDM. Unlike OFDM, FBMC does not use a cycle prefix (CP) to create the potential for improved bandwidth efficiency. In addition, the overlap area between subcarriers is mainly limited to the adjacent channels compared to OFDM because of the essential properties produced by FBMC [5,6].

Recently, FBMC has attracted attention due to its advantage over OFDMA. Not only FBMC presents and adopts in 5G, but also in optical communication. Many studies have explored and investigated its application in Passive Optical Networks, where high spectral efficiency and cost effectiveness are required [5,7].

C. UFMC

Universal Filtered Multi-carrier (UFMC) is new schema developed to gather advantages of FBMC and OFDMA and avoid their drawbacks. In UFMC, filtering functionality is applied per sub-band instead of per subcarrier in series using IDFT [8]. Unlike FBMC, the filter length of UFMC is short and its modulation uses the non-adjacent spectrum resources

by locating different sub-bands with non-adjacent spectrum. Besides, UFMC can efficiently eliminate and reduce the frequency selective fading as OFDM [9].

III. Methodology

Optical communication systems generally use the same procedures as other digital systems except for the transmission techniques. In OWC, data is being sent as analog optical signals, unlike digital technologies. This section presents the methodology used to study OFDM, FBMC & UFMC performance in OWC systems.

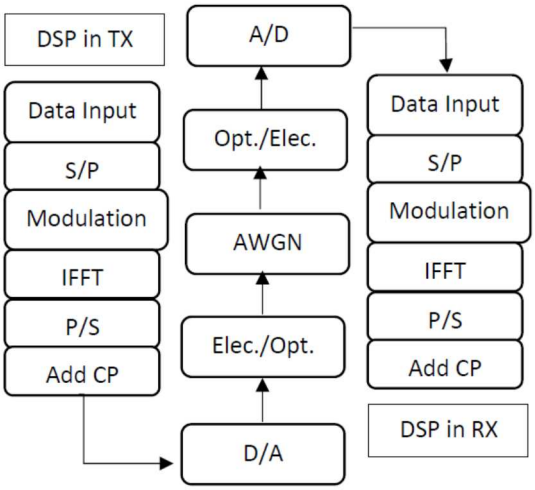

Figure 1: Optical Wireless Communication Block Diagram

Fig. 1 shows OWC system in terms of an additive white gaussian wireless channel. Different modulation schemas are studied such as OFDM, FBMC & UFMC. At the transmitter side, DSP converts data from serial to digital using serial to digital conversion. Then QAM modulation is obtained to assign the signal to different subcarriers as the output from IFFT is OFDM signal. In UFMC, the filter in IFFT output is applied into different sub-bands, while the addition of cyclic prefix (CP) is removed in FBMC. The next sections present & describe the obtained results, simulation parameters, and summary of comparison.

IV. Simulation Results

This section will illustrate the simulation results while the transmitter and receiver of OFDMA, FBMC, and UFMC are programmed using MATLAB. For a fair comparison, all waveforms were implemented with similar parameters.

A. Bit Error Rate

The BER execution with various signal to noise ratios (SNRs) is shown in Fig. 1, where the parameters of these modulation waveforms are as follows: subscribers' number of OFDM and FBMC is 256, and the prototype filter is the rectangle filter with length of 1; the sub-bands' number of UFMC is 2, and the number of subscribers is 128 in each sub-band, while the number of iterations in OFDMA, UFMC & FBMC is 250.

