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Research paper

An Optimal Tone Mapping Technique with Random Phase Sequence Matrix for PAPR Reduction in Wireless OFDM Systems

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Abstract

Orthogonal frequency division multiplexing (OFDM) is most popular technique for wireless multimedia communication due to its extraordinary property that makes it reliable in frequency-selective fading conditions. Despite of its popularity OFDM faces some challenging issues which is difficult to solve. One such issue is peak to average power ratio (PAPR).this paper proposes an optimal tone mapping technique that employs a random phase sequence matrix for complex less PAPR reduction (OTM-PAPR). It works on pre- coding the message symbol constellation using tone mapping . Initially multiplication of phase rotation factor is done and inverse fast fourier transform is done. The optimal tone mapping is achieved by an improved multi-objective fish swarm optimization (IMFSO) algorithm. Here, an OFDM system is implemented using quadrature phase shift keying modulation technique in MATLAB software. The results show that the performance of proposed OTM-PAPR technique is very efficient in terms of PAPR value and computational complexity reduction ratio.

Keywords: *OFDM, PAPR, IFFT, optimal tone mapping, QPSK modulation.*

1. Introduction

OFDM is an efficient transmission scheme that employs multiple subcarriers to carry the information. This technology claims to be the future generation boon for wired and wireless digital communicatio system due to its ability to transmit data at a faster rate, improved spectral efficiency, efficient quality of service and highly robust against narrowband interference and frequency selective fading [1]-[3]. OFDM handles Inter Symbol Interference (ISI) effectively by introducing a guard interval which is obtained by cyclic prefix method. By using a simple equalizer, frequency selectivity of the multipath channel is reduced [4]. OFDM has emerged as a widely accepted technique in enormous communication standards like digitized audio broadcasting(DAB), digital video broadcasting (DVB), wireless local area networks(WLAN), wireless metropolitan area networks(WMAN), wireless personal area networks(WPAN) and also in 3G, 4G, 5G networks [5]. Inspite of its popularity, OFDM still suffers a major drawback of peak to average power ratio in the modulated signal [6]. Generally, a high radio frequency power amplifier is used to get zero distortion, which must operate in its linear region and must have back-off. Thus for an OFDM system, high power amplifier with a wide dynamic range are required. But these amplifiers are highly expensive and are considered as costly component. Thus, in order to reduce the cost of the components used in OFDM system and to bring down the complexity of the hardware components, it is required to reduce the problem of peak average to power ratio. At the same time it must also try to increase the transmitted power, thus increasing the received signal to noise ratio [7]. In any case paying little notice to having these inspiration, there are coupole of inferiorities in which peak average to power ratio is utmost consideration as it causes severe degradation in thee signal to be transmitted which in turn leads to error in the transmission [8]. Generally PAPR introduces intermodulation problem and gives out of band radiation when it passes through non linear devices. [9]. In OFDM, the data sequences which has the same phase will be added coherently, due to which the peak become above the average signal- a problem known as peak to average ratio. Thus in PAPR the peak power of the signal will be much higher than the average power of the system. In order to obtain required power for transmission of signals, most of the radio systems uses high power amplifiers in the transmitter [10].

2. Problem Methodology and System Model

2.1. Problem Methodology

PAPR problem is emerging in OFDM systems which causes non-uniform power spectrum with respect to input of uniform power spectrum. Non uniformity in the power spectrum is identified as peak average to power ratio and it introduces severe degradation of the transmitted signal in an OFDM system. It also increases hardware complexity and reduction in gain of the signal. So it is identified to reduce the distortion caused by PAPR in the transmitted signal. It may also produce intermodulation distortion between the subcarriers of OFDM system and it can also cause distortion in the constellation diagram of the transmitted signal. Thus, power amplifiers must be designed with high power back-off.

