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Reducing PAPR in OFDM Systems using a PTS based Low Computational Complex Algorithm

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Abstract: Orthogonal Frequency Division Multiplexing (OFDM) has proven to be the most promising technique for high speed data transmission over a dispersive channel. It is because of its several advantages such as high spectral efficiency, low implementation complexity, less vulnerability to echoes and non–linear distortion. However, it has few limitations such as peak-to-average-power ratio (PAPR) and bit error rate (BER), which determines the system's power efficiency. This paper addresses the problem of reducing PAPR in OFDM systems. For this purpose, partial transmit sequence (PTS) is chosen, which has proven to be a promising technique for PAPR reduction in OFDM systems. However in this approach, computation of optimal PTS weight factors via exhaustive search requires exponential complexity in the number of subblocks. Therefore in this paper, an efficient algorithm for computing the optimal PTS weights is introduced with the aim to reduce complexity compared to exhaustive search.

Keywords: OFDM; Partial Transmit Sequence; Peak-to-Average Power Ratio and Complementary Cumulative Distribution Function.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has proven to be the most promising technique for high speed data transmission over a dispersive channel [1]. It provides high spectral efficiency, low implementation complexity [2], less vulnerability to echoes and non–linear distortion [3]. Due to these advantages of the OFDM system, it is vastly used in various communication systems. Typical examples include: Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), WiFi (IEEE 802.11a/g/j/n), World Wide Interoperability for Microwave Access (WiMAX-IEEE 802.16), Ultra Wide Band Wireless Personal Area Network (UWB Wireless PAN-IEEE 802.15.3a) and Mobile Broadband Wireless Access (MBWA-IEEE802.20) [4]. Despite these advantages, it has few limitations of PAPR and BER [4]. A high PAPR increases the complexity of the analog–to–digital and digital–to–analog converter and reduces the efficiency of the radio – frequency (RF) power amplifier [5]. There are a number of techniques dealing with the problem of BER & PAPR. Some of these include: constellation shaping, nonlinear companding transforms [6], tone reservation [7] and tone injection (TI), clipping and filtering [8], partial transmit sequence [9] and precoding based techniques. Among these techniques, PTS scheme has been found to an efficient and attractive method that has several advantages over others. In PTS, an input data sequence is divided into a number of disjoint subblocks, which are then weighted by a set of phase factors to create a set of candidate signals. Finally, the candidate with the lowest PAPR is chosen for transmission. This PTS scheme has a major drawback that it requires a very large number of computations to identify and select the optimum candidate signal that has a low PAPR from all the available combinations of candidate signals. This computational complexity has been reduced by implementing several modified techniques like iterative flipping, but all these techniques are implemented by reducing & eliminating some of the candidate signals which causes the information loss.

Therefore, this paper introduces an algorithm for computing the optimal PTS weights with the aim to reduce computational complexity compared to exhaustive search. More specifically, the computational complexity in PTS scheme is reduced by using the correlation property between the available candidate signals, instead of reducing the number of candidate signals and thus no information is being lost. This scheme achieves the PAPR reduction same as the conventional PTS scheme; however, reduces the computational complexity comparatively to a large extent. To better understand, it is advisible to understand first the priniciple of OFDM systems, as defined below.

II. SYSTEM MODEL

A. OFDM System Model

As discussed above, OFDM is a parallel multicarrier transmission scheme, where a high-rate serial data stream is split up into a set of low-rate sub streams, each of which is modulated on a separate subcarrier. To understand the principle of

OFDM systems, consider the block diagram of an OFDM system shown in Figure 1. In Figure 1, an OFDM signal consists of *N* subcarriers that are modulated by *N* complex symbols selected from a particular QAM constellation.

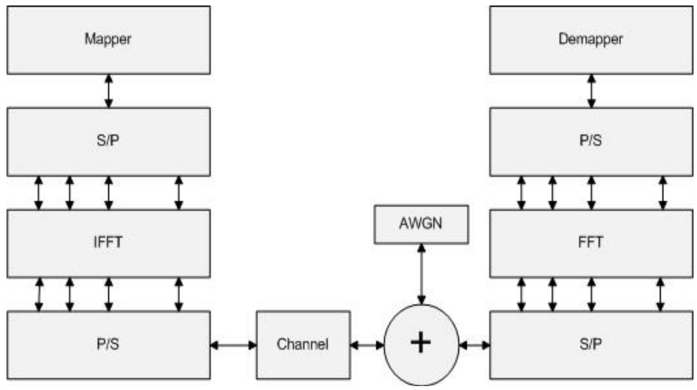

Figure 1: Block diagram of general OFDM system.

