Using M Sequence to Reduce Peak-to-Average Power Ration in PTS-OFDM Systems

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1 Introduction

Orthogonal Frequency-Division Multiplexing (OFDM) is one kind of special multi-carriers modulation techniques for the high-speed data transmission, which are orthogonal with each other to transmit for reducing the effects of multi-paths.

The transmit signals can have high peak values in the time domain since many sub-carrier components are added via an IFFT operation in OFDM system. Therefore, one main disadvantage of OFDM is a large Peak-to-Average Power Ratio (PAPR). This phenomenon will need a high-power linear amplifier to satisfy the changed signals, or the large PAPR will decrease the SONR (Signal-to Quantization Noise Ratio) of ADC (Analog-to-Digital Converter) and DAC (Digital-to-Analog Converter), degrade the efficiency of the power amplifier in the transmitter, make the signal to suffer significant spectral spreading and in-band distortion, and reduce the capability of system. In recent years, many methods for reducing PAPR have been proposed, such as clipping method, signal pre-distortion coding method and selective mapping (SLM) and PTS method, here we use m-sequence to take the place of side information in PTS-OFDM systems for reducing PAPR and calculation complexity. The result can be seen by simulations in paper.

2 Definition of PAPR

In OFDM system, the peak-to-average power ratio of RF signal $s(t)$, that is,

$$PAPR\{\tilde{s}(t)\} = \frac{max|s(t)|^2}{E\{|s(t)|^2\}} \qquad (1)$$

$$PAPR(dB) = 10lg\frac{max|x_n|^2}{E\{|x_n|^2\}} \qquad (2)$$

Where, $E\{\cdot\}$ is mathematics expectation in (1) and (2), therein, the discrete-time signal $x_n$of (2) after IFFT can be expressed as $x_n = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k\, e^{j2\pi kn/N}$, and X_k is the signal in frequency-domain. The above power characteristics can also be measured by defining the crest factor (CF), as RF signals condition:$CF = \sqrt{PAPR} = \frac{max|x_n|}{\sqrt{E\{|x_n|^2\}}}$. For instance, in the PSK/OFDM system with N subcarriers, the resultant peak power can be N times larger than the average power when all of the N subcarrier components happen to be added with identical phases. Assuming that a sequence is applied as the input to IFFT, we can take place of $X_k$by the IFFT of x_n so that the PAPR can be upper-bounded by 2 (i.e., 3dB). This implies that if the complementary sequences are used as the input to IFFT for producing OFDM signals, the PAPR will not exceed 3dB. These two cases are illustrated, between the non-coded OFDM signal with 16-subcarriers and the complementary-coded OFDM signal with 16-subcarries, which can be seen the later reduces the PAPR by about 9dB.

3 Optimum PTS-OFDM System Model

The block diagram of PTS is shown in Figure 1. At the first, the data A= {a_0, a_1, a_2… a_{N-1}} of frequency domain whose length is N is divided into non-overlapping V sections: B_1, B_2… B_V. Each sub-carrier can be only in one section, which has no the other sub-carriers and is filled with “0” for keeping the length of section to be N.

Thus, $$A = \sum_{k-1}^{V} B\kappa \qquad (3)$$

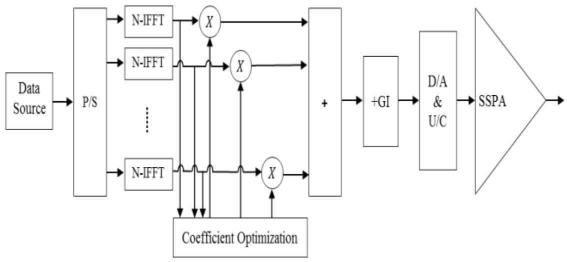

Fig.1 Basic transmitter diagram of PTS-OFDM system

Each sub-carrier in section multiplied by the same rotation factor$C\kappa = e^{j\phi(k)}$,$\phi(k) \in [0, 2\pi)$, and different section could multiply by the same rotation factor. That is for reducing PAPR. Generally, the values of which the phases of the rotation factors are as follows,

$$\phi(k) \in \frac{2\pi i}{W}, i = 0, \dots, W-1 \qquad (4)$$

Therein, W is the number of selected phases, and each sub-carrier multiplied by the rotation factor is that,

$$Y = \sum_{k=1}^{V} B_k \cdot C_k \qquad (5)$$

Y after IFFT can be expressed as:

$$y = \sum_{k-1}^{V} C\kappa \cdot IFFT\{B\kappa\} = \sum_{k-1}^{V} C\kappa \cdot b\kappa \qquad (6)$$

To make PAPR of y be low is by choosing adaptive $C\kappa$. Using IFFT, the advantage of PTS is that to select $C\kappa$ just need to operate $b\kappa$ after IFFT. So, the condition of the optimal rotation factor is expressed as:

$$\{D_1, D_2, \dots, Dv\} = \underbrace{\arg min}_{0 \le w \le W-1} \left(\underbrace{max}_{0 \le u \le U-1} \left|\sum_{k-1}^{V} C\kappa \cdot b\kappa\right|\right) \qquad (7)$$

Where, $\arg\min()$ represents argument for that the given expression achieves the global minimum. In this way, by finding the optimum side information according to equation (6), PAPR distribution of OFDM systems can be improved at the aspect of $V-1$ IFFT transforms.

