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Particle Swarm Optimized Selective Mapping for PAPR Reduction

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Abstract –**OFDM is a bandwidth efficient multicarrier modulation where the available spectrum is divided into subcarriers, with each subcarrier containing a low rate data stream. OFDM has gained a tremendous interest in recent years because of its robustness in the presence of severe multipath channel conditions with simple equalization, robustness against Inter-symbol Interference (ISI), multipath fading, in addition to its high spectral efficiency. However, the Peak-to-Average Power Ratio (PAPR) is a major drawback of multicarrier transmission system such as OFDM. This paper is focused on learning the basics of an OFDM System and have undertaken various methods to reduce the PAPR in the system like companding, SLM, Random Screening-Selective Mapping (RS-SLM) and Particle Swarm Optimization-Selective Mapping (PSO-SLM). The PSO-SLM form largely reduces the PAPR in the system**

Keywords – **Companding, ISI, OFDM, PAPR, SLM, RS-SLM, PSO-SLM.**

I. INTRODUCTION

With the advent of new high data rate wireless applications, demand of the spectrum is rapidly increasing. Communications governmental and regulatory agencies impose regulations on spectrum usage, such as control of allocations and priorities, as well as its features. At this time, most of the prime spectrum has been assigned and it is difficult to find spectrum for the new wireless applications. It can be made available for either expand existing infrastructures or invent new services. Even though much of the spectrum has been allocated and preliminary measurement is that the spectrum is unutilized by primary users. There exist a lot of spectrums holes, which can be easily used by secondary users. FCC is currently working on the concept of dynamic spectrum access, where secondary users can borrow un-used portions of the spectrum from primary users. Cognitive Radio (CR) is employing on proper spectrum utilization because of their rapid adaptability and flexibility.

Orthogonal Frequency Division Multiplexing (OFDM) is promising candidate for flexible spectrum pooling in communication systems [1]. CR is an emerging technology, which intelligently detects a particular segment of the radio spectrum currently in use and selects unused spectrum without interfering to licensed users. One of the challenges of the OFDM is high peak-to-average power ratio (PAPR). A high PAPR brings disadvantages like an increased complexity of the A/D and D/A converters and reduced efficiency of radio frequency (RF) power amplifier. OFDM signal consists of a number of independent modulated subcarriers that leads to the problem of PAPR. If all subcarriers come with same phase, the peak power is N times the average power of the signal where N is the total number of symbols in an OFDM signal. Thus, it is not possible to send this high peak amplitude signals to the transmitter without reducing peaks. Because power amplifier used for the transmission has non-linear nature which causing inter-modulation and out-of-band radiation. The high peak of OFDM signal can be reduced in several ways. The focus of this paper is on OFDM based CR, which can handle the apparent spectrum scarcity and enable high data rate communications. The proposed system exhibits high PAPR reduction for non-contiguous bands spectrum of OFDM based CR

II. PROPOSED METHOD

Companding

In companding the OFDM signal is compressed at the transmitter and expanded at the receiver. Compression is performed according to the well-known μ-Law viz.

$$y = V\,\frac{\log\left[1+\mu\frac{|x|}{V}\right]}{\log(1+\mu)}\,\mathrm{sgn}(x) \qquad (1)$$

Where V is the peak amplitude of the signal, and x is the instantaneous amplitude of the input signal. Decompression is simply the inverse of equation (1).

Selective Mapping (SLM)

In selective mapping (SLM) technique [2] the actual transmit signal lowest PAPR is selected from a set of sufficiently different signals which all represents

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the same information. SLM Techniques are very flexible as they do not impose any restriction on modulation applied in the subcarriers or on their number.