In Figure 1, the baseband modulated symbols are passed through serial to parallel converter which generates complex vector of size N. This complex vector of size N can be expressed as

$$X = [X_0, X_1, X_2, X_3 \dots X_{N-1}] \quad (1)$$

X is then passed through the IFFT block of size $N \times N$ IFFT matrix. The resulted complex baseband OFDM signal with N subcarriers can then be written as

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} dX_k e^{\frac{j2\pi kn}{N}} \quad n = 0, 1, \dots, N-1 \quad (2)$$

After parallel-to-serial conversion, a cyclic prefix (CP) with a length of N_g samples is appended before the IFFT output to form the time-domain OFDM symbol, $s = [s_0, \dots, s_{N+Ng-1}]$. The useful part of OFDM symbol does not include the N_g prefix samples and has duration of T_u seconds. The samples (s) are then amplified, with the amplifier characteristics is given by function F and the output of amplifier produces a set of samples denoted by y. At the receiver front end, the received signal is applied to a matched filter and then sampled at a rate $T_s = T_u/N$. After dropping the CP samples (N_g), the received sequence z, assuming an additive white Gaussian noise (AWGN) channel, can be expressed as

$$z = F(Wd) + \eta \quad (3)$$

Where, the noise vector η consists of N independent and normally distributed complex random variables with zero mean. Subsequently, the sequence z is fed to the fast Fourier transform (FFT), which produces the frequency-domain sequence r as

$$r = W^H z \quad (4)$$

Where, k_{th} element of r is given by

$$r_k = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} z_n e^{\frac{-j2\pi kn}{N}} \quad k=0, 1, 2, \dots, N-1 \quad (5)$$

Finally, the estimated symbols vector $\hat{d}$ can be obtained from r. It is to be noted that ideally, the demodulation is performed based on the assumption of perfect symbol timing, carrier frequency, and phase synchronization. However this is not possible to achieve always in practice. Therefore, the BER is introduced and the same can be defined as the difference of the obtained demodulated signal r_k from the input signal.

The PAPR (as mentioned above) for a continuous time signal $x(t)$ is defined as:

$$PAPR = \frac{max\{|x(t)|^2\}}{E\{|x(t)|^2\}} \quad 0 \le t \le T_u \quad (6)$$

The PAPR for discrete time signals can be estimated by oversampling the vector d by a factor L and computing NL-point IFFT. The PAPR in this case is defined as:

$$PAPR = \frac{max\{|x(n)|^2\}}{E\{|x(n)|^2\}} \quad n = 0,1, \dots, NL-1 \quad (7)$$

PAPR, in quantitative terms, is usually expressed in terms of Complementary Cumulative Distribution function (CCDF) for an OFDM signal, and is mathematically given by

$$P(PAPR > PAPR_0) = 1 - (1 - e^{-PAPR_0})^N \quad (8)$$

Where, $PAPR_0$ is the clipping level. This equation can also be read as the probability that the PAPR of a symbol block exceeds some clip level $PAPR_0$.

B. TRADITIONAL PTS SCHEME

The block diagram of the PTS scheme is shown in Figure 2. As shown in Figure 2, PTS scheme involves transmitting only a part of the data of varying sub-carrier with low PAPR, which covers all the information to be sent in the signal as a whole.

