# Review of UFMC Technique in 5G

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***Abstract*— This article describes about the spectrum utilization of Universal Filtered Multi Carrier (UFMC). UFMC is a multi-carrier modulation technique in fifth generation network (5G). In this paper, we review the different modulation techniques in 5G technology and motivate the need of UFMC technique in 5G wireless communication. In 4G OFDM modulation technique, some drawbacks like side band leakages, high Peak to Average Power ratio (PAPR) and spectrum utilization degrades the performance of the system. But with the advent of Internet of Things (IOT) and the move towards user-centric processing makes the OFDM technique more unfeasible. Another multi-carrier technique called Filter Bank Multi carrier (FBMC) which is better than OFDM, have some issues in practical aspects. So by considering the above parameters a move to another technique called Universal Filtered Multi Carrier (UFMC) is used because of good spectrum usage. This paper also explains about the UFMC system model. Based on the Simulation results in MATLAB, the spectrum utilization of UFMC system is much better than OFDM system.**

***Keywords*— UFMC, OFDM, 5G, IFFT, FFT, DAC, ADC and Spectrum efficiency.**

## I. INTRODUCTION

At present the main data transmission technology in wireless communication system is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is used in LTE/LTE advanced (4G) and IEEE 802.11 (WI-FI) networks. OFDM is a modulation technique with strongly efficient in bandwidth usage. It is immune to multipath fading and Inter Symbol Interference (ISI). The recent advancements in Digital signal processing make the OFDM very popular. Above all advantages, OFDM is having some disadvantages like high Peak to Average Power Ratio (PAPR) and high Bit error rate (BER). The sensitivity of devices used in the OFDM transmitter side such as Digital- to-Analog Converter (DAC) and High Power Amplifiers (HPA) are very harsh to the signal processing loop which affects the performance of the system. When we operate with high power Amplifiers, it produces signal excursions into the non-linear region [4]. The spectrum utilization of OFDM is not better when compare to other modulation techniques like UFMC. Spectrum efficiency plays a main role in rapid Mobile Broadband Networks (MBB). The most valuable resources to the telecom field is Spectrum resources. Spectrum resources represent one of the largest investments in terms of Total Cost of Ownership (TCO). However, Limited spectrum resources hinder MBB development.

But in order to meet the higher requirements in 5G, this OFDM technology is not sufficient. So, the evolution of new technologies like Filter Bank Multi Carrier (FBMC) and Universal Filtered Multi Carrier (UFMC) are emerged. However, FBMC is not the right one because large filter length affects the symbol decoding time and having complex receiver structure in MIMO. Also FBMC is not suitable for burst transmissions or delay sensitive applications. So, the good right candidate in 5G is UFMC [1], [3]. In UFMC filtering is applied to a group of sub carriers. UFMC system not only enables QAM transmission and MIMO schemes, but also provides lower out of band radiation with short frame length. UFMC is best suited for uplink with multiple number of users [2].

### A. Structure of Assessment

This paper has four sections. In section I, a brief introduction to OFDM and FBMC are discussed. In section II UFMC model is discussed. In section III, MIMO technology is discussed and the simulation results are discussed in section IV.

### B. Literature Survey

In OFDM the entire bandwidth is divided into number of sub-carriers and these sub carriers are transmitted in parallel to increase symbol duration to achieve high data rates and to reduce ISI and it is shown in the figure 1. An OFDM signal is the sum of all sub carriers signal which are modulated at the sub channels of equal bandwidth.

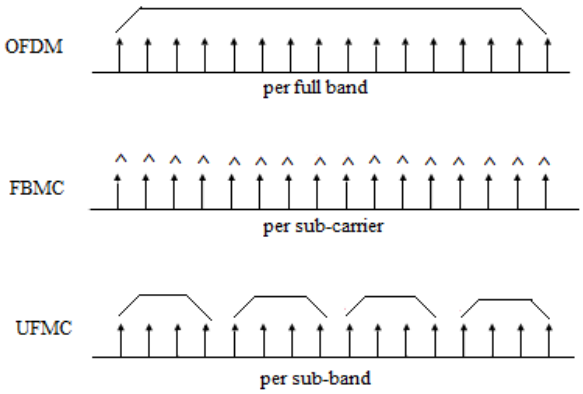


Fig.1. Filtering methods in OFDM, FBMC and UFMC techniques.