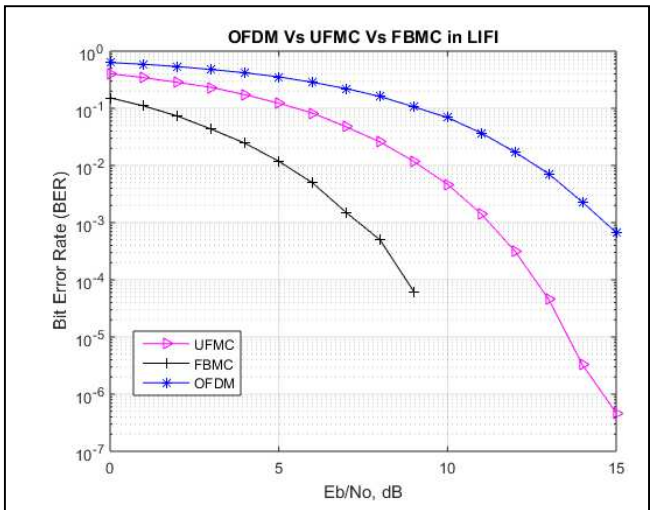

Figure 2: BER vs. SNR levels of FBMC, UFMC, and OFDM based OW system.

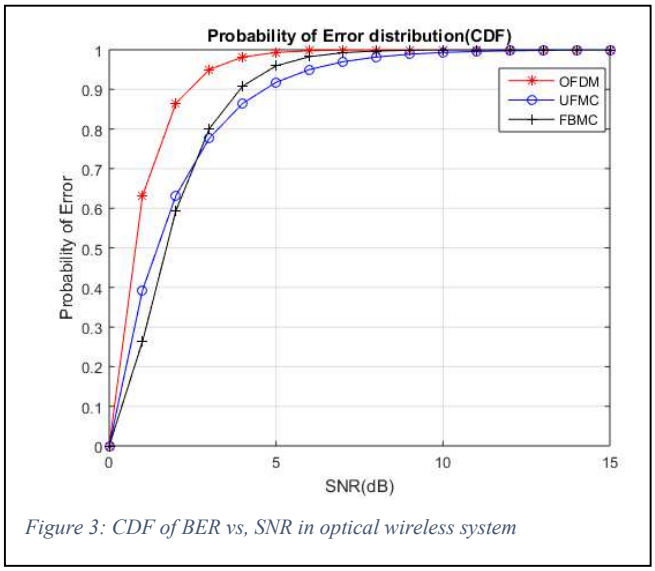

Figure 3: CDF of BER vs, SNR in optical wireless system

It is noticed from Fig. 2& Fig. 3 that the BER of OFDM is the highest while FBMC has the lowest BER results, which means FBMC has the optimum BER performance, efficient signal power, and less errors compared to OFDM and UFMC. OFDM performance is the worst compared to other waveforms, while UFMC has better Bit-Error performance than OFDM and close to FBMC.

B. Channel Spectral efficiency

This simulation is a performance investigation of how channel capacity and throughput is being divided among two users in Li-Fi auto cell or in an optical wireless channel in general.

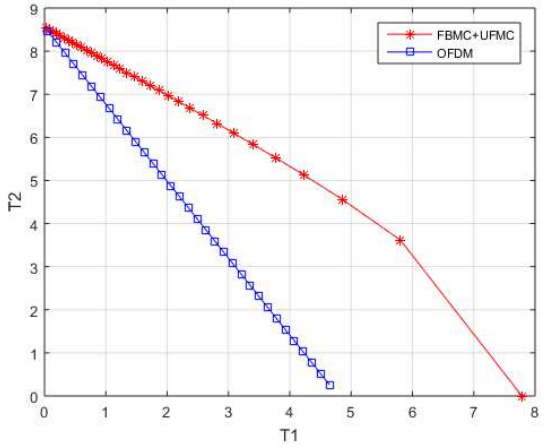

Figure 4: Shannon spectral efficiency between user 1&2 in distinctive channel conditions

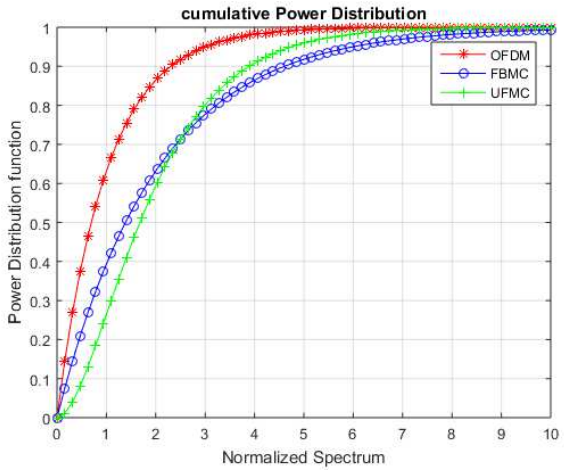

Figure 5: PAPR Distribution for FBMC, UFMC, & OFDM in optical wireless system.

