A NOVEL PTS SCHEME FOR PAPR REDUCTION IN OFDM SYSTEMS

Mihail P. Iliev, Viktor V. Hadzhivasilev
University of Ruse "Angel Kanchev", Ruse, Bulgaria
miliev@uni-ruse.bg, vhadzhivasilev@uni-ruse.bg

Keywords: Orthogonal Frequency Division Multiplexing /OFDM/, Peak-to-Average Power Ratio /PAPR/, Partial Transmit Sequence /PTS/, Selected Mapping /SLM/.

Abstract: One of the main drawbacks of orthogonal frequency division multiplexing /OFDM/ is the high peak-to-average power ratio /PAPR/ of the transmitted OFDM signal. Partial transmit sequence /PTS/ technique can improve the PAPR statistics of an OFDM signal. As ordinary PTS technique requires an exhaustive search over all combinations of allowed phase factors, the search complexity increases exponentially with the number of sub-blocks. This paper proposed a novel scheme which has an adjustable parameter enables us to be able to obtain the best performance. Simulation results show that this scheme can significantly improve the ordinal PTS scheme and greatly reduce the computation complexity.

1 INTRODUCTION

Orthogonal frequency division multiplexing /OFDM/ is an attractive technique for wide-band radio communication because of OFDM's capability to convert a frequency selective fading channel to multiple flat fading channels. Thus, there is no need to implement any equalizers in the receiver. However, multi-carrier signals such as OFDM inherently have a high peak-to-average power ratio /PAPR/ problem. Transmitting the OFDM signals without any distortion requires a sufficient back-off of power amplifiers. This property is not acceptable for handsets with limited resources. Many proposals to reduce the PAPR of OFDM signals have been presented. Amplitude clipping and filtering /ACF/ is a simple and effective method. However, clipping causes signal distortion and degrades detection performance in specific to QAM. Selective mapping /SLM/ (Ib. Abdullah, 2011) and partial transmit sequence /PTS/ are based on the same idea that the PAPR of an OFDM symbol can be reduced by applying a certain phase rotation to a part of the transmit data or sequence. In general, SLM needs more IFFT operations but provides better PAPR reduction. Both SLM and PTS are distortionless unlike ACF. However, side information on the phase rotation pattern must be transmitted besides the main data. The side information requirement slightly decreases the transmission efficiency and impacts on the standardization defining the transmitted signal design.

In the paper, we propose a novel scheme for partial transmit sequence, which is based on finding the lowest PAPR from all binary weighting factors combinations.

The paper is organized as follows: In Section 2, the principle of PTS is described. In Section 3 ordinal PTS and a novel PTS technique is presented. In Section 4, the simulation results are given. Finally, we conclude the paper in Section 5.

2 PRINCIPLE OF PTS /PARTIAL TRANSMIT SEQUENCE/

Partial Transmit Sequence /PTS/ algorithm was first proposed by Müller S. H., Huber J. B., (S. H. Muller, 1997) which is a technique for improving the statistics of a multi-carrier signal. The basic idea of partial transmit sequences algorithm is to divide the original OFDM sequence into several sub-sequences, and for each sub-sequence, multiplied by different weights until an optimum value is chosen.

Fig. 1 is the block diagram of PTS algorithm. We have added Hadamard transform to reduce the occurrence of the high peaks comparing the original OFDM system. The idea to use the hadamard

Iliev M. and Hadzhivasilev V.
A NOVEL PTS SCHEME FOR PAPR REDUCTION IN OFDM SYSTEMS.
DOI: 10.5220/0005415501700174
In *Proceedings of the First International Conference on Telecommunications and Remote Sensing (ICTRS 2012)*, pages 170-174
ISBN: 978-989-8565-28-0

