# Comparative Analysis of PTS and Iterative Flipping Scheme for Reduction of PAPR in OFDMA Networks

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## ABSTRACT
OFDM is one of the promising techniques for achieving high downlink capacities in future cellular and wireless networks.The major problem of orthogonal frequency division multiplexing (OFDM) signals is high peak to average power ratio (PAPR) of the transmitted signal. A high PAPR brings disadvantages like an increased complexity of the A/D and D/A converters and reduced efficiency of radio frequency (RF) power amplifier. The high peak of OFDM signal can be reduced by PAPR reduction techniques. In this paper partial transmit sequences (PTS) and iterative flipping schemes are discussed to reduce PAPR and compared with original scheme (without PAPR reduction scheme). Computer Simulations results show that the both schemes achieve PAPR reductions, but the result shows that PTS scheme can offer better PAPR reduction performance than the iterative flipping.

## Keywords
Orthogonal frequency division multiplexing (OFDM), partial transmit sequence (PTS), peak to average power ratio (PAPR), iterative flipping, Analog to Digital converters, Digital to Analog converters

## 1. INTRODUCTION
Orthogonal frequency division multiplexing (OFDM) is a technique used for high-speed data transmission in wireless communication systems [1]. A major problem associated with orthogonal frequency division multiplexing (OFDM) is its large peak-to-average power ratio (PAPR), which degrades the system performance by introducing nonlinearity in the devices such as power amplifiers (PAs). In order to mitigate nonlinear distortion, linear high power amplifiers and analog to digital converters with a large dynamic range are required, but such power amplifiers are inefficient [2].

To reduce the PAPR of the OFDM signal, many techniques have been proposed in so far. These schemes can be classified into signal distortion schemes and signal scrambling schemes. The signal distortion schemes reduce high peaks directly by distorting the signal prior to amplification. Both clipping and companding techniques are typical signal distortion methods to lower PAPR [3], [4].However, these signal distortion schemes may cause large in-band and out-of-band distortions, resulting in the degradation of the system performance [5].

Signal scrambling techniques are different in how to scramble the codes for the PAPR reduction. Some known scrambling techniques including selective mapping (SLM) [6], partial transmit sequence (PTS) [7], tone reservation (TR) [8], and selective mapping of partial tones (SMOPT) [9]. In PTS scheme, the original data block is partitioned into a number of disjoint sub blocks, and each sub block is weighed by a phase factor to generate different signals representing the same information. Thus the signal with the lowest PAPR is chosen for transmission. The PTS scheme can be used to reduce the PAPR effectively without signal distortion. However the PTS requires an exhaustive search over all combinations of allowed phase factors, the search complexity increases exponentially with the number of sub blocks. Therefore, for larger number of sub blocks, the PTS scheme has high computational complexity. Therefore, a simplified scheme i.e. the iterative flipping algorithm has been proposed in [10], in which the complexity is significantly reduced; at the cost of degradation in PAPR reduction performance.

In this paper, the partial transmit sequences (PTS) and iterative flipping schemes are used reduce the PAPR. Simulations are conducted to compare and evaluate the performance of the PTS scheme and the iterative flipping algorithm.

## 2. PAPR
Consider an OFDM system consisting of N modulated data symbols (subcarriers) from a particular signaling constellation, X = [X0, X1, •••, XN-1] denote the input data in an OFDM block. Each symbol in X is used to modulate a subcarrier. Let , k=0, 1, •••, N-1, denote the nth subcarrier frequency. In the OFDM system, the subcarriers must be Orthogonal to adjacent subcarriers, i.e. = k●△ f, where △ f=1/ (NT) and T is the symbol duration. Therefore, the Complex baseband of the OFDM symbol can be written as:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi k\Delta f}, 0 \le t < NT \qquad (1)$$

PAPR is defined as the ratio of the maximum to the average power during an OFDM symbol period.

$$PAPR = \max_{0\le t<T} \frac{|x(t)|^2}{E\left[|x(t)|^2\right]} \qquad (2)$$

Where E [.] is the expectation operator.

