UFMC: The 5G Modulation Technique

P. Naga Rani,
Pursuing M. Tech (ECE-DECS)
D.M.S.S.V.H College of Engineering,
Machilipatnam, Andhra Pradesh, India,
nagarani687@gmail.com

Dr. Ch. Santhi Rani,
Prof & Head, Department of ECE,
D.M.S.S.V.H College of Engineering,
Machilipatnam, Andhra Pradesh, India,
santhirani.ece@gmail.com

***Abstract*-This paper describes the aspects of Universal Filtered MultiCarrier (UFMC) system and highlights the merits of new modulation method for emerging fifth generation (5G) Wireless Communication Systems. Orthogonal Frequency Division Multiplexing (OFDM) is an excellent choice for fourth generation (4G). 4G modulation methods suffer from the problem of high Peak to Average Power Ratio (PAPR). Side band leakage is another problem in OFDM. Our current 4G systems rely on the OFDM waveform, which is not capable of supporting the diverse applications 5G will offer. The traffic generated by 5G is expected to have very different characteristics and requirements when compared to current wireless technology. As result other multiple access schemes are being investigated. The way to overcome the known limitations of OFDM is UFMC technique. This paper discusses PAPR and Bit Error Rate (BER) of UFMC system for various mapping schemes. Mat lab simulations show that BER values for UFMC are increasing with increase in number of bits per subcarrier. BER of UFMC system is less for 4QAM (Quadrature Amplitude Modulation) mapping method when compared to the other mapping methods but PAPR of UFMC is high when compared with OFDM. PAPR for UFMC is 8.237 and for OFDM it is 8.843 at SNR=5dB when 16QAM Mapping is used. For all other mapping methods PAPR of UFMC system is high compared to PAPR of OFDM. Therefore as a compromise between BER and PAPR of UFMC system, 16QAM mapping method is preferable for UFMC system.**

Keywords - BER, OFDM, PAPR, UFMC, QAM.

I. INTRODUCTION

4G communication systems such as LTE/LTE Advanced, Wi-Fi uses OFDM, as multi-carrier modulation technique. Although it has efficient implementation and robustness to channel delays as highlights but this method suffers from high PAPR results low efficiency of power amplifier, increases the battery consumption. Moreover the OFDM spectrum has high out of band side lobes causing problem of low spectral efficiency. To overcome some of these drawbacks new modulation techniques for 5G communication system are considered.

The applications which use 5G communication system require higher data rates, lower latency and efficient spectrum usage. The way to overcome the known limitations of OFDM is UFMC technique. UFMC is generalization of Filtered OFDM and FBMC modulations. In OFDM the total band is filtered and in Filter Bank MultiCarrier (FBMC) individual subcarriers are filtered where as a group of subcarriers (sub bands) are filtered in UFMC. This subcarrier grouping reduces the filter length (when compared with FBMC).

Single carrier modulation uses one carrier to transmit overall data. This technique is widely used in GSM, CDMA 2000. The main goals to prefer this method are battery power and coverage extensions. Single carrier method requires equalizers to achieve high spectral efficiency. Multicarrier modulation converts a wideband carrier into multiple orthogonal narrowband carriers. For higher data transmission wireless communication systems required to incorporate Multicarrier modulation.

A. Structure of Assessment

This paper contains four sections. A brief introduction is given in section I. UFMC system model details would be discussed in Section II. Section III and Section IV will deal with simulation results and conclusion respectively.

B. Literature Survey

OFDM divides the spectrum into number of orthogonal and non-overlapping subcarriers. In OFDM timing and Carrier Frequency Offset (CFO) errors are high. FBMC is the new modulation technique for 5G to overcome these losses in OFDM [1].

Like OFDM, FBMC is also a multicarrier technique which employs per-subcarrier filtering. Filtering technique is used in FBMC. FMBC's improved synchronization and resistance to misalignments of frequency make the waveform an enticing alternative to OFDM. However, the additional filtering required increases the implementation complexity. For short burst uplink communication with high filter length of FBMC is disadvantageous [2].

The performance of UFMC signals is better than OFDM in terms of side lobe attenuation, BER for discrete narrow band networks [3]. Smart Gradient Project Active Constellation Extension (ACE-SGP), Tone Reservation (TR) methods are used to reduce the PAPR values for FBMC/OQAM signals [4]. UFMC does not have to use a cyclic prefix, although it can be used to improve the inter symbol interference (ISI) protection using special or unified structure of the frame [5].

