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Research on SLM Algorithm for PAPR reduction in MB-OFDM UWB Systems

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Abstract

Multiband orthogonal frequency division multiplexing (MB-OFDM) is one of the key techniques of ultra wideband (UWB) systems. A major drawback of MB-OFDM technique is the high peak-to-average power ratio (PAPR) of the transmit signal. In this paper, a novel phase sequence of selected mapping algorithm which makes the side information not needed is designed to lower the PAPR of MB-OFDM UWB signals. It is also shown that comparable PAPR reduction performance with the original SLM algorithm can be achieved with a small increase in signal power. Simulation results show that there must be equilibriums between SLM computational complexity and PAPR performance. The objective of the new algorithm is to lower PAPR close to ordinary SLM technique with reduced computational complexity with little performance degradation and achieves better system resource utilization.

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Keywords: Ultra wideband (UWB); Multiband orthogonal frequency division multiplexing (MB-OFDM); Peak-to-average power ratio (PAPR); Selected mapping (SLM); Complementary cumulative density function (CCDF)

1. Introduction

With high spectrum efficiency and strong resistance to multipath fading, multi-band orthogonal frequency division multiplexing (MB-OFDM) becomes one of the key techniques of ultra wideband systems. 3.1-10.6GHz bandwidth divided into 14 sub-bands, and bandwidth efficiency is very high to support high-speed wireless data transmission. One of the major drawbacks of MB-OFDM technique is the high peak-to-average power ratio (PAPR) of the transmit signal which affects directly the efficiency of the system. Certain techniques must be used to reduce the PAPR signal, so that the transmitter power amplifier works efficiently and overall system performance can improve remarkable.

After inverse fast Fourier transform (IFFT), the MB-OFDM signal is modulated with N sub-carriers, MB-OFDM symbol sequence is X, $X=\left[X_0 \quad X_1 \quad \cdots \quad \cdots \quad X_{N-1}\right]^T$, and the symbol period is T. N sub-carriers are orthogonal. MB-OFDM signal can be illustrated as:

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$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi nt/NT}, \; 0 \le t \le NT \quad (1)$$

Compared with the single-carrier system, the MB-OFDM signal is modulated by a number of independent sub-carrier signals which is likely to produce peak power, which will bring out peak average power ratio (PAPR). PAPR can be defined as:

$$\gamma_{PAPR}(dB) = 10\lg \frac{\max\{|x(t)|^2\}}{E\{|x(t)|^2\}} \quad (2)$$

So far, a lot of PAPR reduction techniques is brought out, which can be divided into three categories: amplitude restriction, encoding and probability.

Amplitude restriction technique uses a nonlinear method to limit the MB-OFDM signal at or near peak to reduce the PAPR value, which will cause intra-band interference and inter-band noise. Specific methods include amplitude limiting filter, peak windowing and peak cancellation [3]. Encoding technique limits the subsets of codeword, while those below the threshold of the peak codeword can be selected for transmission. It completely avoids the high PAPR which reduces the data transfer rate at the same time. Specific methods are block coding, sequence complement Gray mapping and sequence mapping [4]-[5]. Probability technique does not focus on reducing the signal peak, but reducing the probability of peak. A number of alternative signals were got from the original signal and the lowest PAPR signal was chosen for transmission with some information redundancy. Specific methods include: selective mapping (SLM), partial transmit sequence (PTS), pulse shaping (PS) [6]-[9].

Generally, PAPR is represented as the probability that the signal is greater than a threshold, which is called the complementary cumulative distribution function (CCDF). Assuming the signal between sampling points are independent, the PAPR value of the MB-OFDM signal is greater than the probability threshold is:

$$P_r\{\delta\} = P_r\{\gamma_{PAPR} > \delta^2\} = 1 - (1 - e^{-\delta^2})^N \quad (3)$$

If the over-sampling is considered here, it is difficult to obtain accurate expression of the signal PAPR value. We can assume that N sub-carrier signal PAPR distribution is substantially the same as that of LN sub-carrier signal, while over-sampling factor L is greater than 1. This is roughly equivalent to the impact of a certain number of additional independent samples are added, and its CCDF can be simply replaced N by LN [10]-[13].

2. System Model

In the traditional SLM algorithm, the receiver must know which phase sequence is selected at the transmitter for transmission, which results in the sacrifice of part of the bandwidth for side information transmission. Therefore, side information is very important. Channel encoding is used to protect the accuracy of side information usually, and some more bandwidth would be wasted.

