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Abstract: Orthogonal Frequency Division Multiplexing (OFDM), widely used in digital wireless communication, has a major drawback of high Peak to Average Power Ratio (PAPR). A reduced complexity partial transmit sequence (PTS) scheme has been proposed to solve high peak to average power ratio (PAPR) of orthogonal frequency division multiplexing (OFDM) system.

In the proposed PTS scheme, a function is generated by summing the power of time domain samples at time 'n' in each sub blocks, known as "H_n". Only those samples, having H_n greater than or equal to a preset threshold value (α_T) are used for peak power calculation during the process of selecting a candidate signal with the lowest PAPR for transmission. As compared to conventional PTS scheme, the proposed scheme achieves almost the same PAPR reduction performance with much lower computational complexity.

Keyword:

1. INTRODUCTION

With the rapid growth in digital wireless communication in recent years, need for high speed mobile data transmission has increased. Many wireless communi-cation system being developed, use OFDM to achieve high data rate.

Using OFDM has so many advantages, such as, high spectral efficiency, less Inter Symbol Interference, use of very small guard band and robustness to channel fading. But the main drawback of OFDM is high peak to average power ratio (PAPR). PAPR reductionof OFDM system can be achieved by modifying OFDM signal characteristics in time and frequency domain at the transmitter.

In PTS scheme each point data block is partitioned into a number of disjoint sub blocks and then the IFFT of all sub blocks are optimally combined to form a low PAPR OFDM signal for transmission. The PTS scheme has good PAPR reduction performance, but it requires a bank of IFFT blocks and system perform an exhaustive search for the optimal candidate signal.

A new PTS scheme for PAPR reduction of OFDM signal is being proposed. The proposed method will generate a function H_n by summing the power of the time domain samples at time 'n' in each sub blocks. Only the samples with H_n greater than or equal to a preset threshold value are used for peak power calculation during the optimization process.

In recent years several researchers have proposed different scheme for reducing high PAPR of OFDM signal. In year 2002, some researchers of "Asian Institute of technology" proposed two algorithm to reduce PAPR [1]. The first algorithm is carried out by selecting the input sequence properly using a look up table and the second by scaling the input envelop for subcarriers before they are transformed to the time domain by Inverse Fast Fourier Transform (IFFT). After that ,in 2007 , researcher of "Osaka university" proposed another method of PAPR reduction, using "Neural Network (NN) with tone injection scheme [2], in which *Hopefield* type neural network is applied to an optimum tone selection in tone injection (TI) method, because NN is suitable for global search. In tone Injection method, peak of the signal is reduced by injecting some tones that are removable without the side information in the receiver. Since TI method selects injected tone by a greedy algorithm, which is easily trapped into local minimum points, and PAPR is not reduced sufficiently.

Latter some researchers proposed a new scheme known as "Partial Transmit Sequence (PTS)" to reduce the PAPR of OFDM system sufficiently. In 2009 "PTS-APPR" method by Genetic Algorithm (GA) had been proposed [3]. In this method reduction of PAPR is done by using the hybrid of a Partial Transmit Sequence (PTS) and an Adaptive Peak Power Reduction (APPR) method with "genetic algorithm". In order to reduce PAPR, the sequence of input data is rearranged by PTS. The APPR method is used to control the peak level of modulation signals by an adaptive algorithm.

2. OFDM SYSTEM

Orthogonal Frequency Division Multiplexing (OFDM), special case of which are known as Multicarrier Multi-plexing (MCM), is a bandwidth efficient modulation technique that is tolerant to channel disturbances such as delay spread multipath and impulse noise. OFDM is implemented by serial to parallel converting the input bit stream and using one or more bits to modulate each sub carriers spaced by the inverse of the symbol period. As shown in fig. (1), OFDM utilizes parsing of the input data bit stream into N symbol streams, each with

symbol duration t_s and each of which in turn used to modulate parallel synchronous sub carriers. If the modulation scheme used on the sub carrier can accommodate D bits per symbol and the subcarriers are spaced by $1/t_s$ hertz, which means they are orthogonal over the interval $(0,t_s)$, then the single user bandwidth efficiency of the OFDM scheme is D bps/Hz and symbol duration is $t_s = DNt_b$ seconds, where t_b is bit duration.
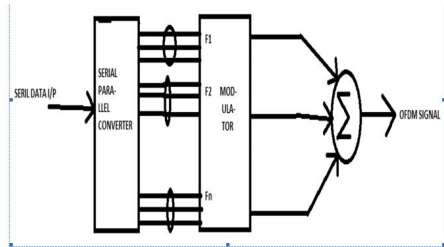

