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A comprehensive probabilistic analysis of PAPR reduction approach with localized mapping

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***Abstract*---**In recent years, OFDMA plays a vital role in current day communications and drastically used in mobile technologies. The Maximum to Expected Power Ratio is key element in transmitter to reduce their ratio using PAPR reduction techniques needed to improve the quality of performance. The localized mapping in implemented in OFDMA and gives greater improvement in reduction of PAPR which improves the performance. The next generation communication needs versatile technologies to develop their performance in order to achieve the good quality of service. The probabilistic approach like Selective Mapping (SLM) and Partial Transmit Sequence (PTS) are proposed in Localized –OFDMA in order to give better solution. In this paper, the proposed approach L-PTS outperforms the L-SLM and better trade-off the power ratio with error rate.

***Keywords*---**OFDMA, SLM, PTS, localized mapping, L-SLM, L-PTS, PAPR.

Introduction

The probabilistic or distortion less technique is to reduce the PAPR by scramble an input data and there is chance of lot of PAPR can be reduced while in transmission. This category does not suffer from the in band/out band effects. However, the spectrum efficiency reduces, and complexity proportional to subcarriers strength (Taewon Hwang, Chenyang Yang. et al., 2009). Moreover, it does not guarantee the peak to expected power ratio lower than threshold limit but well tradeoff. This concept has Selective Mapping (SLM), Partial Transmit

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Sequence (PTS), Tone Injection (TI), Tone Reservation (TR), Active Constellation Extension (ACE), Constrained Constellation Extension (CCE) (Rajiv Saxena & Hem Dutt Joshi, 2013). It may be noted that exemplifying of frequency domain are PTS, SLM and time domain are clipping and filtering, companding functions (Athinarayanan Vallavaraj, Brian G. Stewart. et al., 2009). The probabilistic techniques PTS and SLM are considerable to avoid error rates than companding functions (Rahmatallah and S. Mohan, 2013).

Localized Selective Mapping (L-SLM)

The Fig. 1 illustrates basic L-SLM schematic (V. Sudha & M. Syamkumar, 2017). The multiplication of input sequence $X = [X(0), X(1), ..., X(N-1)]$ can made with U random phase $P^u = [P_0^u, P_1^u, ..., P_{N-1}^u]$.

where $P_v^u = e^{j\phi_v^u}, \phi_v^u \in [0, 2\pi)$ for v =0,1,.....N-1 and u =1,2,.....U.

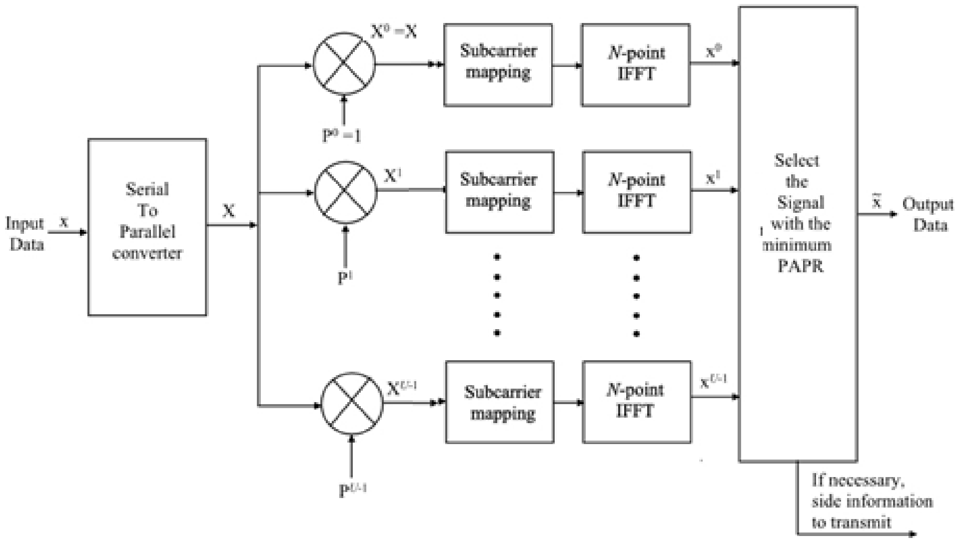

Figure 1. L-SLM for PAPR reduction

So that a altered data block $X^u = [X^u(0), X^u(1), ..., X^u(N-1)]^T$ is fed to IFFT and approved to give $x^u = [x^u(1), x^u(2), ..., x^u(N-1)]^T$.

