Peak-to-Average Power Ratio Reduction of OFDM signals Using Improved PTS Scheme with Low Computational Complexity

ALOK JOSHI[1], DAVINDER S. SAINI[2]
Department of Electronics and communication Engineering
Jaypee Institute of Information Technology, Noida, U.P-201301[1]
Jaypee University of Information Technology, Waknaghat, H.P-173215[2]
INDIA
20. alok@gmail.com[1], dsaini76@gmail.com[2] (http://www.jiit.ac.in ,www.juit.ac.in)

Abstract: - In wireless communication, parallel transmission of symbols using multi carriers is applied to achieve high efficiency in terms of throughput and better transmission quality. Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques for parallel transmission. It effectively mitigates the effect on performance due to Intersymbol Interference and delay spread caused by wireless medium. However high peak to average power ratio (PAPR) is a major demerit of OFDM system. High PAPR leads to increased complexity of circuit and reduced efficiency of RF amplifier. Partial Transmit Sequence (PTS) is one of the most promising techniques for PAPR reduction. In conventional PTS scheme the computation of optimal phase factors necessitates exhaustive searching of all possible and allowable phase factors, this leads to exponential increase of computation complexity in terms of complex additions and multiplications as number of subblock increases. In this paper by exploiting correlation among various candidate phase factors a novel scheme is proposed here which reduces the computation complexity by tremendous margin and at the same time maintaining same PAPR reduction as conventional PTS scheme. OFDM signal Implemented here complies with IEEE 802.11 a standard.

Key-Words: - OFDM, PAPR, PTS, Complex multiplication and addition, Phase weighting.

1 INTRODUCTION

As demand of high transmission rate is increasing day by day parallel transmission using multi-carrier is becoming a need of hour and OFDM is a promising candidate for various application such as Wireless Local area Networks (WLAN), Digital Video Broadcast (DVB), Digital Audio Broadcast (DAB), 4-G pertaining to its high band-width efficiency and its immunity towards ISI and delay spread [1], [2], [3]. OFDM avoids ISI problem by sending many low speed transmissions simultaneously with addition of cyclic prefix.

However high peak to average power ratio is a major problem associated with OFDM system, this leads to increased complexity of analog to digital converter ,digital to analog converter and reduced efficiency of the RF power amplifiers. The transmit signals in an OFDM system can have high peak values in the time domain since many subcarrier components are added via an IFFT operation. Therefore, OFDM systems are known to have a high PAPR (Peak-to-Average Power Ratio), compared with single-carrier systems [4], [5].

When high PAPR OFDM signal pass through a nonlinear device such high power amplifiers (HPA), it causes the out-of-band radiation that affects signals in adjacent bands, and in-band distortions that result in rotation, attenuation, and offset on the received signal. So a large back-off in input OFDM power is required to force the operation in linear region of HPA. Such HPA with large dynamic range are quite expensive and increase overall cost of the system. By reducing PAPR we reduce the overall cost as well as complexity of various components in the OFDM system.

To solve the PAPR problem various schemes are presented till now such as *clipping* technique where clipping is done around the peaks but at the cost of increased distortion, this technique includes clipping and filtering, block scaling, Fourier projection, peak cancellation approaches[6],[7]. Apart from this *Coding* techniques are also included for PAPR reduction, such as Golay complementary sequences, Hadamard, Reed Muller codes, but in this approach PAPR reduction is achieved at higher complexity and lower bandwidth efficiency [8],[9]. *Pre-*

distortion techniques are other methods to handle time variations of nonlinear HPA by modifying input constellation (constellation extension) [10]. *Transform schemes* are also used for PAPR reduction such as Discrete Hilbert Transform (DHT), DFT-spreading [11-15].

Most widely methods used for PAPR reduction is probabilistic *scrambling* techniques where input data block is scrambled and sequence with lowest PAPR is transmitted, such techniques are selective mapping (SLM), Partial Transmit Sequence (PTS), Tone reservation and Tone Injection techniques. These methods do not suffer from the out-of-band power, but the spectral efficiency decreases and the complexity increase as the number of sub-carriers increases [16-20].

Among all mentioned above schemes PTS is the most promising candidate for PAPR reduction due to its PAPR performance without incurring distortion.

In PTS input data is subdivided in to sub-blocks and multiplied by set of weighted phase sequences to create multiple sequence which can be transmitted (partial transmit sequence), among these sequence the one with lowest PAPR is selected for final transmission. To find the optimum candidate an exhaustive search is done over all combination of permissible phase factors and it results in to increased computational complexity which grows exponentially with increase in number of sub-blocks. To reduce the computational complexity most of the proposed schemes suggest reduction of sub-blocks, resulting in to less number of candidate signals [21-28].

In this paper a novel scheme is proposed for finding the allowable phase sequences where one candidate sequence with combination of other sequence leads to calculation of the other candidates using same set of weights. The aim is to reduce computational complexity without decreasing the number sub blocks and candidate signal. This scheme gives at par PAPR performance as conventional PTS scheme uses with OFDM system, but with lower computational complexity. The Paper is organized as follows:

Section 2 details OFDM principle, PAPR problem and partial transmit sequence technique to reduce it. Section 3 discusses the proposed scheme for low complexity PTS. In Section 4 performance of proposed scheme is compared with plain-OFDM in terms of computational complexity and PAPR and paper is concluded in section 5.

