A New SLM Scheme with Clipping for PAPR Reduction in OFDM Systems

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Abstract— Orthogonal Frequency Division Multiplexing (OFDM) has become the most widely adopted technology in wireless communication systems. Usage of OFDM is limited mainly by its high Peak-to-Average Power Ratio (PAPR). Selected mapping (SLM) is well-known technique for peak-power reduction in orthogonal frequency-division multiplexing (OFDM). Proposed technique is modified SLM scheme. SLM is applied for peak to average power ratio (PAPR) reduction in orthogonal frequency division multiplexing (OFDM) systems. The output of modified technique is clipped at transmitter end and the out grown clipped signal is also passed through channel with original clipped signal and then they are added for further processing at receiver end. PAPR reduction is achieved with reasonably good BER with this hybrid technology.

Key words: Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ration (PAPR), Selective Mapping (SLM), Clipping, Bit Error Rate (BER)

I. Introduction

Orthogonal Frequency division Multiplexing (OFDM) has been considered as one of the strong standard for the next generation mobile radio communication systems. It supports reliability and high data rate in the frequency selective fading channel environments. It has other advantages like high spectral efficiency, immunity to impulse interface, less nonlinear impairment. OFDM has been adopted for different wireless communication systems such as Wireless Local Area Networks (WLANs), Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB). Main disadvantage of OFDM signal is high peak-to-average power ration (PAPR) at the transmitter. Due to high PAPR the signal in-band distortion and out-of-band radiation when it passes through a nonlinear device such as a high power amplifier (HPA).It induce the degradation of bit error rate (BER). Thus, reduction of PAPR is one of the most important research area in OFDM system.

Several techniques have been taken into consideration to reduce the PAPR problem of the OFDM signals such as clipping and filtering (CAF) [2], partial transmit sequence (PTS) [8]-[11],selected mapping (SLM) [12]-[17], companding [2]-[8], tone reservation (TR) [2], tone insertion (TI) [2] etc. The companding schemes [2]-[8] compressed large samples and expand small samples. The clipping and filtering [2] limits the OFDM signal at given amplitude to reduce the PAPR. In [2], the clipping scheme was introduce to the OFDM systems; it increased the bit error rate (BER) and enlarged the side lobe. It choose the location of the pilot tone used inside each data sub-block depending on the side information index, and then exploit the power disparity between this pilot tone and the data symbols in the same sub-block to allow for side information recovery at the receiver side. The SLM and the PTS [2],[8-17] methods generate several candidates in OFDM symbols by multiplying the original symbol with different phase rotation vectors, and chose one with the lowest PAPR for transmission. The SLM method [13] was applied, in this it divided each OFDM/QAM symbol into two parts (real and imaginary), randomly adopt the phase rotation vectors for the first 2K parts, with K being the parameter associated with the length of the prototype filter, and then optimized the $(2K + 1)^{th}$ part to reduce the PAPR. Due to the random choice of the phase rotation vectors, the PAPR reduction performance was poor when the length of the prototype filter was long.

The Partial Transmit Sequence (PTS) and the Selective Mapping (SLM) techniques [8-11] have the advantages, of a relatively low complexity, assuming a perfect recovering of the side information and not to affect the bit error rate.

The rest of this paper is organized as follows: Section II describe OFDM system with quadrature amplitude modulation. In Section III different PAPR reduction techniques like, conventional SLM and Clipping are briefly described. Section IV define proposed hybrid SLM scheme. All simulation results are given in Section V. Finally, conclusion of paper is given in Section VI.

II. Orthogonal Frequency Division Multiplexing with Quadrature Amplitude Modulation System Model

The OFDM transmitter structure is shown in Fig. 1, which consists of *N different* subcarriers. After serial to parallel conversion, the input symbols are first modulated with QAM and converted to data matrix X,
which is defined as,

$$X = [X^0, X^1, \ldots, X^{M-1}] \quad (1)$$

Where M is the number of data blocks, and X^m is the m^{th} data block, which is defined as

$$X^m = [X^m_0, X^m_1, \ldots X^m_{N-1}]^T \quad (2)$$

With T denoting the transpose and X^m_k denoting the mth QAM symbol on the kth subcarrier, which is defined as

$$X^m_k = c^m_k + jd^m_k \quad (3)$$

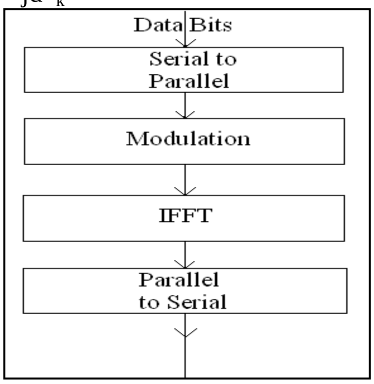

Fig. 1: Typical OFDM Transmitter

Where cmk and dmk are real and imaginary parts of Xmk respectively.

