JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ENHANCED HYBRID APPROACH FOR PAPR REDUCTION IN FBMC-OQAM SYSTEMS

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Abstract

Most of the peak-to-average power ration (PAPR) reduction techniques, such as partial transmit sequence (PTS) algorithm and selective mapping (SLM) algorithm, for conventional OFDM systems are not directly applied to FBMCOQAM systems because of the overlapping structure of filter bank multi-carrier with offset quadrature amplitude modulation (FBMC-OQAM) signals. Furthermore, the complexity of the existing algorithms based on PTS is very high for the FBMC-OQAM systems. In this paper, we propose a low-complexity PTS based on hybrid processing algorithm (H-PTS) to reduce the PAPR values of FBMC-OQAM systems. Firstly, the proposed algorithm processes phase factors of the PTS by double-layers search. As a result, the complexity of searching the optimal phase factors are simplified. Moreover, an efficient algorithm of estimating the PAPR values of the FBMC-OQAM signals is employed scheme based on a two-step optimization structure, named pre-treated partial transmit sequence (P-PTS) to further reduce computational complexity. The first step uses a multiple overlapping symbols joint optimization scheme that the phase rotation sequences for current symbol is determined and optimized according to previous overlapped symbols. And in the second step, it employs a novel segment PAPR reduction scheme based on PTS technique. Simulation results shows that, compared with the conventional PTS (C-PTS) algorithm and segmental PTS (S-PTS) algorithm, H-PTS and P-PTS, the proposed P-PTS algorithm achieve better PAPR reduction as well as lower computational complexity.

Keywords:

PTS, SLM, FBMC-OQAM, PAPR

1. Introduction

Constantly increasing demand of upper data rates, multimedia services support, and ever more bandwidth is creating unprecedented challenges for future mobile communication systems. There seems to be general consensus on the longer term fifth generation (5G) radio access technology (RAT) for far better performance than today's fourth generation (4G) systems [1]. Although OFDM has been widely employed in future evolution (LTE)/4G and other broadband wireless communication systems, it's not taken without any consideration for next generation communication systems. The drawbacks like limited spectral efficiency, spectral out-of-band radiation and strict frequency synchronization make OFDM less attractive [2]. FBMC has drawn increasing attention because it shows strong potential and is one among the promising candidates to exchange OFDM as multicarrier transmission technique, thanks to the high spectral selectivity and robustness against synchronization offsets [3]. Additionally, employing OQAM in FBMC systems are able to do higher spectral efficiency thanks to the extremely concentrated frequency localization and there's no got to insert any guard interval. we will employ several filters with different characters consistent with practical channel environments [4]. Then, the FBMC-OQAM systems are able to do better performance under the environments with higher frequency dispersion, and inherently provide better side-lobe characteristics.

However, one among the common drawbacks of OFDM and FBMC-OQAM is that the high PAPR. In OFDM systems, the distribution of PAPR has been derived by theoretical approaches, and there are various sorts of techniques to unravel the matter of high PAPR [5], like clipping and filtering, selective mapping (SLM), partial transmit sequence (PTS), companding transforms, tone reservation (TR) then on. Because the signal scrambling techniques cause no distortion and make no out-of-band radiation (e.g. SLM, PTS, TR), they're key considerations for PAPR reduction. Besides, some hybrid techniques [6–7] have been suggests for OFDM systems, and truly they add a pretreatment on the idea of original techniques. Because each technique can take full advantage of its own, the mixture of several techniques is able to do better performance.

Although overlapped SLM improves the first SLM for FBMC-OQAM systems, it still uses step-by-step optimization that optimizes each data block separately, and it does not really appreciate into the overlapping of signals. In [9], the authors proposed a scheme named dispersive SLM which is an extended and generalized version of overlapped SLM. this system regard complex symbols because the optimized objects and changing to real symbols could also be a far better choice. However, it just uses one scheme for PAPR reduction and it's no obvious advantages to hybrid method. Ye et al. suggests a completely unique segmental (S-PTS) scheme to scale back PAPR in [10]. The key idea is to divide the overlapped FBMC-OQAM signals into variety of segments, then some disjoint sub-blocks are divided and multiplied with different phase rotation factors in each segment. To enhance the performance of the bandwidth usage with prefix and pilot insertion and BER increment analysis has been seen in [11].

In this paper, we propose a P-PTS scheme supported a two-step optimization structure, termed as P-PTS for simplicity, to scale back the PAPR in FBMC-OQAM systems. Multiple data blocks are considered when reducing the height power, rather than each data block independently. the primary step uses a multiple overlapping symbols joint optimization scheme that the phase rotation sequences for current symbol is decided and optimized consistent with previous overlapped symbols and therefore, the second step uses a completely unique segment scheme supported PTS technique. In Sect. 2, we briefly introduce the FBMC-OQAM system and therefore the definition of PAPR. The proposed scheme is described in Sect. 3, also the analysis of computational complexity. In section 4 simulation results and conclusion are presented.