For this reason, an optimal tone mapping technique is proposed to compute the random phase sequence matrix (RPSM) using improved multi-objective fish swarm optimization (IMFSO) algorithm for complex less PAPR reduction (OTM-PAPR). The main contributions of proposed OTM-PAPR scheme as follows:

- OTM-PAPR scheme is based on pre-coding the constellation symbols with tone mapping after the multiplication of phase rotation factor and before the IFFT in the OFDM signal.
- The optimal tone mapping technique reduces the peak of the signal with the help of counter sequence is provided initially. A predetermined threshold value is included in the algorithm to act as a reference. It compares the data sequence and whenever the value crosses the threshold then the counter sequence value is transmitted.
- The simulations implement by using MATLAB software is carried out by quadrature phase shift keying is used. The results show that the performance of proposed OTM-PAPR technique is very efficient in terms of PAPR value and computational complexity reduction ratio.

2.2. System Model of OTM-PAPR Technique

In OFDM system model, the training sequence is forwarded by serial to parallel (S/P) convertor. Each parallel sequence is converted into fixed length which is then given to inverse fast fourier transform block. After that a guard band is inserted and is given to parallel to serial converter and then it is passed on to the channel where it gets affected by additive white Gaussian noise. In the receiver side, the data sequence will be converted into parallel sequence where the guard interval is removed and then fast fourier transform is performed on the incoming sequence. Assuming first that a QPSK modulation will be used here, the input binary data is mapped according to this modulation scheme. After passing the data stream to serial to parallel block, a pilot signal is inserted in all the subcarriers at a specific time period spaced at equal interval for a given OFDM symbol. Then, the data stream is passed to IFFT block which converts the frequency domain sequence into time domain and the base band signal can be represented mathematically as:

$$p(t)=\frac{1}{\sqrt{p}}\sum_{n=0}^{N-1}P_n e^{\frac{j2\pi nt}{P}}; \qquad 0\le t\le P-1 \tag{1}$$

where P_n is the modulated data signal expressed in frequency domain, P is number of subcarriers. Peak average to power ratio is defined as the ratio of maximum power to average power of the system and is represented as follows:

$$PAPR\left(p(t)\right)=\frac{Max_{0\le t\le P-1}\left|p(t)\right|^2}{E\left[\left|p(t)\right|^2\right]} \tag{2}$$

where $E[\cdot]$ specifies the expectation operator. The PAPR problem mainly are raised by the presence of sinusoidal signals which has different frequency and phase shift. Another major factor associated with PAPR is the complementary cumulative distribution function, that is used to measure the efficiency of PAPR method. The crest factor (CF) is defined as the square root of PAPR.

$$CF=\sqrt{PAPR} \tag{3}$$

The CCDF expression for PAPR of OFDM signals is expressed as follows:

$$CCDF_{PAPR}=Max_{0\le t\le P-1}\frac{p(t)}{E\left[\left|p(t)\right|^2\right]} \tag{4}$$

The power pectral density of the OFDM signal is calculated and compared with the predefined threshold value. The instantaneous power is found by calculating the CCDF for various values of PAPR. It can also b4 denoted as:

$$CCDF=P_n\left(PAPR>CCDF_{PAPR}\right) \tag{5}$$

The block diagram of the proposed PAPR reduction scheme is shown in Fig. 1. Here the incoming serial data block is partitioned into disjoint sub block, where weight optimization of each sub block is done by multiplying by a phase weighting factor which can be obtained by a proposed algotrithm.

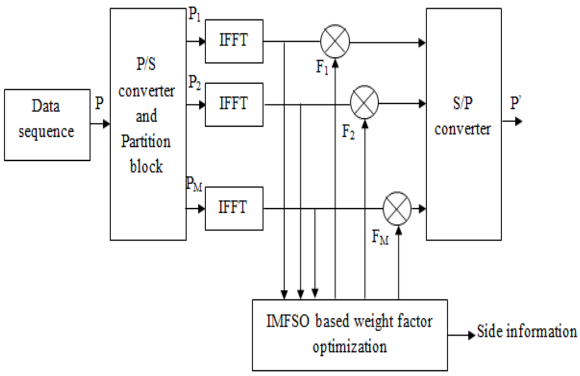

Fig. 1: System model of proposed OTM-PAPR scheme

The optimal tone mapping considers input as weight factor F' and their function is represents as $F'(p)$ and the output IFFT $F''(p)$ is defined as follows:

