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FBMC OQAM-PTS WITH VIRTUAL SYMBOLS AND DFT SPREADING TECHNIQUES

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Abstract

In Filter bank multicarrier (FBMC) systems based on Offset Quadrature Amplitude Modulation (OQAM), namely FBMC-OQAM, has been criticized for its inefficiency in the use of spectral resources and high peak power problems. A novel method like, Discrete Fourier transform (DFT) Spread - Identically Time Shifted Multicarrier (ITSM) with virtual symbols based FBMC-OQAM system is proposed to reduce Peak to Average Power Ratio (PAPR) and to improve spectral efficiency. The four candidate versions of the DFT-spread and ITSM-conditioned FBMC waveform has been generated and one with minimum peak power is selected to calculate PAPR. During a multiple candidate generation, the major computation parts, such as DFT and IDFT are shared and need to be performed only once, unlike the conventional side information (SI)-based PAPR reduction schemes. Then, the fractional complexity overhead is found and compared with the conventional DFT-spread FBMC method. As a result, the proposed scheme achieves an improved PAPR reduction comparable to that of conventional method named as Single Carrier-Frequency Division Multiple Access (SC-FDMA). Also, in order to reduce the usage of side information and to improve the spectral efficiency, the tail shortening method is proposed with the DFT-spread ITSM based FBMC-OQAM which reduces

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the long ramp-up and ramp-down tails at the beginning and the end of each data packet like side information. Simulation results show that, the proposed method gives reduced PAPR and high spectral efficiency with tail-shortening approach which leads to superior out-of-band emissions performance and a much lower error vector magnitude for the demodulated symbols.

1. Introduction

The FBMC-OQAM gains considerable attention for future wireless systems. Although FBMC has a significant number of merits, there are still some issues that need to be resolved. High peak power, low spectral efficiency and high computational complexity are the major issues in the multicarrier modulations like FBMC-OQAM systems. These factors also reduces the overall performance of the FMBC-OQAM systems [1]. Using the combination of DFT Spreading with ITSM-conditioned FBMC and Tail shortening method, a new FBMC is proposed for low PAPR and to improve spectral efficiency. Also in order to improve the spectral efficiency, a novel method is proposed instead of cyclic prefix that avoids ISI/ICI and keeps out of band emission (OOB) which is similar to that of the FBMC without tail-shortening [2]-[9]. The additional, but redundant, symbols at the two sides of the packet are introduced and these symbols are chosen to suppress the waveform tails without introducing any ISI/ICI and without increasing OOB emissions. These symbols are called as virtual symbols because they do not carry any data [10]. The rest of this paper is organized as follows: Section 2 presents a brief description of conventional DFT spread ITSM-FBMC signaling method. Section 3 gives the proposed DFT-spread ITSM with tail shortening virtual symbols. In Section 4, performance evaluation and the computational complexity with the relevant filter designs are presented. Also, the spectral efficiency is found and the results are compared with the existing PAPR reduction schemes for FBMC. Finally in Section 5, the concluding remarks are given.

2. DFT Spread ITSM based FBMC

In Discrete Fourier Transform spread Identically Time Shifted Multicarrier (DFT spread ITSM) scheme, the data frame is divided into consecutive blocks, each of which contains W FBMC symbols. Four versions of the DFT-spread and ITSM conditioned FBMC waveforms are generated. For each data block, first two versions for the l^{th} data block denoted by $xl^{(1)}(t)$ and $xl^{(2)}(t)$ with the symbol index m limited to the l^{th} data block $lW \leq m \leq (l+1)W - 1$.

3. Proposed DFT Spread ITSM with Tail Shortening Virtual Symbols

Let $R\{x\}$ and $I\{x\}$ is the real part of x and imaginary part of x respectively and $[x_n]_{n=a}^{b} = [x_a, x_{a+1}, \ldots, x_b]$. Figure 1 shows that, the state of art implementation structure of the FBMC modulator. The number of sub-carriers are denoted by N. The m^{th} complex input symbol on the n^{th} carrier is denoted by $d_{n,m}$. The $d_{n,m}$ can be expressed as $d_{n,m} = a_{n,m} + jb_{n,m}$, where, $a_{n,m}$ and $b_{n,m}$ denote the real and imaginary data terms, respectively, then $a_{n,m}$ and $b_{n,m}$ are splitted and fed into upper and lower IDFTs with the phase shift terms multiplied. The phase shift term of $a_{n,m}$ (at the n^{th} element of upper IDFT input vector) is denoted by $\eta_{n,m}$ and the phase shift term of $b_{n,m}$ (at the n^{th} element of lower IDFT input vector) is denoted by $\mu_{n,m}$.