Figure1: OFDM System

If a symbol sequence $\{x_n\} = \{x_0, x_1, x_2,\ldots\ldots\ldots x_{N-1}\}$ is used to modulate N simultaneously transmitted subcarriers. Then In the mth signalling interval, the real transmitted signal is

$$X_m(t) = Re[\qquad\qquad\qquad\qquad],$$

For for $(m-1) T_s \leq t < mT_s$

$= 0;$ otherwise.

Where, T_u=duration occupied by data transmission

$1/T_u$ = subcarrier spacing

Δ = guard interval

N= no. of orthogonal subcarrier

$f_n = n/T_u$, = frequency in Hz of nth subcarrier

$T_s = T_u + \Delta$ = symbol duration

It is customary to drop the real part and carrier exponential. Thus doubly infinite duration signal can be written in complex form as

$$Y(t) = \qquad\qquad\qquad\qquad (2).$$

Where   m = index of time interval

Generally we simply consider the complex baseband signal in the m=1 interval, given by

$$x(t) = \overline{\qquad}, \text{ for } 0 \leq t < Tu + \Delta = T_s \ldots\ldots(3)$$

3. PEAK TO AVERAGE POWER RATIO

In an OFDM system, a block of N input symbols, $X = [X_0, X_1, X_2, X_3, X_4, \ldots X_{N-2}, X_{N-1}]^T$ where $[\;]^T$ denotes transpose operation, is formed with each symbol modulating the corresponding subcarrier from a set of N orthogonal frequencies. The resulting complex continuous-time based OFDM signal $x(t)/T$ of a block can be expressed as

$$\overline{\qquad} \ldots\ldots\ldots\ldots (4)$$

Where X_k is the complex modulated symbol on the n-th subcarrier, T is the time duration of an OFDM symbol, and $\Delta f = 1/T$ is the subcarrier spacing.

The PAPR of the transmitted signal $x(t)$ can be defined as

$$PAPR \{x(t)\} = \frac{\qquad}{\qquad} \ldots\ldots\ldots\ldots (5)$$

Since most present systems process discrete-time signals, the corresponding discrete-time OFDM signal $\mathbf{x} = [x_0, x_1, x_2, x_3, \ldots\ldots\ldots x_{N-1}]^T$ can be attained by sampling $x(t)$ with the rate N/T and realized by using IFFT. Therefore, in the discrete-time case, the OFDM signal can be written as

$$x_n = \qquad\qquad\qquad\qquad \ldots\ldots\ldots\ldots (6)$$

However, the sampling rate N/T may not be enough to capture the peak information of the continuous-time signal $x(t)$. In order to approach the PAPR of equation (2) in the discrete-time instance, $x(t)$ is usually oversampled by a factor of L, i.e. with the sampling rate LN/T. It must also be noted that L = 4 is enough to capture the peak information of the continuous-time signal $x(t)$ [4].

It was shown in paper [8] that the power of discrete time OFDM signal x_n has a chai-square distribution with the following complementary cumulative distribution function (CCDF):

$$F(z) = pr\{|x_n|^2 > z\} = e^{-z} \ldots\ldots\ldots\ldots(7)$$

In [7] authors derived an approximation of the CCDF of peak value of OFDM system as: $pr\{\max|x_n|^2 > z\} = 1 - \exp(-Ne^{-z}\sqrt{(\pi/3*\ln N)}\ldots\ldots(8)$

