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Optimized PAPR Reduction Approach by Partial Approximate Gradient Constellation Algorithm for Better Efficiency

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Abstract

In the OFDM communication system, the main disadvantage factor is Peak Average to Power Ratio (PAPR) which limits the performance of the overall system. To limit this factor in the OFDM system there are so many techniques that depends on the nature of the system like clipping, Partial transmission, Selective mapping, Companding transform etc, In this paper, a combinational approach is proposed for peak-to-average power ratio reduction in orthogonal frequency division multiplexing . The key idea of the proposed scheme is to apply partial transmit sequence and approximate gradient project schemes .These two schemes are applied in parallel on two equal halves of subcarrier in an OFDM standard. On one half, partial transmit sequence minimizes the PAPR of OFDM symbols through disjoint sub blocks and optimized phase factor. Approximate gradient project extends the outer constellation points of OFDM symbols dynamically within margin-preserving constraints to reduce the peak magnitude of symbols model ,on the other half. The simulation results show that a reduced PAPR and optimal BER rate of the OFDM system. The data rate is improved and also the computational complexity is reduced when our proposed scheme is compared with the partial transmit sequence scheme

KEYWORDS: Piecewise linear companding, OFDM, PAPR, Power, Gain, AWGN channel

1. INTRODUCTION

OFDM system is Orthogonal Frequency Division Multiplexing system where the sub-carriers are orthogonal to each other. This indicates, non-overlapping of sub-carriers, which results in efficient spectrum utilization. Along with efficient spectrum utilization OFDM has high data rate as one of its advantages. But, due to emphasizing of sub-carriers in same direction high peaks are achieved resulting in high PAPR. This high value of PAPR destroys the orthogonality of the sub-carriers resulting in destruction of the OFDM system. Therefore, it is essential to reduce the PAPR value of the OFDM system. Various efforts are made to reduce PAPR value using different techniques. PAPR reduction techniques are basically classified as distorted and un-distorted techniques. The distorted techniques results in distortion but have no data rate loss while un-distorted techniques have distortion less data but results in data rate loss.

Large envelope fluctuation in OFDM signal is one of the major drawbacks of OFDM. Such fluctuations create difficulties because practical communication systems are peak power limited. Thus, envelope peaks require a system to accommodate an instantaneous signal power that is larger than the signal average power, necessitating either low operating power efficiencies or power amplifier (PA) saturation. In order to amplify the OFDM signal with large envelope fluctuations, PAs with large linear range are required, which makes it very expensive. If PA has limited linear range then its operation in non linear mode introduces out of band radiation and in band distortion. It is also necessary to have D/A and A/D converters with large dynamic range to convert discrete time OFDM signal to analog signal and vice versa. PAPR is generally used to characterize the envelope fluctuation of the OFDM signal and it is defined as the ratio of the maximum instantaneous power to its average power. In addition to this, OFDM system requires tight frequency synchronization in comparison to single carrier systems, because in OFDM, the subcarriers are narrowband. Therefore, it is sensitive to a small frequency offset between the transmitted and the received signal. The frequency offset may arise due to Doppler Effect or due to mismatch between transmitter and receiver local oscillator frequencies. The carrier frequency offset (CFO) disturbs the orthogonality between the subcarriers, and therefore the signal on any particular subcarrier will not remain independent of the remaining subcarriers. This phenomenon is known as inter-carrier interference (ICI), which is a big challenge for error-free demodulation and detection of OFDM symbols.

2. BASIC OFDM SYSTEM

The block diagram of OFDM system is shown in fig.1.The input high data rate streams are converted into number of low data rate streams. This parallel stream is then modulated using QPSK or QAM modulation techniques, which is then applied as input to IFFT block producing OFDM samples. These samples are then converted into OFDM signal using Parallel-to-Serial converter (P/S).The signal is then encoded by adding Cyclic Prefix (CP) and is then transmitted over the channel. The reverse process is done at the receiver

3. PAPR REDUCTION TECHNIQUES

3.1 Clipping

The clipping is one of the simplest distortion based technique to reduce the PAPR of OFDM signal. It reduces the peak of the OFDM signal by clipping the signal to the desired level but it introduces both in-band distortion and out-of-band radiation. To limit out-of-band radiation and PAPR, Jean Armstrong proposed iterative clipping and filtering scheme.