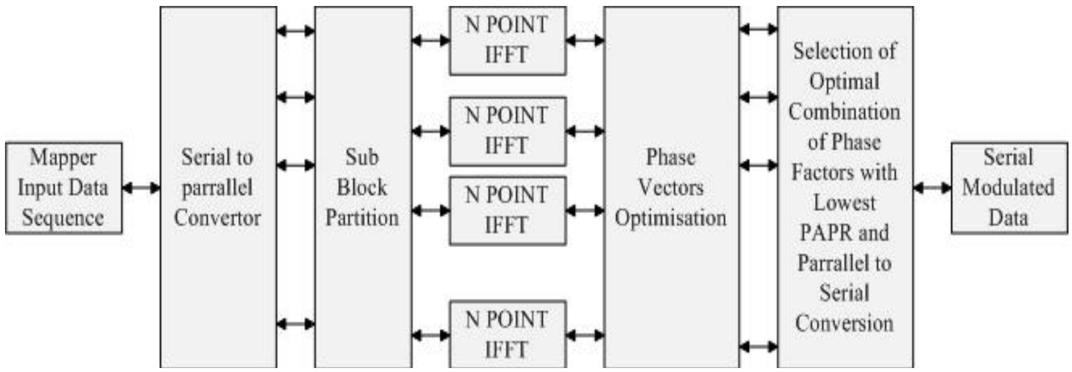

Figure 2: Block diagram of PTS scheme for reducing PAPR in OFDM system.

In PTS scheme (Figure 2), input data block *X* is partitioned into *M* disjoint sub-blocks in a manner that each sub-block is given by

$$X_m = \left[X_{m,0}, X_{m,1}, \ldots, X_{m,N-1}\right]^T \qquad m = 1,2,\ldots,M \tag{9}$$

and, $\sum_{m=1}^{M} X_m = X$. These sub-blocks are combined to minimize PAPR in time domain. The Inverse Discrete Fourier Transform of length NL is performed on each block to obtained the L times oversampled time domain signal of $X_m, m = 1,2,\ldots,M$. These time domain signals X_m are then concatenated with (L-1)N zeroes. These are called the Partial Transmit Sequences. The complex phase factors (Figure 2) given by $b_m = e^{j\theta_m}, m = 1,2,\ldots,M$, are introduced to combine the partial transmit sequences. Finally, the set of these complex phase factors is denoted by $b = [b_1, b_2, \ldots, b_m]^T$. The time domain signal after combining all the partial transmit sequences by the use of the complex phase factors is given by

$$X'(b) = \sum_{m=1}^{M} b_m \,.\, X_m \tag{10}$$

where $X'(b) = [\, X'_0(b),\ X'_1(b), \ldots,\ X'_{NL-1}(b)]^T$.

The next step as shown in Figure 2 above, is to find the set of optimum phase factors, which when used to combine the *M* disjoint blocks will yield a candidate signal with low PAPR. Assuming, that there are *W* phase factors, then it would require for the PTS to search W^M combinations to get an optimal set of phase factors which yields low PAPR signal.

The number of multiplications involved in this traditional PTS scheme with *W* phase vectors is given by

$$\beta_{mul} = N.\left[C_{M-1}^{1}\left(\frac{W}{2}-1\right) + 2C_{M-1}^{2}\left(\frac{W}{2}-1\right)^2 + \cdots + (M-1)C_{M-1}^{M-1}\left(\frac{W}{2}-1\right)^{M-1}\right].2^{M-1} \tag{11}$$

From the above eqn 11, the number of search increases exponentially with increase in the number of blocks *M*. This means conventional PTS scheme requires a large number of computations to get an optimal candidate signal with low PAPR.

C. MODIFIED PTS SCHEME

In eqn 10, there may be certain combinations of phase vectors which may have the same relations. These relations can be investigated through the correlation and convolution properties. In this paper, a correlation property among these phase factors in each subset is used in a manner that the computational complexity can be reduced. To better understand and for simplicity, consider the number of phase factors *W*=2. Corresponding to *W*=2, there are two phase factors (in-phase & out-of-phase factor) with phase factor set as {1, -1}. Similarly, for *W*=4, the phase factors set consists of {1, -1, j, -j}, which indicates real and imaginary in-phase & out-of-phase factors. Using these phase factors, all other phase vectors can be derived from this prototype vector. For example, if *W*=2 & *M*=2, then the prototype vectors are {1, 1} & {1, j). Using this correlation property, all the vectors derived from the same prototype vector differ each other by only a sign change. Based on these phase factors, number of subblocks of the PTS and the vectors, all the candidate signals can be derived. For example, the first candidate signal can be derived from the first prototype vector as

$$X_{1,1} = X_1 + X_2 + X_3 + \cdots + X_m \tag{12}$$

Now, the second candidate signal can be derived from the first candidate signal by using the sign change property as

$$X_{1,2} = X_{1,1} - sign(b_{1,1,m}).2X_m \tag{13}$$

Where, $b_{i,k,m}$ represents the k^{th} phase weighting vector based on the i^{th} prototype vector and is applied to the m^{th} sub-block of the PTS OFDM transmitted signal and *sign*(*A*) indicates the sign of *A*.

