Performance Evaluation of OFDM and UFMC

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Abstract— **Orthogonal frequency division multiplexing (OFDM) was the foremost dominating waveform utilized in fourth generation mobile communication systems. But OFDM cannot meet all the needs of 5G networks. With the development of 5G communication sub-band filtering based waveform universal filtered multi-carrier (UFMC) waveform has paid more attention. UFMC collects the advantages of filtered OFDM (F-OFDM) and Filter bank multi-carrier (FBMC) modulation. This paper compares the out of band emission (OOBE) and bit error rate (BER) of UFMC and OFDM.**

Keywords—OFDM, UFMC, BER, OOBE.

I. INTRODUCTION

OFDM was the most dominating waveform used in telecommunication systems such as LTE, Wi-Fi, WiMAX and Power line communication. To combat the effect of multipath reception in OFDM, wide band frequency selective fading channel is divided into many narrow flat sub-channels [1]. OFDM provides numerous advantages because OFDM can be efficiently implemented using FFT/IFFT and OFDM systems are easily compatible with multiple input multiple output (MIMO) systems [2]. Despite of its advantages OFDM cannot meet the demand of 5G service scenarios, because OFDM has high side lobe in frequency which leads to high out of band emission (OOBE). OFDM has large peak-to-average-power ratio (PAPR). OFDM cannot provide flexibility in waveform design to use the available spectrum efficiently. OFDM requires each sub-carrier to have the same bandwidth and all the sub-carrier should be orthogonal to each other.

To better address the requirement for 5G wireless systems many research activities are ongoing recently to identify alternative new waveforms. The main benefits of most of these new waveform is reduced OOBE compared to conventional OFDM [3]. In order to reduce OOBE, recent research has focused on enhancement of the OFDM by considering additional filtering components. Through different filter designs filtered based OFDM can be used in 5G networks since it supports asynchronous transmission by reducing OOBE [4]. Filter based waveforms can be divided into two types based on the filter granularity: sub-carrier filtering and sub-band filtering. Filter bank multi carrier modulation (FBMC) and Generalized frequency division multiplexing (GFDM) uses sub-carrier filtering. Modulator used in sub-carrier filtering waveform is more complicated than conventional OFDM modulator [5].

Sub-carrier filtering used in FBMC reduces the side lobes which reduces OOBE and inter carrier interference (ICI), which usually occurs due to large side lobes. In OFDM to avoid ICI problem cyclic prefix is used, which reduces the spectral efficiency of OFDM. Spectral efficiency of FBMC is better than OFDM since it does not require cyclic prefix. Since sub-carrier filtering is used in FBMC the tail of the filter's impulse response is long, which makes FBMC not suitable for small packet transmission and low latency service. FBMC is not suitable for MIMO application due to the long filter length [6]. In GFDM to avoid inter burst tails sub-carrier filtering is applied in block wise manner. Drawbacks of GFDM are increased decoding latency, and use of high complex receivers [7].

To overcome the drawbacks of sub-carrier filtering waveforms, sub-band filtering waveforms were proposed. Since sub-band filtering is used, length of filters impulse response is less than sub-carrier filtering based waveforms. In Sub-band filtering complete bandwidth is divided into several sub-bands, OFDM signal is used in each sub-band [8]. Filtered OFDM uses sub-band filtering in which to suit the needs of different services different numerologies may be applied to different sub-bands [9]. Filtered OFDM maintains cyclic prefix as used in conventional OFDM. UFMC also uses sub-band filtering, in which each sub-band has fixed Bandwidth. To avoid inter symbol interference (ISI) due to filtering operation Zero prefix [ZP] is used in UFMC [10]. The length of filter in UFMC is less than or equal to ZP. In this way in UFMC filter tails extend to the ZP's without overlapping with each other. Since cyclic prefix is not used in UFMC spectral efficiency of UFMC is better than OFDM. In UFMC ISI introduced by multipath fading channel cannot be completely mitigated like OFDM, because UFMC does not use cyclic prefix [11] [12]. But if the delay spread of the channel is less than length of the filter, resulting ISI and ICI will be very small hence can be neglected. UFMC can be used for MIMO application. The paper is organized as follows. In section II system model of UFMC is described. Section III gives the simulation and analysis of UFMC compared to the conventional OFDM. Section IV gives the concluding remarks.

