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Proposal and Application of Hybrid SLM-PTS Method in 8QAM-OFDM Optical Access System for Reducing PAPR Influence

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***Abstract*—In this letter, a novel hybrid SLM-PTS algorithm for reducing peak-to-average power ratio (PAPR) influence, is proposed and analyzed in an 10Gbit/s 8QAM-OFDM optical access system. After the serial-to-parallel conversion, transmitted signals are divided into two data subblocks, and one subblock is processed by SLM method and the other is processed by PTS. And then the processed data subblocks are merged into one transmission sequence. In 10Gbit/s optical access systems, through comparing PAPR, bit error rate (BER) and computational complexity, SLM, PTS and hybrid SLM-PTS methods show their respective advantages. The results show that the hybrid SLM-PTS algorithm can provide a possible compromise for PAPR reduction. The proposed hybrid algorithm exhibits lower computational complexity when the used subcarriers number is smaller. Compared with traditional PTS and SLM methods, using the proposed method the value of BER is the lowest under the certain signal to noise ratio (SNR) condition.**

Keywords-optical access system; optical signal processing; 8QAM-OFDM; PAPR; hybrid SLM-PTS

I. INTRODUCTION

Nowadays, a few advanced modulation format techniques (such as optical orthogonal frequency division multiplexing (OFDM) and quadrature amplitude modulation (QAM), are popular and available methods to meet the increasing demand on spectral efficiency and high speed information throughout in optical access networks [1]. Meanwhile, OFDM, which is one of multicarrier modulation (MCM) techniques, offers an excellent performance in terms of tolerance to dispersion, flexibility to dynamic bandwidth and combating ISI (Inter-Symbols Interference), while efficient hardware implementation can be realized using fast Fourier transform (FFT) techniques [2]-[4]. However, one of the drawbacks of the OFDM system is the high Peak-to-Average Power Ratio (PAPR), which degrades the efficiency of nonlinear high power amplifier at the transmitter [5], [6].

To overcome high PAPR problem, researchers have proposed some probability methods to reduce the value of PAPR, such as partial transmission sequence (PTS) and selective mapping (SLM) [7]-[9]. PTS technique introduces phase weighting to achieve phase optimization, and then the divided subblocks are combined [10] for reducing PAPR. SLM method adopts different offset vector, which multiplied by the transmitted information sequence, to selective the transmission sequence with minimum PAPR after Inverse Fast Fourier Transform (IFFT) [11]. But, both technologies have some drawbacks, such as high computational complexity of PTS and limited PAPR reduction of SLM.

For solve the above problem, this paper presents a hybrid algorithm of PTS and SLM method to reduce PAPR in optical access system. After the serial-to-parallel conversion, we divide the input signals into two data sub-blocks, in which one is using SLM method and the other is PTS. Then the processed data subblocks are merged for generating the transmitted sequence. The proposed method provides a good trade off among PAPR, computational complexity and BER.

II. ANALYSIS

Fig. 1 shows the schematic diagrams of the OFDM optical access system with hybrid SLM-PTS scheme using DMT modulation and demodulation. The DMT is one subclass of OFDM, where the output signal after the inverse fast Fourier transform (IFFT) is a real signal. If the DMT modulation is introduced in the optical access system, in-phase and quadrature (IQ) will not be required [12]. The input sequence $X=[X_0, X_1, ..., X_N]$ generated by QAM modulation, where N is the number of subcarriers. After serial-to-parallel conversion, the symbol sequence is divided into two data subblocks, which denoted by X_{SLM} and X_{PTS}, respectively.

For PTS method, the input data blocks are divided into M different subblocks, and set as $X_{PTS} = [X_{PTS1}, X_{PTS2}, X_{PTS3}, ..., X_{PTSM}]$, where M is the number of subblocks, and the condition $X_{PTS} = \sum_{m=1}^{M} X_{PTS\,m}$ is satisfied. Subcarriers have the character of not overlapping with each other after segmentation and zero-padding, which makes it possible for the sequence to be weighted phase weighted. Then, the oversampling sequence is transformed into the time domain waveform by an inverse fast Fourier transform (IFFT). The transformation process is shown below.

