PTS-Clipping Method to Reduce the PAPR in ROF-OFDM System

Jianping Wang, Ying Guo, Xianwei Zhou

Abstract —*In this paper, a novel method combined the linear and nonlinear methods, named as Partial Transmit Sequence followed by Clipping (PTS-Clipping), is proposed to reduce the peak-to-average power ratio (PAPR) of Radio Over Fiber and Orthogonal frequency division multiplexing (ROF-OFDM) system. The main technique of this method is clipping the processed signal whose probability of the peak value has been reduced by PTS technique. Then the PAPR value will be further reduced. It will bring in slight change to the BER performance between with and without clipping. We know that both the ROF and OFDM techniques are key issues of the next generation network. Reduce the PAPR of OFDM is a necessary work. The simulation results show the feasibility of this method.*[1]

Index Terms —ROF -OFDM, PAPR, PTS-Clipping

I. INTRODUCTION

The ROF system has been proved to be a promising technology for next generation network (NGN) access applications for its low transmission loss and ultra-wide bandwidth [1]. The basic idea of Orthogonal Frequency Division Multiplexing (OFDM) was proposed in 1960s, with nearly 50-year history, the first practical application of OFDM technology is the military's high-frequency wireless communication link. However, this multi-carrier transmission technology especially in wireless communication system is the new trend in the past ten years. Thus, the combination of radio-over-fiber (ROF) and orthogonal frequency division multiplexing (OFDM) systems (ROF-OFDM) has attracted considerable attention for future gigabit broadband wireless communication [2]. However, one of the main disadvantages of orthogonal frequency division multiplexing (OFDM) is its high peak-to-average power ratio (PAPR) [3] [4]. So ROF-OFDM system is necessary to overcome the drawback. When OFDM signals transmission in the fiber, the high PAPR is a problem that can not be ignored. When the OFDM symbols which have high power entered to optical fiber, some features of fiber-optic such as dispersion, nonlinear, will have an adverse effect to OFDM signals, and deteriorate the system performance. Thus, how to reduce PAPR of OFDM becomes a very urgent call in the research field. Many methods have been developed to reduce PAPR problem including Golay and Reed-muller coding [5] [6], Selective Mapping (SLM) [7], Partial Transmit Sequence (PTS) [8], Filtering and Clipping [9] [10] [11] and etc. All of these can be summed up to two main methods: linear and nonlinear. Linear methods usually bring in marked increase in computational complexity, and nonlinear methods usually bring in out-of-band radiation which can deteriorate the BER performance.

In this paper we proposed a new method combined the linear and nonlinear methods, named as Partial Transmit Sequence with Clipping (PTS-Clipping) to reduce the peak-to-average power ratio (PAPR). It will bring significant reduction in PAPR, and will bring in slight change to the BER performance between with and without clipping which makes it feasible to be used in real ROF-OFDM system.

The rest of the paper is organized as follows: In Section II, a brief description of PAPR in OFDM system is given, and the PTS-Clipping algorithm is introduced. The simulation results and system performance analysis are shown in section III. Conclusion is presented at Section IV.

II. PAPR PROBLEM

Compared with the single carrier system, the OFDM symbols are summed up of a number of modulated sub carriers, so the synthesis signal may have a relatively large peak power, which will brings high PAPR, then PAPR can be defined as follow[12]:

$$PAPR(dB) = 10\log_{10} \frac{\max_n \left\{ \left| x_n \right|^2 \right\}}{E\left\{ \left| x_n \right|^2 \right\}} \tag{1}$$

x_n is the processed signal via IFFT[12]:

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{n-1} X_k W_N^{nk} \tag{2}$$

For the OFDM system of N sub-channels, we respective the signals to all the same phase summation, the signal peak power will be N times than the mean power, and thus the base-band signal can be written as [12]:

$$PAPR = 10\log_{10} N \tag{3}$$

If we set N=256, for example, the extreme PAPR value of OFDM system is 24dB.

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If an OFDM system includes N sub-carriers, after IFFT computing, the normalized complex base band symbols are [12]:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} \mathrm{X}_{\mathrm{K}} \exp(jk\Delta ft) \tag{4}$$

Xk represents the modulated symbols of the k-th sub carrier.