II. SYSTEM MODEL

Transceiver block diagram of UFMC is as shown in Fig. 1. In UFMC entire bandwidth is divided into N sub-bands, each of which is composed of K sub-carriers. The K sub-carriers are fed in to QPSK or QAM modulator, output of QPSK or QAM modulator is applied to IDFT to generate time domain signal of length N. Output of IDFT is filtered by Dolph-Chebyshev FIR filter with filter length L. For each block of QAM symbols discrete baseband UFMC signal is obtained by summing the filtered signal of each sub-band.

$$x(n) = \sum_{i=0}^{N-1} \sum_{n=0}^{L-1} S_i(n) f_i(m-n) \qquad (1)$$

Where m=0...N+L-1 samples. In UFMC filters are used only at the transmitter. 2N point FFT is used at the receiver for demodulation. If the transmitted signal length in UFMC is N, L is the length of filter channel impulse response then the length of the received signal will be N+L-1. To cope up with the time dispersion a zero padded guard length of L-1 is introduced in each UFMC symbol. Data symbols can be recovered by padding N-L-1 zero's at the end of received signal and then performing 2N point FFT. Only the N even bits of the 2N point FFT are used to recover the data symbols, since odd sub-carriers contain ICI. Orthogonality between sub-carrier is maintained in UFMC.

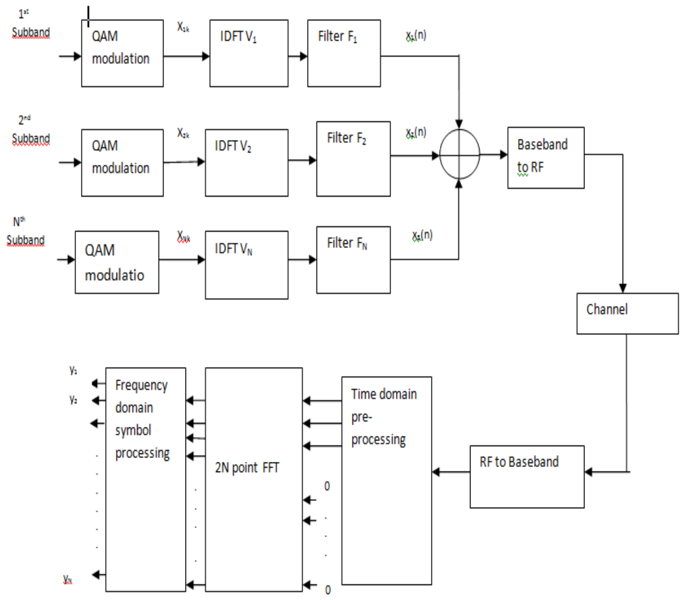

Fig. 1. System model of UFMC

III. SIMULATION RESULT

OFDM and UFMC systems have been simulated using MATLAB.4-QAM and 16-QAM are the modulation techniques used for OFDM and UFMC with a bandwidth of 1.5MHz. In UFMC 10 sub-bands with 200 sub carriers are used, where as in OFDM 200 subcarriers are used for simulations. Filter length used in UFMC is almost same as the length of cyclic prefix in OFDM.

A. Results and discussion

Conventional OFDM uses rectangular pulse shape in time domain, which is sinc in frequency domain whose side lobes drop with frequency as slowly as 1/f. This leads to a frequency spectrum which is not well localized and produces high OOBE. With the help of some appropriate filters used in UFMC system such as Dolph-chebyshev filters reduces the spectral leakage outside the sub-bands. Fig. 2 shows the power spectral density of OFDM and Fig. 3 shows the power spectral density of UFMC. OOBE of UFMC is around 50dB lesser than Conventional OFDM.