In that $\bar{x} = \overline{x^u}$ is to choose minimum peak to expected power ratio signal for transmission from the eq.1. be written as

$$\bar{u} = \arg\min_{u=1,2,......,U} \left(\max_{n=0,1,....,N-1} |x^u[n]| \right) \qquad (1)$$

To recover the original data at the receiver, information index (u) and chosen random phase sequence Pu must be sent as side bits (SI). Finally, it summarizes

SLM needs U -IFFTs operations. Moreover, the SI bits of each block is log2U (K. Shri Ramtej & S. Anuradha, 2018 & 2020).

Novality and Methods

Localized Partial Transmit Sequence (L-PTS)

The schematic of L-PTS is shown in Fig. 2 (M. Thanigasalam & P. Dananjayan, 2016). This PTS is partitioned into input sequence 'N' into subblocks 'V' and $X = \left[X^0, X^1, \ldots\ldots\ldots, X^{V-1}\right]^T$. Here X_i be the subblocks which are consecutive and disjoint among them with equal size. In SLM, scrambling applied to all subcarriers and where as in PTS, scrambling covers the random phase which rotates independently. After this rotation, each portioned subblock has to be multiplied by a equivalent random phase factor b^v and then to IFFT (Yasir Amer Jawhar. et al., 2018 & 2019) .

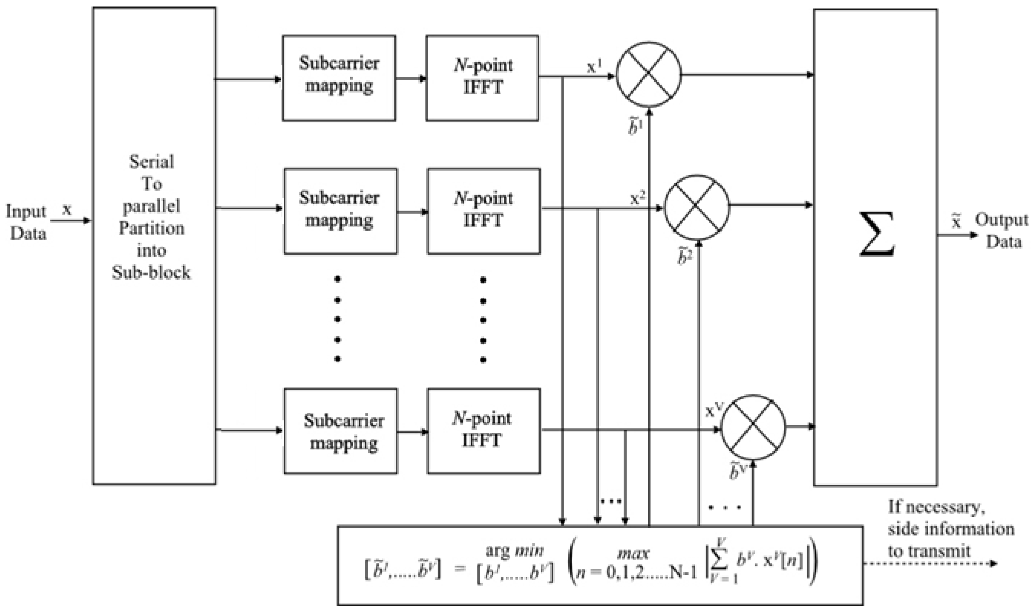

Figure 2. L-PTS for PAPR reduction

i.e., $b^v = e^{j\phi_v}$,   where v= 1,2, ………..V.