In practice, most systems deal with a discrete-time signal, therefore we have to sample the continuous-time signal x (t). Because Nyquist rate sampling probably misses some signal peaks, oversampling by a factor of L is used to approximate the true PAPR of x(t), where L is an integer larger than 2. The L-time oversampled signal can be given by

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{j2\pi nk/(LN)}, n = 0,1,....,LN-1$$

(3)

Where the oversampling factor L≥ 4 in a practical OFDM system [11]. From (3), the L-time oversampled samples can be obtained by performing LN-point inverse fast Fourier transform (IFFT) on the data block X with (L-1)N zero padding. For the discrete-time signal , the PAPR can be calculated as:

$$PAPR = \frac{\max\limits_{0\le n\le LN-1}\left[\left|x_n\right|^2\right]}{E\left(\left|x_n\right|^2\right)}$$

(4)

Where E (•) denotes the expected value.

From the central limit theorem, for large number of values of N, the real and imaginary values of x (t) becomes Gaussian distributed. The amplitude of the OFDM signal, therefore, has a Rayleigh distribution with zero mean and a variance of N times the variance of one complex sinusoid. The complementary cumulative distribution function (CCDF) is the probability that the PAPR exceeds a certain threshold .

$$CCDF\left(PAPR\left(x\left(n\right)\right)\right) = P_r\left(PAPR\left(x\left(n\right)\right)\right) > PAPR_0$$

………..

(5)

Due to the independence of the N samples, the CCDF of the PAPR of a data block with Nyquist rate sampling is given by

$$P = P_r\left(PAPR\left(x\left(n\right)\right) > PAPR_0\right) = 1 - \left(e^{PAPR_0}\right)^N$$

………

(6)

In this equation assumes that the N time domain signal samples are mutually independent and uncorrelated and it is not accurate for a small number of subcarriers. Therefore, there have been many attempts to derive more accurate distribution of PAPR [12].

## 3. PTS TECHNIQUE

The PTS technique is a powerful PAPR reduction technique, first proposed by Muller and Huber in [13]. Thereafter various related papers have been published. In this section, we show two representative PTS techniques, the original PTS technique and Cimini and Sollenberger’s iterative flipping technique [10].

The block diagram of the PTS scheme is shown in Fig.1. In the PTS scheme, the input data X is partitioned into M disjoint sub blocks

$$X^{(m)} = \left[X_0^{(m)}, X_1^{(m)}, X_2^{(m)}, .......X_{N-1}^{(m)}\right], m = 1, 2, ......M$$

All the subcarrier positions which are presented in other sub blocks must be zero so that the sum of all the sub blocks constitutes the original signal, i.e.

$$X = \sum_{m=1}^{M} X^{(m)} \qquad (7)$$

There are three sub block partition techniques, namely adjacent partition, interleaved partition, and random partition. The random partition technique is the best choice for PAPR reduction, whereas the interleaved partition has the worst PAPR reduction performance.

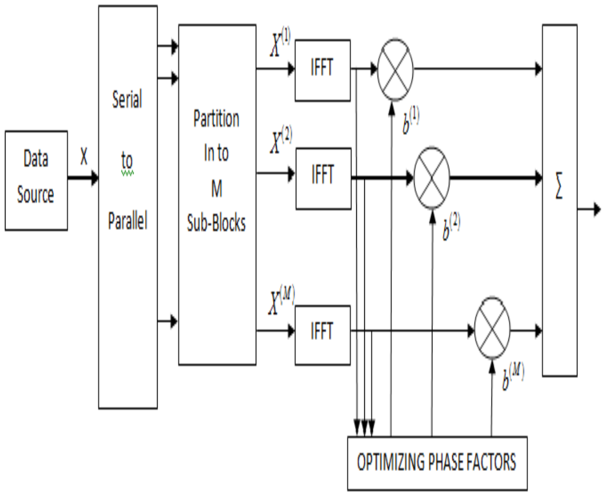


**Fig.1.The block diagram of PTS scheme**

Each sub block is multiplied by a phase factor and then added together. After the IFFT operation, a candidate signal is yielded. This operation can be represented by:

$$x' = \sum_{m=1}^{M} IFFT\{b^{(m)}.X^{(m)}\} = \sum b^{(m)}.IFFT\{X^{(m)}\} = \sum_{m=1}^{M} b^{(m)}.x^{(m)}$$

………

(8)

And

$$b^{(m)} \subseteq \Theta, \qquad \Theta = \left\{e^{j\theta_1}, e^{j\theta_2}, .....e^{j\theta_V}\right\}$$

(9)

Where is the so-called partial transmit sequence, and Θ is the set including V phase factors. Now the objective is to find the optimum combination of phase factors, which minimizes the PAPR of the resulting signal. However, the search complexity increases exponentially with the number of sub blocks[10].

