Influence of Filter Length and Side Lobe Attenuation of Dolph-Chebyshev window on UFMC for 1024QAM

Malay Ranjan Tripathy[1*], Demissie Jobir Gelmecha[2], Balwant Singh[3], Rishi Asthana[4], Ram Sewak Singh[5]

[1]*ASET, Amity University, Noida, U.P., (India)-201303*
[2,5]*School of Electrical Engineering & Computing, Adama Science & Technology University,* Ethiopia
[3]*IMSEC Ghaziabad, India*
[4]*AIMT Greater Noida, (India)*
**mrtripathy@amity.edu*

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ABSTRACT

Enhanced mobile broad band, massive machine type communication and ultra-reliable along with low latency is the requirement of the 5G (fifth generation) communication system. Although OFDM (Orthogonal frequency division multiplexing) waveform is used by 4G (fourth Generation) which is not able to fulfill these requirement of the 5G, due to side band leakage, high peak to average ratio and low spectrum utilization. UFMC (Universal filter multi carrier) is multicarrier modulation technique, which is proposed to implement in the existing communication system to get improved performance compared with OFDM. Actually UFMC is derivative of OFDM, so that both of them have a lot of similarity. Absence of CP in UFMC reduces the filter length but receiver side zero padding is done before applying FFT (Fast Fourier transform). UFMC uses additional sub-band per filters which contributes in the reduction of spectral side lobe levels outside the sub-band. Presented article going to analyze the performance of UFMC in terms of BER (bit error rate) on different filter length along with various side lobe attenuation of Dolph-Chebyshev window function. This article applies higher order modulation technique i.e. 1024QAM to get higher data rate.

Keywords – Filter, OFDM, Quadrature Amplitude Modulation, Dolph-Chebyshev, multiplexing, UFMC.

1. INTRODUCTION

OFDM (orthogonal frequency division multiplexing) is a multi-carrier modulation technique[1] . It contributes tremendously for 4G communication system. It has robustness to channel delay, single tap frequency domain equalization and efficient implementation. But it requires strict synchronization requirement. Due to higher side-lob it also reduces spectral efficiency which is not good for communication system. So, there must requirement of the improvement to overcome these factors.

If LTE (Long term evolution) system allocated 20 MHz channel bandwidth along with 100 resource block and 12 subcarriers[2]. Where 15Khz subcarrier spacing which mean LTE uses only 18MHz of the allocated spectrum. So there is 10% loss of spectrum. Basic physical layer parameter for LTE network is given in table 1. OFDM is very demanding modulation technology to improve data rate[1]. 4G uses the same because of attractive fundamental characteristics[2]. Basic features of OFDM is, it uses multiple carriers (known as subcarriers) to carry the information stream and each subcarrier are orthogonal to each other. Additionally, OFDM uses guard interval between each symbol to minimize the channel delay spread and ISI (Inter symbol interference). Protection to discriminating fading, avoidance of interference, improvement in the spectral efficiency, protection from narrow band effect and simple channel equalization are the few advantages of OFDM technique. While it have some disadvantage as, high PAPR and sensitivity to carrier offset and drift. To overcome these disadvantages, advance communication system must have to find new waveform contender which have capability to achieve asynchronous transmission, improved spectral efficiency, low out of band emission and latency.

Table 1: Basic physical layer parameter of LTE

Channel BW (MHz)	**1.4**	**3**	**5**	**10**	**15**	**20**
Occupied BW (MHz)	1.08	2.7	4.5	9	13.5	18
No. of Subcarriers(UL)	72	180	300	600	900	1200
No. of Subcarriers(DL)	73	181	301	601	901	1201
No. of Resource blocks (RBs)	6	12	25	50	75	100
No of Subcarriers per RB	12	12	12	12	12	12
FFT size	128	256	512	1024	1536	20148

Among various waveforms, UFMC have easily tunable subcarriers and less complex design which achieves almost above described requirement for new generation communication system. UFMC is also known as unified filtered OFDM[4].

2. UNIVERSAL FILTER MULTI CARRIER (UFMC)

Basically FBMC uses F-OFDM (filtered OFDM)[5]. Here entire band is filtered by F-OFDM and individual subcarriers are filtered by FBMC (filter bank multi carrier)[6], while groups of subcarriers are filtered by UFMC (universal filtered multi carrier). Filter length, which is used in FBMC can be reduced by subcarrier grouping. Additionally UFMC is able to use M-ary QAM (Quadrature amplitude modulation) means it uses existing MIMO (Multi Input Multi Output) system and retain complex orthogonality.