2. FBMC-OQAM system

In a baseband FBMC-OQAM system, we use real symbols that are modulated supported OQAM then transmit them. The info block number is M, the subcarrier number is N and subcarrier spacing is 1/T, where T is that the complex symbol interval.to be reduced and be flexibly traded off with PAPR reduction performance. By using the filter, inter-symbol interference (ISI) and inter-carrier interference (ICI) are often easily avoided thanks to the well-localized pulse shape of the filter both in time domain and frequency domain. Since the length of the filter is FT, the spanning of every FBMC-OQAM signal lasts until FT, too. In another word, current signal is overlapped over by adjacent data blocks, which is that the reason why conventional PAPR reduction techniques can't be directly applied to FBMC-OQAM systems. So, the concept of signals s(t) is different from the first OFDM signals, and therefore the general definition of PAPR for OFDM systems is not any longer useful for FBMC-OQAM systems, too. consistent with the entire length, we firstly divide the FBMC-OQAM signals into (M/2+F) intervals equally with the time duration T.

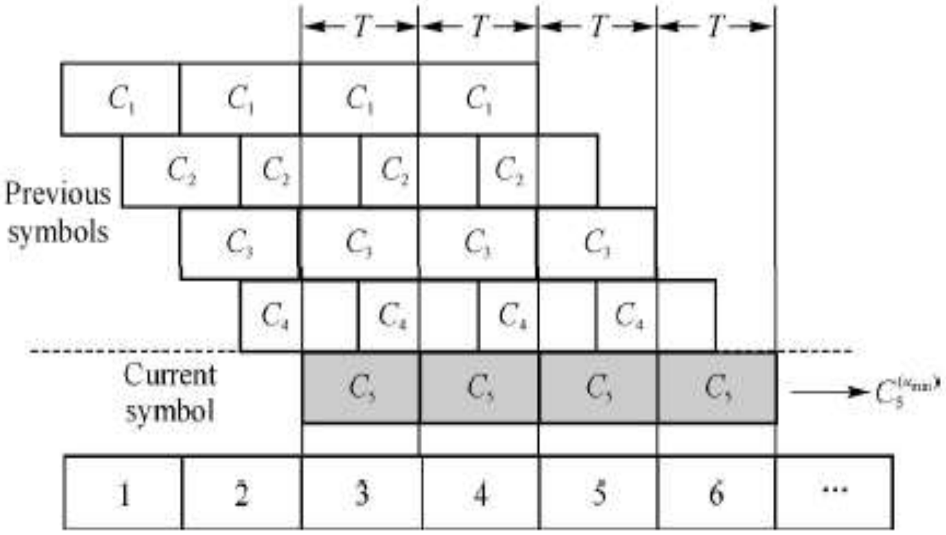
OFDM systems, and therefore the difference lies within the optimization of phase rotation sequence for current symbol is decided and optimized consistent with previous overlapped FBMC-OQAM symbols. In other words, all the symbols overlapped with the present symbol should be taken under consideration when selecting optimized phase rotation sequences to scale back PAPR. Besides, because the spanning of every FBMC-OQAM signal lasts until FT, to settle on the optimally rotated symbols. The key idea is to divide the overlapped FBMC-OQAM signals into variety of segments, then some disjoint sub-blocks are partitioned and multiplied with different phase rotation factors in each segment. However, thanks to the inherent complexity of PTS scheme, only using PTS to scale back PAPR causes high computational complexity, and therefore the complexity is tough to be reduced and be flexibly traded off with PAPR reduced performance.