After applying the SLM technique, the complex envelope of the transmitted OFDM signal becomes,

$$x\,(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} x_n e^{j2\pi n\Delta f t} \quad , (0 \leq t \leq NT) \quad (2)$$

Where $\Delta f = \frac{1}{NT}$, and NT is the duration of an OFDM data block. Output data of the lowest PAPR is selected to transmit. PAPR reduction effect will be better as the copy block number U is increased. SLM method effectively reduces PAPR without any signal distortion. But it has higher system complexity and computational burden. This complexity can less by reducing the number of IFFT block.

Random Screening-Selective Mapping (RS-SLM)

SLM scheme would select one sequence after IFFT modules, thus it need N IFFT modules, which makes system highly complicated. According to [3], the more random the sequence is, the smoother the frequency spectrum will become. Thus in order to reduce the complexity of this system, we propose an improved algorithm which is called RS-SLM. This scheme selects one sequence with the best randomness before IFFT modules, thus only one IFFT module is necessary, saving the complexity of the system.

Particle Swarm Optimized-Selective Mapping (PSO-SLM)

In order to obtain more effective reduction in PAPR, the SLM scheme would select one sequence after IFFT modules, thus it need N IFFT modules, which makes system highly complicated. According to [3], the more random the sequence is, the smoother the frequency spectrum will become. Thus in order to reduce the complexity of this system, we propose an improved algorithm which is called Selective Mapping with Particle Swarm Optimization (PSO). This scheme selects one sequence with the best randomness before IFFT modules, thus only one IFFT module is necessary, saving the complexity of the system. The principle of PSO-SLM can be expressed as followed:

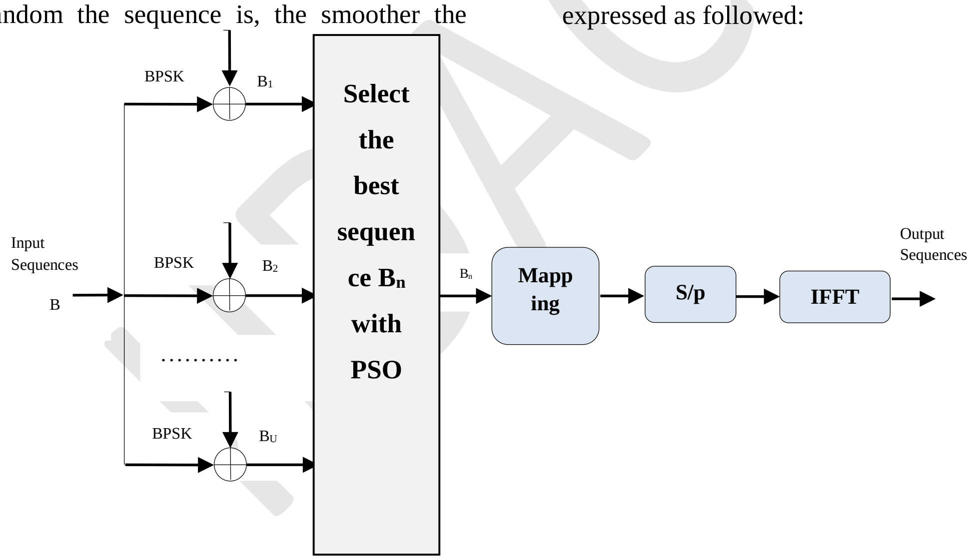

Figure 1: Block diagram of PSO-SLM principle

The specific process of the PSO-SLM scheme is represented as follows:

Suppose the input random sequence B is:

$$B = (x_1, x_2, x_3, \ldots . x_N) \quad (3)$$

Where the number of subcarriers is N, x_n ($1 \leq n \leq N$), which is either 0 or 1. The BPSK is adopted to modulate the input signal sequences as:

$$B_n = (x_{n,1}, x_{n,2}, x_{n,3}, \ldots . x_{n,N}) \qquad (1 \leq n \leq U) \quad (4)$$

B_n is composed of 1 and -1, PSO-SLM selects one sequence which has the best randomness as the output. In this scheme the key point is judge the extent in randomness of the sequence:

1. Judging the nature of randomness of B_n sequences. The closer the number of 1 and -1 is, the more random the sequence is, supposing:

$$S_n = \sum_{i=1}^{N} x_{n,i} \qquad (1 \leq n \leq U) \quad (5)$$

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Where $S_n > 0$ represents the numbers of 1 that is greater than -1, $S_n < 0$ stands for the opposite scenario. The S_n approaches 0, the randomness of the sequence increases.