3.2 Companding

Companding is another popular distortion based scheme for PAPR reduction in OFDM system. In another work Wang et al. proposed a scheme based on μ-law companding to reduce the PAPR of OFDM signal. In μ-law companding scheme the peak value of the OFDM signal before and after companding remains same, which keeps peak power of the OFDM signal unchanged but the average power of the OFDM signal after companding increases and therefore the PAPR of the OFDM signal gets decreased. But due to increase in the average power of the OFDM signal the error performance of μ-law companding scheme degrades.

3.3 Linear Companding Transform

Linear companding transform (LCT) has been proposed by Aburakhia et al. to reduce the PAPR of the OFDM signal. LCT also treats large and small signals on different scale but has two inflexion points to achieve more Flexibility in designing the companding function. The abrupt change in the transformed signal at inflexion point degrades the power spectral density (PSD). Trapezoidal companding (TC) proposed by Hou et al. is an efficient method to reduce the PAPR of OFDM signal with low BER. TC transforms the Rayleigh distributed magnitude of original OFDM signal to a trapezoidal distribution and called "Trapezoidal Companding". Trapezoidal companding utilizes a piecewise function defined in three intervals of OFDM signal magnitude.

3.4 Trapezium Distribution

Jeng et al. proposed trapezium distribution based companding (TDBC) to transform the Rayleigh distribution of original OFDM signal to biased linear distribution called "Trapezium distribution". All the companding schemes distort the shape of the original OFDM signal and PAPR reduction capability is achieved at the cost of BER performance degradation.

4. PAPR OF OFDM SIGNAL

The PAPR of OFDM signal represented in (1) is given by:

$$\text{PAPR}=\frac{\text{Peak power}}{\text{Average Power}}=\frac{max|x(t)|^2}{E[|x(t)|^2]}$$

Where E [·] denotes expected value. The value of PAPR is required to be as low as possible else the orthogonality of signal gets destroyed.

5. COMPLEMENTARY CUMULATIVE DISTRIBUTIVE FUNCTION (CCDF)

The performance evaluation of PAPR is done using the parameter named as Complementary Cumulative Distributive Function (CCDF). CCDF is defined as the probability by which the PAPR is greater than the threshold value of given PAPR0.

CCDF is mathematically represented as: CCDF = Pr [PAPR > PAPR0]

6. PROPOSED METHOD

The proposed algorithm proposes parallel switching of PTS (Partial Transmission Sequence) and PAGC (approximate gradient project constellation) as shown below in figure 2