The PTS algorithm can be described in following steps.

1.Divide the OFDM subcarriers into M clusters.

2.Generate the OFDM signals for each cluster.

3.Combine the M output OFDM signals with weighting factors bi.

4.The weighting factors are generated with some optimization algorithm

The receiver has to know the generation scheme (sequences) in order to recover the data.

## 4. ITERATIVE FLIPPING ALGORITHM

As discussed in previous scheme, the optimization process of the PTS scheme needs to evaluate all the combinations of phase factors. In [10], a simplified scheme called iterative flipping algorithm has been introduced and the computation complexity reduces to be linear with the number of sub blocks M.

The iterative flipping algorithm can be described as the following steps:

1.Partition the input data X into M disjoint sub blocks to form the partial transmit sequences as described in the PTS scheme.

2. is initialized to 1 for all m and the PAPR is computed.

3.The first bit is changed, i.e. and the resulting PAPR is recomputed. If the new PAPR is smaller than that in the previous step,is updated with -1; otherwise, is reverted back to 1.

4.The algorithm repeats in this fashion until all M bits have been explored.

Obviously, in the iterative flipping scheme as discussed in [10], the search complexity of this algorithm reduces to the number of sub blocks.

## 5. SIMULATION RESULTS

In this section, we present simulation results to show the performance of the PTS and Iterative flipping techniques. Simulation has been done in Matlab and following parameters have been considered for simulation purpose:

**Table 1.Simulation parameters**

| Simulation parameters | Type/Value |
|---|---|
| Number of subcarriers(N) | 256 |
| Number of sub blocks(M) | 2,4,8 |
| Oversampling factor(L) | 4 |
| Modulation Scheme | BPSK |
| No. of iterations | 1000 |

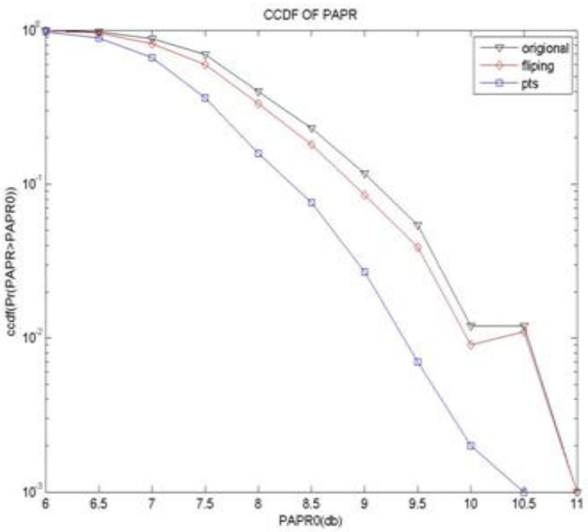


**Fig.2. CCDFs of PAPR in PTS, iterative, original schemes with M=2 sub blocks (N=256, L=4, BPSK modulation)**

Fig.2 to Fig.4 shows the graph for the complement cumulative distribution function (CCDF) of PAPR in original, PTS and Iterative flipping schemes in the case of M=2, 4, 8 sub blocks, respectively. The CCDF of the PAPR denotes the probability that the PAPR of a data block exceeds a given threshold PAPR. It is easy to observe that the PTS and iterative flipping schemes can reduce the PAPR of OFDM Signals, but the ability is different. The PTS scheme exhibit better PAPR reduction performance than the iterative flipping scheme, but its complexity is more than iterative flipping scheme.

Fig.2 shows the CCDFs of PAPR in various schemes When M=2 sub blocks. In this case, PTS scheme achieve best PAPR reduction then iterative scheme. Although iterative scheme also reduce PAPR, but at some threshold PAPR its performance is same as original scheme. From Fig.2, it is seen that the PAPR reduction performance of PTS scheme, and iterative flipping scheme outperforms. The PAPR in original-scheme, PTS-scheme and iterative flipping scheme are 8.9583dB, 8.0499dB, and 7.8422dB, respectively.