2 OFDM System and PAPR Reduction with PTS

The OFDM system achieves high data transmission rate by splitting the stream in to lower data rate parallel streams which are transmitted simultaneously using orthogonal subcarriers. Fig.1 Shows the various building block of a typical OFDM system.

OFDM signal with N subcarriers is represented as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k \phi_k(t) \tag{1}$$

Where:

X_k = Input data symbol carried by k^{th} subcarrier

$$\phi_k(t) = \begin{cases} e^{j2\pi f_k T}, t \in (0,T) \\ 0, otherwise \end{cases}$$

$$f_k = f_0 + \frac{k}{T}, k = 0,1,2....N-1$$

T = Symbol Duration

An OFDM signal consists of a number of independently modulated sub carriers, which can give a large peak-to-average power (PAP) ratio when added up coherently. When N signals are added with the same phase, they produce a peak power that is N times the average power. PAPR for a signal $x(t)$ transmitted in time interval τ is defined as:

$$PAPR\{x(t),\tau\} = \frac{\max\limits_{0\le t\le T}\{|x(t)|^2\}}{E\{|x(t)|^2\}} \tag{2}$$

Where: $\max[x(t)]^2$ is the peak signal power for $t \in \tau$

$E\{[x(t)]^2\}$ is the average signal power

Peak value of the signal

$$\max\{|x(t)|^2\} = \max[x(t).x(t)^*] = N^2 \tag{3}$$

Similarly the mean square value (average signal power) is

$$E\{|x(t)|^2\} = E[(x(t).x(t)^*] = N \tag{4}$$

So when all the subcarriers are equally modulated, and all the subcarriers align in phase and the peak value hits the maximum, the PAPR will be

$$PAPR = N \tag{5}$$

To calculate more precise value of PAPR more number of symbols should be taken in to account otherwise some peak may get omitted resulting in to erroneous value of PAPR. This problem can be overcome by over sampling of *x(t)*. To perform oversampling by a factor of *L*, *LN* point IFFT of input data sequence is taken by inserting *(L-1) N* zeros.

Cumulative distribution function (CDF) of $Z_{\max}$ is given as:

$$F_{Z_{\max}} = P(Z_{\max} < z)$$

$$= \left(1 - \exp(-z^2)\right)^N \tag{7}$$

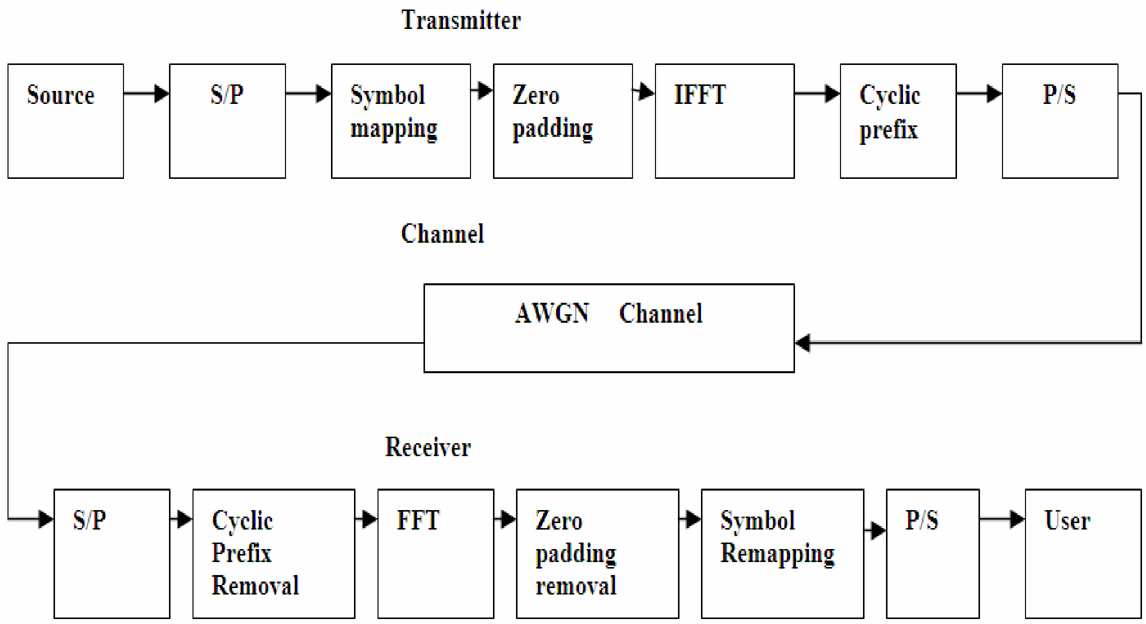

Fig 1. OFDM system

In practice to evaluate the performance of PAPR reduction scheme complementary cumulative distribution function (CCDF) is used.

Assuming real and imaginary parts of the OFDM signal *x(t)*, have asymptotically Gaussian distribution for a large number carriers. Then the amplitude of OFDM signal has Rayleigh distribution. Let z_n be the magnitude of complex samples of OFDM signal. Assuming average power of *x(t)* is unity, then z_n are the independent distributed Rayleigh random variables, having probability density function given by [5]:

$$f_{z_n}(z) = \frac{z}{\sigma^2}\exp\left(-\frac{z^2}{2\sigma^2}\right) = 2z.\exp(-z^2),\ n = 0,1........N-1 \tag{6}$$

Where $2\sigma^2 = 1$.

Let $Z_{\max} = crest\ factor = \sqrt{PAPR}$

However in CDF our main concern is minimum values, whereas in CCDF we emphasize on peak amplitude excursions.