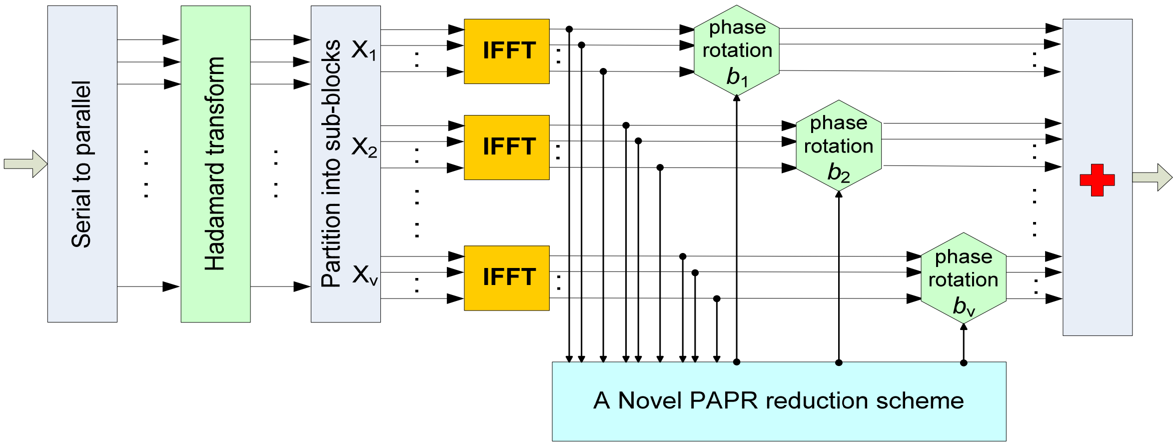

Figure 1: Block diagram of PTS algorithm.

transform is to reduce the autocorrelation of the input sequence to reduce the peak to average power problem and it requires no side information to be transmitted to the receiver.

From the left side of diagram, we see that the data information in frequency domain X is separated into V non-overlapping sub-blocks and each sub-block vectors has the same size N. Hence, we know that for every sub-block, it contains N/V nonzero elements and set the rest part to zero. Assume that these sub-blocks have the same size and no gap between each other, the sub-block vector is given by

$$\hat{X} = \sum_{v=1}^{V} b_v X_v \quad (1)$$

where $b_v = e^{j\varphi_v} (\varphi_v \in [0, 2\pi]) \{v = 1,2,...,V\}$ is a weighting factor been used for phase rotation.

The signal in time domain is obtained by applying IFFT operation on X_v, that is

$$\hat{x} = IFFT(\hat{X}) = \sum_{v=1}^{V} b_v IFFT(X_v) = \sum_{v=1}^{V} b_v x_v \quad (2)$$

Select one suitable factor combination $b = [b_1, b_2, ..., b_v]$ which makes the result achieve optimum. The combination can be given by

$$b = [b_1, b_2, ..., b_v] = \arg\min_{(b_1, b_2, ..., b_v)} (\max_{1 \le v \le N} \left| \sum_{v=1}^{V} b_v x_v \right|^2) \quad (3)$$

where argmin (·) is the judgment condition tat output the minimum value of function. In this way we can find the best *b* so as to optimize the PAPR performance. The additional cost we have to pay is the extra *V*-1 times IFFTs operation.

In conventional PTS approach, it requires the PAPR value to be calculated at each step of the optimization algorithm, which will introduce tremendous trials to achieve the optimum value. Furthermore, in order to enable the receiver to identify different phases, phase factor *b* is required to send to the receiver as sideband information (usually the first sub-block *b*1, is set to 1). So the redundancy bits account for $(V-1)\log_2 W$, in which V represents the number of sub-block, W indicates possible variations of the phase. This causes a huge burden for OFDM system, so studying on how to reduce the computational complexity of PTS has drawn more attentions, nowadays.

The optimization is achieved by searching thoroughly for the best phase factor. Theoretically, $b = [b_1, b_2, ..., b_v]$ is a set of discrete values, and numerous computation will be required for the system when this phase collection is very large. For example, if φ_v contains W possible values, theoretically, b will have W^v different combinations, therefore, a total of $V * W^v$ IFFTs will be introduced.

