A KIND OF PAPR REDUCTION METHOD BASED ON PRUNING WPM AND PTS TECHNOLOGY

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Abstract  Wavelet packet multicarrier system gains widespread concern because of its better resistance performance to Inter-Symbol Interference (ISI) and Inter-Carrier Interference (ICI), as well as the higher spectrum efficiency. However, multicarrier system has a high Peak to Average Power Ratio (PAPR), which will lead to many problems such as lower system performance. In order to solve the problem, a kind of PAPR reduction method based on pruning Wavelet Packet Modulation (WPM) and Partial Transmit Sequences (PTS) technology is proposed in this paper, through proper pruning of the full-tree structure of wavelet packet modulation in the PTS technology to reduce the number of nodes in the system, and finally improve the reduction effect of PAPR. Simulation results show that when Complementary Cumulative Distribution Function (CCDF) is $10^{-3}$, PTS based on pruning WPM compared with PTS technique and pruning technique has improved about 1 dB and 1.5 dB, which will not affect the system’s Bit Error Rate (BER) performance in the wavelet packet multicarrier system.

Key words  Multicarrier modulation; Wavelet packet; Pruning wavelet packet; Peak to Average Power Ratio (PAPR); Partial Transmit Sequences (PTS) technology

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I. Introduction

Nowadays, for the requirements of different services and service quality, multicarrier modulation technique is widely used in a variety of communication systems, in which wavelet packet modulation technique attract more and more attention because of its high spectrum utilization rate. However, if a plurality of sub-carriers are accumulated in the same direction on a certain moment, a large peak will be produced and this requires a very large linear region in the transmitting power amplifier. Once the signal peaks get into the nonlinearity of the amplifier area, it will lead to signal distortion, thereby destroying the orthogonality between sub-carriers, leading to system performance reduction\(^1\). Normal circumstances, most of the signal peaks are at a relatively stable linear region, only a few peaks fluctuates, blindly increasing the linear region of the power amplifier not only is inefficient, but also greatly increases the cost of the transmitter. Therefore, it is necessary to find an effective method to reduce the signal Peak to Average Power Ratio (PAPR).

At present, for the PAPR problem, there are many literatures, such as Refs. [2,3], pointing at the Fast Fourier Transform (FFT)-based multi-carrier modulation systems; little research pointing at wavelet packet transform-based multi-carrier modulation system is made. Ref. [4] applied the conventional Selective Mapping (SLM) technology to the wavelet packet modulation system, compared with the conventional Orthogonal Frequency Division Multiplexing (OFDM) system, it can more effectively reduce the PAPR value of the system. Refs. [5,6] directly processed on the envelope of the signal, which was also introduced into the orthogonal wavelet packet multiplexing system, it reduced the PAPR value, but also brought the energy leakage, causing the system information loss. So far, Refs. [4–6] are based on full tree structure of wavelet packet modulation, which has the problem of high hardware cost and large calculation load. For this problem, Refs. [7,8] proposed pruning tree structure of wavelet packet modulation, by proper pruning, it can greatly reduce the complexity of the

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system, at the same time achieve better PAPR mitigation effect. In this paper, the thought of Ref. [7] is merged into the Partial Transmit Sequences (PTS) technology, and a new PTS technique based on pruning wavelet packet modulation is proposed. Simulation results prove that when Complementary Cumulative Distribution Function (CCDF) is less than $10^{-1}$, the technology can improve the PAPR performance of the transmitting terminal above 1 dB, which is compared with the single use of the pruning technique or PTS technique.

II. Wavelet Packet Multicarrier Modulation System

As a new broadband transmission technology, Multi-carrier modulation technology can effectively overcome the Inter-Symbol Interference (ISI) of the system, in which high-speed data stream is divided into several separate low-speed sub bit streams that are modulated with a plurality of different sub-carriers to realize the parallel transmission of data. Contrary to the traditional modulation method based on FFT, Wavelet Packet Modulation (WPM) has better resistance to Inter-Carrier Interference (ICI) and resistance to ISI and other excellent features. Therefore, it is widely concerned.

In the multicarrier modulation system based on wavelet packet, the transmitting data respectively modulates the different nodes of wavelet packet functions after series-to-parallel conversion, and the modulated signal $x(t)$ can be expressed below:

$$x(t) = \sum_{(l,m)\in \Gamma} \sum_{n} S_{lm}(n) \phi_{lm}(t - n T_i)$$  \hspace{1cm} (1)

where, $l$ represents the $l$ layer decomposition, $m$ represents the $m$ branch of each layer, and $\phi_{lm}$ represents the basis function of the $m$ branch of the $l$ layer, namely the scale function of $V_l$ scale space. $S_{lm}(n)$ represents the digital signal who modulating the scale function $\phi_{lm}$ at node $(l,m)$; $\Gamma$ represents the collection of sequence $(l,m)$ of wavelet packet functions. Eq. (1) may also be equivalent to the following expressions:

$$x(t) = \sum_l \sigma_{ol}(k) \phi_{ol}(t - n T_0)$$  \hspace{1cm} (2)

where

$$\sigma_{ol}(k) = \sum_{(l,m)\in \Gamma} \sum_n f_{lm}(k - 2^n n) S_{lm}(n)$$  \hspace{1cm} (3)

Here, $f_{lm}$ represents the equivalent filter coefficient from the nodes $(l,m)$ to the root node $(0,1)$, $\phi_{01}$ represents the scale function of $V_0$ scale space. By the above definition, a basic structure of wavelet packet multicarrier modulation systems can be built as shown in Fig. 1. The IDWPT represents Inverse Discrete Wavelet Packet Transformation, namely wavelet packet reconstruction; and DWPT is short for discrete wavelet packet transformation, namely wavelet packet decomposition. Then Fig. 2 is the three-level full tree structure of IDWPT. $X_i, i = 0,1,\ldots,7$ is the input sequence after serial-parallel conversion, $s$ is the wavelet packet modulation signal, and $(l,m)$ is the $m$ tree node of the $l$ layer. Wherein $(-3,0), (-3,1), (-3,2), (-3,3), (-3,4), (-3,5), (-3,6), (-3,7)$ are all the terminal nodes; $(-2,0), (-2,1), (-2,2), (-2,3), (-1,0), (-1,1), (0,0)$ are all the internal nodes; $(0,0)$ is the root node.

III. Definition of PAPR

The PAPR is the ratio of the signal peak power