A CCDF curve shows how much time the signal spends at or above a given power level. The power level is expressed in dB relative to the average power.

To find the probability that maximum value exceeds a given threshold we calculate CCDF. CCDF for an OFDM signal is given by

$$= P(Z_{\max} > z)$$
$$= 1 - P(Z_{\max} < z)$$
$$= 1 - \left(1 - \exp(-z^2)\right)^N$$

$$P(PAPR > PAPR_0) = 1 - \left(1 - \exp(-PAPR_0)\right)^N \tag{8}$$

Where $PAPR_0$ is certain clipping level or PAPR value.

For larger value of number of sub carriers the CCDF is higher as compared for lower number of carriers.

2.1 Partial Transmit Sequence (PTS)

Partial Transmit Sequence is one of the most sought technique for PAPR reduction in OFDM (Fig 2). Here the input frequency domain data block is first partitioned into disjoint sub-blocks. Then each of the sub-blocks are then padded with zeros appropriately and weighted by complex phase factors.

The data vector $X=[x_{0,}x_1,x_2,........x_{N-1}]^T$ is divided in V disjoint sets, { $X_v, v=1,2..V$ }, using same number of carrier for each group then V group sum:

$$X'=\sum_{v=1}^{V} X_v b_v \quad (9)$$

Where $b_v = e^{j\phi_v}$ are the phase factors. In time domain the x_v, IFFT of X_v is called Partial transmit sequence [20-24].

The phase factor is chosen such that PAPR of *x'* is minimum.

$$\left[\tilde{b}_1,..........\tilde{b}_V\right]=\underset{[b_1......b_V]}{\arg\min}\left(\max_{n=0,1....N-1}\left|\sum_{v=1}^{V} b_v x_v[n]\right|\right) \quad (10)$$

Corresponding time domain signal with lowest PAPR is:

$$x' = \sum_{v=1}^{V} \tilde{b}_v x_v \quad (11)$$

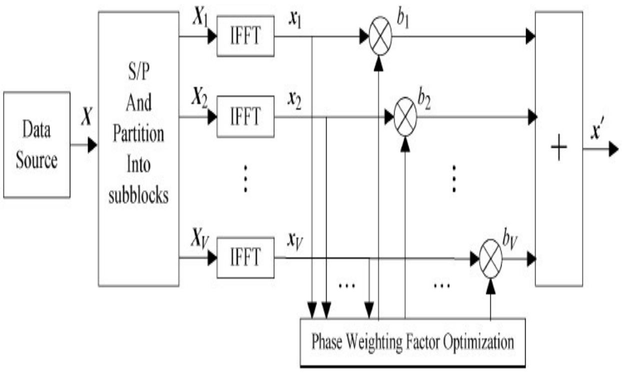

Fig 2. Block diagram of PTS technique

If there are *W* allowable phase weighting factors, *V* sub-blocks are used and we choose phase weighting factor for the first block b_1=1 to optimize rest of *V-1* sub-blocks for each input sequence, overall W^{V-1} combinations are to be analyzed to select candidate with minimum PAPR. This analysis requires number of complex multiplication and addition. Each candidate requires *(V-1)* complex addition and multiplication, so total number of complex multiplication and additions are $W^{V-1}\times(V-1)$ each contributing to computational complexity. At receiver to recover the signal, some side information about phase weighting sequences are required, this side information requires $\lfloor \log_2 W^V \rfloor$ bits to be transmitted separately.

3 Proposed Scheme for Computational Complexity Reduction in PTS and its analysis

To reduce the complexity we try to generate candidate signals from one another as a weighted sequence, by exploiting the correlation between the candidate signals.

If no of **sub block V=4** and no of phase weights *W*=2 i.e. 1 and -1. The candidate sequences are given by:

$$\mathrm{Y}_1 = X_1+X_2+X_3+X_4$$

$$\mathrm{Y}_2 = X_1+X_2+X_3-X_4$$

$$\mathrm{Y}_3 = X_1+X_2-X_3+X_4$$

$$\mathrm{Y}_4 = X_1+X_2-X_3-X_4$$

$$\mathrm{Y}_5 = X_1-X_2+X_3+X_4$$

$$\mathrm{Y}_6 = X_1-X_2+X_3-X_4$$

$$\mathrm{Y}_7 = X_1-X_2-X_3+X_4$$

$$\mathrm{Y}_8 = X_1-X_2-X_3-X_4$$

.

Therefore, each term in the candidate sequence denotes one complex multiplication each, except for the first term for which phase weight is always one.

Total complex Multiplication in conventional PTS (*V*=4) = $W^{(V-1)} * (V-1)$ =24

Similarly,

Total complex Additions in conventional PTS (*V*=4) = $W^{(V-1)} * (V-1)$ =24

In proposed scheme to reduce these complex number of additions and multiplication, we define following seeds or generator *G*:

$$G^1 = \begin{bmatrix} X_1 + X_2 \\ X_1 - X_2 \end{bmatrix}$$

Complex addtions =2; multiplications =2

$$G^2 = \begin{bmatrix} X_3 + X_4 \\ X_3 - X_4 \end{bmatrix}$$

Complex additions =2; multiplications =4

Where G_i^j is the i^{th} element of j^{th} seed matrix.