$$F''(p)=i_{\max}\times\frac{1-e^{\frac{-F'(p)}{F'_0(p)}}}{1-e^{\frac{-F'(p)}{F'_{\min}(p)}}} \tag{6}$$

where $F'_{\max}$ is the maximum intensity value for the display device and $F'(p)$ the adaptation factor and it is computed as follows:

$$F'(p)=K_1\times\mu_x+\frac{(i*h)(p)}{2} \tag{7}$$

where $(K_1\times\mu_x)$ is the global component with the μ_x denotes the global mean of input image and $\frac{(i*h)(p)}{2}$ the local component because convolution operation $(*)$ is a local process.

3. Weight Factor Optimization Using I proved Multi-Objective Fish Swarm Optimization (IMFSO) Algorithm

Fish swarm (FS) [11] is one of the algorithms that gets its name from the actual behavior of the fish swarm. This algorithm shows the property that it can converge at a faster rate, independent of initial value, can handle any type of distortions and highly robust. The proposed improved multi-objective fish swarm optimization (IMFSO) algorithm is for time varying and changing environments. All the constraints of a changing environment is satisfied by this algorithm. In IMFSO algorithm, actual behaviors of conventional FS optimization algorithm is modified by the new parameter i.e. entropy of weight vector. IMFSO scenario can be articulated by a matrix called decision matrix (DM) and it is comprises of n number of multi-functional trust attributes $A_1, A_2 \cdots A_n$ and m number of possible solution $S, S_2 \cdots S_m$ for weight vector calculation.

$$DM = \begin{array}{c} \\ S_1 \\ S_2 \\ \vdots \\ \vdots \\ S_m \end{array} \begin{array}{c} \begin{array}{ccccc} A_1 & A_2 & \cdots & \cdots & A_n \end{array} \\ \begin{bmatrix} i_{11} & i_{12} & \cdots & \cdots & i_{in} \\ i_{21} & i_{22} & \cdots & \cdots & i_{2n} \\ \vdots & \vdots & \ddots & & \vdots \\ \vdots & \vdots & & \ddots & \vdots \\ i_{m1} & i_{m2} & \cdots & \cdots & i_{mn} \end{bmatrix} \end{array} \quad (8)$$

In weight vector calculation the set of weight W_S is employed to the m feasible solutions and the set of importance weight W_t is applied to the calculation of first decision maker.

$$W_s = \{W_{s1}, W_{s2}, \cdots W_{sl}\} \quad (9)$$

$$W_t = \{W_{t1}, W_{t2}, \cdots W_{tl}\} \quad (10)$$

The arrangement of entropy qualities for every measure is then used to compute the entropy weights. So as to figure entropy weights with which to change the choice network for a computation a level of contrast is gotten by subtracting entropy from one:

$$d_x = 1 - E(C_x) \text{ where } x = 1,2,\ldots,m \quad (11)$$

The degree of difference expresses the inherent contrast intensity among the assessments of each criterion. The greater the relative value of di the more important that criteria is in discriminating between the n alternatives, and the greater weight it is objectively assigned in the calculation. The entropy weight W for each criteria x is then calculated to form the set of entropy weights (W_e).

$$W_x = \frac{d_x}{\sum_{x=1}^{m} d_x},\ x = 1,\ 2,\ldots,m \quad (12)$$

$$W_e = (W_1, W_2, \cdots W_x, W_m) \quad (13)$$

$$\text{where} W_x \geq 0, \sum_{x=1}^{m} W_x = 1$$

The choice grid of fluffy numbers is then balanced by the figured entropy weights and the leader's criteria weights.