II. SYSTEM MODEL

Now-a-days UFMC is a highly research involved 5G modulation method. UFMC, a novel multicarrier modulation technique works equivalent to the generality of filtered OFDM

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and FBMC modulations. Unlike self-subcarrier modulation in FBMC, a group of subcarrier modulation is performed in UFMC. The subcarrier grouping reduces the length of the filter compared with FBMC and also reduces time to perform modulation. QAM type of modulation is used in UFMC. Transmitter block diagram is shown in Fig.1 and Receiver block diagrams of UFMC are shown in Fig.2 and the system parameters of UFMC are displayed in Table I.

Table I: System parameters

Parameter	Value
Number of FFT points	512
Sub band size	20
Number of sub bands	10
Sub band offset	156
Filter length	43
Side lobe attenuation	40
Bits per subcarrier	2,4,6,8
SNR(dB)	15

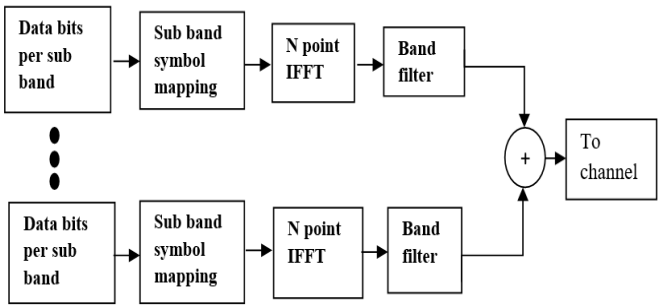

Fig.1. UFMC transmitter block diagram

UFMC employs the division of full band into sub bands. The modulation technique processes these sub bands individually and each sub band consists of fixed number of subcarriers. The narrowband and closely spaced Individual sub bands undergoes N-point Inverse Fast Fourier Transform (IFFT) to get time domain (x_i) of each sub band from Frequency Domain (X_i) of each sub band. After performing N point IFFT on each sub band the output can be expressed as

$$y_i = IFFT\{x_i\} \quad (1)$$

Each sub band output resulting from IFFT is filtered by filter length L. The resulting output signal is expressed as

$$y = \mathrm{H} \bullet \sim Q \bullet y_i \quad (2)$$

H is toeplitz matrix with dimensions (N+L-1)*N and ~Q represents inverse Fourier matrix.

IFFT operation ensures that the sub band carriers do not interfere. UFMC uses Band filter to perform A Chebyshev filtering operation. Band Filter filters each sub band and each sub band responses summed. The filtering approach in UFMC reduces out of band spectral emission for proper design of filter. Filter with parameterized side lobe attenuation is employed to filter the IFFT output per sub band [1].

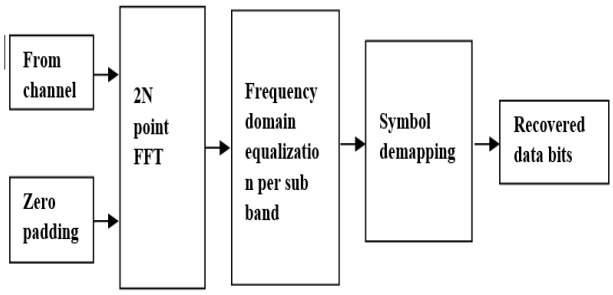

Fig.2. UFMC receiver block diagram

UFMC receiver performs 2N point Fast Fourier Transform (FFT) on data obtained from channel. A guard interval of Zeros is added between successive IFFT symbols. This prevents the Inter Symbol Interference (ISI) due Transmitter filter delay.

$$\sim Y = FFT\left\{\left[y^T, 0, 0, \ldots\ldots, 0\right]\right\} \quad (3)$$

Discard even subcarrier points to get N length frequency domain receive signal Y. FFT coverts data received in time domain into frequency domain. Equalization detects the transmitted data. The Symbol demapping is performed prior to the frequency domain equalization to get the original data bits.

III. SIMULATION RESULT

Fig.3 and Fig.4 depicts the Power Spectral Density values for 200 subcarriers. The overall band is divided into 10 sub bands, each sub band having 20 subcarriers with less side lobes. Efficient utilization of power is vital criteria in wireless communication system. On comparing Fig.3 & Fig.4 the utilization of spectrum is good in UFMC than OFDM. BER and PAPR of UFMC system for various mapping techniques using MATLAB simulations are listed in Table II. From the Table II it is observed that BER of UFMC is increasing when number of bits per subcarrier is increasing. UFMC system BER is small for 4QAM mapping method. The PAPR values of UFMC system are high compared to OFDM except for 16QAM mapping method. Even though BER of UFMC system is less, PAPR of UFMC system is high for 4QAM mapping method. Therefore compromise between BER and PAPR 16QAM mapping method is used for UFMC system.