By increasing the V, W, the computational cost of PTS algorithm will increase exponentially. For instance, define phase factor b_v contains only four possible values, that means $b_v \in [\pm 1, \pm j]$, then for each OFDM symbol, 2*(*V*-1) bits are transmitted as side information. Therefore, in practical applications, computation burden can be reduced by limiting the value range of phase factor $b = [b_1, b_2, ..., b_v]$ to a proper level. At the same time, it can also be changed by different sub-block partition schemes.

3 ORDINAL PTS TECHNIQUE

Cimini and Sollenberger's (L. J. Cimini, 2000) ordinal technique is developed as a sub-optimal technique for the PTS algorithm. In their original paper, they only use binary weighting factors. That is $b_v = 1$ or $b_v = -1$. These can be expanded to more phase factors. The algorithm is as follows. After dividing the data block into V disjoint sub-blocks, one assumes that $b_v = 1$, (v = 1, 2, … ,V) for all of sub-blocks and calculates PAPR of the OFDM signal. Then one changes the sign of the first sub-block phase factor from 1 to -1 ($b_1 = -1$), and calculates the PAPR of the signal again. If the PAPR of the previously calculated signal is larger than that of the current signal, keep $b_1 = -1$. Otherwise, revert to the previous phase factor, $b_1 = 1$. Suppose one chooses $b_1 = -1$. Then the first phase factor is decided, and thus kept fixed for the remaining part of the algorithm. Next, we follow the same procedure for the second sub-block. Since one assumed all of the phase factors were 1, in the second sub-block, one also changes $b_2 = 1$ to $b_2 = -1$, and calculates the PAPR of the OFDM signal. If the PAPR of the previously calculated signal is larger than that of the current signal, keep $b_2 = -1$. Otherwise, revert to the previous phase factor, $b_2 = 1$. This means the procedure with the second sub-block is the same as that with the first sub-block. One continues performing this procedure iteratively until one reaches the end of sub-blocks (V*th* sub-block and phase factor b_v).

4 MODIFIED PTS TECHNIQUE

In this section, we present a modified PTS technique which is similar to Cimini and Sollenberger's technique. We made simulation with 4 and 8 phase factors to reduce the PAPR of the OFDM signal:

$$W=4 \quad b_v=[1 \;\; j \;\; -1 \;\; -j]$$

And

$$W=8 \quad b_v=\left[1 \;\; 1/\sqrt{2}+j/\sqrt{2} \;\; j \;\; -1/\sqrt{2}+j/\sqrt{2} \;\; -1 \;\; -1/\sqrt{2}-j/\sqrt{2} \;\; -j \;\; 1/\sqrt{2}-j/\sqrt{2}\right]$$

The basic idea of the proposed algorithm is first to find and use this combination of binary weighting factors, which gives the lowest PAPR. Secondly we can repeat the process using changed matrix in first step. The result phase factor $b=[b_1, b_2, ..., b_v]$ will be multiplication from all found binary weighting factors. We can reduce all possible combinations, using only this binary weighting factors which begun with 1. The process is repeated P times, where P is an adjustable parameter.

