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Using evolutionary computation technique for trade-off between performance peak-to average power ration reduction and computational complexity in OFDM systems ☆

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ABSTRACT

A low-complexity partial transmit sequence (PTS) technique for reducing the peak-to-average power ratio (PAPR) of an orthogonal frequency division multiplexing (OFDM) system is presented. However, PTS technique requires an exhaustive search over all combinations of allowed phase weighting factors, and the search complexity increases exponentially with the number of sub-blocks in OFDM system. Hence, there has been a trade-off between performance PAPR reduction and computational complexity in PTS OFDM system. The proposed is a sub-optimum PTS for PAPR reduction of OFDM system. Simulation results demonstrate that the superiority of evolutionary computation technique-particle swarm optimization (PSO) based on PTS which can be utilized for finding the optimum phase weighting factors, and can achieve the lower PAPR and computational complexity of OFDM systems. In addition, our evolutionary computation technique can be used to reduce reduction PAPR with comparable performance to genetic algorithm-based PTS, with much less computation cost.

1. Introduction

Orthogonal frequency division multiplexing (OFDM) technique is a very attractive technique for high bit transmission in a radio environment [1]. The high peak-to-average power ratio (PAPR) is the main drawback of the OFDM system, in which the OFDM transmitters require expensive linear amplifiers with wide dynamic range. Moreover, the amplifier non-linearity will cause inter modulation products resulting in unwanted out-of-band power and increased interference. Recently, many reductions PAPR have been proposed for OFDM system, as clipping [2] and peak windowing, block coding [3], scrambling [4], nonlinear commanding transform schemes [5,6]; OFDM is an attractive technique for achieving high bit rate selective mapping [7,8] and phase optimization [9–13], and both are the most attractive ones due to their good system performance and low-complexity.

Among these methods, partial transmit sequences (PTS) scheme is the most efficient approach and a least distortion-less scheme for PAPR reduction by optimally combining signal sub-blocks. In PTS technique, the input date block is broken up into disjoint sub-blocks. The sub-blocks are multiplied by phase weighting factors and then added together to produce alternative transmit containing the same information. The phase weighting factors, which amplitude is usually set to 1, are selected such that the resulting PAPR is minimized. The number of allowed phase weighting factors should not be excessively

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high, to keep the number of required side information bits and the search complexity within a reasonable limit. However, the exhaustive search complexity of the ordinary PTS technique increases exponentially with number of sub-blocks, so it is practically not realizable for a large number of sub-blocks. To find out a best weighting factor is a complex and difficulty problem.

The advent of evolutionary computation has inspired new resources for optimization problem solving, such as the optimal design of code division multiple access (CDMA) and fuzzy system. In contrast to traditional computation systems which may be good at accurate and exact computation, but have brittle operations, evolutionary computation provides a more robust and efficient approach for solving complex real world problem. Many evolutionary algorithms, such as genetic algorithm (GA) [14,15], ant colony optimization (ACO) [16], simulated annealing (SA) [17] and particle swarm optimization (PSO) [18–24], have been proposed. GAs is stochastic search procedures based on the mechanics of natural selection, genetics, and evolution. Since they simultaneously evaluate many points in the search space, they are more likely to find the global solution of a given problem. PSO is a population-based stochastic optimization technique based on the movement of swarms and inspired by social behavior of bird flocking or fish schooling. Compared with GA [14,15], PSO has some attractive characteristics. It has memory, so the knowledge of good solutions is retained by all particles; whereas in GA, previous knowledge of the problem is destroyed once the populations changed. It has constructive cooperation between particles, particles in the swarm share information between them. In this paper, we present a novel approach to tackle the PAPR problem to reduce the complexity based on the relationship between the phase weighting factors and the sub-block partition schemes. Specifically, we apply the PSO to search the optimal combination of phase factors with largely reduced complexity. Numerical results show that the proposed scheme can achieve better PAPR reduction with lower computational complexity compared with that of the GA approaches.

The rest of this paper is organized as follow. In Section 2, definition of PAPR of OFDM system and the principles of PTS techniques are introduced. The particle swarm optimization algorithm-based PTS OFDM system has been examined in Section 3. Section 4 provides some performance results and a comparison of the proposed method with related work. Some conclusions are given in Section 5.

2. OFDM system and partial transmit sequence (PTS) scheme

2.1. Peak-to-average power ratio (PAPR) definition

In contemporary implementation of OFDM system, inverse fast Fourier transform has usually been used to modulate multiple sub-band signals in an OFDM symbol. For an OFDM system with N subcarriers, the complex baseband signal can be written as

$$X(t) = \frac{1}{\sqrt{N}} \sum_{N-1}^{n=0} X_n \exp(j2\pi n \Delta f t), \quad 0 \leqslant t \leqslant NT \tag{1}$$

where X_n is the data symbol at nth subcarrier, Δf is the subcarrier frequency spacing. The PAPR of the transmitted signal in (1) is defined as

$$\text{PAPR} = \Omega = \frac{\max_{0 \leqslant t \leqslant T} |x(t)|^2}{E[|x(t)|^2]}, \tag{2}$$

where $\max |x(t)|^2$ is the maximum values of the OFDM signal power, and $E[\bullet]$ is the average of those value. In principle, PAPR reduction techniques are concerned with reducing $\max |x(t)|$. However, since most systems employ discrete-time signal, the amplitude of samples of $x(t)$ is dealt with in many of the PAPR reduction techniques. Usually, complementary cumulative distribution function (CCDF) is used to measure the performance of PAPR reduction techniques, which denotes the probably that the PAPR of OFDM symbols Ω exceeds a given thresholds Ω_0. By applying the central limit theorem while assuming that the number of sub-channels is sufficiently large, the time domain symbol is approximately zero-mean complex Gaussian distributed and the power distribution becomes a central chi-square distribution with two degrees of freedom.

2.2. Partial transmit sequence

In the PTS technique, an input data a block of N symbols is partitioned into disjoint sub-blocks. The subcarriers in each sub-block are weighted by a phase weighting factor for that sub-block. The phase weighting factors are selected such that the PAPR of the combined signal is minimized. For further PAPR reduction, the PTS scheme can be easily combined with the investigated symbol transform scheme. The principle structure of PTS method is shown in Fig. 1 as that in [11]. PTS method is to divide data block into sub-blocks or clusters and then multiply the appropriate phase weighting factors to each sub-blocks to reduce PAPR. We define the data block as a vector $\mathbf{X} = [X_1 \quad X_2 \quad \dots \quad X_N]^T$. Then, X is partitioned into M disjoint sub-blocks represented by the vector $\mathbf{X}$ such that

$$\mathbf{X} = \sum_{i=1}^{M} \mathbf{X}_i \tag{3}$$