3. Proposed P-PTS scheme for PAPR reduction of FBMC-OQAM signals

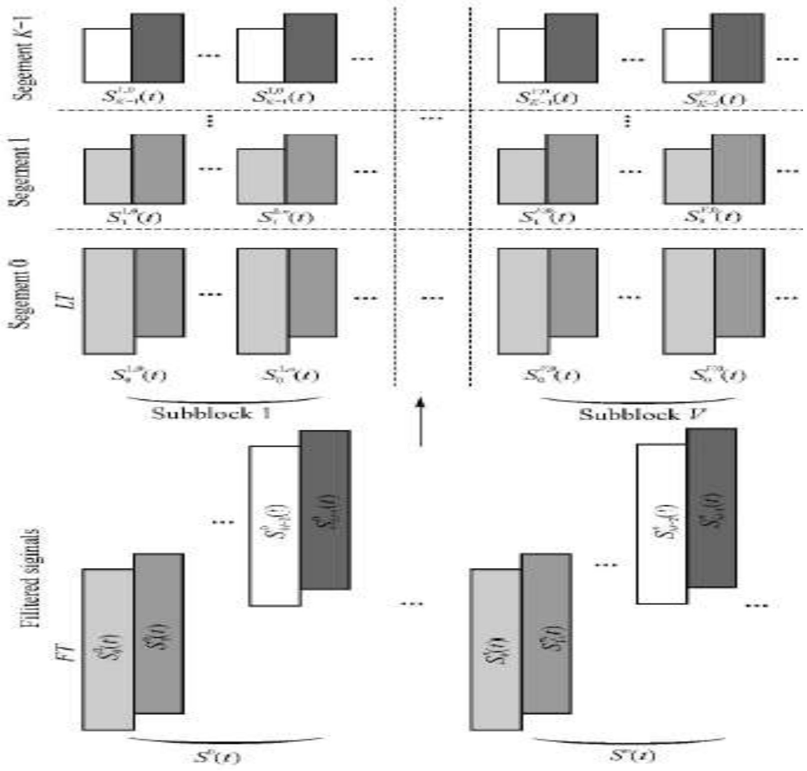
A propose a P-PTS scheme which is based on a two-step optimization structure to reduce the PAPR for FBMC-OQAM systems. Due to the overlapping structure of FBMC-OQAM signals, we take into account multiple overlapped data blocks when reducing the peak power, instead of each data block independently. The first step is similar to conventional SLM scheme in OFDM systems, and the difference lies in the optimization of phase rotation sequence for current symbol is determined and optimized according to previous overlapped FBMC-OQAM symbols. In other words, all the symbols overlapped with the current symbol should be considered when selecting optimized phase rotation sequences to reduce PAPR. Besides, because the spanning of each FBMC-OQAM signal lasts until FT, to choose the optimally rotated symbols, the value of PAPR has been computed over [0, FT) instead of [0, T).

The second step employs the scheme which is similar to S-PTS in [14]. The key idea is to divide the overlapped FBMC-OQAM signals into a number of segments, and then some disjoint sub-blocks are partitioned and multiplied with different phase rotation factors in each segment. However, due to the inherent complexity of PTS scheme, only using PTS to reduce PAPR causes high computational complexity, and the complexity is hard to be reduced and be flexibly traded off with PAPR reduction performance.

The proposed P-PTS scheme uses the two-step optimization structure which is a more effective measure to deal with the problem of overlap. Compared with S-PTS, it can achieve much better PAPR reduction performance with lower computational complexity. Besides, the proposed P-PTS introduces two key parameters, so different parameter combinations can be used, and computational complexity and performance can be traded off flexibly. The detail of two-step optimization structure is described in the below figure.



(a) The first step



(b) The second step

Fig. 1 Block diagrams of the first and second steps of the proposed P-PTS scheme

The main steps of the proposed P-PTS scheme can be summarized as the following steps:

Step 1 Generate U phase rotation sequences $\{P^{(u)}, u = 1,2,\ldots\ldots,U\}$ of length N, the u th sequence $P^{(u)}$ can be expressed by

$$P^{(u)} = \left[P_0^{(u)}, P_1^{(u)}, \ldots, P_{N-1}^{(u)} \right]; \quad u = 1, 2, \ldots, U \qquad (1)$$

Where,

$P_i^{(u)} = \exp(\mathrm{j}\varphi_i^{(u)}),\ i = 0,1,\ldots,N-1$, and $\varphi_i^{(u)}$ is a random phase with uniform distribution between $(0 - 2\pi)$

Step 2 Multiply the original data blocks by the above sequences. The FBMC-OQAM symbols $C_m^{(u)}$ can be generated by

$$\boldsymbol{C}_m = \left[a_{m,0}, a_{m,1}, \ldots, a_{m,N-1} \right]$$

$$\boldsymbol{C}_m^{(u)} = \boldsymbol{P}^{(u)}\boldsymbol{C}_m = \left[P_0^{(u)} a_{m,0}, P_1^{(u)} a_{m,1}, \ldots, P_{N-1}^{(u)} a_{m,N-1} \right] \qquad (2)$$

Step 3 Generate the FBMC-OQAM signals $S^{(u)}(t)$ by the following formula considering the overlap of previous symbols:

$$s^{(u)}(t) = \underbrace{\sum_{n=0}^{N-1} \sum_{m'=0}^{m-1} a_{m',n}^{(u_{\min})} h\left(t - \frac{m'T}{2}\right) \mathrm{e}^{\mathrm{j}\frac{2\pi n}{T}t} \mathrm{e}^{\mathrm{j}\phi_{m',n}}}_{\text{overlapping past symbols}} + \underbrace{\sum_{n=0}^{N-1} a_{m,n}^{(u)} h\left(t - \frac{mT}{2}\right) \mathrm{e}^{\mathrm{j}\frac{2\pi n}{T}t} \mathrm{e}^{\mathrm{j}\phi_{m,n}}}_{\text{current symbols}} \qquad (3)$$

Where $a_{m,n}^{(u_{min})}$ are from previous selected symbols $C_m^{(u)}$.