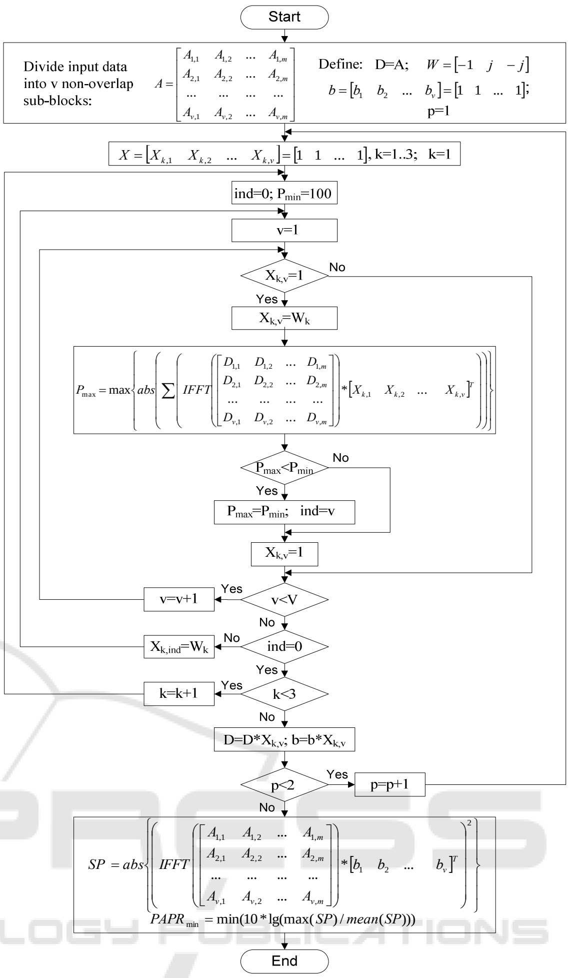

Figure 2: Block scheme of proposed PTS algorithm.

There is and another feature – when finding the lowest PAPR, we first chose this sub-block which gives minimum PAPR and then we try to find next sub-block, which will reduces mostly PAPR. If there is no one /no further improvement is possible/, we may try next binary combinations. Finally we choose this combination of binary weighting factors, which gives lowest PAPR.

The basic structure of the modified PTS technique is illustrated in Fig 2. For the clarity we choose P=2 and W=4. In this case we will have only three /k=3/ binary combinations: (1, -1), (1, j), (1,-j) we are interested in.

After dividing the data block into V disjoint sub-blocks, let one choose first combination k=1 and $X_{k,v}$ =1, (v=1, 2, … ,V) for all sub-blocks and calculates PAPR of the OFDM signal. Then one changes the first sub-block /v=1/ phase factor from 1 to W_k= -1 /$X_{k,v}$ = -1/, and calculates the PAPR of the signal again. If PAPR of the current signal is lower than previously calculated signal, remember index /ind=v/ and PAPR minimum. Restore current phase factor to 1 /$X_{k,v}$ = 1/. Repeat this procedure until the end of the sub-blocks. Then if there is a PAPR improvement, change sub-block with the remembered index to W_k /$X_{k,ind}$ = -1/. One continues performing this algorithm iteratively until there is a PAPR improvement for those sub-blocks, which has phase factor set to 1.

If there is no further improvement, we can try next binary combination k=2 /W_k=j/ and so on, until the end of all possible combinations.

Finally, we choose these binary weighting factors $X_{k,v}$, (v=1, 2, … ,V) which gives the lowest PAPR.

At last, if we multiply the input matrix with the chosen weighting factors, we can repeat the entire process /P=2/. The result phase factor $b=[b_1,b_2,...,b_v]$ will be multiplication from all found binary weighting factors $X_{k,v}$, (v=1, 2, … ,V).

5 SIMULATION RESULTS

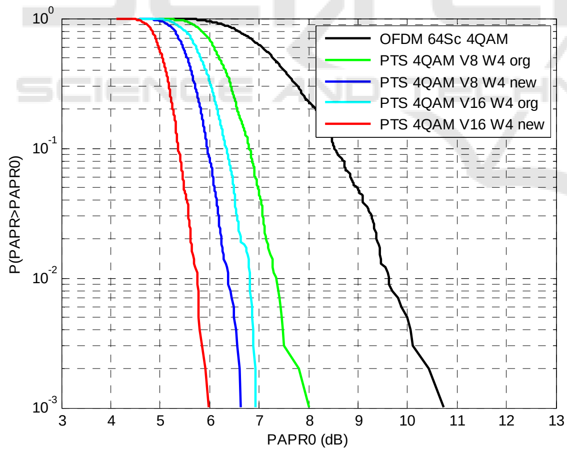

Figure 3: Comparison between ordinal and a novel PTS technique of PAPR reduction performances with different values of V.