$$\begin{aligned}
\eta_{n,m} &= 1(\text{or} - 1) \text{ if } n = \text{even}, \\
&= j(\text{or} - j) \text{ if } n = \text{odd}, \\
\mu_{n,m} &= j(\text{or} - j) \text{ if } n = \text{even}, \\
&= 1(\text{or} - j) \text{ if } n = \text{odd},
\end{aligned} \quad (1)$$

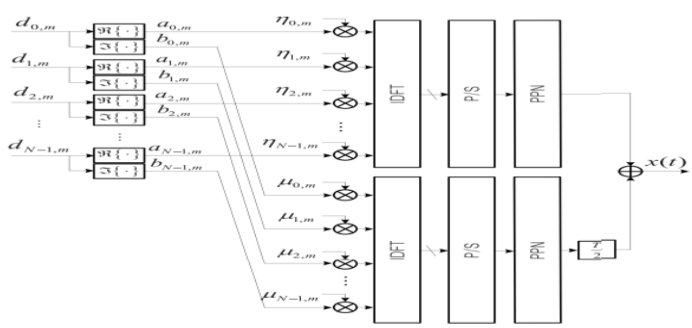

Figure 1. Implementation structure of FBMC.

3.1. Tail Shortening by Virtual Symbols

The Filter Bank Multi-carrier system is adopted by filters with long length which results, ramp-up at the beginning and ramp-down at the end (which are called as tails) of each data burst and covers multiple symbol intervals. There are two methods used to shorten the tails. (i) Hard truncation, (ii) Truncation with windowing. The packet ends at the same position as shown in Figure 2

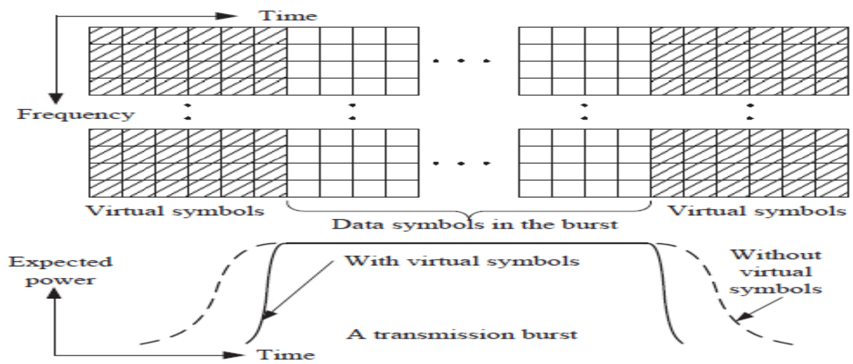

Figure 2. Virtual symbols in an FBMC burst.

4. Performance Evaluation

The performance of the proposed scheme is simulated using Matlab R2018a. The number of sub-carriers N assumed are 512 and 1024. The results are obtained and compared with the conventional techniques. The raised cosine windowing method is considered to design the digital filters with overlapping factor $K = 4$. The number of filter coefficients considered is 7. This simulation is performed using 16 OQAM digital modulation technique. Table I shows the simulation parameters.

4.1. Simulation Environment

Table 1. Simulation Parameters

Simulation parameters	Remarks
Simulation tool	MATLAB R2018a
No.of Subcarriers	512, 1024
Subcarrier index	0.5
Phase factors	1 and -1
Overlapping factor K	4
No. of filter coefficient	7
Modulation	16 OQAM
Filter Type	Raised cosine window

4.2. Transmission and Reception using Proposed Technique

The transmission and reception performance is observed in Figure 3. To execute this simulation, 96 number of FBMC symbols per frame is considered which is denoted by M. Number of sub frames per symbol is assumed as $w = 1$. Four different sub carriers are assigned as $N = 512$ and 1024 and digital modulation considered as 16 OQAM. This result shows that, there is no phase difference between the transmitted and received symbols.