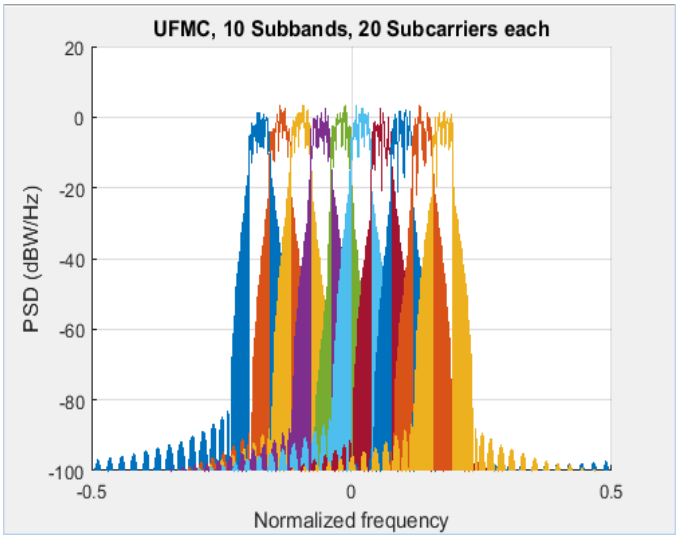

Fig.3. PSD of UFMC

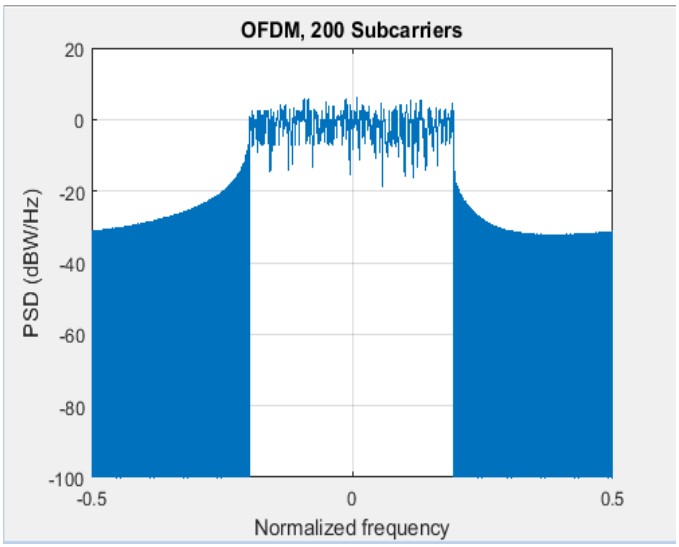

Fig.4. PSD of OFDM

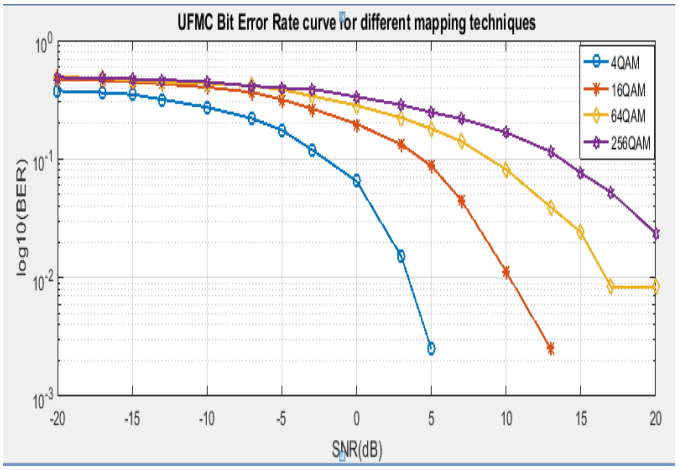

Fig.5. the snap shot of UFMC Bit Error Rate performance using different mapping techniques such as 4QAM, 16QAM, 64QAM, 256QAM.

Table II: Bit Error Rate and Peak to Average Power Ratio of UFMC for different mapping techniques at 5dB Signal to Noise Ratio.

Mapping Technique	BER of UFMC	PAPR of UFMC	PAPR of OFDM
4QAM	0.0025	9.04	8.4377
16QAM	0.0875	8.2379	8.8843
64QAM	0.18	8.6229	9.9269
256QAM	0.24688	8.0416	7.2553

IV. CONCLUSION

UFMC is promising waveform candidate for 5G.The way to overcome the known limitations of OFDM is UFMC technique**.** In this paper our finding shed towards 5G technique, UFMC performance. The PAPR of UFMC is better compared to 4G technique (OFDM) using 16QAM Mapping method. PAPR for UFMC is 8.237 and for OFDM it is 8.843 at SNR=5dB when 16QAM Mapping is used**.** The BER performance of UFMC gives 0.0025dBusing 4QAM Mapping method is better compared with 16QAM, 64QAM, 256QAMMapping methods. PAPR value of UFMC is better for 256QAM method. Therefore as a compromise between BER and PAPR it is observed to consider 16QAM as a mapping scheme for UFMC system.

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