Then, $x^m{}_k(t)$, $k = 0, 1. . . N - 1$ are modulated with N orthogonal subcarriers to obtain,

$$s_k^m(t) = \{c_k^m + jd_k^m\}e^{jk\left(\frac{2\pi}{T}t\right)} \quad (4)$$

Next, $s_k^m(t)$ on all different N subcarriers are make up together to obtain the m^{th} OFDM symbol vector $s^m(t)$ as,

$$S^m(t) = [s_0^m(t), s_1^m(t), \dots, s_{N-1}^m(t)]^T \quad (5)$$

which can also be expressed in the vector form, called an OFDM signal sequence, as

$$S(t) = [S^0(t), S^1(t), . . . , S^{M-1}(t)] \quad (6)$$

Then, the PAPR for $s(t)$ in the p^{th} time interval is defined as the ratio between the maximum instantaneous power and its average power, which can be written as

$$\xi^p = 10\log_{10}\frac{\max_{pT\le t\le(p+1)T}|s(t)|^2}{P_{ave}}, p=0,1,\dots,M+K-1 \quad (7)$$

where Pave is the average power of s(t), X is the input data matrix, X^m is the m^{th} data block, X_k^m is the m^{th} QAM symbol on the k^{th} subcarrier, $s^m(t)$ is the m^{th} OFDM/QAM symbol, s(t) is the OFDM/QAM signal.

III. PAPR REDUCTION SCHEMES

SLM method has some advantages like reduce PAPR, good BER performance, lower complexity etc. Here conventional SLM and Clipping methods are introduced. In SLM, signal will multiply with different phase rotation vectors and choose signal with minimum PAPR. Clipping is use to clip signal amplitude. At some specific level of peak amplitude level of signal will clipped at desirable level.

A. *Convetional SLM Scheme:*

Conventional SLM method reduces the PAPR by optimally choosing one phase rotation vector from a given set for each OFDM symbol. Over different OFDM symbols, the phase rotation vectors might be different, which denote the set of candidate phase rotation vectors as,

$$ß = \{ b^0, b^1, . . . , b^{U-1}\} \quad (8)$$

where U is size of B.

The u^{th} phase rotation vector is define as,

$$b^u = [b_0^u, b_1^u, \dots, b_{N-1}^u]^T, \text{ where } 0 \le u \le U-1 \quad (9)$$

With $b_k^u = e^{j(2\pi i/W)}$, i=0, 1… W-1.

For convenience, denote as $b^{m.u} = [b_0^{m,u}, b_1^{m,u}, \dots, b_{N-1}^{m,u}]^T$ as phase rotation vector used by m^{th} OFDM symbol $s^m(t)$. Usually B is assumed to be known at both the transmitter and the receiver.

After $s_k^m(t)$ is generated as in (4), SLM generates $\tilde{s}_k^m(t)$ by multiplying the corresponding element in the selected phase rotation vector,

$$\tilde{s}_k^m(t) = s_k^m(t)b_k^{m,u} \quad (10)$$

Then, the new OFDM symbol $\tilde{s}^m(t)$ is expressed as,

$$\tilde{s}^m(t) = \sum_{k=0}^{N-1} s_k^m(t)b_k^{m,u} \quad (11)$$

The PAPR with conventional SLM for m^{th} symbol $s^m(t)$, m=0, 1… M-1, can be formulated as,

$$\min_{b^{m,u}} \max_{mT\le t\le\left(m+K+\frac{1}{2}\right)T} \left|\sum_{k=0}^{N-1} s_k^m(t)b_k^{m,u}\right|^2 \quad (12)$$

After obtaining the PAPR reduced OFDM signal $\check{S}(t)$, the transmitter will send side information to the receiver about which phase rotation vector is selected for $s^m(t)$, m =0, 1, . . . , M − 1. At the receiver, the side information is correctly received and the original data matrix X can be thus successfully recovered.

We will illustrate the PAPR reduction performance achieved by the conventional SLM algorithm in Section V.

B. *Clipping:*

Clipping is simplest way to reduce PAPR in OFDM system. Clipping compare amplitude of signal which has to transmit with threshold value of clipping level and it clipped at that level with threshold. No additional information is needed to transmit. At receiver side no any further changes need to decode date. Clipping is good by using this technique we get better result in PAPR but BER performance degrade.

