# Comparison of Various Modulation Techniques of DM, FBMC & UFMC

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*Abstract-* **To design a new waveform for 5G communications with a lower peak / average power ratio and a high Spectra Efficiency methods / Statistical analysis: In this document, orthogonal frequency division multiplexing (OFDM), filter bank Multi-carrier (FBMC) and Universal Multi-Conveyor Filtered (UFMC) are compared and the PAPR of these techniques is analyzed Applying different subcarriers and modulation techniques. Discoveries: Spectral efficiency is poor in OFDM due to presence of a cyclic prefix and efficiency can be improved by FBMC and UFMC. The use of separate filters for individuals. the subcarriers eliminate the cyclic prefix and an increase in the subcarriers further reduces the PAPR. The PAPR varies according to the modulation techniques used. Application / improvements: UFMC is the best waveform technique for 5Gwhen compared to OFDM and FBMC, which will have less PAPR and PAPR is further reduced by applying Optimization techniques**

**Index Terms- 4G, 5G, UFMC, OFDM, Spectral Efficiency, FBMC**

## I. INTRODUCTION

The 4G technology LTE uses OFDM technique in which a large number of closely spaced orthogonal subcarriers are used to carry data. Although the sidebands from each carrier overlap, they can still be received without the interference because they are orthogonal each other. There is no need of guard bands to separate subcarriers. Cyclic prefix is the addition of some repeated bitsat the end of each OFDM symbol1.Due to the addition of cyclic prefix, circular convolution takes place which eliminates the inter symbol interference. But due to the use of cyclic prefix, 10% of the bits are repeated which decreases spectral efficiency. OFDM also suffers from high PAPR. Because of these major drawbacks, it is not an efficient technique for 5G communications. The special features of 5G when compared to 4G are IoT(Internet of Things), M2X communications, Tactile Internet, WRAN (Wireless Regional Area Network) and Very large data rate wireless connectivity (upto 10Gb/s). These applications cannot be satisfied by OFDM technique. Hence there is a need of new techniques like FBMC and UFMC2

### 1.1 FBMC

This section compares the FBMC technique with OFDM. In FBMC, each subcarrier is filtered individually. It uses the very narrow band filter with long time length3. Due to the use of filter for each subcarrier, OOB emissions are greatly reduced. In FBMC, first prototype filter is to be designed. After that filters are designed for each sub-carrier based on the prototype filter by frequency shifting. All the filters together are called filter bank4. The main difference between OFDM and FBMC is OFDM uses one rectangular filter for all subcarriers whereas FBMC uses one filter for each subcarrier. FBMC has high spectral efficiency when compared to OFDM because cyclic prefix is not used in FBMC. Computational complexity is very high for FBMC because of usage of each filter for every subcarrier5. It is suitable for single user transmission but multiple input multiple output transmission is not possible efficiently. Due to these drawbacks, it is also not an efficient technique for 5G communications.

### 1.2 UFMC

This section describes block diagram of transmitter and receiver of UFMC and compares UFMC with OFDM and FBMC.UFMC combines the advantages of OFDM and filter bank in FBMC. In UFMC, first the total bandwidth is divided into sub-bands. Each sub-band has some subcarriers. Instead of filtering each subcarrier like in FBMC, filtering a block of subcarriers is done in this technique.

The Figure 1 in the 8th shows the block diagram of UFMC transmitter. In UFMC, total bandwidth is first divided into B sub-bands. Each sub-band has k subcarriers. Now data bits are given to each subband6. After that the data bits become parallel by the use of serial to par-allel converter. Now the output of s/p converter is given to symbol mapper. Symbol mapper assigns symbols to bits. The output of symbol mapper is given to IFFT. Here the IIFT acts as a modulator. It is very difficult to design modulators for every subcarrier. The output of IFFT is serialized by parallel to serial converter and that output will be filtered with pulse shaping filter of length L. The filter is chebyshev filter. The output of each filter is added and the resulting signal is passed through channel. The input data represented by X is converted to B sub-blocks. And each sub-block is passed through N point IFFT representing with matrix 'V'. The output of IFFT will be serialized and passing through filter representing with matrix 'F'.For the $i^{th}$ sub-band the data blocks represent with $S_{i,k}$, IFFT matrix with $V_{i,k}$ and filter with $F_{i,k}$. The output of fil-ter bank is shown in equation 1.