$$X = IFFT\left\{\sum_{v=1}^{V} b^v X^v\right\} = \sum_{v=1}^{V} b^v IFFT\left\{X^v\right\} = \sum_{v=1}^{V} b^v x^v \qquad (2)$$

The PTS is given as $\{x^v\}$ and the minimum PAPR can be obtained by suitable selection of phase factor.

$$\left[\bar{b}^1, \ldots\ldots, \bar{b}^V\right] = \underset{\left[\bar{b}^1, \ldots\ldots, \bar{b}^V\right]}{\arg\min}\left(\max_{n=0,1,\ldots,N-1}\left|\sum_{v=1}^{V} b^v x^v[n]\right|\right) \qquad (3)$$

The summation of all partial blocks at the output is declared as lower most finest PAPR signal can be expressed as

$$\bar{x} = \sum_{v=1}^{V} b^{-v} x^{v} \quad (4)$$

Generally, the phase factor $\{b^v\}_{v=0}^{V}$ has to be chosen to reduce search complexity. The element set of permissible phase factor is $b = \{e^{j2\pi i/w}|_{i=0,1,........,w-1}\}$. So the search complexity has to be grow exponentially with all subblocks from available element set of phase factors W^{V}-1.

- Type of subblocks
  The PTS demands V -IFFTs operations for each block and side bits is $\log_2 W^V$ bits. The factors influences a) subblock (V) b) phase factors (W) c) partitioning subblocks. There are three ways to partitioning the subblocks is given as: adjacent, interleaved and pseudo-random. The pseudo random type provides the best performance among the available.

- Search complexity
  The demerit of PTS is the difficulty of locating set of phase vector particularly when the subblocks are more. The schemes more suggested to diminish complexity. The computations count is restricted scheme as $V \ll W^V$. where arg min (·) represents the condition that outputs minimum of the specific function. Consequently, it can choose the finest 'b' to enhance the peak to expected power ratio performance. The extra cost has to pay for calculation of V−1 times IFFTs operation. The IFFT sequence $\tilde{x}_n$ can be characterized as follows:

$$\overline{x_k} = \frac{1}{N} \sum_{k=0}^{N-1} \overline{X_k} e^{j2\pi \frac{n}{N} k} \quad (5)$$

  It has been observed that, the pulse shaping operation does not improve the performance of localized FDMA system. Therefore, the peak to expected power ratio without pulse shaping can be stated as:

$$PAPR = \frac{\max\limits_{k=0,1,....,N-1} \left|\overline{x_k}\right|^2}{\frac{1}{N} \sum_{k=0}^{N-1} \left|\overline{x_k}\right|^2} \quad (6)$$

  The equivalent output signal with lowermost PAPR can be stated as

$$\bar{x} = \sum_{v=1}^{V} b^{-v} x^{v} \quad (7)$$

- Computational Complexity
  The performance improvement of PTS algorithm based on number of subblocks and for SLM by increasing phase vectors. However, dependent on subcarriers. The computational complexity categorically divided into two parts that are preprocessing stage and IFFT stage in table 1 (GBSR. Naidu & V. Malleswara Rao, 2017).

Preprocessing complexity

It is assumed subcarriers N =64, 128, 256,...... , and signaling constellation M =2, 4, 8, 16,...... , is the without loss of ambiguity. For PTS Complexity, The data sequence is partitioned into V -subblocks and each subblock is multiplied by a phase factor (W) is the signaling points chosen from 'M' constellation points. Each subblock is multiplied with a phase factor to optimize the PAPR. Hence, there is NW (V −1) complex multiplications. For SLM Complexity, The OFDM signal is multiplied by U phase vectors and each phase vector contains N number of phases. So there is UN number of complex multiplications are performed. Here, N = subcarriers, V = subblocks and W = phase factor.