From Fig. 3, it can be seen that a novel PTS algorithm undeniably improve the performance of OFDM system, moreover, with the increasing of V, the improvement of PAPR reduction performance becomes better and better. Assume that we fix the probability of PAPR at 0.1% and compare the CCDF curve with different values of V. Form the figure, we notice that the CCDF curve has nearly 1.5dB improvement when V=8, compared to the ordinal PTS algorithm. When V=16, the 0.1% PAPR is about 6dB, so an optimization of 1dB is achieved. If we compare PAPR reduction to the conventional OFDM system, we can observe that an improvement of nearly 5dB is reached.

However, the downward trend of CCDF curve is tended to be slow when we keep on increasing V, which means too large sub-block numbers V will result in small improvement of PAPR reduction performance, but anyway we have to increase sub-block numbers V, if we have a many of sub-curriers.

Therefore, practically, we prefer to choose a suitable value of V.

The simulation result in Fig. 4 shows the varying PAPR reduction performance with different W, when using ordinal and modified PTS reduction scheme. Simulation specific parameters are: the number of sub-carriers N=64, 4-QAM constellation modulation, the number of sub-blocks V=8. From the figure we notice that the CCDF curve has al least 1/3dB improvement when W=8, compared to W=4. We can conclude that the larger W value takes, the better PAPR performance will be obtained when the number of sub-block V is fixed, but pay for the enormous computation time. Therefore, practically, we prefer to fix W=4.

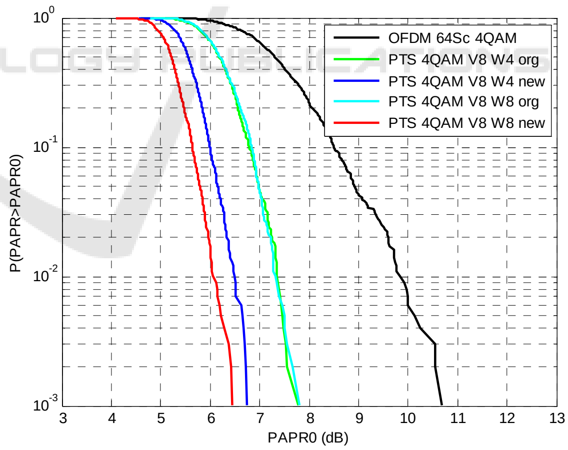

Figure 4: Comparison between ordinal and modified PTS technique of PAPR reduction performances with different values of W.

On the next scheme, shown on Fig. 5, we compare PAPR reduction performances with different number of sub-carriers, when W is fixed /four phase rotations/ and modulation is 4-QAM. We observe that if the number of sub-curries is increased the PAPR reduction performance has been slowed down.

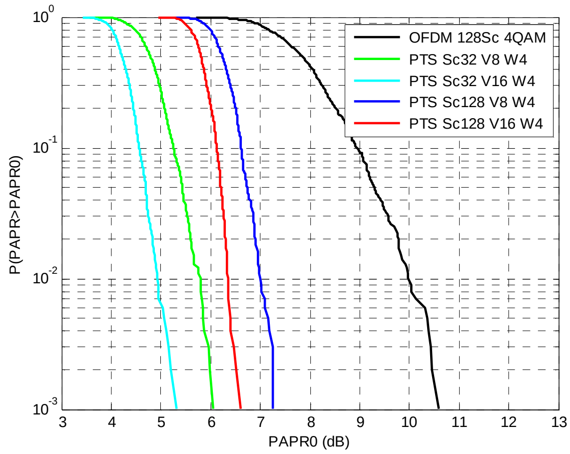

Figure 5: Comparison of PAPR reduction performances with different values of *V* and number of sub-curriers.