Similarly, the (i+1)th candidate signal can be derived from the first prototype vector as

$$X_{1,i+1} = X_{1,i} - sign(b_{1,i,m}).2X_m \tag{14}$$

The first candidate signal of the 2nd prototype vector is denoted by $X_{2,1}$ and can be derived from $X_{1,prev}$ as

$$X_{2,1} = X_{1,prev} + b_{1,prev,m}(A_{2,m} - 1)X_m \tag{15}$$

Where, $prev = 2^{M-1}$ indicates the previous prototype vector, and $A_{i,j}$ is the value which denotes the change of real & imaginary phase factors in the various prototype vectors. So in general, the (i+1)th candidate signal can be derived from the second prototype vector as

$$X_{2,i+1} = X_{2,i} - sign(b_{2,i,m}).2X_m \tag{16}$$

Combining all the above equations from 12 to 16, the candidate signals can be generally expressed as

$$X_{i+1,1} = X_{i,prev} + b_{i,prev,m}(A_{i+1,m} - 1)X_m \tag{17}$$

And,

$$X_{k+1,i+1} = X_{k+1,i} - b_{k+1,i,m}.2X_m \tag{18}$$

From eqns 17 & 18, the candidate signals can be derived with reduced computational complexity and the one with minimum PAPR is selected for transmission. For example, consider the partial transmission of sequences by taking 3 subblocks i.e. M=3 and 4 phase factors set i.e. W=4. Rewriting the eqns 17 & 18 using M=3 & W=4 to get the candidate signals as

$$X_{1,i+1} = X_{1,i} - sign(b_{1,i,m}).2X_m \tag{19}$$

$$X_{2,1} = X_{1,4} + sign(b_{1,4,3})(A_{2,3} - 1)X_3 \tag{20}$$

$$X_{2,i+1} = X_{2,i} - sign(b_{2,i,m}).2X_m \tag{21}$$

$$X_{3,1} = X_{2,4} + sign(b_{2,4,2})(A_{3,2} - 1)X_2 \tag{22}$$

And, similarly the equations can be written to get the last candidate signal i.e. $X_{4,4}$. From the above eqns, the number of multiplications required by the proposed PTS is given by

$$\alpha_{mul} = N.\left[\left(\frac{W}{2}\right)^{M-1} - 1\right] \tag{23}$$

Similarly from above eqns, the number of additions required by the proposed PTS scheme has reduced to N because it is only necessary to calculate the X_m. Hence, the ratio of the addition complexity of proposed scheme to that of conventional PTS scheme is $\frac{1}{M-1}$.

Thus, it can be observed from these equations that due to the correlation property, the computational complexity has been reduced to a large extant. The computational complexity is usually expressed in terms of Computational Complexity Reduction Ratio (CCRR), which is given by

$$CCRR = \left(1 - \frac{Proposed\ PTS\ complexity}{Conventional\ PTS\ complexity}\right) * 100\% \tag{24}$$

For M=6, computed addition CCRR is 80% and multiplication CCRR is 98% with the proposed PTS scheme compared to the conventional PTS scheme. With these results, it can be interpreted that the proposed PTS scheme can reduce the computational complexity to a very large extant comparing to the conventional PTS scheme.