Step 4 Use Eq. (7) to compute the PAPR of $S^{(u)}(t)$ on a certain interval T_0.

$$D_{\mathrm{PAPR}_{s(t)}^{(u)}} = \frac{\max\limits_{t \in T_0} \left| s^{(u)}(t) \right|^2}{E\left[\left| s^{(u)}(t) \right|^2 \right]} \qquad \textbf{(4)}$$

where T_0 is any arbitrary interval that includes [(mT)/2, (mT)/2+4T] interval.

Among $D_{PAPR_{s(t)}^{(u)}}$, the index u is chosen for the signal with least PAPR as per the below criterion. Then store the index and update the current overlapping input signal.

$$u_{\min} = \min_{0 \leq u \leq U-1} D_{\mathrm{PAPR}_{s(t)}^{(u)}}$$

$$\boldsymbol{C}_m^{(u_{\min})} = \boldsymbol{P}_m^{(u_{\min})} \boldsymbol{C}_m$$

where $P_m^{(u_{min})}$ represents the best phase rotation sequence to achieve the least PAPR for C_m .

Step 5 It is obvious that the filtered signal on the *n*th subcarrier can be represented by

$$S^{n}(t)=\sum_{m=0}^{M-1} \mathrm{e}^{\mathrm{j}\phi_{m,n}} a_{m,n}^{(u_{\min})} h(t-m\tau_{0}) \tag{5}$$

where $a_{m,n}^{(u_{min})}$ are the updated symbols and can be calculated by Eq. (9). The length of $S^n(t)$ is (*M*/2+*F*) *T*, and we divide $S^n(t)$ into several segments with the same duration $T_s(T_s = LT, L \geq F/2, L \in \mathbb{Z})$.*ra* It is obvious that the number of segments is *K* = [(*M* 2 + *F*) *T*]/T_s . The signal on the *n*th subcarrier in the *k*th segment as

$$S_{k}^{n}(t)=S^{n}(t)R_{T_{s}}(t-kT_{s}); \quad k=0,1,\ldots,K-1$$

With,

$$R_{T_s}(t-kT_s)=\begin{cases}1; & kT_s \leqslant t \leqslant (k+1)T_s \\ 0; & \text{eles}\end{cases}$$

Step 6 Then, *N* signals in the *k*th segment $S_k^v(t)$ are partitioned into *V* random disjoint sub-blocks $S_k^v(t) = \{S_k^{v,n}(t), n = 0,1, \ldots, N-1\}$, satisfying

$$S_{k}^{v,n}(t)=\begin{cases}S_{k}^{n}(t); & \frac{N}{V}(v-1)\leqslant n\leqslant \frac{N}{V}v-1 \\ 0; & \text{eles}\end{cases} \tag{6}$$

Then modulating the signals to subcarriers, and *V* signals in the *k*th segment are obtained as

$$s_{k}^{v}(t)=\sum_{n=0}^{N-1} S_{k}^{v,n}(t)\mathrm{e}^{\mathrm{j}\frac{2\pi n}{T}t}; \quad v=1,2,\ldots,V \tag{7}$$

Step 7 And the signal $S_k^v(t)$ is multiplied with the phase rotation factor {1, 1} b_k^v $\in \{1,-1\}$, since {1, −1} is easily implemented and as good as any other phase sequence in terms of the PAPR reducing capability. Obviously, the number of rotation factor is *V*.

Then, the optimal phase factor combination of $S_k^v(t)$ with the minimum PAPR is selected as

$$\left.\begin{array}{l} \arg\min\limits_{b_k^v} \max\limits_{kT_s\leqslant t\leqslant (k+1)T_s} \left|\sum\limits_{v=1}^{V} b_k^v s_k^v(t)\right| \\ \text{s.t.} \\ \quad b_k^v \in \{1,-1\}; \quad k=1,2,\ldots,K-1 \end{array}\right\}$$

The proposed P-PTS scheme introduces two key parameters *V* and *U*, so we can change the value of the two to achieve better PAPR reduction performance. Compared with S-PTS scheme, different parameter combinations can flexibly be traded off between computational complexity and PAPR reduction performance.

4. Results and Conclusion

An improved PTS based on hybrid processing algorithm (H-PTS) for FBMC-OQAM systems is proposed to reduce computational complexity. In contrast to existing C-PTS and S-PTS algorithms, the proposed H-PTS and P-PTS scheme are compared, and P-PTS offers a good PAPR performance and significantly reduces computational complexity. The top-layer algorithm further reduces the peak value of adjacent data groups and adjacent data blocks overlap with each other.