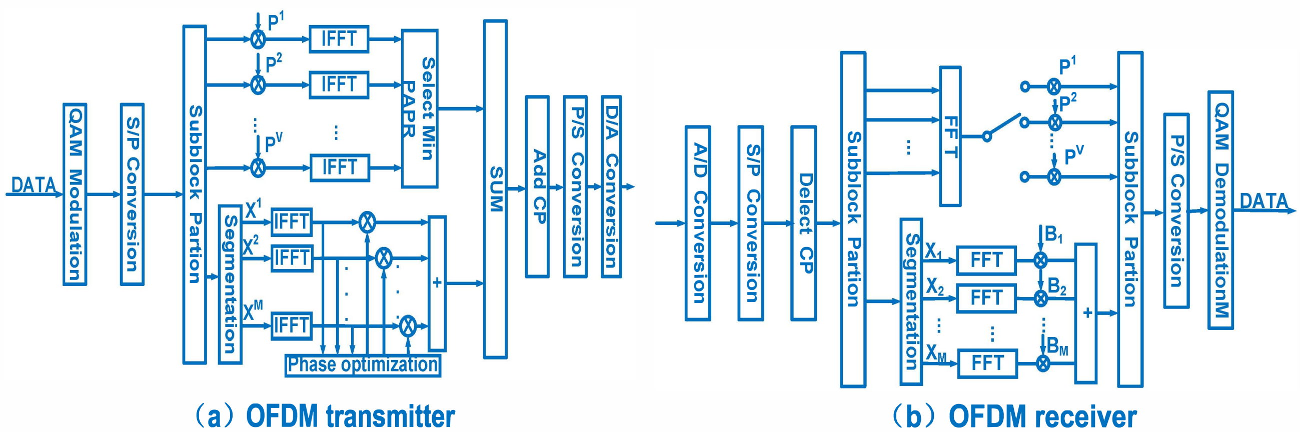


Figure 1. Block diagrams of the hybrid SLM-PTS method. (a) OFDM transmitter. (b) OFDM receiver.

$$x_{PTS\,m} = \sum_{m=1}^{M} \tilde{B}_m X_{PTS\,m} \tag{1}$$

where $\widetilde{B}_m = [\widetilde{B}_1, \widetilde{B}_2, ..., \widetilde{B}_M]$ is the phase weighting factors, which meets the condition of $\widetilde{B}_m = e^{-j\varphi_m}$. In order to reduce the computational complexity, we limit the value of $\widetilde{B}_m$ (only set the value in{+1,-1}). Since different phase weighting factors result in different weighted data sequences, we need to take the weighted sequence with the minimum peak for transmission.

$$[B_1, B_2, B_3, ..., B_M] = \operatorname{argmin}(\max(|x_{PTS\,m}|)) \tag{2}$$

where argmin() is given the value of optimization phase B_m as the value of $\max(|x_m|)$ is the minimum. Then, we take B_m into (1) to obtain the transmission sequence, as shown below.

$$x_{PTS} = \sum_{m=1}^{M} B_m X_{PTS\,m}$$

For SLM method, SLM method is one of popular schemes to reduce PAPR because it is simple to implement, without introducing any distortion to the signal. Its basic principle is to copy the input data block into a plurality of data blocks, and then every data block is multiplied by different phase offset, and selects a data block with minimum PAPR.

It is seen from the above, a new sequence X_{SLM} is generated by segmentation, and then copies it into N_2 blocks, where N_2 is the number of subcarriers of X_{SLM}. Then, we define the phase offset $P^{(v)} = [p_{v,0}, p_{v,1}, p_{v,2}, ..., p_{v,N_2-1}]$ v=1,2,...V, which satisfies the condition of $P^{(v)} = e^{j\varphi^m}$. Similarly, we restrict the value of $P^{(v)}$ (only set the value in{+1,-1,j,-j}). As shown in (3), the IFFT transform is completed after the multiplication of $P^{(v)}$ and X_{SLM}.

$$x_{SLM\_v} = \sum_{m=1}^{M} P^{(v)} X_{SLM} \tag{3}$$

The PAPR is calculated for V phase rotated OFDM data blocks:

$$PAPR = 10\lg \frac{\max\ (|x_{SLM\_v}|^2)}{mean\ (|x_{SLM\_v}|^2)} \quad v = 1,2,3...,V \tag{4}$$

The PAPR of the M sequences is obtained by using (2) and (3), respectively, and the sequence in which have the smallest PAPR is transmitted.

$$p = \arg\min(PAPR(x_{SLM\_v})) \quad v = 1,2,3...,V \tag{5}$$

where argmin() gives the phase offset which the PAPR of x_{SLM} is smallest. we take (5) into (3) to obtain a transmission sequence. Then, x_{SLM} and x_{PTS} are combined into symbols sequence x_n with cyclic prefix(CP), and the symbol sequence modulated by Intensity modulator after parallel-to-series converter and digital-to-analog conversion.