△ *f* is the interval frequency between neighbor channels. For QPSK modulation, Xk = {1,-1, j, -j}. According to the central limit theorem, as long as the number of sub carriers N large enough, you can determine the real and imaginary parts of x(t), which will follow the Gaussian distribution, the zero mean, 0.5 variance (real and imaginary separately parts half of the entire signal). We generally use complementary cumulative distribution function (CCDF) to indicate the PAPR of OFDM symbols, the formula is as follows [12]:

$$P\{PAPR > z\} = 1 - P\{PAPR \le z\} = 1 - (1 - e^{-z})^N \tag{5}$$

Therefore, simulation analysis is generally used to measure the CCDF of the OFDM system to value the PAPR distribution.

We know that the limitations of ROF-OFDM are divided into two parts, one is the PAPR of OFDM, and the other is the proper character of fiber. Both of them can increase the nonlinear of the whole system, the high power asks some devices for high performance, such as the A/D convert , amplifier and modulator must have high dynamic range, all of these requirements increase the system complexity. So we must solve the high PAPR problem.

In paper [13], the authors also combined PTS with clipping, but their clipping algorithm theory is different with mine. They adopted the clipping method which mainly based on impulse cancellation on ROF-OFDM system simulation. When the signals are in high amplitude, impulse cancellation method records the time and brings in a phase change, and then introduces an impulse to replace the high PAPR value. This method must calculate all of the parameters so as to achieve the requirement of the system.

In this article we also use the simply clipping combined with PTS method, but it will be easier than Shu mei Huang's. The main algorithm theory of PTS-Clipping method is to select a proper clipping threshold.

The basic principles of Practical Transmit Sequence (PTS): first of all, we use vector data to define the symbols. X vector and then divided into M-group, respectively by $\{X_m, m=1,2,\ldots\ldots,M\}$. The division has a variety ways; assume that each group includes the same number of sub carriers, then the M-group sum up as follows [14]:

$$X^{'} = \sum_{m=1}^{V} b_m X_m \tag{6}$$

$\{b_m, m=1,2,\ldots\ldots,M\}$ is the weighted coefficient, and $b_m=\exp(j\varphi_m)$, $\varphi_m \in [0,2\pi]$, these are called the auxiliary information. Then we adopt IDFT(Inverse Discrete Fourier Transform) to X', so we obtain x'=IDFT{X'}. Referred to the IDFT instructor, we use of V separate IDFT, all of the groups calculated to be[14]:

$$x^{'} = \sum_{m=1}^{V} b_m \cdot IDFT\{X_m\} = \sum_{m=1}^{M} b_m \cdot X_M \tag{7}$$

We introduction M-part series to send X_M=IDFT$\{X_m\}$, choose appropriated weighted-coefficients $\{b_m, m=1,2,\ldots\ldots,M\}$, makes the signals' peak power to be optimization. To achieve the optimization weighted-coefficients, $\{b_m, m=1,2,\ldots\ldots,M\}$ should meet the follow function[14]:

$$\{b_1, b_2, \cdots\cdots, b_m\} = \underset{\{b_1, b_2, \cdots\cdots, b_m\}}{\operatorname{argmin}} \left(\max_{1 \le n \le N} \left| \sum_{m=1}^{M} b_m \cdot X_m \right|^2 \right) \tag{8}$$

argmin(.) represents the sentence condition that make the function achieve the minimum value. Thus we use M-1 IDFT search the optimization weighted-coefficients b_m, and achieve the purpose of reducing the PAPR value of OFDM system. In order to accelerate the Fourier transformation, we adopt IFFT (Inverse Fast Fourier Transform). The schematic diagram is below.

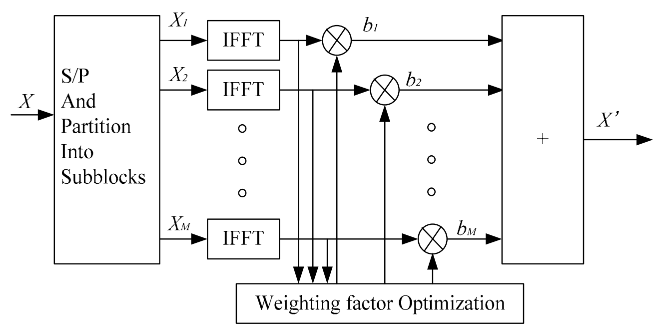


Fig. 1. PTS Principle

Clipping method sets a clipping threshold, when the amplitude of the signals over the threshold, then cut the high peak power, so that the peak power had a pre-distortion. Clipping formula is as follows [9]:

$$y(n) = \begin{cases} -A & if x(n) < -A \\ x(n) & if \; -A \le x(n) \le A \\ A & if x(n) > A \end{cases} \tag{9}$$