High PAPR value and high BER are the major disadvantages in OFDM. The sensitivity of devices used in the OFDM transmitter side like DAC and HPA are very harsh to the signal

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processing loop which affects the performance of the system [5]. The spectrum utilization of OFDM is not good in OFDM because many side lobes might pick up interfering signals, which in turn results in the increase of noise level at the receiver. Both OFDM and FBMC supports MIMO technology, but OFDM has some drawbacks [7]. In OFDM 'Cyclic Prefix' is must to avoid Inter Symbol Interference (ISI) and to convert the channel to a number of sub-carrier channels. But in FBMC, Cyclic Prefix is not used, but it has the capability to convert the channel to a set of sub-carrier channels and to remove ISI. Both OFDM and FBMC supports MIMO system. The primary reason of using OFDM in MIMO system is to remove interference and the main aim of FBMC is to overcome some of the shortcomings in OFDM. FBMC is the betterment of OFDM. So, FBMC is equals to the derivative of OFDM. Both plays a prominent role in the area of wireless communication modulation techniques. But by using filter banks it has possible to get our desired results than OFDM. In Massive MIMO FBMC concept, the complexity of the system and delay can be reduced by reducing the sub-carriers. In Massive MIMO FBMC system, Analysis can be done at Receiver side and Synthesis at Transceiver side.

The sub-carriers spectral localization in OFDM are weak which might results in spectral leakages and also interference issues with unsynchronized signals.

Spectrum efficiency improvement proposed by HUAWEI has given solutions to improve the spectrum efficiency. Refarming and Time Division Duplexing (TDD)/ Frequency Division Duplexing (FDD) co-ordination**.** Refarming means termination of existing allocation bands in the radio spectrum and the more productive reallocation of the spectrum into smaller bands. Refarming solution helps operators dramatically increase spectrum efficiency and network coverage at low cost [8]. TDD/FDD coordination maximizes the utilization of fragments through optimization and global network simulation centre.

## II. UFMC SYSTEM

UFMC, a generalization of Filtered OFDM and FBMC multi-carrier modulation technique. Generally in filtered OFDM, entire band is filtered where as in FBMC individual sub carriers are filtered. But in UFMC group of sub carriers are filtered [6]. This is the main difference in Filtered OFDM, FBMC and UFMC multi-carrier. Grouping of sub carriers helps in reducing the filter length in UFMC. IN UFMC, to retain the complex orthogonality, QAM is used which works with existing MIMO. The whole UFMC transmitter section is shown in figure 2. Here the full band of 'N' sub carriers are partitioned into several sub bands. Each sub band has a fixed number of sub carriers. In transmitter section no need of employing all sub bands for a transmission. To get rid of from the sub band carrier interfere, Inverse Fast Fourier Transform (IFFT) is used. At each N-point IFFT, sub bands are computed and zeros are allocated for unallocated carriers. IFFT converts frequency domain ($X_i$) to time domain ($x_i$). After the N-point IFFT, the output can be written as

$$Y_i = \text{IFFT}\ \{x_i\} \tag{1}$$

Now the time domain signals comes from the IFFT goes to Band filter of length 'L' block. Each sub band output is filtered by band filter of Length 'L' It is expressed as

$$y = H. \sim Q.\ y_i \tag{2}$$

Where H is called toeplitz matrix having dimensions (N+L-1) and '~Q' is called as Inverse Fourier matrix.

Actually band filters uses Chebyshev window/filtering operation. Here parameterized side lobes attenuation is used to filter the IFFT outputs. Now all the outputs from the band filters are summed at the end and passes through the channel.

From the channel the data bits are transmitted to UFMC receiver. UFMC receiver do's 2N-point Fast Fourier Transform (FFT). FFT converts the data of time domain to frequency domain. It is shown in the form of equation

$$\sim Y = \text{FFT}\ \{\ [y^T, 0, 0, \ldots\ldots\ldots, 0]\ \} \tag{3}$$

To prevent Inter Symbol Interference (ISI), guard intervals of zeros are added between successive IFFT symbols. ISI is due to transmitter filter delay. To receive N length frequency domain signal 'Y', even sub carriers are discarded. Now the data goes for equalization process and the original data bits are retrieved by symbol demapping. It is shown in the UFMC receiver section figure 3.