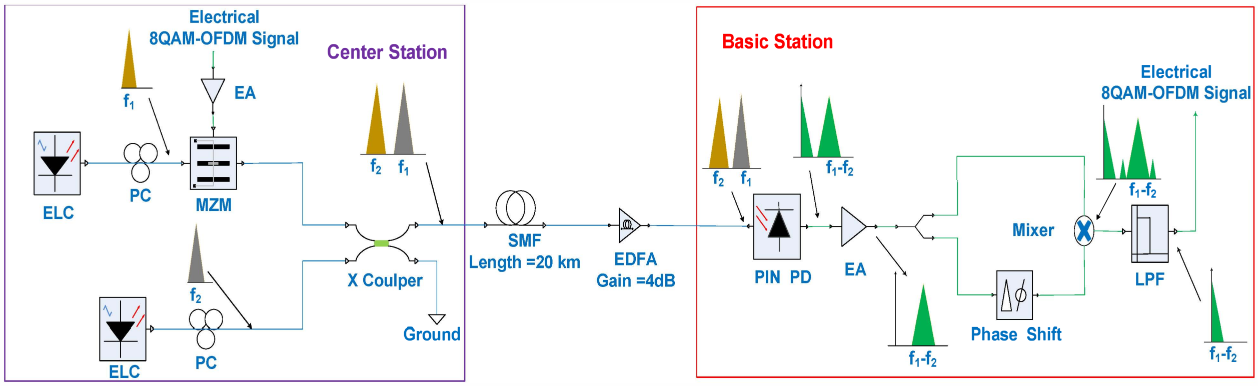


Figure 2. System configuration. (ECL, external cavity laser; EA: electrical amplifier; SMF, single mode fiber; PC: polarization controller; EDFA: erbium doped fiber amplifier; PIN PD: positive intrinsic-negative photodiode.).

III. RESULTS

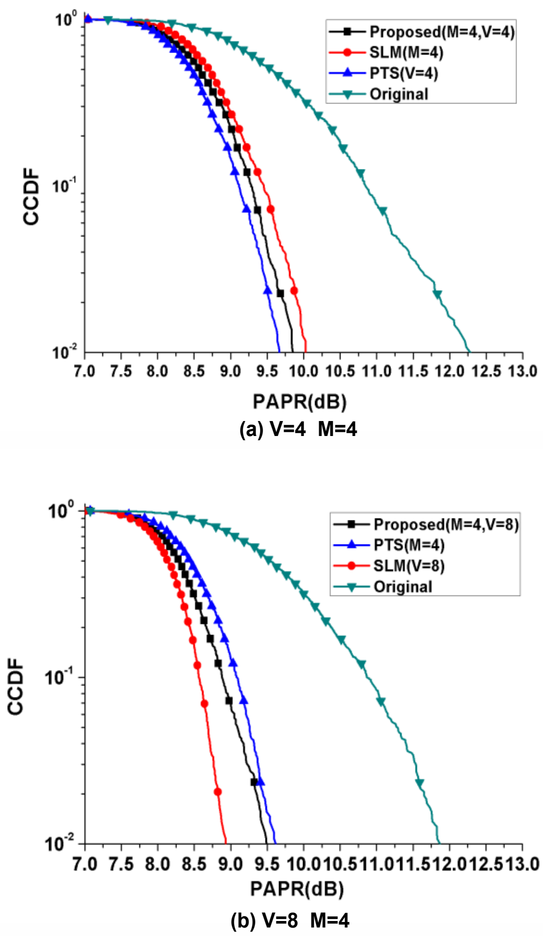


Figure 3. CCDF curves of PAPR with Original, SLM, PTS and the proposed method.

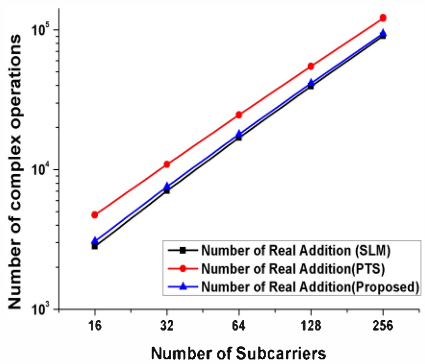
As we know, one of the main drawbacks of the OFDM signal is its high PAPR. The proposed scheme has two possibilities: (a) PTS is superior to SLM for reduction peak to average power ratio (set V=4, M=4); (b) PTS is worse than SLM in terms of limiting peak to average power ratio (set V=8, M=4). Using two kinds of method above, the measured complementary cumulative distribution function (CCDF) curves of the PAPR are shown in Fig. 3 (a), (b), respectively. It can be observed that as expected the 8QAM-OFDM signals with any kind of probability scheme have lower PAPR probability than original scheme. Note that, the proposed scheme, in both cases, has a good compromise for PAPR reduction.