Where x(n) is the real band pass sample, y(n) is the clipped signal, and A is the clipped level. In the following discussion, we will use a normalized clipping level, which we call the clipping ratio (CR, $CR = A^2$). Then we simplify above equation:

$$y(n) = \begin{cases} \dfrac{\sqrt{CR}}{\sqrt{|x(n)|^2}} x(n), & if |x(n)|^2 > CR \\ x(n), & if |x(n)|^2 \le CR \end{cases} \tag{10}$$

To implement the PTS-Clipping, we use function (10) to clipping the optimization transmission sequence X' (we can find it in figure 1). According to the system acquirement, we use the following function to calculate the clipping ratio. PAPR0=10logCR, PAPR0 is the threshold value, CR is the clipping ratio. Due to the relation between PAPR0 and the system BER that PAPR0 is in inverse ratio to BER, we should choose the proper threshold value.

III. SIMULATIONS AND ANALYSIS

The main idea of PTS-Clipping is to use the merit of PTS method and then use simply nonlinear clipping method to cut the high power value of these minority symbols, considering the out-of-band power leakage, we add filtering after clipping, so we can improve the BER performance of the system.

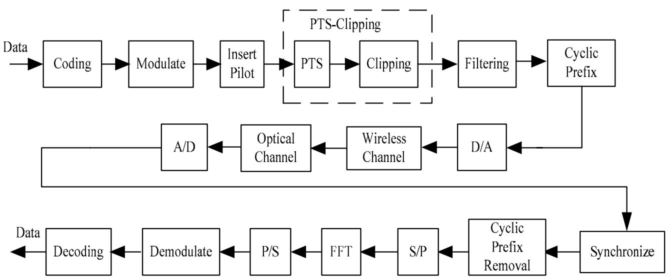


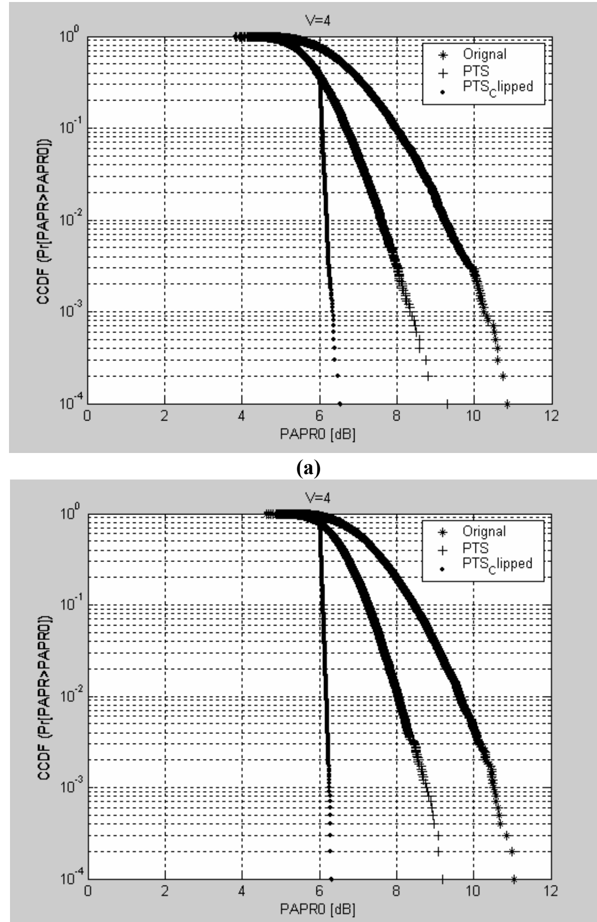
Figure 2 ROF-OFDM system simulation model

First of all, the data stream uses Golay coding, and then employs MPSK or MQAM modulation. Before transform the sequence from serial to parallel we insert the pilot, which will help us to exactly recover the data at the receive part. We introduce PTS-clipping method to process the modulated sequence, and then add cyclic prefix to elimination the interference between each OFDM sub-carriers. After D/A conversion, the signal is sent into the wireless channel. The electro signal arrived at the base station; the first step is electro-optical conversion. Then the optical signal injects into the optical channel and transmits to center control station.