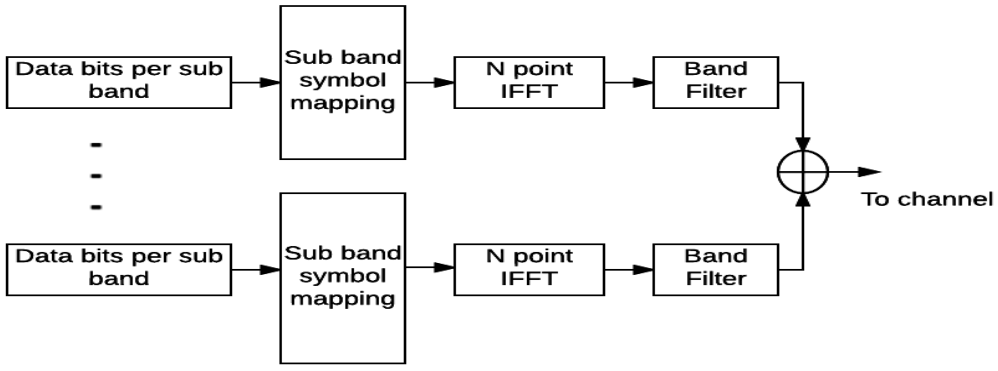


Fig. 2. UFMC Transmitter section

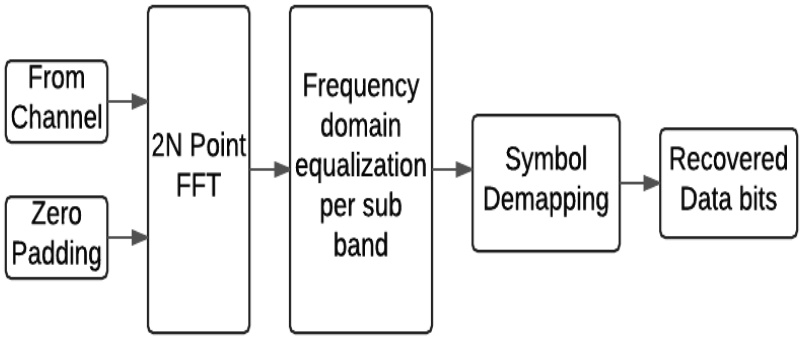


Fig. 3. UFMC Receiver section

## III. MIMO TECHNOLOGY

MIMO is a marvellous wireless technology that can provide very good performance when compared to single-input and single-output. MIMO means installing multiple transmitting antennas at the transmitter side and multiple receiving antennas at the receiver side and together called as MIMO. Generally the short technical term for Multiple Input and Multiple output is MIMO. In general massive means very large. So, installing very large antenna array at each base station to serve many number of users simultaneously is known as Massive MIMO and is shown in the figure 4.

This section would have been discussed the importance and need of Massive MIMO technology. Organizations like Rusk Lund Test beds at Lund University and Commonwealth Scientific and Industrial Research Organization (Australia) are working on MIMO 5G technology [9]. The research areas and projects on MIMO 5G technology are listed in the table I.

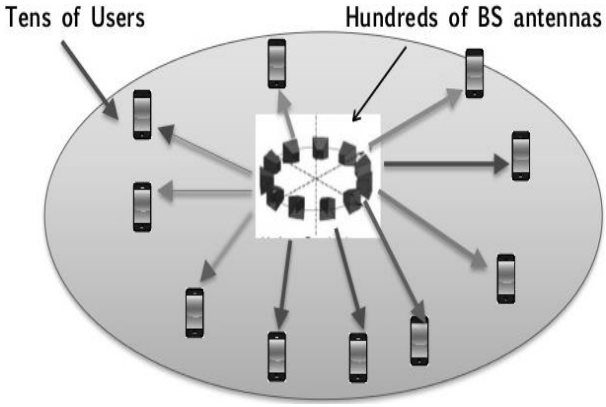


Fig. 4. Massive MIMO Technology

TABLE I: RESEARCH AREAS AND PROJECTS ON MIMO 5G TECHNOLOGY

| SL. no | Research Project/Research groups | HTTP location | Research field |
|---|---|---|---|
| 1 | MOST (Ministry of science and Technology 863-5G project) | http://www.most.gov.cn/eng/programm | Massive MIMO and Radio-Access-Network (RAN) architecture |
| 2 | MAMMOET (Massive MIMO for Efficient Transmission) | http://www.mammoet.project.eu | Massive MIMO |
| 3 | 5G PPP (5G Infrastructure Public Private Partnership) | http://5g-ppp.eu | Next generation of communication networks and ubiquitous super-fast connectivity |
| 4 | METIS (Mobile and wireless communication Enablers for Twenty-Twenty) | http://www.metis2020.com | Providing holistic system to 5G technology system. |