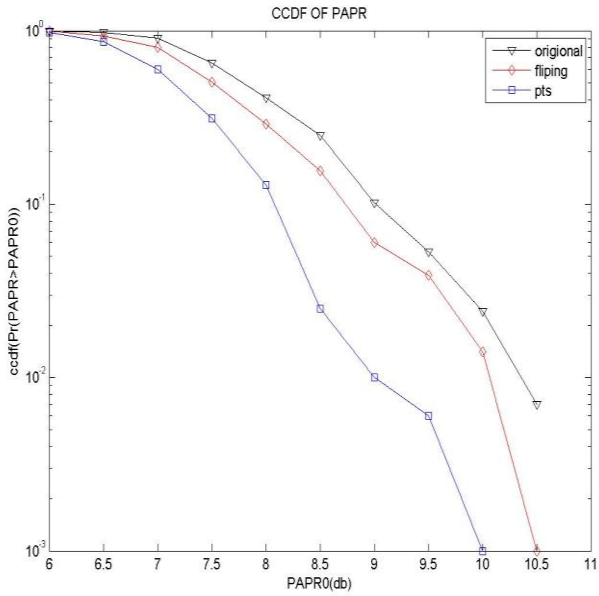


**Fig.3. CCDFs of PAPR in PTS, iterative, original schemes with M=4 sub blocks (N=256, L=4, BPSK modulation).**

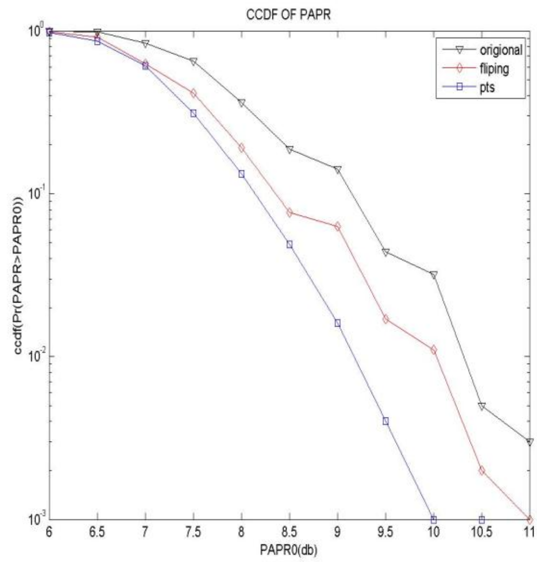


**Fig.4. CCDFs of PAPR in PTS, iterative, original schemes with M=8 sub blocks (N=256, L=4, BPSK modulation).**

Fig.3 shows the CCDFs for M=4, which are similar to the case M=2. PTS-scheme has better performance than the iterative flipping scheme. For original scheme, its PAPR is within 7.4709dB. The PAPRs in PTS scheme, iterative scheme are 6.9698dB, 7.3285dB, respectively. From Fig.3, it can be seen that the performance of PTS-scheme and iterative scheme is much better than that of the previous case (M=2)

Fig.4 illustrates the case of M=8 sub blocks. In this case, we observe some changes. The PTS-scheme exhibits better performance than Iterative flipping scheme as compare to previous case (for M=2, 4).

For original scheme, its PAPR is 7.8711dB. The PAPRs in PTS scheme and iterative scheme are 6.1080dB, 6.9145dB, respectively.

From the simulation results, it is clear that PTS scheme can achieves more PAPR reduction as the sub blocks increase, although performance of iterative flipping scheme is somewhat degraded when the number of sub-blocks increases. Thus PTS scheme show better PAPR reduction performance

## 6. CONCLUSION

In this paper, PTS and Iterative flipping schemes are used for PAPR reduction in OFDM systems. The simulation results show that both the PTS and iterative flipping schemes can lower the PAPR. From the simulation result it can be seen that as the number of sub-blocks increases, the performance of both the scheme increases. To further evaluate their PAPR reduction performance, we compare the PTS schemes with the original scheme and iterative flipping algorithm. The results show that the PTS scheme offer better PAPR reduction than iterative flipping scheme. As the numbers of sub block increases the PTS-scheme give better PAPR reduction.

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