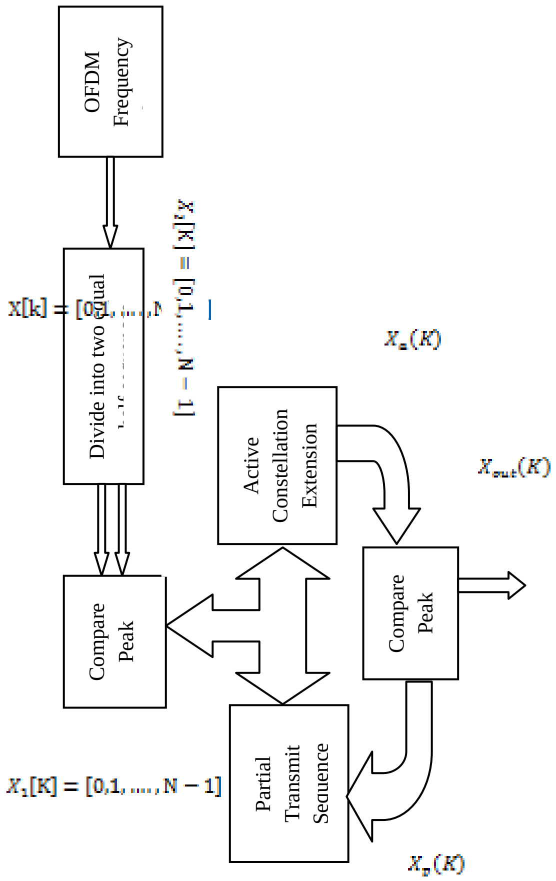


Figure 2: Proposed block diagram

The OFDM subcarriers which related to symbols are divided into two equal halves after that we can calculate their peak power. The higher peak power containing sequence of half OFDM symbols is fed to AGP blocks and other half is moved to PTS block for the processing. Finally both results are combined and it shows the better performance as compared to individual methods.

The steps included in proposed algorithm are given below,

1. Original OFDM subcarrier (X[k]) is divided into two equal halves (i.e. $X_1[k]$ and $X_2[k]$).
2. Apply AGP on selected half subcarriers $X_1[k]$ and simultaneously PTS on rest half no of subcarriers $X_2[k]$.
3. Set initial iteration t=0, compute IFFT i.e. $x'_{a[k]}$ and select optimal iteration as conventional method.
4. Apply clipping by level C that is helping to maintain constant envelope signal. Although phase is same as the phase in the original sequence:

$$x_a = \begin{cases} x'_a[n] & |x'_a[n] < C| \\ C\, e^{j\theta[n]} & |x'_a[n] \geq C| \end{cases} \quad (12)$$

Where, $x'_a[n] = x'_a[n] e^{j\theta[n]}$.

5. Obtain clipping signal portion as shown below,

$$K_{clip}[n] = \bar{x}_a[n] - x'_a[n] \quad (13)$$

And transform K_{clip} into frequency domain K_{clip}.

6. Enforce all AGP constraints to K_{clip} which are acceptable extensions for given mapped constellation and set all other interior point to original location. Apply IDFT to obtain new extended constellation k'_{clip}.
7. Assume suitable gradient ρ and compute new sequence:

$$x_a^{t+1}[n] = x_a^t[n] + \rho k'_{clip} \quad (14)$$

8. Calculate PAPR of $x_a^{t+1}[n]$. Update t=t+1, and perform check operations using following two conditions. Firstly PAPR should be minimum as well as secondly we require maximum iteration count has been reached.
9. Compute FFT on $x_a^{t+1}[n]$ to get optimum extended constellation $X_a[k]$.
10. Apply PTS on $X_2[k]$ $(Figure\ 4)$ with same partition as in conventional technique. I.e. V sub blocks of

equal size having adjacent partitioning. Now new partial sequence is

$X_p = [X_p^1, X_p^2, \dots, X_p^v]$.

11. Generate set of the phase vector P=$[p^1, p^2, \dots, p^v]$ and multiply with partial sequence. Compute IFFT of new sequence i.e., $X_p^v[n]$.

12. Perform check operation equal to candidate sequence $M = 4^{v-1}$ for minimum PAPR symbol from partial sequence.

13. Consider minimized PAPR sequence as follows:

$\bar{x}(n) = \sum_{V=1}^{V} X_p^v[n]$ (15)

Compute its frequency domain signal $X_p[k]$.

14. Prepare side information from (15) for receiver to know the corresponding optimal phase vector as :

$P_{rx} = \underset{[p^1, p^2, \dots, p^v]}{\arg\min} \left(\underset{n=0,1,\dots,N-1}{max} \left| \sum_{V=1}^{V} X_p^v[n] \right| \right)$ (16)

15. Finally, arrange optimal half sequences with minimized PAPR in frequency domain according to their original location as given below:

$X_{out}[k] = [X_a[k] \; X_p[k]]$ (17)