$$x_k = \sum_{i=1}^{B} F_{i,k} \cdot V_{i,k} \cdot S_{i,k}$$

where $S_{i,k}$ represents data blocks

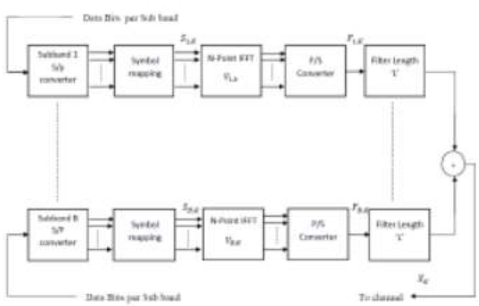

Figure No.1 Block diagram of UFMC receiver

$F_{i,k}$ represents Chebyshev filter

$V_{i,k}$ represents IFFT to eplitz matrix

$$F_{i,k} = \frac{\cos\left\{M\cos^{-1}\left[\beta\cos\left(\frac{\pi k}{M}\right)\right]\right\}}{\cos[M\cosh^{-1}(\beta)]} ,$$

$$k = 0, 1, 2, \ldots\ldots\ldots M-1$$

$$\beta = \cosh\left[\frac{1}{M}k^{-1}(10^{\alpha})\right] , \alpha = 2,3,4 \qquad (2)$$

where $\alpha$ represents attenuation of side lobe

Figure 2 shows the block diagram of UFMC Receiver. The received data from the channel is given to the serial to parallel convertor and then passed through FFT to demodulate the data. After that the output of FFT is given to parallel to serial converter. It converts all the parallel data streams into single stream. The symbol demapper converts the symbols into bits and original data is retrieved. UFMC has more spectral efficiency compared to OFDM. There is no cyclic prefix insertion like in OFDM. There is no repetition of the same bits, there-fore it utilizes all the allocated spectrum efficiently10

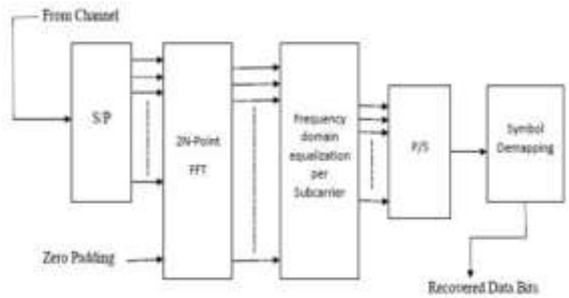


Figure No2. Block diagram of UFMC transmitter

UFMC has less side lobes than OFDM. As side lobes decreases the interference on adjacent subcarriers also decreased. In OFDM, the signal consists of a large number of independently modulated subcarriers which can give a large PAPR when they are added in phase. In UFMC, total bandwidth is divided into sub-bands. As the probability of number of subcarriers adding up in phase is less in UFMC, the maximum power decreases. Hence PAPR is low for UFMC when compared with OFDM

## II. PROPOSED WORK

The implemented project involves comparison of physical layer candidates to 5 G. 5 G standard is not completely established and thus uses a number of modulation techniques. Here, we compare modulation techniques such as OFDM, FBMC, UFMC. The comparison involves simulating these modulations over different set of parameters. The results obtained includes measurements such as spectral efficiency, BER vs SNR, PAPR and power spectral density. The implementation is performed using MATLAB.

Table No.1 Parameter

| Properties | Values |
|---|---|
| FFTLength | 5 1 2 |
| Bits per Sub carrier | 4 |
| OFDM | |
| CyclicPrefixLength | 4 3 |

| | |
|---|---|
| UFMC | |
| Length of Filter | 4 3 |
| Stop Band Attenuation | 4 0 |
| FBMC | |
| Spreading Factor | 4 |

a. Comparison of Spectral Density

The spectral density of FBMC and UFMC over OFDM is compared. The simulation plots two graphs with reference to the same respectively. The spectral density represents the strength of the signal over a time period ( i.e) the possible bandwidth over which the bits can be sent successfully. A modulation's sp ectal density is efficient if the strength is closer to the normalized frequency

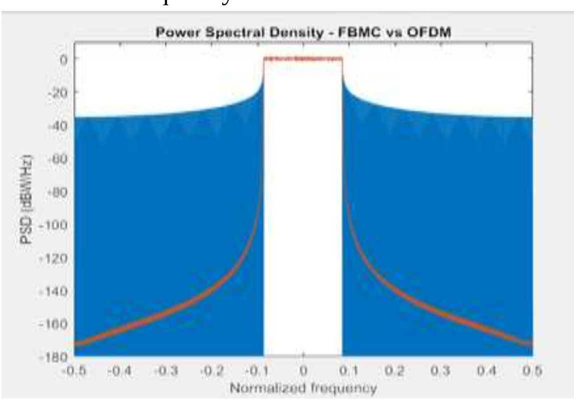


Figure No.3 Power spectral Density FBMC vs OFDM

The red shaded region represent the spectral density of FBMC while blue that of the OFDM. It can be seen from the above graph that the spectral density of FBMC is greater than that of the OFDM. The FBMC has the spectral density closest to the normalized frequency when compared to all other 5 G modulation techniques such as OFDM,UFMC.