If, 'N' full band subcarriers are used to divide the sub bands. Equal numbers of subcarriers are allocated to each sub-band, for transmission while few sub-bands are not need to use. Here multiple subcarriers are used for transmission so N point FFT (Fast Fourier Transform) is required. So that N-point- IIFT for each sub-band is computed and insert zero for unallocated carriers. Filtering of length 'L' is used for each sub-band. After the filtering of the each sub-band, these must be summed for the purpose of transmission. One point must be noted that filtering is able to reduce out of band spectral emission. Different filter per sub-band can be applied however this manuscript uses same filter for each sub-band. This manuscript also uses Chebyshev window function with parameterized side lobe attenuation to filter the IFFT output per sub-band[7]. UFMC transmitter is shown in figure 1.

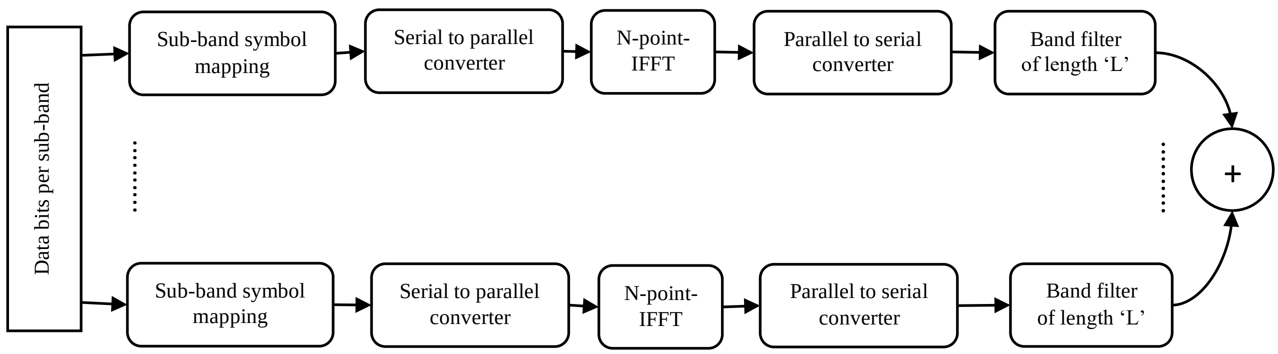

Figure 1: UFMC Transmitter

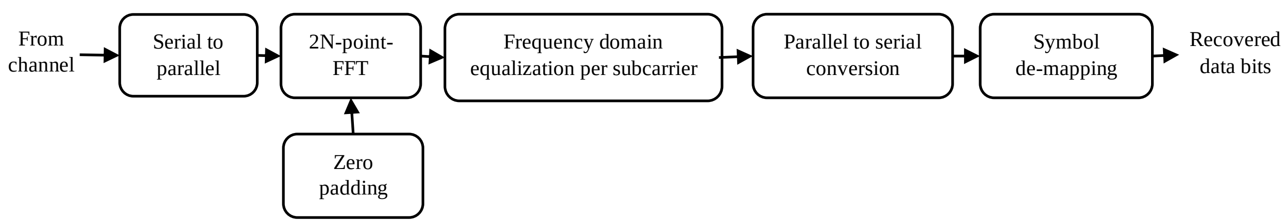

Figure 2: UFMC Receiver

Now, at the receiver side, the sub-band filtering extends the receive time window to the next of two power length for the FFT operation where every alternate value corresponds to a subcarrier main lob. There are interference problems due to side lobes of the spectrum and this can overcome with the help of equalizers. Here, every alternate frequency value corresponds to subcarrier main lobe and which is able to equalizing the joint effect of the channel and the sub-band filtering. This manuscript only equalized only the sub-band filter because no channel effects are modeled. This manuscript also added noise to analyze the effect of noise on the transmitted signal. UFMC receiver is shown in figure 2.

Let we have 'n' users who wants to transmitt the information by a communication stsem which is using UFMC. At the transmitter side first of all complex symbols of user 'n' genrates from the base band modulator. Symbol genrated by individual users are mapped to sub-band symbol. Basically sub-band mapping, breaks a signal into various frequency band and encodes each one independentely. These serially genrated waveform provides to N-ponit IFFT (Inverse fast fourier transform). Now conversion of parrel to serial take place to make a block of stream. These block of of stream provides to band filter of length 'L', which transmitt this information to chhanel.