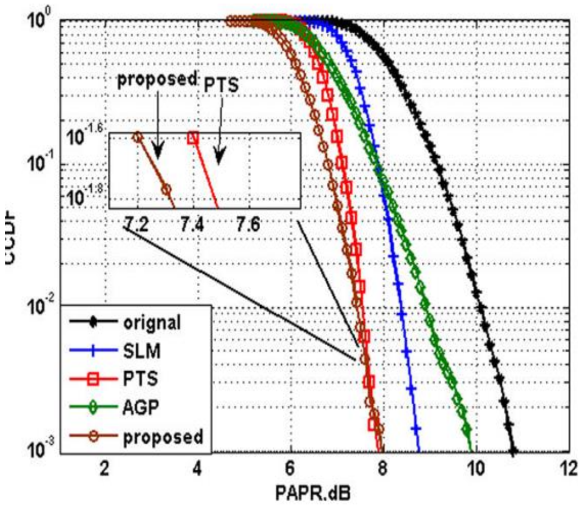
The proposed scheme requires less channel side information than PTS scheme as well as it reduces the peak regrowth of OFDM system.

Complexity

One of the advantages of proposed scheme is to reduce the computational complexity of the system. The SLM and PTS methods are dependent on number of sub block to search the optimum phase vectors whereas AGP requires iterations to find optimal constellation.

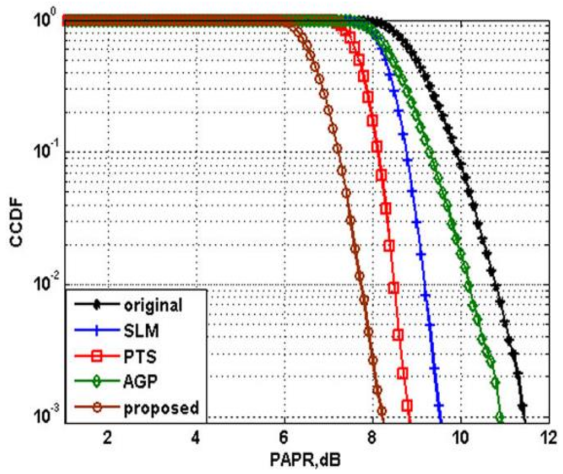
The proposed scheme in our project (PAGC) requires the no of the complex multiplications and the complex additions are calculated as $[V \times \left(\frac{N}{4}\right) \times \log_2\left(\frac{N}{2}\right) + t \times \left\{N + \left(\frac{N}{4}\right) \times \log_2\left(\frac{N}{2}\right)\right\}]$ and $[M + (4 \times V) + 2\} \times \left(\frac{N}{2}\right) + t \times \{2 \times N + \left(\frac{N}{2}\right) \times \log_2\left(\frac{N}{2}\right)\}]$ respectively. Comparing to PTS scheme the PAGC shows a huge reduction in complexity.

7. RESULTS



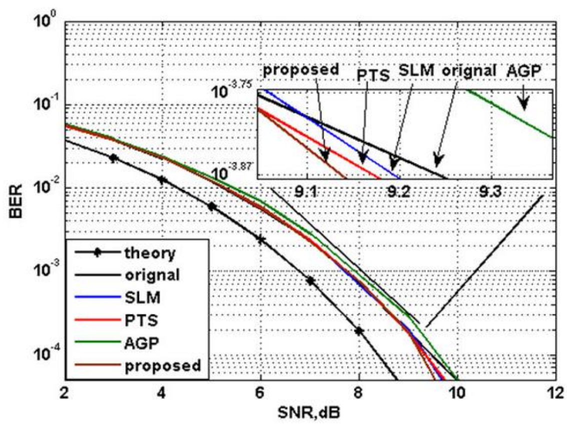
(a)

Figure 3: PAPR reduction in wireless LAN (WLAN) same for same CCDF as compared to PTS scheme.