Theoretically, the side information D_v can be chosen from$[0,2\pi)$, however, D_v can be chosen from a certain discrete group such as $\{\pm 1, \pm j\}$ for reducing the calculation complexity.

The receiver needs to get$\{D_v, v = 1,2, \dots, V\}$. Hence, an unambiguous representation of it must be transmitted to the receiver, which represents the redundancy associated with PTS peak power reduction method.

4 m-Sequence to Reduce PAPR

As far as above, the optimum method of finding side information for reducing PAPR in PTS-OFDM systems needs an amount of complex calculation due to the introduction of V-1 N points IFFT transform and large scale side information D_v. During the search of optimum parameters, the calculated result must be stored for finding the minimum peak value, so the procedure includes the feedback operations to make the system overburden. Therefore, we need a method to cancel the feedback operations in calculating side information.

Assuming D_1=1, then there are only V-1 side parameters which need to be determined. If one n-bit generation polynomial of m-sequence is given, $2^n - 1$ of which will be produced with the different initial states simultaneously. The shift versions of m-sequence are also based on its different initial states. And then m-sequence with length of $2^n - 1$ takes the place of $\{D_v\ (v = 1, \dots, V)\}$ of PTS, in which “0” in m-sequence can be mapped into “1”, while “1” can be mapped into “-1”. According to the characteristics of m-sequence, the occurrence probability of “1” and “-1” in the side information is equal. These sequences can be used as side information for calculation to select the minimum PAPR.

As the result, it is not necessary to send the selected exact m-sequence to the receiver, and only initial state of the selected one is needed. In this case, as long as the receiver can get the accurate information about the initial state of the selected m-sequence, it will lower the transmission bandwidth and some protect requirements of side information.

5 Simulation and BER of systems

The conditions of simulation are all based on IEEE 802.16a standard with adopting QPSK, subcarriers N=256, SUI-3 channel model. During simulation, we assume the receivers can receipt bits of the optimum auxiliary information accurately. The number of simulation frames is 1000; the subcarriers are divided into 8 sub-PTSs; when $D_1 = 1$ in m-sequence of PTS algorithm, the initial state of m-sequence is gotten as ‘10011101’ with length of $2^3 - 1 = 7$ and its shift versions

Figure 2 shows the different curves of the simulation on BER (bit error rate) to SNR (signal to noise ratio) in PTS-OFDM system. It expresses the mPTS and optimum PTS to affect the performance on bit error to the system. From here, we can see these 3 curves are almost coincident, so, that illustrates the effects of mPTS and optimum PTS on bit error is very small.

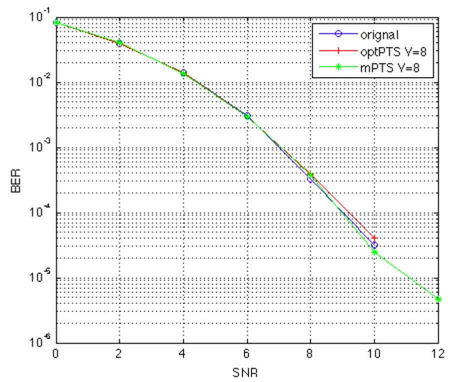

Fig.2 BER of PTS-OFDM System

According to the figure, 1% of symbols have been more than 9.5dB in the original OFDM system. The optimum PTS and mPTS under the same conditions is 6.6dB, 7.6dB respectively, the difference of which is just 1dB, while in both of them, the PAPR threshold that 1% exceeds threshold are 6.8dB and 8.2dB respectively. However, combining with the average time which is spent by each frame optimization, the spent time of optimum PTS is 3,2955s, but the time of m-sequence of PTS is just 0.0014132s. Compared to their algorithms, we can see, the m-sequence of PTS method has lower complexity. Meanwhile, the effect of this method will be increased with the sections of divided subcarriers increasing. In another word, when we choose V=16, the probability that PAPR exceeds a certain threshold is lower than that case in V=8.

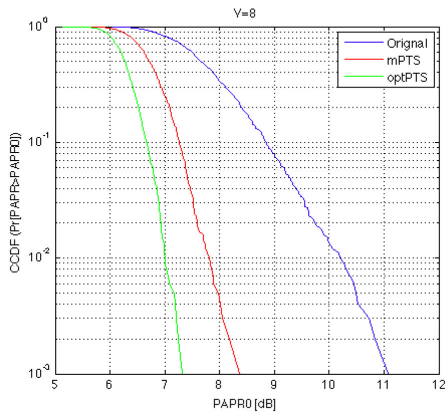

Fig.3 The curves distribution of PAPR in PTS-OFDM system

6 Conclusion

In this paper, m sequence is proposed to take the place of side information in PTS-OFDM for reducing PAPR, which not only lower the calculation complexity obviously, even we increase the divided sub-sequences of PTS for getting the better effects during reducing PAPR, calculation complexity can still be controlled well. In addition, this method which can lower the emergent probability of those high peak signals can improve this kind of probability method of PAPR well.

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