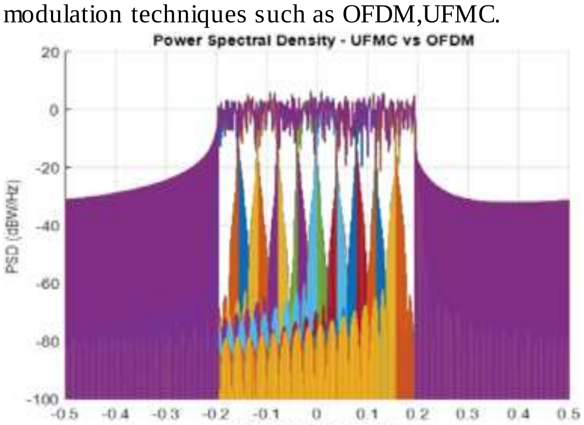


Figure No. 4 . Power spectral Density UFMC vs OFDM

The middle shaded region represent the spectral density of UFMC while blue that of the OFDM. It can be seen from the above graph that the spectral density of UFMC is greater than that of the OFDM. Thus it is seen that the FBMC and UFMC are a better option when compared to that of the OFDM. Thus making one of the two a wiser option for 5 G.

b. Comparison i n Spectral Efficiency

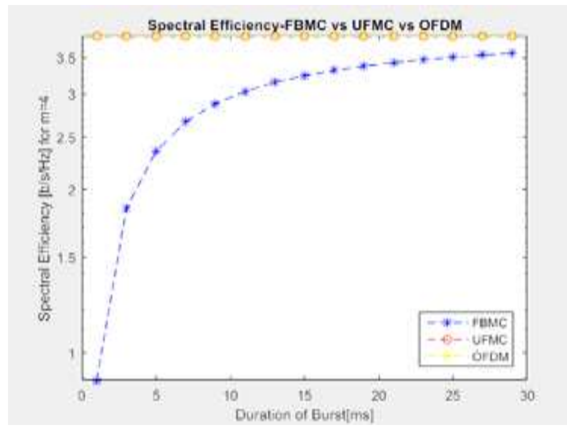


Figure no.4 .Spectral Efficiency UFMC vs FBMC vs OFDM

The graph denotes the spectral efficiency of the three, OFDM, UFMC and FBMC. The graph is generated by varying the duration of burst from 0 to 3 0 . Since the no. of cyclic prefix and the filter length are equal the OFDM and the UFMC overlap each other over the given bursts. It's observed that the FBMC 's spectral efficiency increases with the increase in duration of bursts. It is greater than other two if duration of bursts is larger.

c. Comparison of PAPR

All of the three have high PAPR which is a drawback in these. Among these FBMC has the highest PAPR followed by OFDM and UFMC.

Table No.2 Comparison

| | |
|---|---|
| OFDM | 8.8843 dB |
| FBMC | 10.1178 dB |
| UFMC | 8.2379 dB |

d. Comparison of BER vs SNR

Variation in the SNR affects the quality of the constellation. The simulation of BER vs SNR was generated for SNR from 0 to 1 5 dB. FBC has the best performance compared to the other techniques. It is is closer to zero from 5 dB.