Now the same candidate sequences for PTS can be generated by grouping together above defined matrices as follows:

$Y_1 = G_1^1 + G_1^2$

Complex additions =1; multiplications =0

$Y_2 = G_1^1 + G_2^2$

Complex additions =1; multiplications =0

$Y_3 = G_1^1 - G_2^2$

Complex additions =1; multiplications =0

$Y_4 = G_1^1 - G_1^2$

Complex additions =1; multiplications =0

$Y_5 = G_2^1 + G_1^2$

Complex additions =1; multiplications =0

$Y_6 = G_2^1 + G_2^2$

Complex additions =1; multiplications =0

$Y_7 = G_2^1 - G_2^2$

Complex additions =1; multiplications =0

$Y_8 = G_2^1 - G_1^2$

Complex additions =1; multiplications =0

Now in the new scheme:
Total number of Complex addition =12
Total Number of Complex Multiplications = 6

This is much less then the 24 complex addition and multiplication in conventional PTS. To measure the performance of proposed scheme we calculate Computational Complexity Reduction Ratio (CCRR). This is given by the formula:

$$CCRR = \left(1 - \frac{Computations\ for\ new\ Scheme}{Computations\ for\ conventional\ PTS}\right) \times 100 \quad (12)$$

CCRR values for Complex addition and multiplication comes out in proposed scheme are $CCRR^+$ =50 and $CCRR^\times$=75

For no. of sub-blocks V=5

Candidate signals:

$$Y_1 = X_1 + X_2 + X_3 + X_4 + X_5$$

$$Y_2 = X_1 + X_2 + X_3 + X_4 - X_5$$

$$Y_3 = X_1 + X_2 + X_3 - X_4 + X_5$$

$$Y_4 = X_1 + X_2 - X_3 + X_4 + X_5$$

$$Y_5 = X_1 - X_2 + X_3 + X_4 + X_5$$

$$Y_6 = X_1 + X_2 + X_3 - X_4 - X_5$$

$$Y_7 = X_1 + X_2 - X_3 + X_4 - X_5$$

$$Y_8 = X_1 - X_2 + X_3 + X_4 - X_5$$

$$Y_9 = X_1 + X_2 - X_3 - X_4 + X_5$$

$$Y_{10} = X_1 - X_2 + X_3 - X_4 + X_5$$

$$Y_{11} = X_1 - X_2 - X_3 + X_4 + X_5$$

$$Y_{12} = X_1 + X_2 - X_3 - X_4 - X_5$$

$$Y_{13} = X_1 - X_2 + X_3 - X_4 - X_5$$

$$Y_{14} = X_1 - X_2 - X_3 - X_4 + X_5$$

$$Y_{15} = X_1 - X_2 - X_3 + X_4 - X_5$$

$$Y_{16} = X_1 - X_2 - X_3 - X_4 - X_5$$

$$G^1 = \begin{bmatrix} X_1 + X_2 \\ X_1 - X_2 \end{bmatrix}$$

Complex additions =2; multiplications =2

$$G^2 = \begin{bmatrix} X_3 + X_4 \\ X_3 - X_4 \end{bmatrix}$$

Complex additions =2; multiplications =4

$G^3 = [X_5]$

Complex additions =0; multiplications =0

With the help of above generators all the possible candidates can be derived as following

$Y_1 = G_1^1 + G_1^2 + G^3$

Complex additions =2; multiplications =0

$Y_2 = G_1^1 + G_1^2 - G^3$

Complex additions =2; multiplications =0

$Y_3 = G_1^1 + G_2^2 + G^3$

Complex additions =2; multiplications =0

$Y_4 = G_1^1 + G_2^2 - G^3$

Complex additions =2; multiplications =0

$Y_5 = G_2^1 - G_1^2 + G^3$

Complex additions =2; multiplications =0

$Y_6 = G_1^1 - G_2^2 - G^3$

Complex additions =2; multiplications =0

$Y_7 = G_1^1 - G_1^2 + G^3$

Complex additions =2; multiplications =0

$Y_8 = G_1^1 - G_1^2 - G^3$

Complex additions =2; multiplications =0

$Y_9 = G_2^1 + G_1^2 + G^3$

Complex additions =2; multiplications =0

$Y_{10} = G_2^1 + G_1^2 - G^3$

Complex additions =2; multiplications =0

$Y_{11} = G_2^1 + G_2^2 + G^3$

Complex additions =2; multiplications =0

$Y_{12} = G_2^1 + G_2^2 - G^3$

Complex additions =2; multiplications =0

$Y_{13} = G_2^1 - G_2^2 + G^3$

Complex additions =2; multiplications =0

$Y_{14} = G_2^1 - G_2^2 - G^3$

Complex additions =2; multiplications =0

$Y_{15} = G_2^1 - G_1^2 + G^3$

Complex additions =2 and multiplications =0

$Y_{16} = G_2^1 - G_1^2 - G^3$

Complex additions =2; multiplications =0

Total complex additions in conventional PTS (V=5) $= W^{(V-1)} * (V-1) = 64$

Total complex multiplications in conventional PTS (V=5) = $W^{(V-1)} * (V-1)$ = 64

Total complex additions in proposed scheme=36

Total complex multiplications in proposed scheme =6

Therefore in proposed scheme CCRR$^+$ =43.75 and CCRR$^\times$=90.625

Similarly, for no. of sub-blocks V=6

$$G^1 = \begin{bmatrix} X_1 + X_2 \\ X_1 - X_2 \end{bmatrix}$$

Complex additions =2; multiplications =2

$$G^2 = \begin{bmatrix} X_3 + X_4 \\ X_3 - X_4 \end{bmatrix}$$

Complex additions =2; multiplications =4

$$G^3 = \begin{bmatrix} X_5 + X_6 \\ X_5 - X_6 \end{bmatrix}$$

Complex additions =2; multiplications =4

The possible candidate signals can be derived as following:

$Y_1 = G_1^1 + G_1^2 + G_1^3$

Complex additions =2; multiplications =0

$Y_2 = G_1^1 + G_1^2 + G_2^3$

Complex additions =2; multiplications =0

. .