Noise will be introduced in channel. Now signal with noise is received by the detector where these serial waveform convert in parallel form to perform the FFT (Fast Fourier transform) operation. Here we are transmitting large number of data to get higher data rate, so there will be inter symbol interference (ISI). UFMC use equalizers to overcome the effect of the ISI. Output of equalizers are again converted in the serially to get symbol de-mapping. After symbol de-mapping we will get recovered data bit.

3. DOLPH-CHEBYSHEV WINDOW

Chebyshev polynomials [8]can be defined as:

$$F_n(x) = \begin{cases} \cos(n\,cos^{-1}x), & |x| \leq 1; \\ \cosh(n\,cosh^{-1}x), & |x| > 1 \end{cases}$$

we can obserb that $F_n(x)$ has 'n' zeros in the interval (-1, +1) as well as 'n+1' extrema for the same interval. This function oscillates between '-1' and '+1' for 'x' in ithe interval (-1, +1) also. Again $F_n(x)$ is greater than '1' if x is greater than '1' and for large value of 'x' the function $F_n(x)$ approximatelly equal to $2^{n-1}x^n$. Now, if we transform this function in frequency domain, the oucome become,

$$W(f) = \frac{F_{2M}\,[x_0 \cos\,(f_0/2)]}{T_{2M}\,(x_0)}$$

Here x_0 is greater than '1' and $x_0\cos(f/2)$ is equal to 1 for all value of 'f'. we can see that W(f) is symmetric about the origin. Response of W(f) is maximum for 'f' equal to zero and reponse approches to zero as 'f' tends to $\pm\pi$. The function W(f) is reprents the form of finte Fourier transform. So that W(f) become

$$W(f) = \sum_{n=-M}^{+M} w_n e^{-inf}$$

and,

$$w_n = \frac{1}{N}[1 + \frac{2}{F_{2M}\,(x_0)} \sum_{m=1}^{M} F_{2M}\left(x_0 \cos\frac{f_m}{2}\right) \cos m f_n]$$

Where $|n| \leq M$, length of the filter N=2M+1 and $f_m = 2\pi m/N$. here W(f) is real and even, w_n is also real and $w_{-n} = w_n$. The weights [wn: $-M \leq n \leq +M$] define the Dolph-Chebyshev window[9]. This window function used to modify the coefficients og low pass filter. It is also able to reduce the Gibbs oscillation. This manuscript uses the same to reduce the BER for UFMC so that to achieve the improvement in the performance.

4. SIMULATION AND RESULT

Presented manuscript considered parameters for the purpose of the simulation i.e. Number of FFT point is 1024, Sub-band size is 10, Number of sub-bands is 20, Value of sub-band off-set is 312, Order of the Quadrature Amplitude Modulation (QAM) is 10 and SNR is 20.

Note that sub-band size must be greater than one and number of sub-bands ($N_{sub\text{-}band}$) depends upon number of FFT points (N_{FFT}) and size of sub-band ($S_{sub\text{-}band}$)

$$N_{FFT} \geq N_{sub-band} * S_{sub-band}$$

Again offset value of sub-band defined as:

$$Sub - band\ offset = \frac{N_{FFT}}{2} - \frac{S_{sub-band} * N_{sub-band}}{2}$$

This manuscript uses Dolph-Chebyshev window. Performance of Universal Filter Multi Carrier (UFMC) is presented in term of BER i.e bit error rate, by varying the length of filter and side-lobe attenuation .Here we considered the filter length as 10, 20, 30, 40, 50 and 60 which is shown in table 2 by FL_10, FL_20, FL_30, FL_40, FL_50 and FL_60 respectively.