IV. PROPOSED SCHEME

Fig.4 shows the block diagram of proposed technique which uses SLM method with clipping. In proposed method, data source are first pass through serial to parallel with QAM modulation with M different data blocks. After modulation each modulated data in each data block are multiply with different phase rotation vectors B. After passing through IFFTs it choose one with minimum PAPR. After taking signal with lower PAPR, It passes through parallel to serial with clipping and the signal will transmit into channel.

The input symbols are first serial-to-parallel converted to data matrix X, which is defined as,

$$X = [X^1, X^2, . . . , X^m, . . . , X^M] \quad (13)$$

Where M is the number of data blocks, and X^m is the m^{th} data block, it has serially QAM data which is defined as,

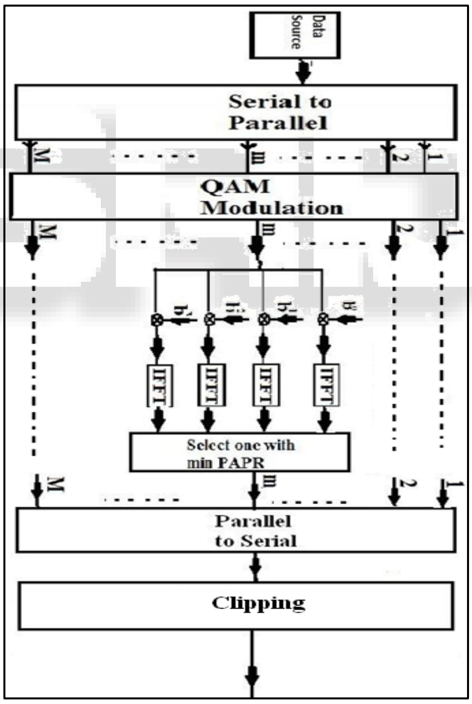

Fig. 2: Proposed Method

$$X^m = [X^m{}_0, X^m{}_1 . . . X^m{}_{N-1}] \quad (14)$$

$X^m{}_k$ denoting the m^{th} QAM symbol on the k^{th} place, which is defined as,

$$X^m{}_k = c^m{}_k + jd^m{}_k \quad (15)$$

Where c_k^m and d_k^m denote the real and imaginary parts of X_k^m respectively.

Now signal of each data blocks are multiplied with set of phase rotation vectors.

which is given as,

$$ß = \{ b^0, b^1, . . . , b^{U-1}\} \quad (16)$$

where U is size of B.

The u[th] phase rotation vector is define as,

$$b^u = [b_0^u, b_1^u, \dots, b_{N-1}^u]^T, \text{ where } 0 <= u <= U-1 \quad (17)$$

with $b_0^u = e^{j(2\pi i/W)}$, i=0,1,…,W-1.

After X^m generated in (14), hybrid SLM generate X_u^m by multiplying the corresponding element in the selected phase rotation vector,

$$X_u^m = X^m b^u \quad (18)$$

Here, we have U different signals with same data in one data block which will be passing through IFFT and select one with minimum PAPR.

$$x^m = \min \text{PAPR}(\text{IFFT}(X^m{}_u)), \text{ where } 0 <= u <= U-1 \quad (19)$$

If $X^m{}_3$ have minimum PAPR form { $X^m{}_1$, $X^m{}_2$, …, $X^m{}_{U-1}$} then $x^m = X^m{}_3$.

After getting different M x^m signals, it take serial data from parallel to serial value of and signal will clipped with clipping. In clipping we check amplitude level of signal and clip with threshold at that sample

At receiver side, reverse step by step process will done to recover data, at receiver phase rotation information will need which can be received from side information. So in this new hybrid SLM method side information is needed to transmit to recover data at receiver end.

V. SIMULATION RESULTS

Simulations are conducted to evaluate the PAPR reduction performance of the proposed SLM algorithm. For all the simulations of PAPR the oversampling factor is adopted as 4. The channel used in it is AWGN channel and modulation scheme is 16-QAM with N = 1024 and M = 1000.

In Fig. 4, we plot the CCDF curves for conventional SLM algorithms with different values of U. original signal PAPR is 11.4055 which is reduced with different values of U, when U=4 PAPR=8.9676, for U=8 PAPR= 8.2392 and for U=16 PAPR = 7.777 at CCDF = 10^{-4}. It is observed that with U=4, 8 and 16 PAPR could be reduced about 2.4379, 3.1663 and 3.6285 dB respectively. So when value of U will increase we get better PAPR reduction. But as increase in U computational complexity and number of simulations are increases with 2^U.