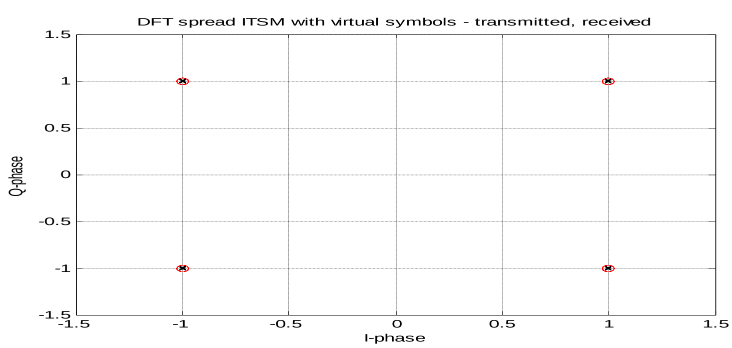

Figure 3. Constellation of Proposed Technique using 16 OQAM Digital Modulation.

4.3. Spectral Efficiency

It is defined as the amount of bits transmitted per hertz. The spectral efficiency comparisons of conventional DFT spread FBMC and proposed DFT spread ITSM with Tail shortening symbols are depicted from Fig. 4 and 5. These results are simulated with respect to SNR in dB for different sub-carriers.

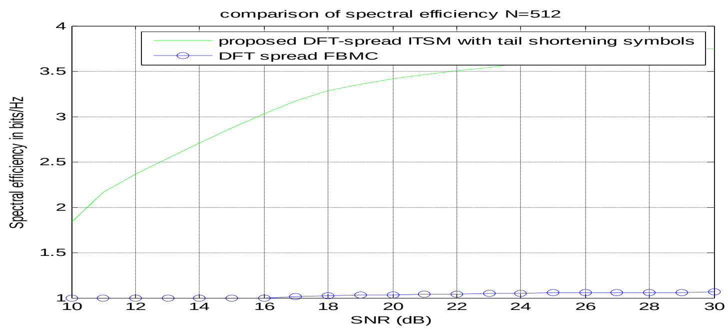

Figure 4. Spectral efficiency comparison for sub-carrier $N = 512$.

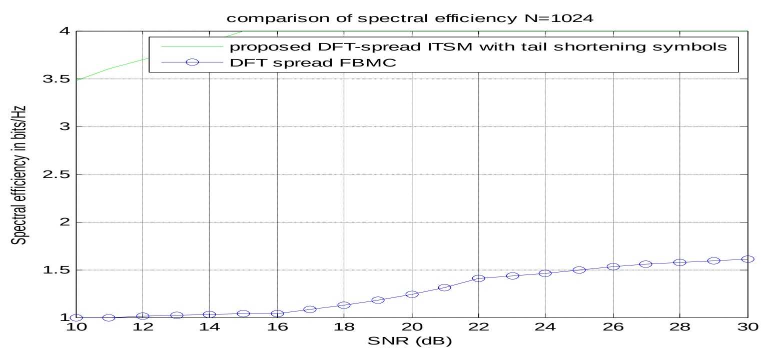

Figure 5. Spectral efficiency comparison for sub-carrier $N = 1024$.

The inferences of these results are, the spectral efficiency of both conventional and proposed schemes are nearly equal when less numbers of sub-carriers are assigned. Then, the spectral efficiency of proposed system shows high for higher numbers of sub-carriers with high SNR. As a result, it has been proved that, the proposed system can be adopted for higher numbers of sub-carriers and gives high spectral efficiency with higher SNR than compared to the conventional one.

4.4. PAPR Comparison

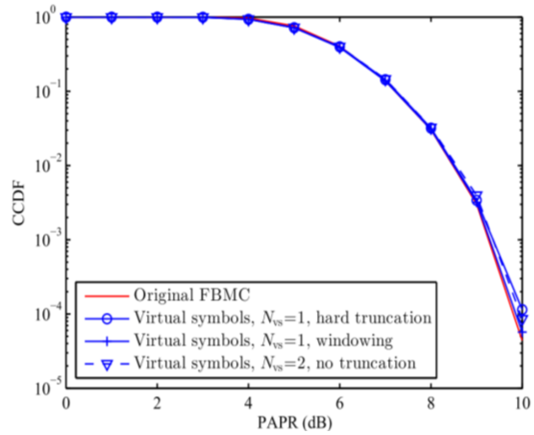

Figure 6. PAPR for conventional systems.