And then, we consider the computational complexity comparison of PTS, SLM and the proposed scheme with different number of subcarriers while using different number of V branches and M segmentation. Fig. 4 demonstrates the real number addition complexity of PTS, SLM and proposed algorithm in the case of N=16, 32, 128 and 256. When V=4, M=4 and N=128, the computation al complexity of proposed method ratio of SLM and PTS were 1.05 and 0.76, respectively. It is worth noting that the computational complexity of the proposed algorithm ratio of SLM and PTS were 0.95 and 0.74 respectively as V=4, M=4 as N=32, which is better than SLM or PTS.

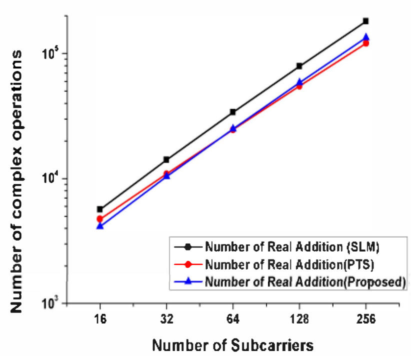
To sum up, it can be seen that the computational complexity of the SLM, PTS and the proposed method are mainly limited by number of N subcarriers. To reduce the computational complexity and PAPR simultaneously, we should choose as few as possible number of N subcarriers. The number of N subcarriers in the total transmission sequence can not be too few, since the scheme with more subcarriers has higher spectral efficiency, tolerance to dispersion and flexibility to dynamically bandwidth allocation. When the computational complexity of SLM is less than PTS, the proposed algorithm has a good trade off. Instead, the computational complexity of the proposed algorithm exhibits better performance in fewer subcarriers. According to the user can bear the complexity of DSP processing, we can choose the appropriate method to reduce PAPR in practical application.

We analyzes the BER performance of SLM, PTS and the proposed algorithm after 20km SMF transmission under different signal-to-noise ratios (SNR) as shown in Fig. 5.

From the results, we can see that the BER is lower than 10^{-3} as the SNR is higher than 15dB using SLM, PTS and the proposed scheme in both case. Compared with PTS and SLM method, the proposed method, in which V=4 and M=4, has advantage when the SNR is less than 25dB. In the second case, the proposed method has more advantage when the SNR is greater than 30dB. Hence, the proposed method provides a trade off among PAPR, computational complexity and BER.

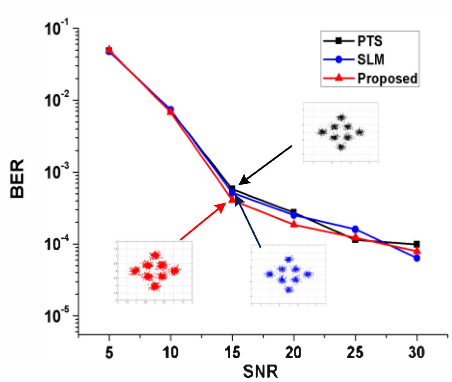


(a) V=4 M=4

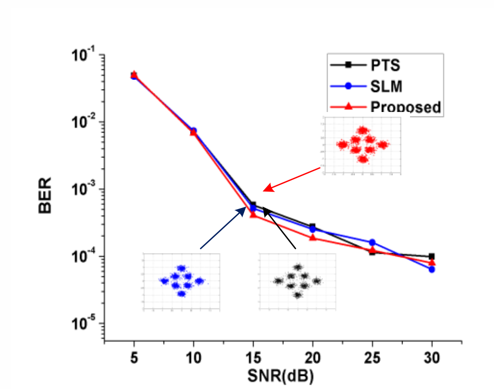


(b) V=4 M=8

Figure 4. Complex operations as a function of the number of subcarriers.



(a) V=4 M=4



(b) V=4 M=8

Figure 5. BER as a function of SNR.

IV. SUMMARY

In this paper, analysis of computational complexity and BER performance is implemented in 8QAM-OFDM optical access system using SLM, PTS and the hybrid algorithm of PTS and SLM techniques for reducing PAPR influence. The results shows that the hybrid SLM-PTS algorithm can provide a possible compromise for PAPR reduction. The proposed hybrid algorithm exhibits lower computational complexity when the used subcarriers number is smaller. Compared with traditional PTS and SLM methods, using the proposed method the value of BER is the lowest under the certain signal to noise ratio (SNR) condition.

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