Table 2: BER of given filter length for various side-lobe attenuation

Side lobe Attenuation (dB)	BER					
	FL_10	FL_20	FL_30	FL_40	FL_50	FL_60
0	0.0435	0.048	0.0475	0.0455	0.05	0.05
1	0.0435	0.048	0.0475	0.046	0.05	0.049
5	0.0435	0.0475	0.047	0.0445	0.05	0.0475
10	0.0435	0.0475	0.0475	0.045	0.0515	0.0475
15	0.0435	0.047	0.046	0.045	0.052	0.047
20	0.0435	0.047	0.046	0.0455	0.052	0.047
25	0.0435	0.0465	0.046	0.0455	0.0515	0.046
30	0.0435	0.0465	0.046	0.046	0.051	0.046
35	0.0435	0.0465	0.046	0.046	0.051	0.046
40	0.0435	0.0465	0.046	0.046	0.0515	0.046
45	0.0435	0.0465	0.046	0.046	0.0515	0.046
50	0.0435	0.0465	0.046	0.046	0.0515	0.046

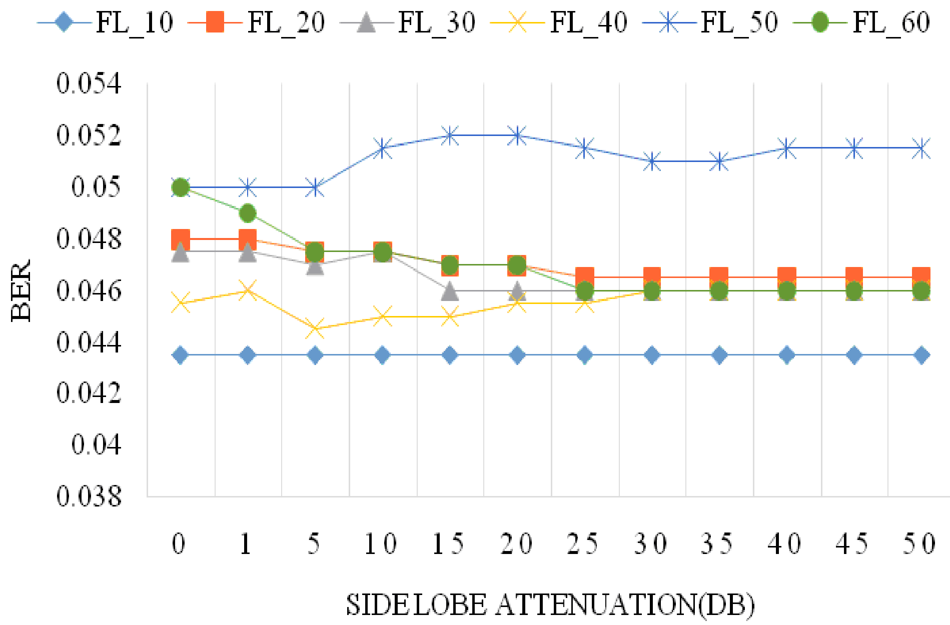

Figure 3: BER of given filter length for various side-lobe attenuation

Again Dolph-Chebyshev window apply side lobe attenuation as 0, 1, 5, 10, 15, 20, 20, 25, 30, 35, 40, 45, and 50 for every considered filter length. As per demand of novel communication, we have to increase data rate, so this manuscript applies 1024QAM. Because higher order modulation technique can increase data rate but there is problem of interference. due to the interference higher order modulation technique increase bit error rate i.e. BER [10]. Here we are using 1024QAM along with signal to noise ratio (i.e. SNR) 20dB and analyzed BER for described parameter.

5. CONCLUSION

Data rate can be increased by increasing order of modulation. But the basic problem is inter symbol interference. Nowadays, to achieve higher data rate, implementation of higher order modulation technique is compulsory. Again 5G technology implements device to device (D2D) technique to get improved data rate, which uses orthogonal frequency division access (OFDM) for down link and single carrier OFDM (SC-OFDM) for up-link. One point must be remembering that both of them uses higher order modulation technique. To reduce the effect of the interference this technology adopts many types of filtering operation on the same i.e. F-OFDM (Filtered OFDM), RRC (Root raised cosine), FBMC (Filter bank multicarrier), UFMC (Universal filter multi carrier) and etc. This manuscript uses UFMC to analyze. Basically, UFMC implements FFT (Fast Fourier technique), QAM (Quadrature amplitude modulation), Dolph Chebyshev window. This manuscript observes the effect of window length and side lob attenuation. Simulation result shows that, at the lower filter length (10 in this manuscript) there is no effect (in terms of BER) of the variation of side lobe attenuation, but as order of filter length increases side lobe attenuation have remarkable effect on the performance of the system. One point also be noted that at lower filter length (10, 20, 30), BER is reducing while at higher filter length (40, 50, 60), BER in increasing as side lobe attenuation increases. So, proper selection of filter length along with side lobe attenuation makes perfection in the UFMC performance.

6. REFERENCES

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