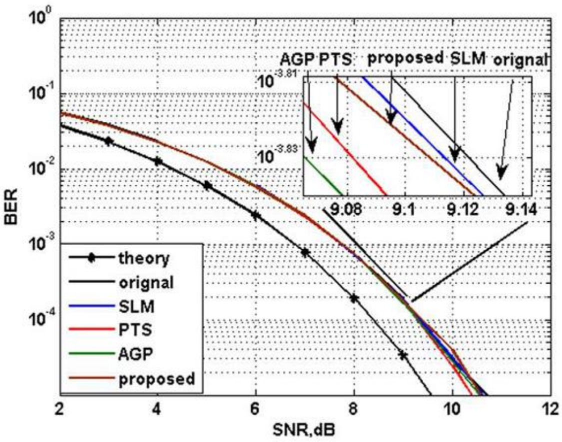
(b)

Figure 4: PAPR reduction in wireless WIMAX the PAPR reduction is approximately 0.5 dB



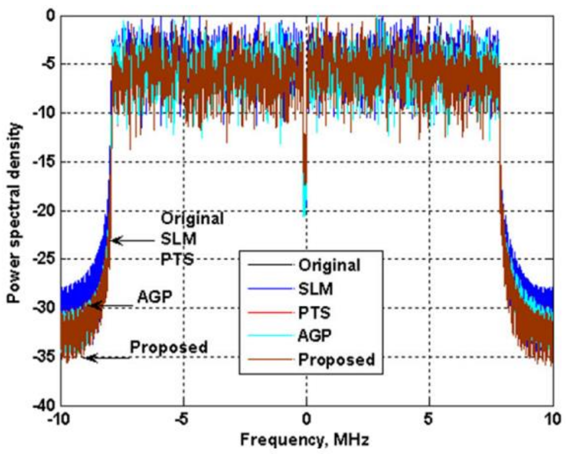
(a)

Figure 5: BER performances in the presence of (AWGN) This clearly shows that the proposed method improves the BER performance for wireless LAN at 9.1 dB (approx.) signal-to noise ratio (SNR) and it is almost same as conventional technique for wireless LAN



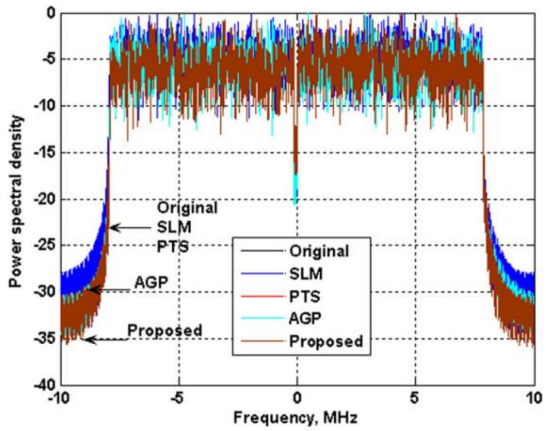
(b)

Figure 6: BER performances in the presence of (AWGN) This clearly shows that the proposed method improves the BER performance for wireless LAN at 9.1 dB (approx.) signal-to noise ratio (SNR) and it is almost same as conventional technique for WIMAX



(a)

Figure 7: 7(a) Power spectrum through which the in-band ripples and out-band radiation are showed by particular bandwidth. It is observed that the proposed scheme not only allows smaller in-band ripples but also less out-of-band radiations as compared to conventional schemes.



(b)

Figure 7: 7(b) Power spectrum through which the in-band ripples and out-band radiation are showed by particular bandwidth. It is observed that the proposed scheme not only allows smaller in-band ripples but also less out-of-band radiations as compared to conventional schemes.

8. CONCLUSION

In this paper, a parallel combinational approach i.e., partial approximate gradient constellation (PAGC), based on PTS and AGP scheme for PAPR reduction in OFDM signals is proposed. In proposed technique OFDM subcarriers is divided into two equal halves. Each one of them is used as an input for conventional methods in parallel. The PAPR simulation results exhibit diminution of 0.2 dB and 0.5 dB in comparison to PTS for IEEE 802.11a (Wireless LAN) and IEEE 802.16e (WiMAX) respectively. Further the results also confirm that with large number of subcarriers, the proposed scheme works really well. Moreover, the power spectrum spreading is almost identical and BER performance is significant at low SNR when compared with conventional techniques. When the results of PAGC are compared with PTS schemes a reduction of more than 20% in computational complexity is observed .In DAB, DVB, HIPERLAN/2 and LTE systems etc, the proposed scheme can be used efficiently.

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