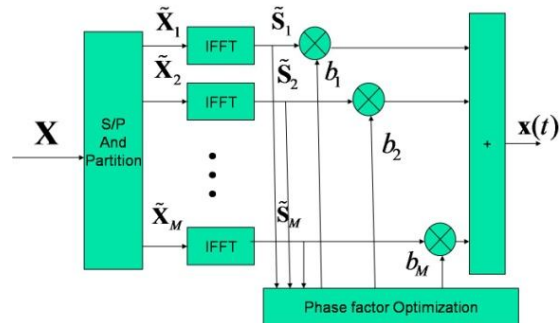## 4. CONVENTIONAL PTS SCHEME

Figure2: PTS System

In the conventional PTS scheme, the N- point input data block $X = [X_0, X_1, X_1, X_2, \ldots\ldots\ldots X_n]$ is evenly divided into M disjoint sub blocks. The IFFT output of each sub block (i.e. $x_m = [x_{m,0}, x_{m,1}, x_{m,2}, \ldots\ldots, x_{m,N-1}]^T$, m = 1, 2, ...,M) is multiplied by a rotation factor (b_m^c) selected from the W- element set $\{\Theta = e^{j\theta i}, = 0, 1, \ldots, W-1\}$, and then summed together to form a candidate signal x_c as follows.

$$^c = \qquad\qquad = [x^c_0, x^c_1, x^c_2 \ldots x^c_{N-1}]^T,$$
$$c = 1, 2, 3, \ldots, C \ (9)$$

Where C is the number of candidate signals and

$$x^c_n = \qquad\qquad ; n = 0,1,2,\ldots\ldots N-1$$

is sample of the th candidate signal. The optimal candidate signal with the lowest PAPR is selected as

= arg ⎯⎯⎯⎯⎯⎯⎯ (10)

Where c_{opt} is the side information used to indicate the optimal vector of the rotation factor

= [,.................]^T.

Finally, as well as c_{opt} are transmitted to the receiver. In general, b_1^c is fixed without any performance loss, and the number of candidate signals is = W^{-1}. Since the values of x_m with $1 \le m \le M$ are unchanged for a given X during the generation of candidate signals, we consider only the computational complexity of the optimization process for the purpose of comparison with proposed PTS methods. For the conventional PTS scheme, this includes CNM complex multiplications and (M−1) complex additions in equation (9); N complex multiplications and

(N-1), comparisons as given in equation (10).

5. PROPOSED PTS SCHEME

New PTS scheme has been implemented as shown in Fig. 1, where the operations have been summarized as follows:

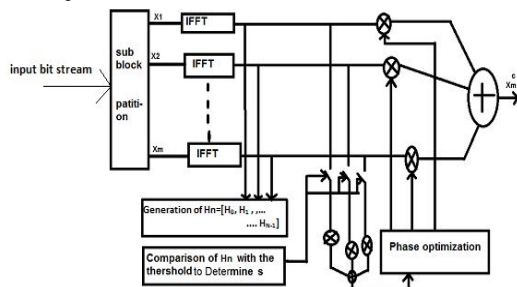1. Evenly partition the input data block X into ' 'disjoint sub blocks X_m, 1<m<M

Figure3: Proposed PTS System

2. Find x_m= IFFT{X_m} = [$x_{m,0}$, $x_{m,1}$, ..., $x_{m,N-1}$]^T, 1<m<M
3. Compute H_n = [H_0,H_1,H_2.............H_{N-1}]^T, Where H_n= , $0 \le n \ge$ N-1
4. Record the time indexes n with $H_n >= \alpha_T$, $0 \le n \le$ (N-1), as a set S,
5. For the candidate signal X^c, 1≤c≤C, only the samples with n ∈ {S} are computed and are used To compute the PAPR of X^c
6. Select the optimal vector b^{copt} , which give the signal with minimum PAPR value.
7. Use b^{copt} to generate all samples of optimal candidate signal having minimum PAPR (X^{copt}) for transmission using equation (9) and (10).

Here, in the proposed scheme only those samples, which have cost function H_n greater than preset threshold value, are only considered for the peak power calculation during optimisation process. Hence it involves less number of multiplication and addition and thus it reduces the computational complexity.

6. SIMULATION & RESULT ANALYSIS

In this section the performance results of PAPR are presented. The CCDF (CCDF= pr(PAPR>PAPR0)) for the OFDM signal is calculated by using MATLAB and adopted to evaluate the PAPR performance. In simulation 3 sets of 500 independent OFDM symbols, with 3 different sets of sub careers i.e.