The simulation results in Fig. 6 compares PAPR reduction performances with different modulation schemes /4-QAM and 16-QAM/ and fixed values of *V*, *W* and number of sub-curriers. We may notice that the number of constellation points almost has no effect of PAPR characteristics.

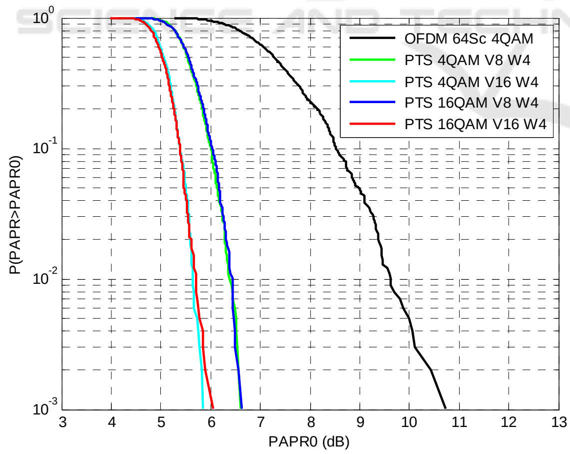

Figure 6: Comparison of PAPR reduction performances with different values of V and variable QAM size.

Finally, on the Fig. 7 we made comparison between different number of sub-blocks and an adjustable parameter - *P*. We can see that the trend of CCDF curve is tended quickly to be slow-down when we keep on increasing *P*. Therefore, practically it is suitable to choose *P*=2 and to determinate the number of sub-blocks on dependency of sub-curriers, as we discuss above - see Fig. 3.

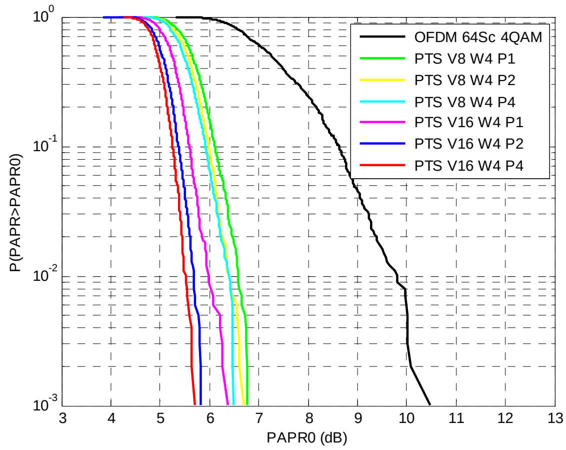

Figure 7: Comparison of PAPR reduction performances with different values of *P* and number of sub-blocks.

6 CONCLUSION

One of the major problems associated with OFDM is its high PAPR. In this chapter, we proposed a novel PTS algorithm to reduce efficiently the PAPR of OFDM signal. There is an adjustable parameter, which enables us to be able to obtain the best performance.

Simulation results show that the proposed novel algorithm can yield good PAPR reduction with low computational complexity.

REFERENCES

Ib. Abdullah, Z. Mahamud, Sh. Hossain, "Reduction of PAPR in OFDM using SLM for different route number", IJRRCS, June 2011

S. H. Muller, J. B. Huber, "OFDM with reduced peak-to-average power ratio by optimum combination of partial transmit sequence," *IEEE Electronic Letters*, Vol. 33, No. 5, Feb. 1997

L. J. Cimini, Jr. and N.R. Sollenberger, "Peak-to-average power ratio reduction of an OFDM signal using partial transmit sequences," *IEEE Communication Letters*, vol. 4, Mart 2000

Y. Cho, J. Kim, W. Yang, Ch. Kang, "MIMO-OFDM Wireless Communications With MATLAB", John Wiley & Sons, Singapore, 2010