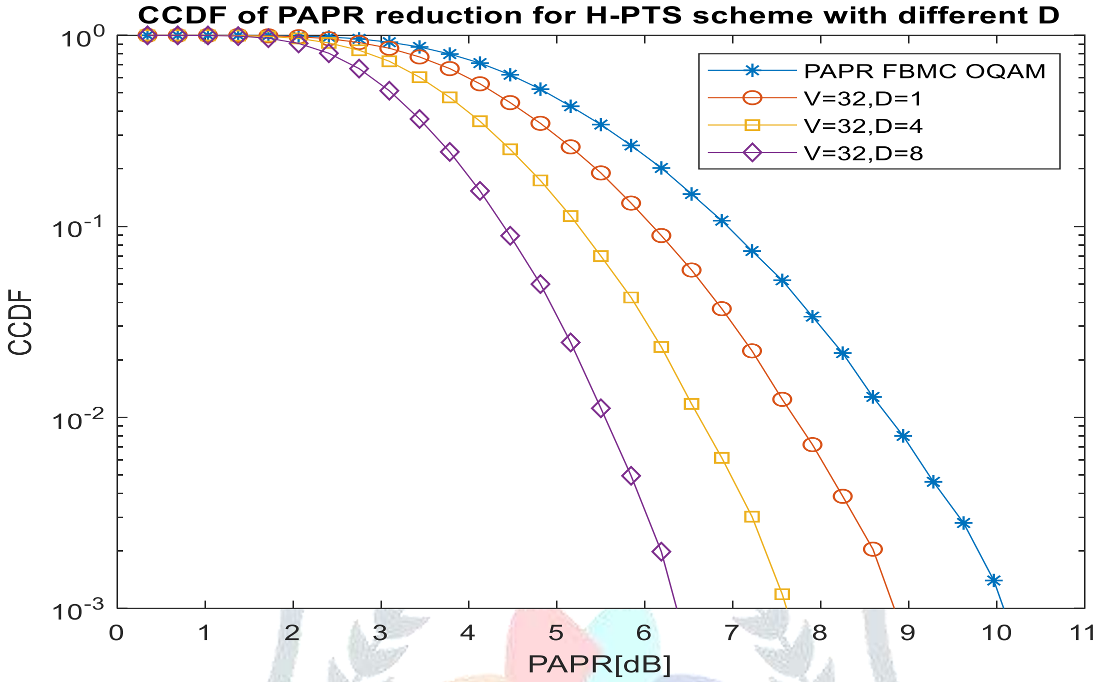


Fig: 2. CCDF Of PAPR Reduction for H-PTS Scheme With Different D

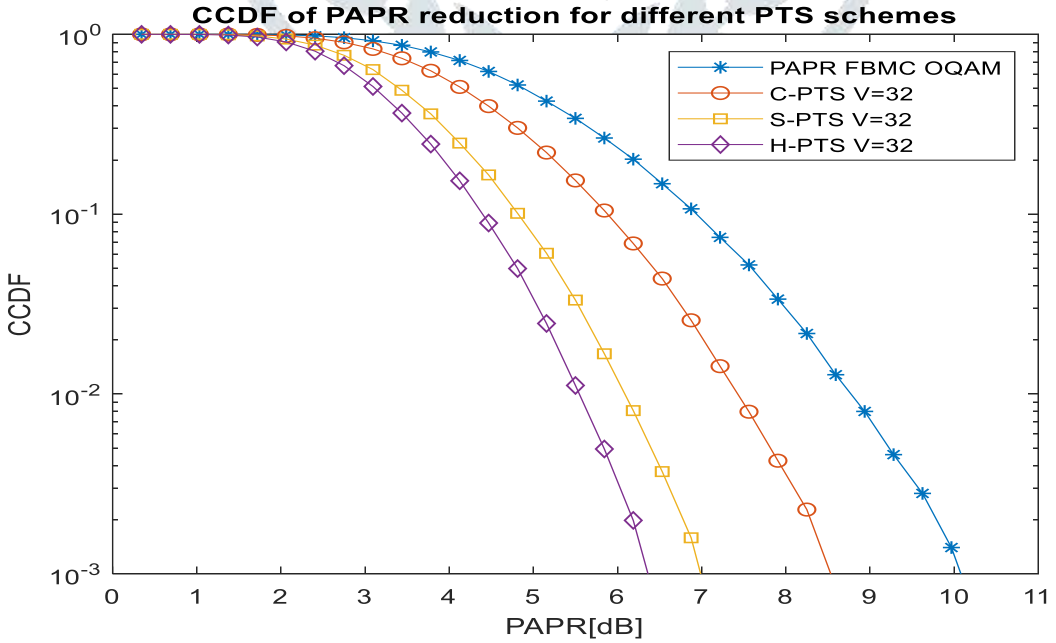


Fig:3. CCDF of PAPR Reduction for Different PTS Schemes

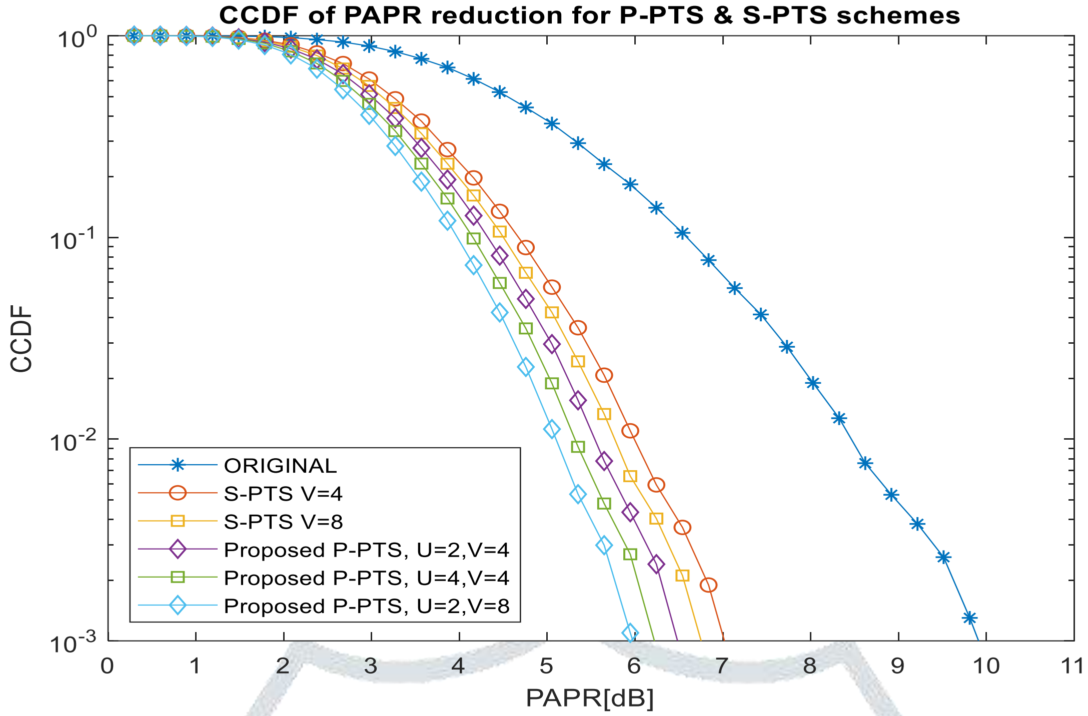


Fig:4. CCDF of PAPR Reduction for P-PTS &S-PTS Schemes

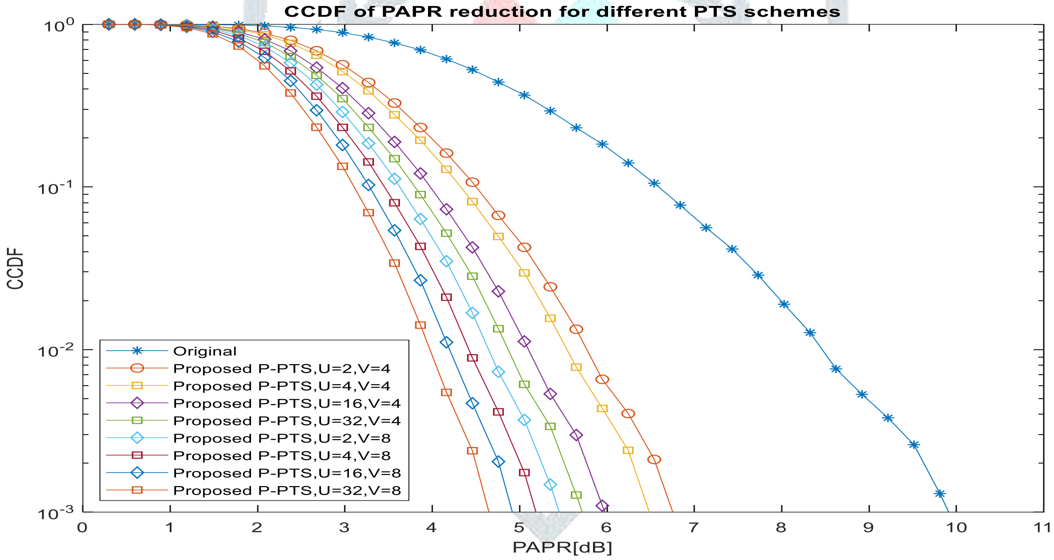


Fig:5. CCDF of PAPR Reduction for different PTS schemes

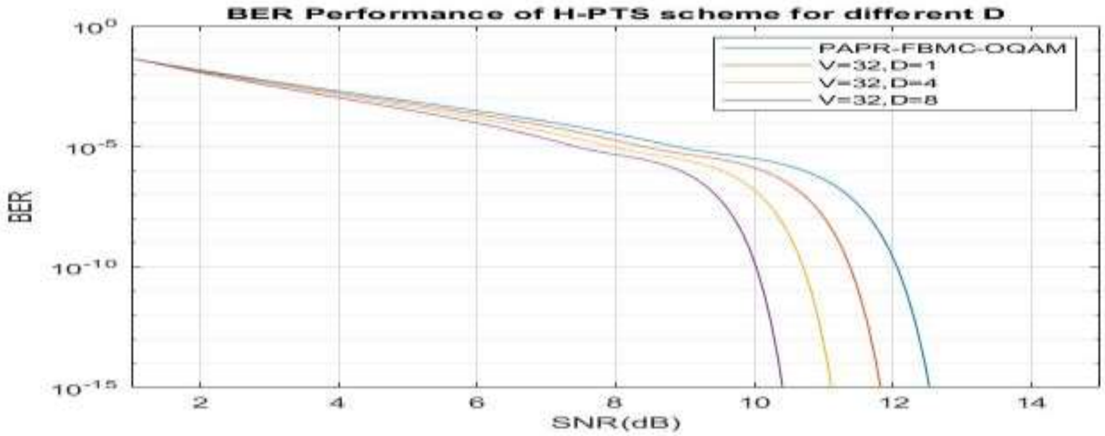


Fig 6. BER Performance of H-PTS Scheme for Different D