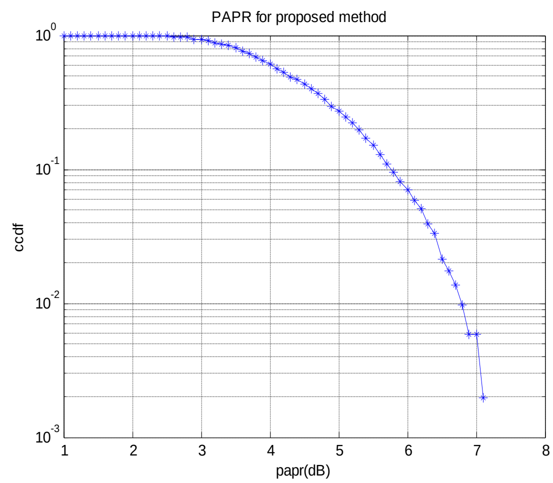

Figure 7. PAPR for proposed systems.

PAPR is the ratio of peak power to the average power of all N sub-carriers. The Peak to Average Power Ratio values of Conventional and proposed method is shown in Figures 6 and 7 respectively. The proposed method proves and shows better result (low PAPR) such as 7.2 dB for 10^{-3} CCDF (complementary Cumulative Distribution Function) but the conventional system shows high PAPR value which is 8.4 dB for same 10^{-3} CCDF.

4.5. Prototype Filter Responses

Figure 8 shows the magnitude response comparison of prototype filters between proposed and conventional techniques. The design of filter is done using FIR type raised cosine windowing method. The length of prototype filter is assigned as $l_p = K^* M - 1$ where K is the overlapping factor $(K = 4)$ and M is number of sub-channels. These responses clears that, the bandwidth is reduced by tail shortening using virtual symbols in proposed DFT spread ITSM technique. So this proposed system may be considered as bandwidth efficient system.

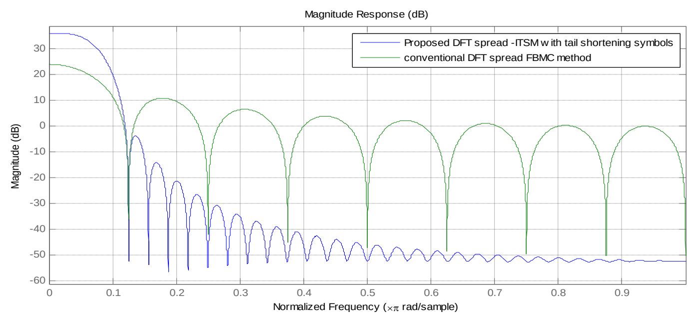

Figure 8. Comparison of prototype filter responses of FBMC-OQAM system.

The comparison of filter responses for different overlapping factors $(K = 2, K = 3, K = 4)$ are shown in Figure 9. Bandwidth of the system is increased if the K value reduced. On the other hand, the selection of higher overlapping factors helps to get bandwidth efficient system.

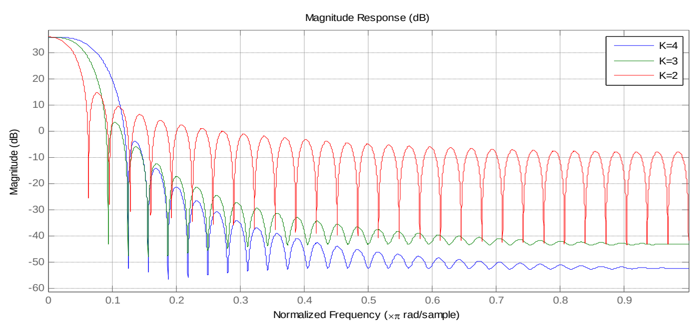

Figure 9. Comparison of Prototype Filter Responses for different overlapping factors K.

5. Conclusion

A low PAPR and high spectral efficient FBMC with OQAM scheme was proposed and confirmed its better performance than compared to the existing scheme. To achieve this, the DFT spread ITSM with tail shortening virtual symbol technique is simulated and the results are compared with the conventional one. As a result, the proposed technique gives better performance which has low PAPR and high spectral efficiency. Also, the Prototype filers are designed to accommodate specified sub-carriers. The ICI and ISI are eliminated by introducing the virtual symbols. So, the proposed technique gives better performance than compared to the conventional one.

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