In our new SLM algorithm, a new phase sequence is provided. In the traditional SLM algorithm, the magnitude of the rotation vector is 1, and the phase changes. But in our new phase sequence, part of the vector magnitude will be greater than 1, and the rest of the vector remain unchanged as the value to 1. After such a vector multiplication, most of the OFDM data signal remains the previous value, the rest is modulated. The new rotation sequence does not need to send side information.

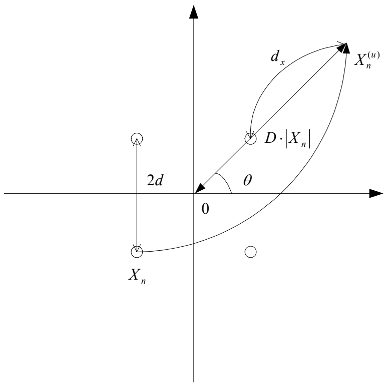

Fig. 1 new rotation vector in QAM constellation

In our new SLM algorithm, MB-OFDM symbol sequence copies U times. The u phase sequence is $P^{(u)} = [p_0^{(u)}, p_1^{(u)}, \cdots, p_{N-1}^{(u)}]^T$ where $p_n^{(u)} = (De^{j\pi})^{k_n^{(u)}}$, $k_n^{(u)} \in \{0,1\}$, $n = 0,1,\cdots,N-1$, $u = 1,2,\cdots,N$. D is magnitude gain. For $(De^{j\pi})^{k_n^{(u)}}$, when $k_n^{(u)}$ equals to 0, rotation vector is 1; while $k_n^{(u)}$ equal to 1, the phase sequence can be regarded as being modulated, as indicated in Figure 1. In fact, we can see $P^{(u)}$ depends on $k_n^{(u)}$. After a vector multiplication, most of the data signal to maintains the original value, and only a small part is modulated. The computational complexity greatly reduced.

The value of D is very important, because the receiver must recover the transmission signal at the absence of sideband. As indicated in Figure 1, in order to receive data signal correctly and control transmitter symbol error rate (SER), $D = (\sqrt{2}d + d_x)/(\sqrt{2}d)$, while $d_x \geq 2d$.

At the receiving side, we need to know that if the symbol sequence is modulated. After fast Fourier transform (FFT), phase sequence estimation $\hat{p}_n^{(u)} = (De^{j\pi})^{\hat{k}_n^{(u)}}$ must be re-generated. If symbol sequence is modulated, $\hat{k}_n^{(u)} = 1$; Otherwise $\hat{k}_n^{(u)} = 0$. Generated phase sequence compares with all phase sequence and calculates Hamming distance, and the phase sequence with the smallest Hamming distance is selected as the one that is used at the transmitter.

3. Simulation Results

The number of MB-OFDM sub-band is 14, and sub-band bandwidth is 528MHz. $N = 128$, and MB-OFDM symbol number is 2048. Figure 2 shows PAPR. of sampling signal.

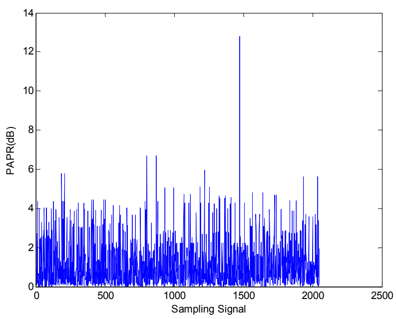

Fig. 2 PAPR value of MB-OFDM system

The new SLM algorithm uses QAM modulation, $L=4$, $U=8$, $D=2.4$. The maximum allowable number of modulated subcarriers M is taken 1,2,4. Figure 3 shows the simulated curve.

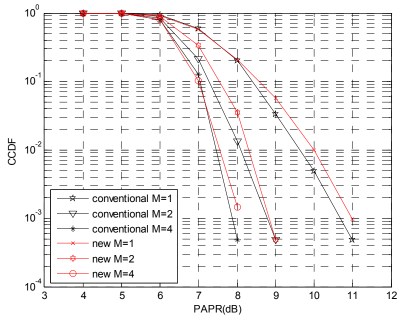

Fig. 3 Simulation result of the new SLM algorithm

From Figure 3, the new SLM PAPR reduction algorithm is very effective, close to the traditional SLM algorithm. More important, it eliminates the transmission of side information. Without side information transmission, the new SLM PAPR reduction algorithm is very effective with a small increase in power, and the whole system maintains a good SER.

4. Conclusions

In this paper, a new SLM improved algorithm is proposed. With a small increase in power, improved algorithm uses a new phase sequence without side information. However, phase sequence estimation at the receiver side increases the complexity, and multi-channel operation of IFFT still remains.

5. Acknowledgement

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