III. IMPLEMENTATION

To do the PAPR analysis and to evaluate the performance of the proposed PTS based PAPR reduction method, the same is implemented using MATLAB by undertaking the following steps:

1. To do the PAPR analysis of OFDM system with the mentioned PTS based function, firstly binary data is generated randomly.
2. The generated binary data is then converted into symbols and is then modulated by M-QAM (where M=4, 16, 64, 256).
3. The serial data is then converted into parallel data and IFFT is performed as normal in OFDM procedure.
4. The parallel signal is then converted to serial data and a non-linear polynomial function is applied to reduce the PAPR. The PAPR is then calculated and the serial OFDM signal is then passed through a multipath channel with AWGN noise added.
5. The received signal is again passed through the serial to parallel converter, which is then demodulated and converted back to serial data to retrieve back the signal.

IV. RESULTS & DISCUSSION

To evaluate the performance of the proposed PTS based PAPR reduction method, extensive simulations have been performed in MATLAB. To do the PAPR analysis of the proposed PTS based PAPR reduction method, data is generated randomly and then modulated by M-QAM (where M = 4, 16, 64). The order of FFT and IFFT is taken as 64. The results obtained are shown in Figures 3 to 6. From Figure 6, it is evident that the PAPR for the proposed scheme is same as that of the traditional PTS scheme. However as discussed above, the correlation property used has significantly reduced the computational complexity. The number of candidate signals is not reduced so the information content remains the same.

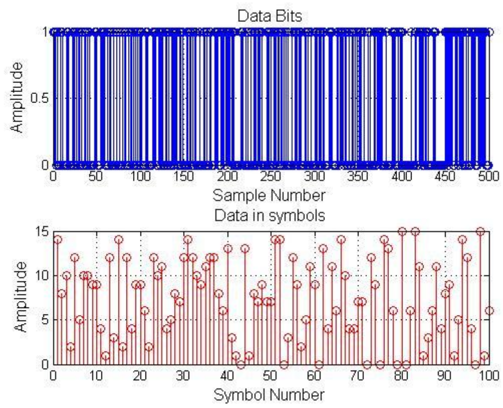

Figure 3: A typical example of input binary signal and its corresponding symbols.

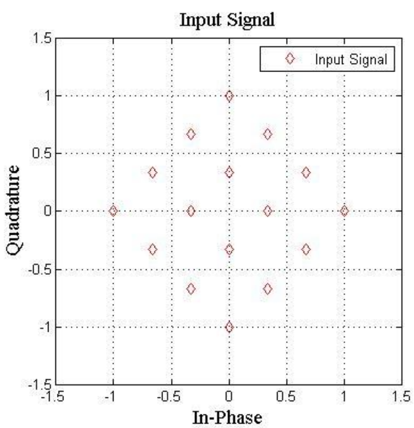

Figure 4: QAM modulated input signal with constellation size 4.

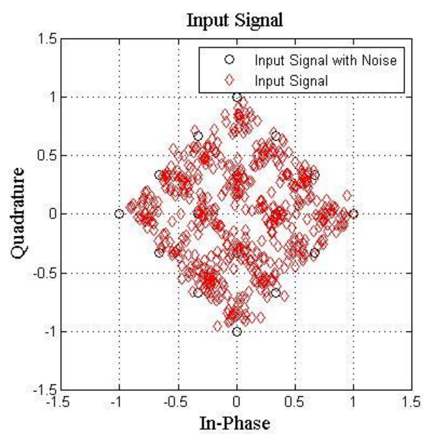

Figure 5: CCDF plots of PAPR of OFDM with QAM modulation for constellation size 4.

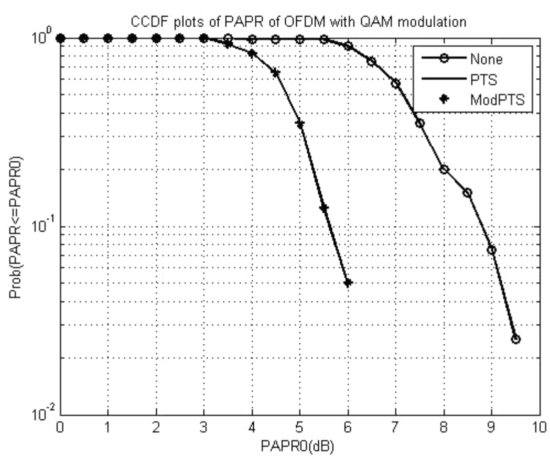

Figure 6: CCDF plots of PAPR of OFDM with QAM modulation for constellation size 64.