The impact of modulation schema used in optical wireless channel, such as Li-Fi auto cell, is illustrated on Fig. 4. Considering one user is at the cell edge while the other user is at the interference area, FBMC & UFMC will have almost same results and their average capacity outperforms OFDM [13,14].

C. *Power Distribution*

Peak to average power ratio (PAPR) is being studied in the following simulation. This simulation is done by calculating power spectral density for FBMC, UFMC & OFDM in optical wireless system, Li-Fi system as an example, and then calculating its PAPR. CDF power distribution of the results obtained is shown in Fig. 5.

Fig. 5 describes the power distribution in optical wireless system. As illustrated, OFDM case, the system reaches to its maximum power before UFMC & FBMC. Furthermore, FBMC has the best power distribution curve compared to OFDM & UFMC while UFMC produces better result compared to OFDM. The results obtained explain why FBMC is the best choice for its power reduction in 5G mobile system [10, 11]. In addition, FBMC & UFMC produce better power distribution than OFDM, while FBMC still have the most optimum power reduction among the three-modulation schema in Li-Fi system.

Fig. 6 presents Power Spectral density (PSD) of FDMC & OFDM. It clearly states that out of bands harmonics are significantly large in OFDM modulation comparing to FBMC. The result observation also gives an evidence that optical systems, such as Li-Fi or VLC, have more power & spectral efficiency with FBMC than those implemented with OFDMA.

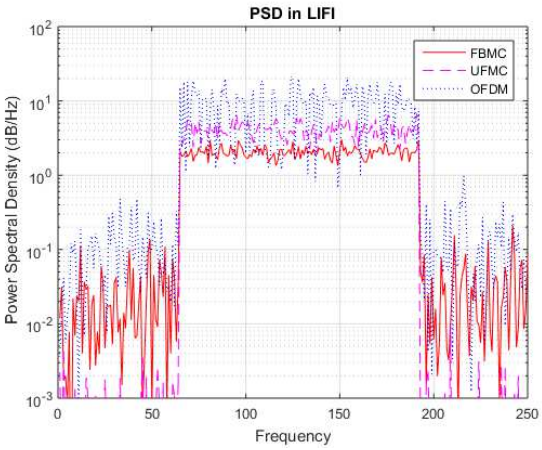

Figure 6: Power Spectral Density of FBMC & OFDM in Optical. channel

V. SUMMARY

Summary of the simulation results is grouped in Table 1. Similar results and observations were made for 5G mobile communication as presented in [10,11]. Table compares the three-modulation schema OFDM, FBMC & UFMC in an optical wireless system and referring to the results from section III in this paper.

Table 1: summary comparison among OFDM, FBMC & UFMC.

Simulations	Modulation Schemas		
	OFDM	***FBMC***	***UFMC***
BER	High	Low	Medium
PAPR	Meduim	High	Medium
Out of band	High	Low	Low
Spectral effeciancy	Low	High	High
CP	Yes	No	No
Orthognality	Yes	Yes	Yes
Complexity	No	Yes	No

VI. CONCLUSION

This article presents the applied version of FBMC, UFMC in optical wireless communication technologies, specifically VLC & Li-Fi. This article explained their own merits and drawbacks and finally evaluated them experimentally and compared the performance of these modulation schemes. Both UFMC and FBMC produced a suitable result for wireless light communication (Li-Fi and VLC); however, FBMC results with better performance in BER, SINR, PAPR, and channel spectral efficiency. Hence, our research proposed FBMC as the best schema for the upcoming OWC technology (Li-Fi). While UFMC is better for small optical wireless applications such as VLC due to its simplicity and good performance.

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