4. Result and Performance Analysis

In this section, the performance of proposed OFDM-PAPR scheme is analyzed by different metrics and the simulation of OFDM system is implemented using MATLAB software by employing quadrature phase shift keying technique in OFDM. The subcarriers selected in this scheme is set as P which corresponds to 128, 256 and 512 with the sub blocks 'M' is considered as 2 and 4. Here, PAPR is measured for three different values of trade-off factors, B = 0.5, 1 and 2.To evaluate the complementary cumulative distribution function of PAPR, random integer frames of OFDM have been generated. To obtain accurate PAPR calculations the signal is over sampled in the presence of noise. An additive white Gaussian noise was introduced in the channel during data transmission. The improvement of the proposed OTM-PAPR scheme is compared with existing PTS scheme with same simulation parameters. The simulation parameter of proposed scheme is summarized in Table 1

Table 1: Simulation parameters

Parameter	Value
Number of sub-carriers (P)	128, 256 and 512
Number of sub-blocks (M)	2 and 4
Modulation scheme	QPSK
Phase weighting factor (B)	0.5, 1 and 2
Number of generated OFDM signal	1000

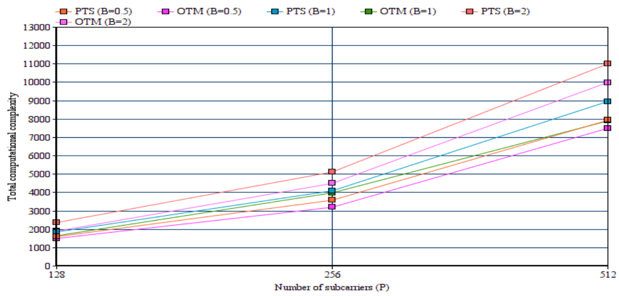

Fig. 2: Performance comparison of total computational complexity for M = 2

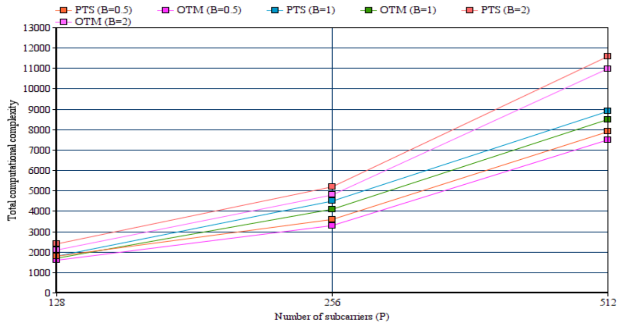

Fig. 3: Performance comparison of total computational complexity for M = 4

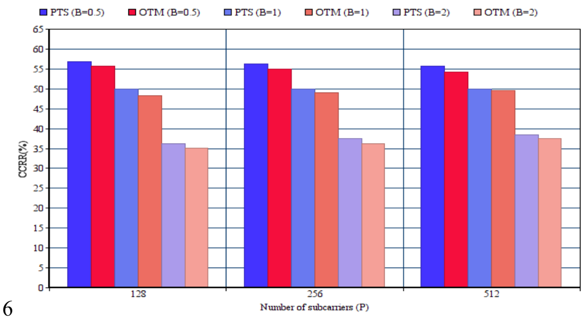

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Fig. 4: Performance comparison of CCRR for M = 2

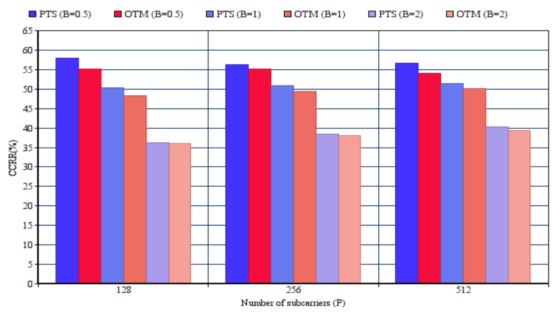

Fig. 5: Performance comparison of CCRR for M = 4

5. Conclusion

We have proposed an optimal tone mapping technique for complex less PAPR reduction (OTM-PAPR). The constellation symbol with tone mapping is performed after the multiplication of phase rotation factor and before the IFFT in the OFDM signal.

The improved multi-objective fish swarm optimization (IMFSO) algorithm is used to achieve the random phase sequence matrix (RPSM). For performance analysis the proposed OTM-PAPR scheme have implemented an MATLAB with OFDM system employing QPSK modulation. The simulation results prove the effectiveness of proposed OTM-PAPR scheme in terms of PAPR value, total computational complexity and computational complexity reduction ratio (CCRR).

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