V. CONCLUSION

This paper presented the results obtained on applying a modified PTS technique for reducing PAPR in OFDM systems with M-QAM modulation. It is observed from the graphs that the proposed approach offers the same degree of reduction in PAPR as that of the traditional PTS scheme. However, traditional PTS scheme employs large computations to reduce the PAPR which is a major drawback. The proposed scheme has significantly reduced the computational complexity compared to the conventional PTS scheme. Thus, the proposed PTS scheme not only reduces the computational complexity to a great extant but also achieves the same PAPR reduction as that of the conventional system.

REFERENCES

[1] H. B. Jeon, J. S. and D. J. Shin (2011). A Low-Complexity SLM Scheme Using Additive Mapping Sequences for PAPR Reduction of OFDM Signals. *IEEE Transactions On Broadcasting.* Vol. 57, No. 4, pp. 866-75.

[2] Ghassemi and T A. Gulliver (2007). SLM-Based RADIX FFT for PAPR reduction in OFDM systems. *IEEE International Conference on Signal Processing and Communications (ICSPC 2007*). pp 1031-34.

[3] C. P. Li, S. H. Wang and C. L. Wang (2010). Novel Low-Complexity SLM Schemes for PAPR Reduction in OFDM Systems. *IEEE Transactions On Signal Processing.* Vol. 58, NO. 5, pp 2916-21

[4] H. Liang, Y. R. Chen, Y. F. Huang, C. H. Cheng (2009). A Modified Genetic Algorithm PTS Technique for PAPR Reduction in OFDM Systems. *Proceedings of the 15th Asia-Pacific Conference on Communications (APCC 2009).* pp 182-185.

[5] H. Li, T. Jiang and Y. Zhou (2011). An Improved Tone Reservation Scheme With Fast Convergence for PAPR Reduction in OFDM Systems. *IEEE Transactions On Broadcasting.* Vol. 57, No. 4, pp. 902-06.

[6] P. Varahram and B. M. Ali (2011). Partial Transmit Sequence Scheme with New Phase Sequence or PAPR Reduction in OFDM Systems. *IEEE Transactions on Consumer Electronics.* Vol. 57, No. 2, pp. 366-71.

[7] J. C. Chen, "Application of quantum-inspired evolutionary algorithm to reduce PAPR of an OFDM signal using partial transmit sequences technique," *IEEE Trans. Broadcast*., vol. 56, no. 1, pp. 110-113, Mar. 2010.

[8] Y. Wu and W. Y. Zou, "Orthogonal frequency division multiplexing: A multi-carrier modulation scheme," *IEEE Trans. Consum. Electron.*, vol. 41, no. 3, pp. 392-399, Aug. 1995.

[9] T. Jiang and Y. Wu, "An Overview: Peak-to- Average Power Ratio Reduction Techniques for OFDM Signals," *IEEE Trans. Broadcast*,, Vol. 54, No. 2, June 2008.

[10] A. D. S. Jayalath and C. Tellambura, "Adaptive pts approach for reduce of peak-to-average power ratio of OFDM signal," *Electron. Lett.*, vol. 36, no. 14, pp. 1226-1228, Jul. 2000.

[11] L. J. Cimini, and N. R. Sollenberger," Peak-to-Average Power Ratio Reduction of an OFDM Signal Using Partial Transmit Sequences," *IEEE Communications Letters*, Vol. 4, No. 3, March 2000.

[12] W. S. Ho, A. S. Madhukumar, and Francois Chin," Peak-to-Average Power Reduction Using Partial Transmit Sequences: A Suboptimal Approach Based on Dual Layered Phase Sequencing," *IEEE Trans. Broadcast*,, Vol. 49, No. 2, June 2003.

[13] T. Jiang, Y. Yang, and Y. H. Song, "Exponential Companding Technique for PAPR Reduction in OFDM Systems" *IEEE Trans. Broadcast*,, Vol. 51, No. 2, June 2005.

[14] J. Hou, J. Ge, D. Zhai, and J. Li, "Peak-to-Average Power Ratio Reduction of OFDM Signals With Nonlinear Companding Scheme" *IEEE Trans Broadcast*, Vol. 56, No. 2, June 2010.