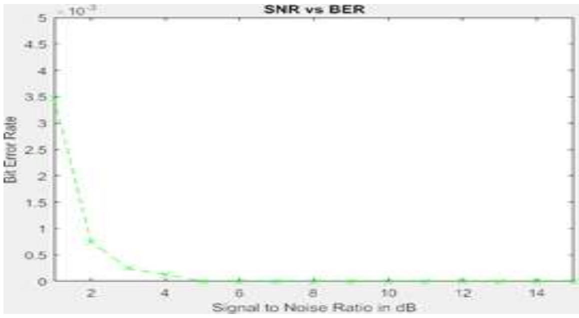


Figure No.5 SNR vs BER UFMC

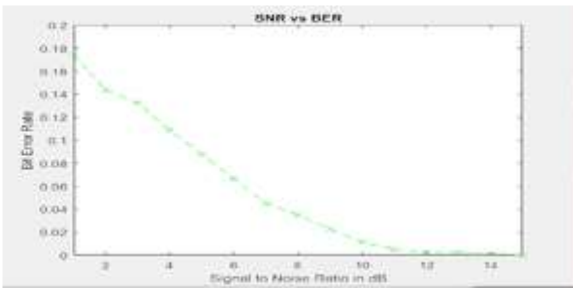


Figure No.6 SNR vs BER FBMC

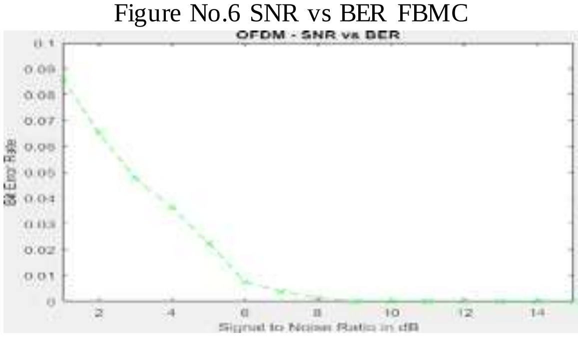


Figure No.7SNR vs BER FBMC

## IV. CONCLUSION

The goal of the project to obtain a performance analysis of different modulation schemes FBMC, UFMC, OFDM implemented in 5 G communications. This helped in obtaining the efficiency of the modulation techniques considering parameters like PAPR, BER, Spectral Density and Spectral Efficiency. This could further be enhanced by applying the modulation schemes across different wireless communication channels. MIMO feature could be added to test the capability of the system for multiple users

## REFERENCES

[1] Boccardi, F.; Aydin, O.; Doetsch, U.; Fahldieck, T.; Mayer, H.,"User-centric architectures: Enabling CoMP via hardware virtualization," Personal Indoor and Mobile Radio Communications (PIMRC), 2012 IEEE 23rd International Symposium on, vol., no., pp.191,196, 9-12 Sept. 2012.

[2] Farhang-Boroujeny, B., "OFDM Versus Filter Bank Multicarrier," Signal Processing Magazine, IEEE, vol.28, no.3, pp.92,112, May 2011.

[3] Bellanger, M., "Physical layer for future broadband radio systems,"Radio and Wireless Symposium (RWS), 2010 IEEE , vol., no., pp.436,439, 10-14 Jan. 2010.

[4] Wunder, G. et al.; “5GNOW: Non-Orthogonal, Asynchronous Waveforms for Future Mobile Applications,” accepted for Communications Magazine, IEEE, 5G Wireless Communication Systems: Prospects and Challenges, February 2014.

[5] Wunder, G. et al.; “5GNOW: Challenging the LTE Design Paradigms of Orthogonality and Synchronicity,” Mobile and Wireless Commun. Syst. for 2020 and Beyond, Workshop @77th IEEE Veh. Technol. Conf. Spring (VTC’13 Spring), Jun. 2013.

[6] Ndo, G.; Hao Lin; Siohan, P., "FBMC/OQAM equalization: Exploiting the imaginary interference," Personal Indoor and Mobile Radio Communications (PIMRC), 2012 IEEE 23rd International Symposium on , vol., no., pp.2359,2364, 9-12 Sept. 2012.

[7] Schaich, F.; Wild, T.; Chen, Y.; “Waveform contenders for 5G suitability for short packet and low latency transmissions,” submitted to IEEE Veh. Technol. Conf. Spring (VTC’14 Spring), Apr. 2014.

[8] Bellanger, M., "Efficiency of Filter Bank Multicarrier Techniques in Burst Radio Transmission,"Global Telecommunications Conference (GLOBECOM 2010), 2010 IEEE , vol., no., pp.1,4, 6-10 Dec. 2010.

[9] Vakilian,V.; Wild, T.; Schaich, F.; ten Brink, S.; Frigon, J.-F.; “Universal Filtered Multi-Carrier Technique for Wireless Systems Beyond LTE,” 9th Int. Workshop on Broadband Wireless Access at IEEE Globecom’13, Atlanta, Dec. 2013.

[10] Schaich, F.; Wild, T.; “Waveform contenders for 5G – suitability for short packet and low latency transmissions”, accepted for publication at VTC spring 2014, Seoul, South Korea, May 2014.