2. Judging the numbers of B_n sequence's oscillation which is adding the number of sequence's transitions first, and then compare it with half of the sequence's width. Suppose:

$$T_n = \sum_{i=1}^{N-1} \left| \frac{x_{n,i+1} - x_{n,i}}{2} \right| - \frac{N}{2} \qquad (1 \le n \le U) \qquad (6)$$

Then when the T_n is smaller, the nature of random of the sequence is better.

3. Removing the sequences that has a smaller period, As the sequences with short period usually have a high PAPR, we need to exclude them, suppose:

$$W_{n,1} = \sum_{k=1}^{N-2} x_{n,k}, x_{n,k+2} \qquad (1 \le n \le U) \qquad (7)$$

$$W_{n,2} = \sum_{k=1}^{N-3} x_{n,k}, x_{n,k+3} \qquad (1 \le n \le U) \qquad (8)$$

$W_{n,1}$ and $W_{n,2}$ present the coefficient of autocorrelation when τ = 2 or τ = 3, respectively, while the period of one sequence is small, these prices will be great. Therefore, when the price of $W_{n,1}$ and $W_{n,2}$ are smaller, the period of the sequence will be longer. Thus we obtain four indexes for judging the randomness of one sequence, S_n, T_n, $W_{n,1}$, $W_{n,2}$.

On the basis on this concept, we replace the calculation and give all signals to Particle Swarm Optimization as input so that optimized signal will have minimum randomness thus at the end it will get selected for further processing.

III. Simulation And Results

The performance of proposed algorithms has been studied by means of MATLAB simulation.

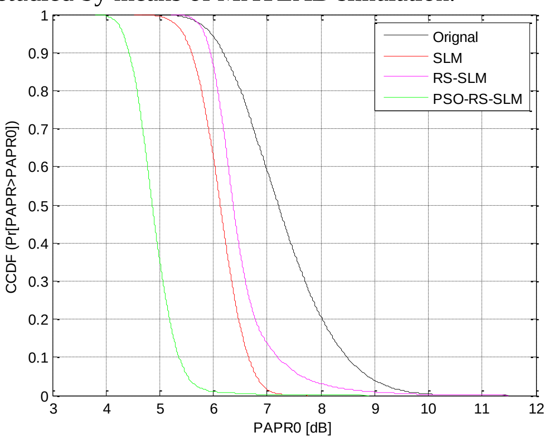

Figure 2: Standard CCDF v/s PAPR calculation graph with FFT=128

The above simulation result shows the comparative graph between CCDF and PAPR with FFT=128 for original signal, SLM, RS-SLM and PSO-RS-SLM. The X axis indicates the PAPR value and Y axis represents CCDF. It can be observed by above graph that the PSO-RS-SLM outperforms than other methods.

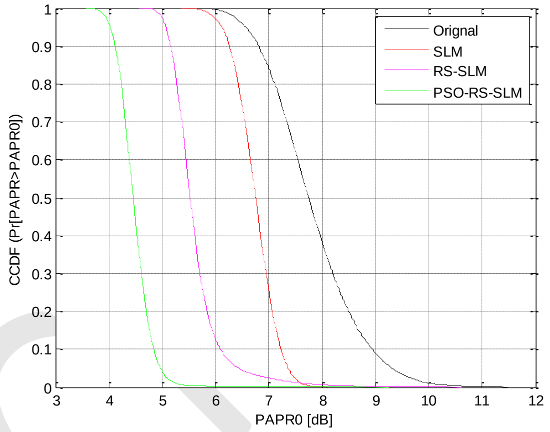

Figure 3: Standard CCDF v/s PAPR calculation graph with FFT=256

The above simulation result shows the comparative graph between CCDF and PAPR with FFT=256 for original signal, SLM, RS-SLM and PSO-RS-SLM. The X axis indicates the PAPR value and Y axis represents CCDF. It can be observed by above graph that the PSO-RS-SLM outperforms than other methods.