. .

$Y_{31} = G_2^1 - G_1^2 + G_2^3$

Complex additions =2; multiplications =0

$Y_{32} = G_2^1 - G_1^2 - G_1^3$

Complex additions =2; multiplications =0

Total complex additions in conventional PTS (V=6) $= W^{(V-1)} * (V-1) = 160$

Total complex multiplications in conventional PTS (V=6) = $W^{(V-1)} * (V-1)$ = 160

Total complex additions in proposed scheme = 70

Total complex multiplications in proposed scheme =10

Therefore in proposed scheme CCRR$^+$ = 56.25 and CCRR$^\times$=93.75

For number of sub-blocks V=7

$$G^1 = \begin{bmatrix} X_1 + X_2 \\ X_1 - X_2 \end{bmatrix}$$

Complex additions =2; multiplications =2

$$G^2 = \begin{bmatrix} X_3 + X_4 \\ X_3 - X_4 \end{bmatrix}$$

Complex additions =2; multiplications =4

$$G^3 = \begin{bmatrix} X_5 + X_6 \\ X_5 - X_6 \end{bmatrix}$$

Complex additions =2; multiplications =4

$G^4 = [X_7]$

Complex additions =0; multiplications =0

Corresponding candidate signals are:

$Y_1 = G_1^1 + G_1^2 + G_1^3 + G^4$

Complex additions =3; multiplications =0

$Y_2 = G_1^1 + G_1^2 + G_1^3 - G^4$

Complex additions =3; multiplications =0

. .

. .

. .

$Y_{63} = G_2^1 - G_1^2 - G_1^3 + G^4$

Complex additions =3; multiplications =0

$Y_{64} = G_2^1 - G_1^2 + G_1^3 - G^4$

Complex additions =3; multiplications =0

Total complex additions in conventional PTS (V=7) $= W^{(V-1)} * (V-1) = 384$

Total complex multiplications in conventional PTS (V=7) = $W^{(V-1)} * (V-1)$ = 384
Total complex additions in proposed scheme=198
Total complex multiplications in proposed scheme = 10
Therefore in proposed scheme CCRR^{+} =48.4 and CCRR$^{\times}$=97.39

For number of sub-blocks V=8

$$G^1 = \begin{bmatrix} X_1 + X_2 \\ X_1 - X_2 \end{bmatrix}$$

Complex additions =2; multiplications =2

$$G^2 = \begin{bmatrix} X_3 + X_4 \\ X_3 - X_4 \end{bmatrix}$$

Complex additions =2; multiplications =4

$$G^3 = \begin{bmatrix} X_5 + X_6 \\ X_5 - X_6 \end{bmatrix}$$

Complex additions =2; multiplications =4

$$G^4 = \begin{bmatrix} X_7 + X_8 \\ X_7 - X_8 \end{bmatrix}$$

Complex additions =2; multiplications =4
Corresponding candidate signals are:

$$Y_1 = G_1^1 + G_1^2 + G_1^3 + G^4$$

Complex additions =3; multiplications =0

$$Y_2 = G_1^1 + G_1^2 + G_1^3 - G^4$$

Complex additions =3; multiplications =0

.
. .
……

$$Y_{127} = G_2^1 - G_1^2 - G_1^3 + G^4$$

Complex additions =3; multiplications =0

$$Y_{128} = G_2^1 - G_1^2 + G_1^3 - G^4$$

Complex additions =3; multiplications =0

Total complex additions in conventional PTS (V=8) $= W^{(V-1)} * (V-1) = 896$
Total complex multiplications in conventional PTS (V=8) = $W^{(V-1)} * (V-1) = 896$
Total complex additions in proposed scheme=392
Total complex multiplications in proposed scheme =14
Therefore in proposed scheme CCRR^{+} = 56.25 and CCRR$^{\times}$=98.4

4 Analysis and Simulation Results

All the simulations are done in MATLAB 7.0 and simulation parameter are as per IEEE802.11a standard, given in Table 1 [29], [30], [31].

IEEE 802.11 is a set of standards carrying out wireless local area network (WLAN) computer communication in the 2.4, 3.6 and 5 GHz frequency bands. This standard specifies an OFDM physical (PHY) layer that splits an information signal across 52 separate sub-carriers.

Table 1. OFDM Time Base Parameters in IEEE802.11a

Parameter	**Value**
FFT size (*nFFT*)	64
Number of subcarriers (*nDSC*)	52
FFT sampling frequency	20 *MHz*
Subcarrier spacing	312.5 *KHz*
Subcarrier index	{-26 to -1, +1 to +26}
Data symbol duration, T_d	3.2 μs
Cyclic prefix duration, T_{cp}	0.8 μs
Total symbol duration, T_s	4 μs
Modulation schemes	BPSK,QPSK,16 & 64-QAM

Four of the sub carriers are pilot subcarriers that the system uses as a reference to disregard frequency or phase shifts of the signal during transmission. A pseudo binary sequence is sent through the pilot subchannels to prevent the generation of spectral lines. The remaining 48 subcarriers provide separate wireless pathways for sending the information in a parallel fashion. The resulting subcarrier frequency spacing is 0.3125 MHz (for a 20 MHz with 64 possible subcarrier frequency slots).