In 5G mobile communication system, Massive MIMO plays very significant role. High energy consumption and spectral crisis are still the major challenges in 4G (the fourth generation mobile communication). We know that there is a huge good

demand for higher data rate, so all the telecommunication companies started the research work on 5G. MIMO system technology primarily concentrates on higher spectral efficiency and focuses on high coverage area for all cell edge users. In a communication system, fading and multi path delays are creating problems which results in errors and also affects the performance of the system. So, In order to overcome these problems there are some techniques called Filter Bank Multi carrier (FBMC), Universal Filtered Multi-Carrier (UFMC) and Orthogonal Frequency Division Multiplexing (OFDM) which overcomes the above said problems in communication system. The UFMC MIMO model consists of MIMO encoder, MIMO decoder, UFMC Modulators and UFMC demodulators and it is shown in figure 5.

In a conventional Massive MIMO system, Ultra-linear 50 watt amplifiers are utilized. In any case, now specialists are utilizing minimal effort speakers with yield controls in mille-watt. Chang and Saltzberg are the two writers and researchers which were at that point talked about Multi Carrier procedure twenty years back. When the system is operated with power amplifiers, the multi-carrier systems such as OFDM and FBMC produces signal excursions into the non-linear region which leads to distortions. The spectral leakage cannot be modified or corrected but compensated by using prediction algorithm technique at the transmitter side. The FBMC technique is not only using in 4G/5G, but it is also using in Aeronautical communication system. Here they used L-band for air to ground communication. In this they introduced a new concept called spectrally shaped Filter Bank Multi Carrier (SS-FBMC) to obtain the error flow free BER results. International Civil Aviation Organization (ICAO) is doing improvements or developments in Aeronautical communication system based on SS-FBMC.

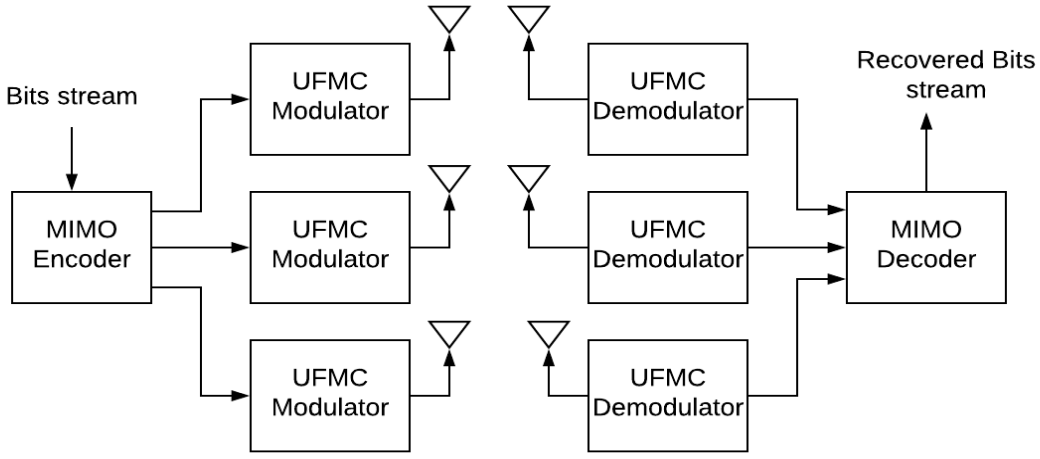


Fig. 5. UFMC MIMO

Table II: System parameters

| Parameter | Value |
|---|---|
| Total number of FFT points | 512 |
| Sub band size | 20 |
| Sub band Offset | 156 |
| Bits per sub carrier | 2, 4, 6, 8 |
| Number of sub bands | 10 |
| Filter Length | 43 |
| Side lobe attenuation | 40 |
| SNR (dB) | 15 |

Table III: PAPR values for UFMC and OFDM for different mapping techniques at 5dB SNR.

| Mapping technique | PAPR of UFMC | PAPR of OFDM |
|---|---|---|
| 4 QAM | 9.04 | 8.4377 |
| 16 QAM | 8.2379 | 8.8843 |
| 64QAM | 8.6229 | 9.9269 |
| 256 QAM | 8.0416 | 7.2553 |

## IV. SIMULATION RESULTS

200 sub carriers are used in power spectral density of OFDM and FBMC. And divided the overall band into 10 sub bands, each sub band have 20 sub carriers. Efficient power utilization is the major criteria in wireless communication system [7]. From the figures 6 and 7, the spectrum utilization is very good in UFMC system than OFDM system. Average power ratio of UFMC for different mapping techniques are listed in Table III. PAPR values in UFMC are high except for 16QAM. PAPR for UFMC is better for 256 QAM. From the table we can say the PAPR 16 QAM mapping scheme is better for UFMC system. The BER for 4, 16, 64 and 256 mapping techniques are also shown in figure 8.