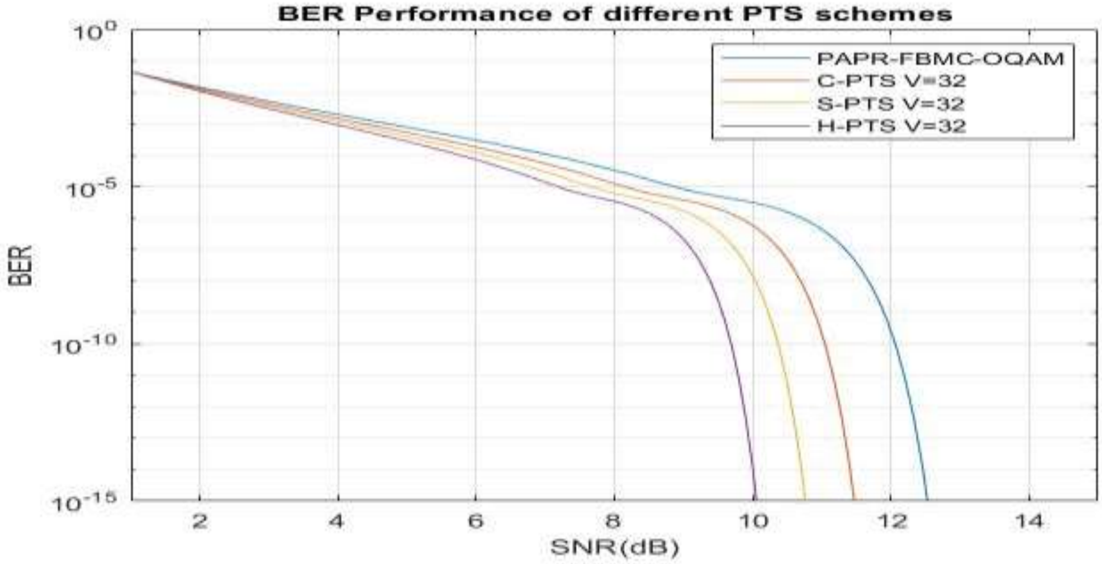


Fig 7. BER Performance of Different PTS Schemes

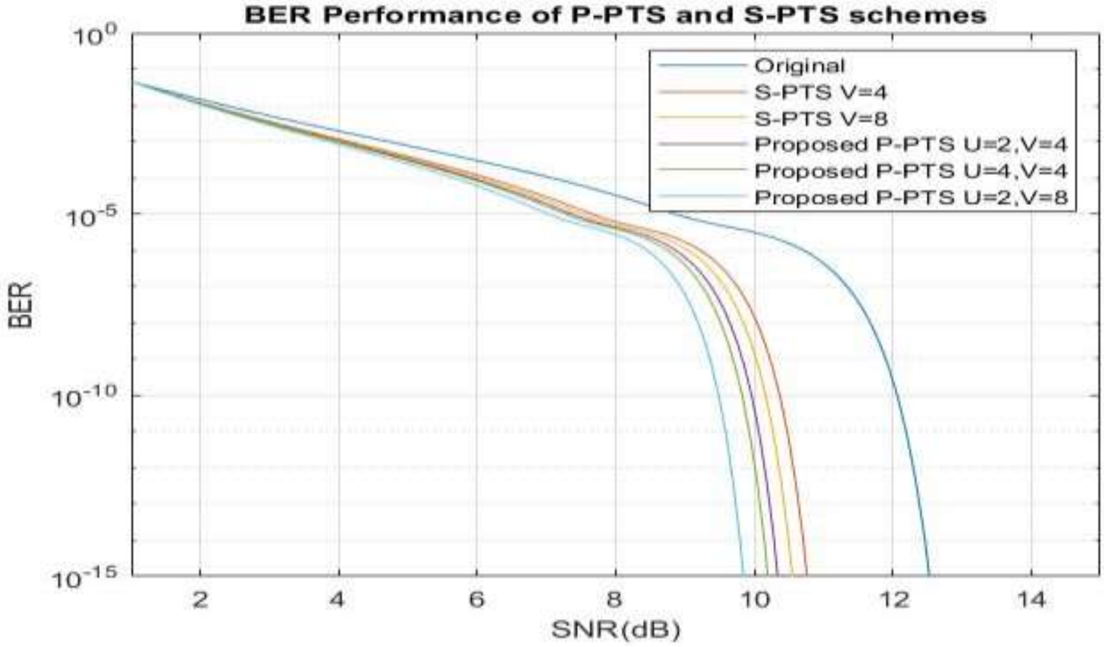


Fig 8. BER Performance of P-PTS And S-PTS Schemes

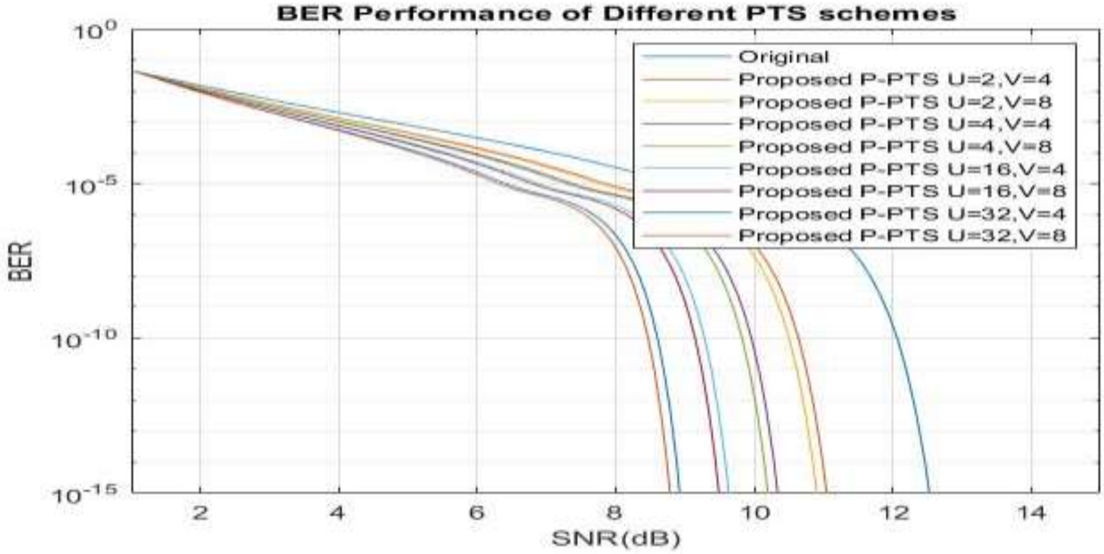


Fig 9. BER Performance of Different PTS Schemes

Fig 2 shows the CCDF of PAPR reduction for h-pts scheme with different d values and here h-pts shows better PAPR reduction. Fig 3 shows the CCDF of PAPR reduction for different pts schemes. Fig 4 shows the CCDF of PAPR reduction for p-pts &s-pts schemes. Fig 5 shows the CCDF of PAPR reduction of different pts schemes. Fig 6 shows the BER performance of h-pts scheme for different d values. Fig 7 shows the BER performance of different pts schemes. Fig 8 shows the BER performance of p-pts & s-pts schemes. Fig 9 shows the BER performance of different pts schemes.

Finally, PAPR reduction & better BER performance shown by P-PTS scheme compared to all pts schemes. The computational complexity of top-layers and low-layers algorithms and TSPI algorithm has reduced by two orders of magnitude compare with the C-PTS algorithm and the S-PTS algorithm. To deal with the problem of overlap more effective, we take fully into account the overlapping structure of FBMC-OQAM symbols and use a two-step optimization structure in P-PTS. The simulation results show that the proposed p-pts scheme can achieve better PAPR reduction performance than the comparatively to H-PTS.

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