For simulation purpose mapping scheme used is 64-QAM, number of symbols used for simulation are 10^6 for more accurate results. .

The computational complexity reduction in new scheme in terms of CCRR is given below in Table 2. The results suggest that there is significant reduction in computational complexity in terms of high value of CCRR as compared to conventional OFDM system (CCRR=0).

CCRR values especially for multiplications are reducing as number of sub-blocks are increasing, for *V=8* it is 98.4 %, whereas for *V=4* it is just 75% reduction in computational complexity. However

CCRR for addition is almost at 50% for all the values.

Table 2: CCRR Comparison of Proposed Scheme

No. of Sub-blocks (*V*) for *W=2*	**$CCRR^{\times}$**	**$CCRR^{+}$**
4	75	50
5	90.625	43.75
6	93.75	56.25
7	97.39	48.4
8	98.4	56.25

Reducing the number of candidate signal is a general approach to reduce the computational complexity in PTS-based OFDM system; however this results in performance degradation in terms of PAPR reduction.

The approach proposed here exploits the correlation among the candidate PTS signals in a way that all the candidate signals can be generated with same set of generators leading to reduction of computational complexity, so with same number of candidate signal this approach achieves same PAPR reduction as achieved with convention PTS scheme at much lower computations. The computational complexity decreases more when we increase number of sub-blocks used.

As shown in Fig 3, the PAPR performance of the conventional OFDM is significantly improved in OFDM with PTS scheme. The PAPR performance of proposed PTS and conventional PTS is same in terms of CCDF (complementary cumulative density function). Further increasing the number of sub-blocks for partitioning, leads to better PAPR performance.

As far as spectrum of OFDM signal is concerned, there is no distortion caused by using PTS scheme as in PTS scheme we change only phase of each subcarrier in frequency domain, which do not induce any kind of distortion and spectrum remains unchanged and intact.

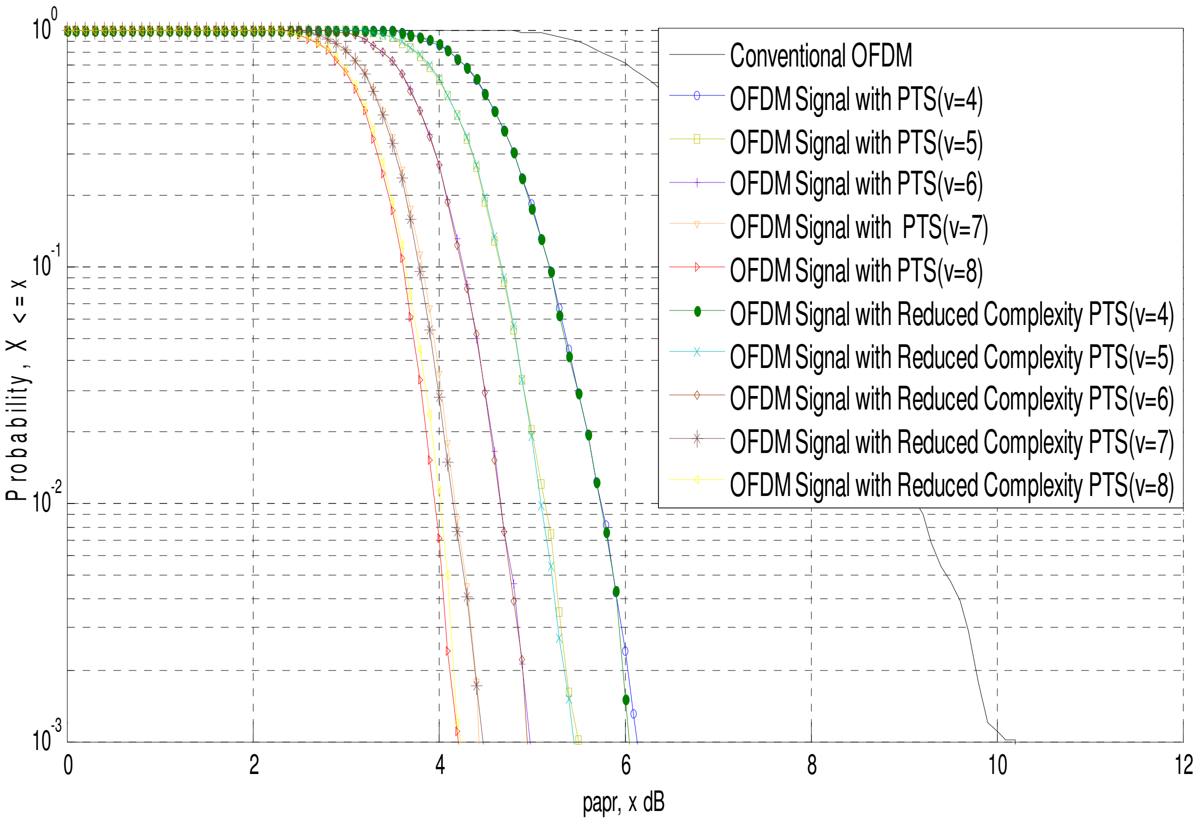

Fig .3: CCDF comparison of conventional OFDM, OFDM with PTS and OFDM- with proposed PTS scheme for *V*= 4, 5, 6, 7, 8

At the same time in our scheme of low complexity PTS, as we have not changed the number of candidate signal, they are same as conventional PTS, which again implies that new PTS scheme with low complexity will not incur any change in power spectrum of OFDM signal.