Table 1
Computational complexity of PTS and SLM algorithms at preprocessing stage

Method			Computational complexity					
N =subcarriers			64	128	256	512	1024	2048
PTS V=subblocks, W=weight factor	W=2	V=2	128	256	512	1024	2048	4096
		V=3	256	512	1024	2048	4096	8192
		V=4	512	1024	2048	4096	8192	16384
	W=4	V=2	256	512	1024	2048	4096	8192
		V=3	1024	2048	4096	8192	16384	32768
		V=4	4096	8192	16384	32768	65536	131072
SLM U=Phase vector	U=2		128	256	512	1024	2048	4096
	U=4		256	512	1024	2048	4096	8192
	U=8		512	1024	2048	4096	8192	16384
	U=16		1024	2048	4096	8192	16384	32768

Complexity in IFFT process

For N -point IFFT, it necessitates $N/2*\log_2 N$ number of complex multiplications and $N*\log_2 N$ number of complex additions. Here, computational complexity of different algorithms at IFFT stage calculated. For L-PTS method, V number of sub-block data are to be processed in IFFT. Hence, $VN/2*\log_2 N$ of multiplications and $VN*\log_2 N$ number of additions are required. For L-SLM method, U number of OFDM symbols each carrying N data points are to be processed in IFFT. Hence, $UN/2*\log_2 N$ of multiplications and $UN*\log_2 N$ number of additions are required (GBSR. Naidu & V. Malleswara Rao, 2020).

Results and Discussions

Table 2 illustrates the simulation results of SLM & PTS method for OFDMA and Localized OFDMA. For 16-QAM offers less PAPR than the Q-PSK, it may be observed that PTS and SLM for OFDMA are in the range of 8.9-9.1 dB where as these of Localized -OFDMA are in the range 5.6-8.3 dB. So it is imply clear that SLM and PTS applied to Localized -FDMA (N=512) make it far better than OFDMA (N=256). For both methods, select suitable subcarriers count with U=4, V=4, W=4 and M=16. The localized subcarrier mapping is applied to both SLM and PTS at U=2, 4 and V=2, 4 for 16-QAM is PTS=5.67 dB than SLM=8.36 dB. It is obvious that for PTS method, PAPR reduction is enhanced compared to SLM, So that a trade-off with BER over AWGN channel environment from Fig. 3 to 4.

Fig. 3 to 4 show that PAPR is reduced by balancing V=4 &W=4. The basic principle underlying this fact is that in PTS, PAPR reduction is possible by fixing weight factor W and varying the number of subblocks V. Overall, the reduction is enhanced for higher order 16-QAM; However, there is a slight increase in PAPR is moving from 16-QAM to 64-QAM (faster increase is seen in case of 1024-QAM at CCDF of 10e-3. For Localized -FDMA, better results have been observed compared to OFDMA (3-4dB).

Table 2 shows a) gradual decrease in PAPR considering the comparison of various simulation b) trade-off indicates better reduction in PAPR having balanced ratio of V and W c) PAPR reduction can't be minimized if the number of subcarriers is high. Overall, from the simulation results, it is evident that PAPR can be reduced by balancing subcarriers N and subblocks V. d) balancing the CCDF (determines PAPR performance) and BER (error performance). The equalizer MMSE is used to improve the system performance.

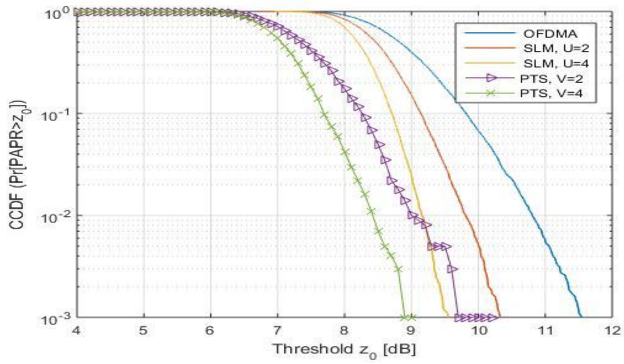

Figure 3. PAPR Analysis of SLM, phase vector U=2, 4 and PTS, subblocks V=2, 4, 16-QAM, subcarriers N=256, oversampling L=8 (OFDMA)