We use IEEE802.11a [15] as the PHY protocol; adopt 52 sub-carriers. The sampling rate was selected as two times than Nyquist sampling. Over sampling can actually reflect the PAPR performance of OFDM symbols. In this simulation system we adopt QPSK model. PAPR0 was set at 6dB, and the corresponding CR is 4. Gaussian channel was chosen as the wireless channel model. Gaussian white noise, whose mean value is 0.5 and variance is zero, was the main source of noise.

We know that clipping is almost the simplest method in PAPR reduction. Using clipping method will not increase the complexity of the system. The system complexity mainly depends on the complexity of PTS algorithm. If we choose different division function of PTS, there will have different computational complexity. We have adopted a split-cutting law in PTS part which only needs IFFT transformation once. So we can promise the whole simulation system has the lowest algorithm complexity.

The simulation results are shown in figure3 and figure 4.



(b)
Figure 3 the PAPR0 and CCDF curves

Figure3 illustrates the PAPR performances that use PTS and PTS-clipping**.** Figure 3(a) clarifies the PAPR-CCDF property that adopts Nyquist sampling, and Figure 3(b) clarifies the PAPR-CCDF property that adopts two times over sampling. From figure 3(a) and (b) we can see that when we adopts over sampling, the clipping effect is better than Nyquist sampling.

Let's compare the PTS curves between figure3(a) and (b). In (a), we see that the probability is 0.8% when the PAPR0 value is 8dB. However, in (b), the probability is 1%. It conforms that over sampling can reflect the original characteristic of OFDM symbols. Although PTS technique has reduced the probability that high PAPR values occur, this is not efficiently enough for optic-fiber channel. We know that low inject power is indispensable for optic-fiber channel due to the optic-fibers' nonlinear. In order to consider this requirement, the system imposes on the clipping technique which can fatherly process OFDM symbols to reduce the PAPR. According to the simulation results we conform that the PTS-clipping method is feasible. After finished clipping, the probability that high PAPR value occurs is nearly reduced to 0.01%. The highest values of OFDM symbols approach to 6dB. And when we adopt Nyquist sampling, the highest PAPR value is reduced from 8.8dB to 6.5dB in contract to over sampling where the highest PAPR value is reduced from

9.2dB to 6.3dB. In our simulation study, the PAPR reduction is more than 2.3dB. If we combine this technique with optic-fiber communication system, the system performance will be improved.

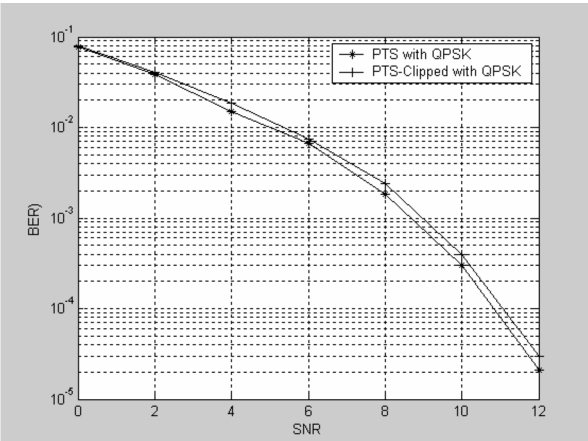


Figure 4 BER-SNR curves

Figure4 respectively descript the performances of BER-SNR of QPSK signals which are processed by PTS and PTS-clipping. From this figure, we see that the BER lightly deteriorate. However, figure3 shows that the PAPR performance obviously improves. It is clear that this will provide great benefit to optical channel. The performance of system has been improved at the cost of BER.

IV. Conclusion

In this paper we investigated the method of PTS and clipping on the performance of ROF-OFDM system. The simulation results show that the proposed PTS-clipping scheme can provide better performance in terms of PAPR reduction when BER has been slightly changed. This scheme is feasible to optic-fiber communication system.

The wire channel in the system is equivalent to optical channel. If we do some research in real optical channel, we should do more work on the associate numerical computation software with optical fiber communication system simulation software.

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