Fig. 4 shows that the power spectral density curve for conventional OFDM and OFDM with PTS are completely overlapping, suggesting that PTS do not change or distort the power spectrum of OFDM.

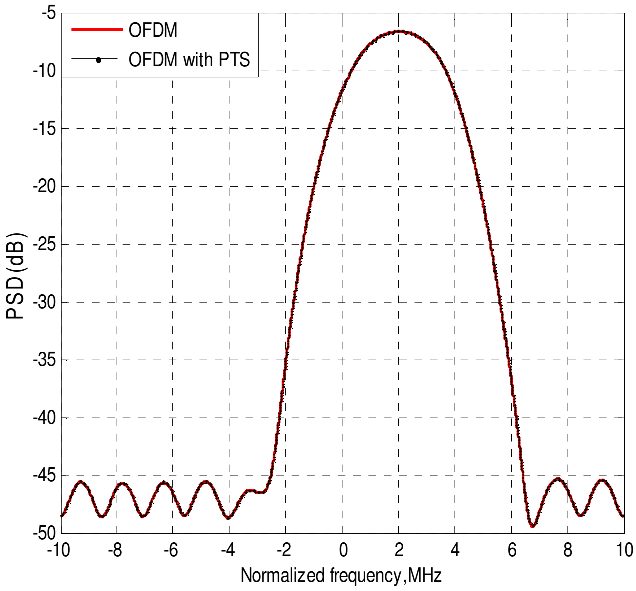

Fig.4 PSD curves for OFDM and OFDM with PTS

5. Conclusion

High Value of PAPR is one of the biggest drawbacks which hamper the performance of OFDM system. In Convention OFDM system PTS technique is one of the most sought choices for PAPR reduction, but in PTS computational complexity increases significantly as number of sub-blocks are increased.

In this paper a novel scheme for reduction of computational complexity in PTS is suggested without decreasing the number of candidate signals. In the result section it is shown that the computational complexity is reduced significantly and at the same time PAPR reduction is same as convention PTS technique in terms of CCDF. Apart from this there is no change in spectrum of the original OFDM signal.

References

[1] Y.Wu, W.Y. Zou, “Orthogonal frequency division multiplexing: A multi-carrier modulation scheme”, *IEEE Transaction on Consumer Electronics*. Vol. 41, Issue 3,1995, pp. 392–399.

[2] Haitham J.Taha, M.F.M.Salleh, “Multi-carrier Transmission Techniques for Wireless Communication Systems: A Survey”, *WSEAS Trans. on Communication*. Vol. 8, issue 5, 2009, pp.457-472,

[3] Richard Van Nee, Ramjee Prasad, “ OFDM for Wireless Communications”, Boston: Artech House, 2000

[4] S. H.Han, J. H. Lee, “An overview of peak-to-average power ratio reduction techniques for multicarrier transmission”, *IEEE Trans. on Wireless Communications*, Vol. 12.Issue 2, 2005, pp. 56–65.

[5] C.Y.Soo, J.Kim, W. Y.Yang, C. G. Kang, “MIMO OFDM Wireless communication with MATLAB”, *IEEE Press*., 2010, pp.209-241.

[6] J.Armstrong,“Peak-to-average power reduction for OFDM by repeated clipping and frequency domain filtering”, Electronics Letters, 28TH February 2002, Vol.38, Issue 5, pp-246-247.

[7] L. Wang, Ch. Tellambura, “A Simplified Clipping and Filtering Technique for PAPR Reduction in OFDM Systems”, *IEEE Signal Processing Letters*, Vol.12, Issue 5, 2005,pp. 453-456

[8] J.T.Zhu, G. Z.Jianbin, “Block Coding Scheme for Reducing PAPR in OFDM Systems with Large Number of Subcarriers”, *Journal of Electronics (China)*. Vol. 21, 2004, pp. 482-489

[9] W.Zhong-peng, X.Jiang-nan, L.Fan, C. Lin, “Hadamard precoding for PAPR reduction in optical direct detection OFDM systems”, *Optoelectronic Letters*. Vol. 7,Issue 5.2011,DOI: 10.1007/s11801-011-1044-5

[10] B. S. Krongold, D. L. Jones, “PAPR reduction in OFDM via active constellation extension, *IEEE Trans. on Broadcasting,* Vol. 49, Issue. 3, 2003, pp. 258–268

[11] Chin-Liang Wang, Ching-Hsien Chang, J.L Fan, J.M. Cioffi, “Discrete Hartley Transform Based Multicarrier Modulation”, *in proceedings of IEEE International Conference on Acoustics, Speech, and Signal Processing*, , Vol.5, 2000. pp. 2513-2516.

[12] Z.Sembiring, M.F.A Malek, H. Rahim, "Low Complexity OFDM Modulator and Demodulator Based on Discrete Hartley Transform", in Proceedings of Fifth Asia International Conference Modelling Symposium (AMS), 2011, pp.252-256.

[13] Chhavi Sharma, Shiv K. Tomar, A.K.Gupta, "PAPR Reduction in OFDM System using Adapting Coding Technique with Pre distortion Method", *WSEAS Trans. On Communication*, Vol. 10,Issue 9, 2011, pp.255-262.