In Fig. 5, we show the CCDF curves for hybrid SLM with clipping and conventional SLM algorithm. Original signal PAPR is 11.8629 which is reduced with hybrid SLM, when U = 4 for conventional SLM PAPR is 10.1192, when in hybrid SLM with clipping PAPR is 7.7481. Compared with the original OFDM signal without PAPR reduction at CCDF = 10^{-4} with U=4 in SLM, hybrid SLM with clipping PAPR respectively.

So with using of clipping in SLM we get much reduced PAPR.

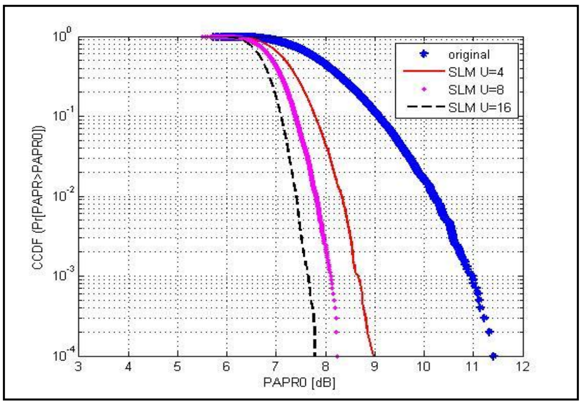

Fig. 4: CCDF Vs. PAPR For Convention SLM With Different U, 16-QAM, N = 1024.

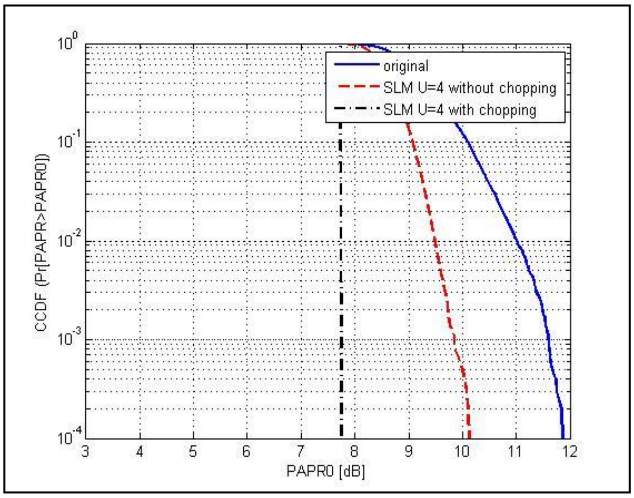

Fig. 5: CCDF vs. PAPR for SLM with clipping and conventional SLM with U=4, 16-QAM, N=1024.

BER of hybrid SLM scheme with different clipping system is as shown in Fig.6. It shows that BER of hybrid SLM scheme with clipping is not much higher than BER of conventional SLM, BER of conventional SLM (U=4), hybrid SLM with clipping, are 0.0112 and 0.0213 at 8db of EbNo. So with clipping BER good performance with much better PAPR reduced.

VI. CONCLUSION

OFDM is a very efficient technique for wireless communications due to its spectrum efficiency and channel robustness. In this paper, we have employed new hybrid SLM scheme, leading to conventional SLM and clipping. Computation complexity of hybrid SLM is not much increase but as per simulation results PAPR performance with BER of hybrid SLM scheme is good. So hybrid SLM is good choice for PAPR reduction in OFDM/QAM system.

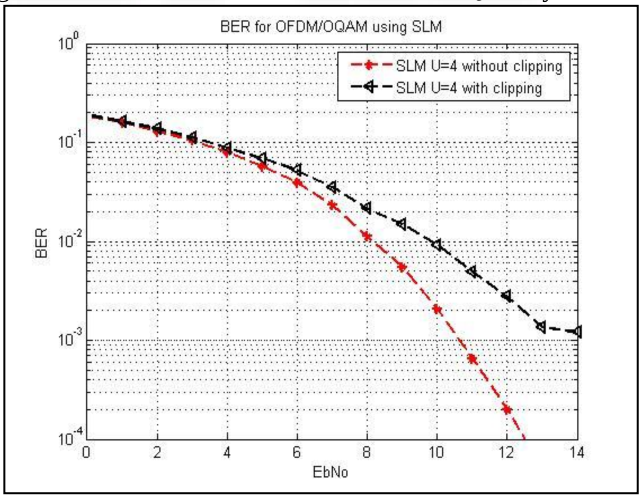

Fig. 6: BER Vs. Ebno of Conventional SLM (U=4), SLM With Clipping.

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