N=64, N=128 & N=256 were randomly generated. The applied signal modulation is quadrature amplitude modulation (QAM). Oversampling factor taken is L=4. Input data are partitioned into M= 4 disjoint sub blocks with rotation factor set {1 -1 j -j} (W=4). So number of candidate signals generated is 4^3= 64. Results of this simulation has been shown in figure(4) – figure(8).

Figure (4) shows, one symbol period of QAM modulated input signal. It has 64 samples in one symbol, and symbol period is taken 1 ms. This signal is partitioned into 4 disjoint sub blocks as shown in fig.(5).
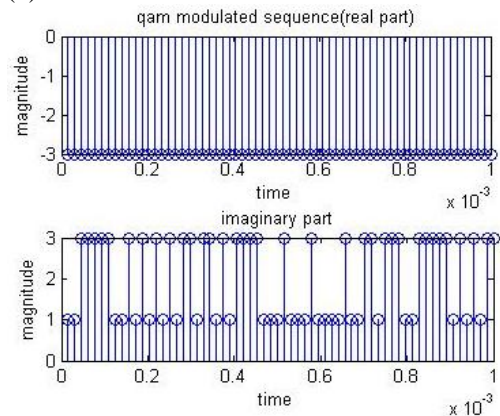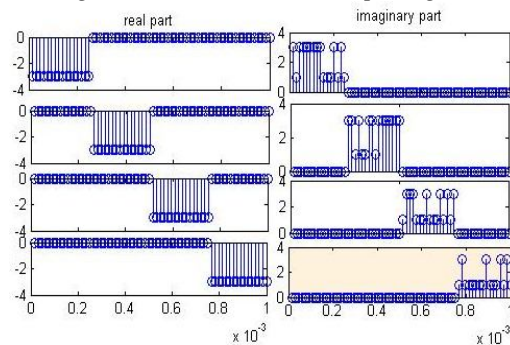

Figure 4: QAM modulated input signal

Figure 5:Partitioned qam modulated signal in 4 sub blocks

Above figure shows the QAM modulated signal partitioned into 4 disjoint sub-blocks.

After partitioning, optimisation has been done and optimal signal has been obtained for different values of preset threshold. These preset threshold are determined by a parameter which is the lower bound of the probability to find the peak correctly (ϒ). I.e. pr{max|x_n|^2>z} = ϒ. Where z is the threshold power (z=Φ_N). With the help of equation (8), threshold value for given ϒ can be given as

$$\alpha T = \Phi_N/M \ldots\ldots\ldots\ldots(11)$$

Where, $\Phi_N = -\ln[\ln(1-\Upsilon)/-N(\pi/3*\ln(N))^{(0.5)}]\ldots\ldots(12)$

Here $(1-\Upsilon)$ is the probability of missing the peak. PAPR performance for different values of Υ & N has been compared by CCDF curve of PAPR.
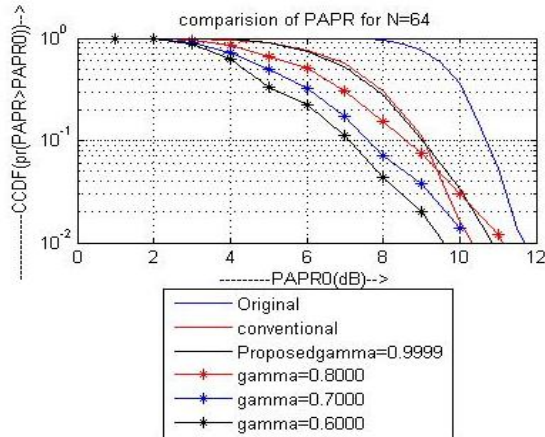
Figure (6): CCDF curves of PAPR of original signal, conventional PTS scheme and proposed scheme with different values of Υ, and N=64.