[14] I.Baig, V.Jeoti, "A ZCMT Precoding Based Multicarrier OFDM System to Minimize the High PAPR", *Wireless Personal Comm.,* 2012,DOI: 10.1007/s11277-012-0501-1

[15] P.Varahram, B. M. Ali, "Low Complexity Partial Transmit Sequence with Complex Gain Memory Predistortion in OFDM Systems",*Wireless Personal Comm.,* DOI 10.1007/s11277-012-0532-7

[16] A. Joshi, Davinder S. Saini, "PAPR Analysis of Coded- OFDM System and Mitigating its Effect with Clipping, SLM and PTS" , *in proceedings of IEEE International Conference (ICIMU-2011),* 2011,pp. 1-5.

[17] L.Wang, J. Liu, "Cooperative PTS for PAPR reduction in MIMO-OFDM", *Electronics Letters* , Vol.47, Issue 5, 2011, pp.351 -352.

[18] D.W.Lim, H.S. Noh, H.B Jeon, J.S.No, D.J. Shin, "Multistage TR scheme for PAPR reduction in OFDM signals", *IEEE Trans. on Broadcasting*. Vol. 55, Issue 2, 2009, pp. 300–304.

[19] R.J.Baxley, G.T. Zhou, "Comparing Selected Mapping and Partial Transmit Sequence for PAR Reduction," *IEEE Transactions on Broadcasting,* , Vol.53, Issue 4, 2007,pp.797-803.

[20] Hsinying Liang, Zhe Lin, Houshou Chen, Cheng-Ying Yang, "A modified genetic algorithm PTS technique with error correction for PAPR reduction in OFDM systems", *in proceedings of International Symposium on Information Theory and its Applications (ISITA),* 2010, pp.1050-1053

[21] L.J Cimini, N.R.Sollenberger, Peak-to-average power ratio reduction of an OFDM signal using partial transmit sequences", *IEEE Communication Letters*, Vol. 4, Issue. 3, 2000, pp. 86–88,.

[22] B.M.Lee, J.P.Rui, K. Youngok, "A computationally efficient tree-PTS technique for PAPR reduction of OFDM signal". *Wireless Personal Communication,* 2010, doi:10.1007/s11277-010-0062-0.

[23] A.D.S. Jayalath, C. Tellambura, "Adaptive pts approach for reduce of peak-to-average power ratio of OFDM signal," *Electronics Letters*. Vol. 36, Issue 14, 2000, pp. 1226–1228.

[24] W.S Ho, A.S Madhukumar, F. Chin, "Peak-to-average power reduction using partial transmit sequences: A suboptimal approach based on dual layered phase sequencing", *IEEE Trans. on Broadcasting*. Vol. 49, Issue 2, 2003, pp. 225–231.

[25] L.Yang, R.S. Chen, Y.M. Siu, K.K. Soo, "PAPR reduction of an OFDM signal by use of PTS with low computational complexity. *IEEE Transactions on Broadcasting*. Vol.52, no.1, 2006, pp. 83- 86.

[26] T. Jiang, W.D. Xiang, P.C Richardson,, "PAPR reductions of OFDM signals using partial transmit sequences with low computational complexity", *IEEE Transaction on Broadcasting*. Vol. 53, Issue. 3, 2007, pp. 719–724.

[27] S.J.Ku, C.L Wang, C.H.Chen, "A reduced-complexity PTS based PAPR reduction scheme for OFDM systems", *IEEE Transaction on Wireless Communication*. Vol. 9, Issue. 8, 2010,pp. 2455–2460.

[28] A.Ghassemi, T.A.Gulliver, "A Low-Complexity PTS-Based Radix FFT Method for PAPR Reduction in OFDM Systems", *IEEE Transactions on Signal Processing*, Vol.56, Issue.3,2008, pp.1161-1166.

[29] IEEE 802.11 detailed documentation [Online]. Available: http://standards.ieee.org/getieee802 , Last accesed on 15/12/2012

[30] A. Joshi, Davinder S. Saini, "Performance Analysis of Coded OFDM for Various Modulation Schemes in 802.11a Based Digital Broadcast Applications", *in Proceedings of International Conference (BAIP 2010), Springer,* LNCS-CCIS, 2010, pp. 60-64.

[31] A. Joshi, Davinder S. Saini, " Performance Analysis and PAPR Reduction of Coded OFDM (with RS-CC and Turbo coding) System using Modified SLM, PTS and DHT Precoding in Fading Environments", in

WSEAS Trans. on Communication. Vol. 12, Issue 1, 2013, pp.14-28.

Alok Joshi received B.E degree in Electronics & Communication Engg. in 2001 from G.B. Pant Engg. College (H.N.B, Garhwal University) Uttarkhand, India and M.Tech in Digital Communication in 2006 from U.P.T.U Lucknow, India. He has total teaching experience of 10 years in various technical universities in India. Currently working with Jaypee Institute of Information Technology, Noida, India. His research interests are coded OFDM systems and pursuing PhD in same domain

Davinder S Saini was born in Nalagarh, India in January 1976. He received B.E degree in electronics & telecommunication engineering from College of Engineering Osmanabad, India in 1998. He received M.Tech degree in communication systems from Indian Institute of Technology (IIT) Roorkee, India in 2001. He received PhD degree in electronics and communication from Jaypee University of Information Technology Waknaghat, India in 2008. He is with Jaypee University of Information Technology Waknaghat since june 2002. Currently he is Associate Professor in electronics and communication department. His research areas include Channelization (OVSF) codes and optimization in WCDMA, routing algorithms and security issues in MANETs