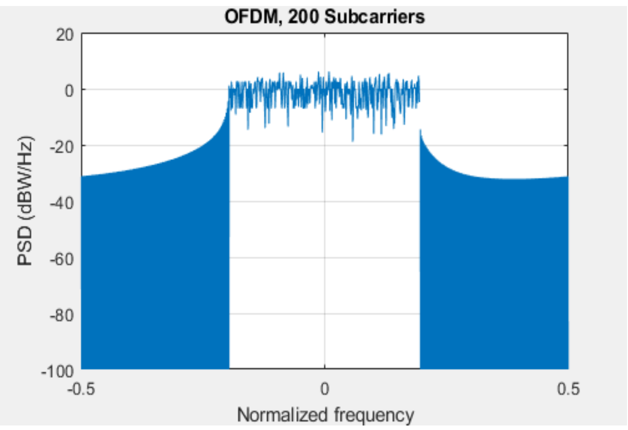

Fig. 2. Power spectral density of OFDM System

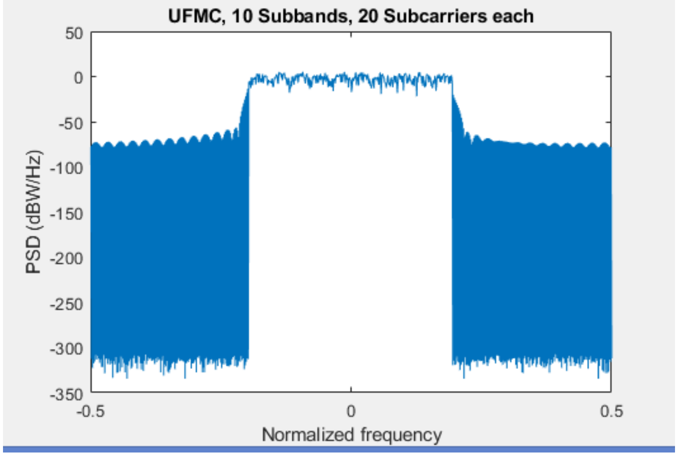

Fig. 3. Power spectral density of UFMC System

UFMC not only has a low OOBE performance, but also it has same BER performance as conventional OFDM. Fig. 4 shows the SNR versus BER variation of UFMC for 4-QAM modulation. Fig. 5 shows the SNR versus BER variation of UFMC for 16-QAM modulation Scheme. From Fig. 4 and 5 it is clear that BER performance of UFMC is almost same as that of OFDM. Simulation result shows that as the modulation order increases SNR increases.

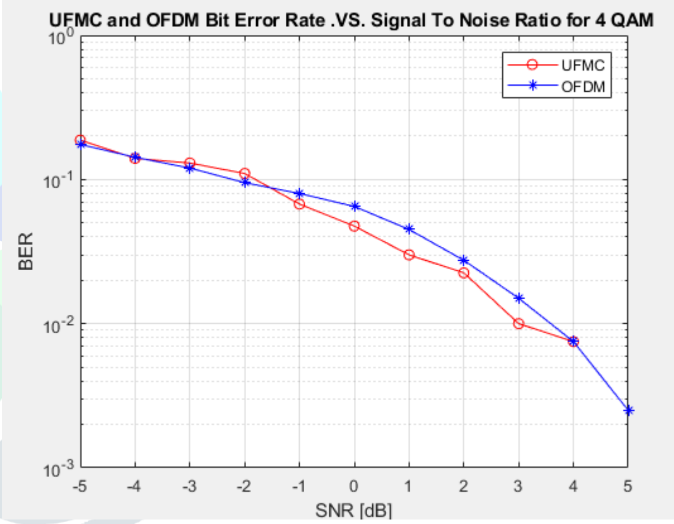

Fig. 4. SNR versus BER comparison of OFDM and UFMC for 4-QAM.

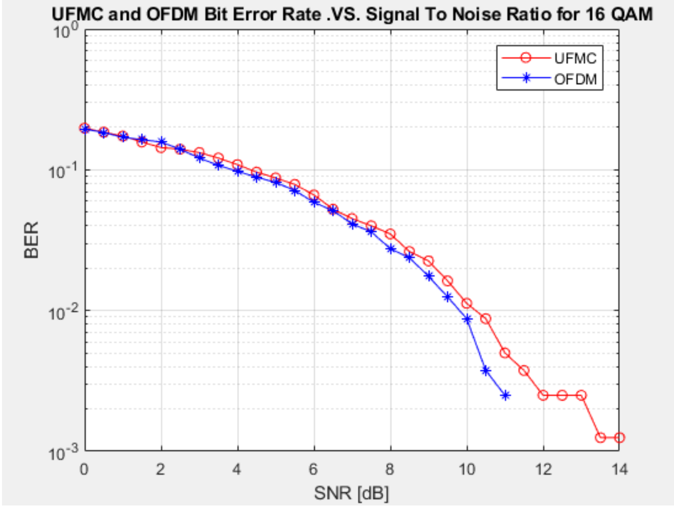

Fig. 5. SNR versus BER comparison OFDM and UFMC for 16-QAM.

IV. CONCLUSION

Due to the requirement of asynchronous transmission in future 5G networks, UFMC has gained lot of attention recently. Performance investigation reveals that UFMC is a feasible substitute for OFDM. Our simulation results show that UFMC can achieve much lower OOBE compared to OFDM with almost same BER performance as that of OFDM. Therefore as a replacement of OFDM, UFMC can be expected to be used for asynchronous transmission in future 5G networks.

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