Figure (6) shows CCDF curves for N=64. Here PAPR performance of proposed scheme for 4 different values of Υ has been compared. Here it is observed that for Υ= 0.9999 and 0.8000, proposed scheme has more PAPR than conventional PTS scheme. But as the value of Υ decreases, PAPR performance of proposed scheme improves.
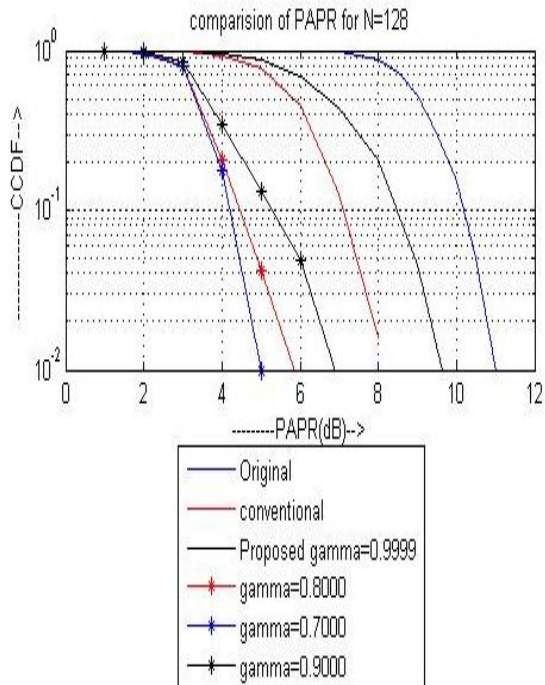
Figure (7): PAPR performance comparision for N=128.

Figure (7) shows PAPR performance comparison of proposed method & conventional PTS method for N=128. For this value of N, PAPR for different values of Υ also has been listed in table (1). This table

shows that PAPR of original signal is 11dB, that is for conventional PTS is 8 dB and for proposed PTS with Υ =0.9999 is 9.6 dB. But as the value of Υ decreases PAPR performance of proposed scheme improves and gives better performance than conventional PTS scheme.

Values of N	PAPR value of original OFDM signal (dB)	PAPR value For PTS scheme (dB)	PAPR Of Proposed PTS scheme with Υ=0.9999 (dB)
64	11.75	10.3	10.8
128	11.00	8.00	9.60
256	9.3	6	5.25

Table1:-.PAPR performance comparison for different values of N

Figure (8) shows the CCDF curves for N=256, for different methods. We observe that as the value of N increases PAPR decreases for all the signals.

And PAPR performance also improves with decreasing value of Υ. CCDF curve for Υ = 0.8000 and 0.7000 coincides on each other. Table (2) lists PAPR for original signal, conventional PTS and proposed PTS scheme for different values of N.. From this table it is clear that as the value of N increases, PAPR of OFDM signal improves.
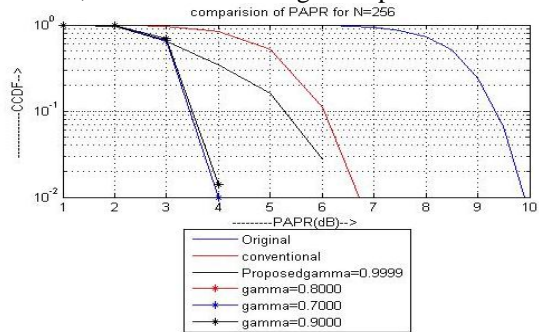
Figure (8): CCDF Curves for PAPR Of OFDM signal with N=256 for original, conventional and proposed PTS scheme.

7. CONCLUSION

In this paper, a new PTS scheme with reduced complexity has been proposed, in which a new criterion for selecting samples for peak power calculation during optimisation process has been developed.

Table 2: PAPR performance of proposed schemeFor for N=128 & different values of Υ

Values of Υ	PAPR of original signal (dB)	PAPR of conventional PTS scheme (dB)	PAPR of proposed PTS scheme (dB)
0.9999	11	8	9.6
0.9000	11	8	6.9
0.8000	11	8	5.85
0.7000	11	8	5

By observing simulation results, it has been concluded that for ϒ = 0.9999 it has slightly poor performance than conventional PTS scheme. But as the value of ϒ decreases PAPR performance of proposed scheme improves, but probability of missing the peak (1-ϒ) increases. For N=256 and ϒ=0.8000, lt reduces the PAPR to approximately 4 dB, but in this case 40% ((1-0.800)*100%) peaks are missing in the candidate signals. So finelyit can be concluded that the proposed scheme gives better performance than conventional PTS, with reduced complexity, for appropriate value of preset threshold chosen, on the cost of missing peak.

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