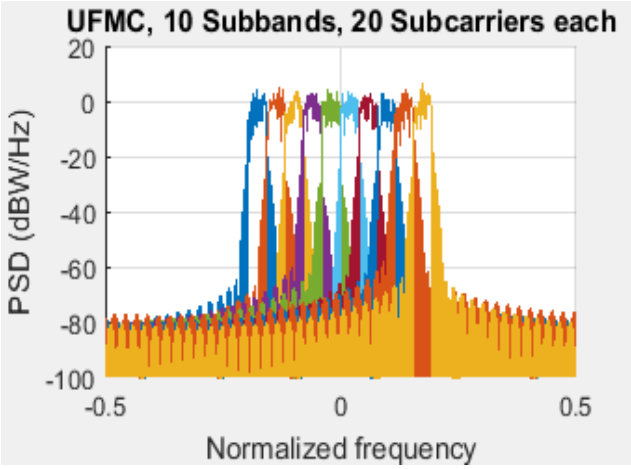


Fig. 6. PSD of UFMC

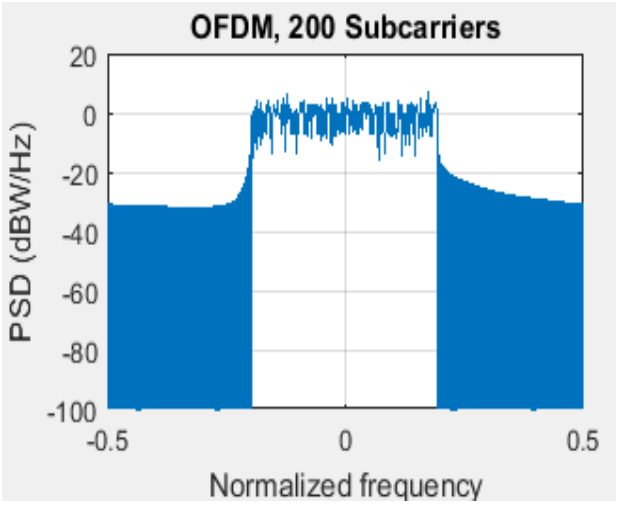


Fig. 7. PSD of OFDM

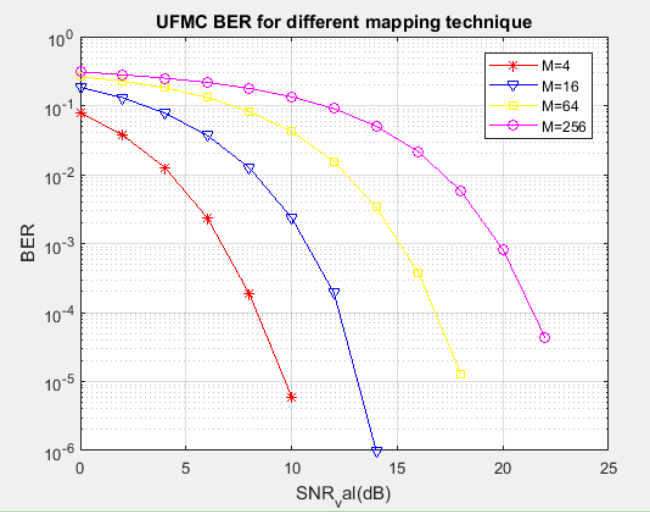


Fig. 8. BER of different mapping techniques

## CONCLUSION

From the figures 6 and 7, it is proved that the spectrum utilization in OFDM is not good and the spectrum utilization in UFMC technique is good because of lesser side lobes. And the PAPR values for both UFMC and OFDM are 8.2848 dB and 7.5653 dB. So, the PAPR of UFMC is better compared to OFDM (4G technique) using 16 QAM mapping method. Orthogonal Frequency division Multiplexing (OFDM), in 4G have some drawbacks like side band leakages and high Peak to Average Power ratio (PAPR) issues. With the advent of Internet of Things (IOT) and the move towards user-centric processing makes the OFDM technique more unfeasible. So, UFMC is a right candidate for 5G.

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