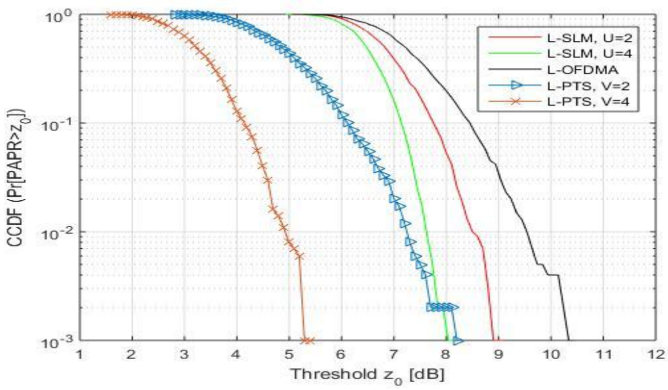

Figure 4. PAPR Analysis of L-SLM, U=2, 4 and L-PTS, V=2, 4, 16-QAM, subcarriers N=256, oversampling factor L=8 (Localized -OFDMA)

The simulations were describing the PAPR reduction based on subcarriers (N) proportionally rises and inverse relation with subblocks (V) for PTS, phase vectors (U) for SLM and also the simulations of L-PTS outperforms the L-SLM, conventional PTS and SLM methods for BER at suitable selection of subblocks because of the subblocks degrades the BER which is observed in the Fig. 3 & 4.

Table 2
PAPR vs BER for SLM and PTS (OFDMA vs L-OFDMA) based on subblocks (V) and phase vectors (U)

Type		PAPR in dB at CCDF=10^{-3}		BER at SNR=10dB	
		Q-PSK	16-QAM	Q-PSK	16-QAM
SLM, U=4		9.033	9.049	0.0636	0.0485
PTS	V=2	9.784	11.030	0.0152	0.0015
	V=4	7.625	8.902	0.0220	0.0083
L-SLM, U=4		6.947	8.365	0.0522	0.0362
L-PTS	V=2	6.991	8.266	8.51e-5	3.52e-7
	V=4	4.912	5.672	0.0109	4.23e-3

Conclusion

This paper describes probabilistic techniques like Selective Mapping (SLM), and Partial Transmit Sequence (PTS). The SLM and PTS are implemented in OFDMA and O-FDMA (Localized OFDMA). The main observation is that PTS performs better than the SLM for both OFDMA and Localized-OFDMA technologies. The new modulation 16-QAM outperforms Q-PSK in case of both SLM and PTS. The Altered PTS for Localized-OFDMA performs better than that for OFDMA in the matter of BER as well as PAPR. In considering FDE at Rx, it is found that MMSE performs better than ZF equalizer. Overall, PTS is flexible to use in 5G communication and capable of giving good results on terms of power ratio PAPR and error rate BER.

An important requirement of L-OFDMA is the need to have joint equalization at the receiver. This implies increased receiver complexity as compared to OFDMA. Several low complexity algorithms have shown attractive results for utilization in equalization for L-OFDMA. These algorithms are of the same order of complexity as the linear system of ZF and MMSE. The Simulation results have proved the superiority of Localized-OFDMA over OFDMA. The performance of L-OFDMA vs OFDMA in presence of large PAPR and complexity has been discussed. The main features of this paper are 1) High PAPR dealt with probabilistic methodologies and the related computational complexity. 3) Simulation results for performance of L-OFDMA vs OFDMA with PTS and SLM. It is pertinent at this stage to examine the performance of PTS/SLM with emphasis on their difference. Specifically, in the case of PTS/SLM which has best performance for Localized-OFDMA over OFDMA.

Acknowledgments

Authors don’t have any conflicts

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