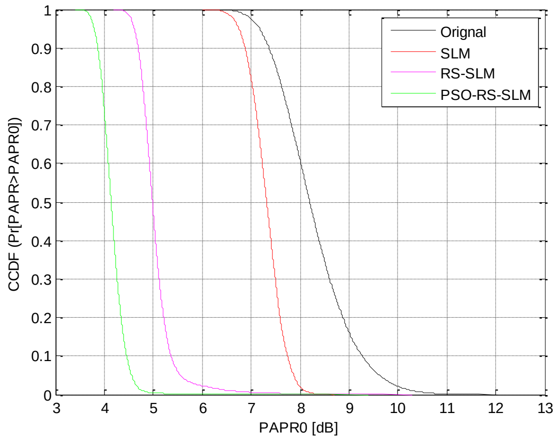

Figure 4: Standard CCDF v/s PAPR calculation graph with FFT=512

The above simulation result shows the comparative graph between CCDF and PAPR with FFT=512 for oricginal signal, SLM, RS-SLM and PSO-RS-SLM. The X axis indicates the PAPR value and Y axis represents CCDF. It can be observed by above graph that the PSO-RS-SLM outperforms than other methods.

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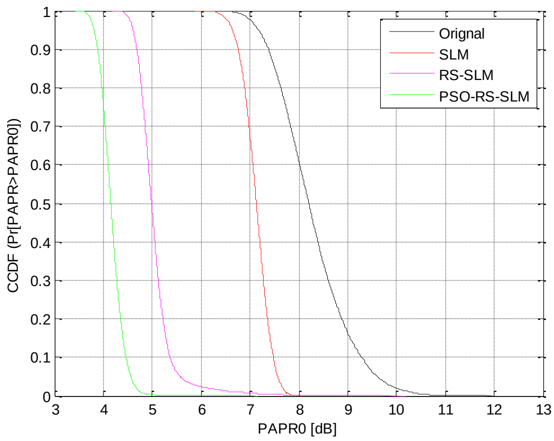

Figure 5: Standard CCDF v/s PAPR calculation graph with FFT=512, n=16

The above simulation result shows the comparative graph between CCDF and PAPR with FFT=512, n=16 for original signal, SLM, RS-SLM and PSO-RS-SLM. The X axis indicates the PAPR value and Y axis represents CCDF. It can be observed by above graph that the PSO-RS-SLM outperforms than other methods.

IV. CONCLUSION

Orthogonal frequency division multiplexing (OFDM) signals have a generic problem of high peak to average power ratio (PAPR) which is defined as the ratio of the peak power to the average power of the OFDM signal. The drawback of the high PAPR is that the dynamic range of the power amplifiers (PA) & digital-to-analog (D/A) converters required during the transmission and reception of the signal is higher. As a result, the total cost of the transceiver increases, with reduced efficiency. After analyzing some specific algorithms, we propose a hybrid algorithm by combining the Companding technique, Selective Mapping (SLM), Random Screening-Selective Mapping and Particle Swarm Optimized-Selective Mapping which includes an idea of the PAPR constraint, along with the implementation and analysis of the proposed algorithm for PAPR reduction of the OFDM signals. This algorithm is implemented and tested in the OFDM transceiver designed using MATLAB. The simulation result conclude that the output obtained by PSO-RS-SLM technique reduces the PAPR drastically as compared to other schemes. Here, by using SLM hardware cost increased but at the same time PAPR reduced.

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