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Robust Optimal PSO based Wavelet Feature Selection in MIMO OFDM Systems

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***Abstract*— Orthogonal Frequency Division Multiplexing (OFDM) when combined with multiple-input multiple output (MIMO) technology offers attractive bandwidth efficiency and higher link reliability in future 4 G wireless technologies. However the major disadvantage of OFDM is, the signals transmitted through multiple antennas suffer from high peak to average power ratio (PAPR) which affects the transmission efficiency. A scheme for PAPR reduction in wavelet packet OFDM based on discrete cosine harmonic wavelet packet transform (DCHWPT) using particle swarm optimization (PSO) is proposed. The optimization technique selects a best wavelet tree from fully decomposed wavelet packet tree structure with minimum PAPR is selected for transmission. Results show that PAPR is considerably reduced as the level of decomposition is increased for the wavelet packet structure.**

***Index Terms*—PAPR, MIMO, OFDM, DCHWP, BER, CCDF, PSO**

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is an attractive multi carrier modulation method for high rate data transmissions in wireless communications. It offers various advantages such as higher bandwidth efficiency, robustness to various interferences, ability in handling frequency selective fading and multipath fading. The data is carried by large number of orthogonal and overlapped sub carriers, where each sub carrier will be modulated by a preferred modulation scheme at low rate, thus offering high spectral efficiency. The performance of OFDM signals is severely affected as it exhibits high peak to average power ratio (PAPR). The presence of PAPR demands the high power amplifier used at the transmitter region to be linear, in order to compensate for the larger peaks in the signal and an analog to digital and digital to analog converter with wide dynamic range. However, this is not a practical solution considering its high cost of implementation. Hence, the better solution is to reduce the PAPR of the transmitted signal. Many PAPR reduction techniques are available such as Partial Transmit Sequence (PTS), Selective Mapping (SLM), Tone Reservation, commanding technique etc. Among them the most recommended schemes are PTS and SLM as it provides considerable reduction in PAPR without any distortion. Using the discrete wavelet packet transform (DWPT) the signals are mapped from time domain to wavelet domain thus offering flexibility as wavelets can be localized in both time and frequency. Wavelet packet also offers negligible side lobe energy leakage and avoids the loss of orthogonality of the transmitted signal thus reducing the inter carrier interference. Thus wavelet packets are more effectively used in digital communications [9].

This paper proposes a PAPR reduction scheme for MIMO OFDM scheme based on DCHWPT using Particle Swarm Optimization (PSO). Discrete cosine harmonic wavelet packet transform (DCHWPT) is used here which utilizes the desirable properties of harmonic wavelet packet transform and discrete cosine transform (DCT) [6] [7]. Using DCT provides low energy compaction, computational simplicity, real nature. Harmonic wavelet packet transform provides built in decimation without any filtering and easier reconstruction by simply concatenating the coefficients. The application of PSO on the fully formed tree structure selects the optimal wavelet coefficients, and among them the one with minimum PAPR is selected for transmission. The simulation results shows that the proposed scheme offers better PAPR performance [5].

II. PEAK-TO-AVERAGE POWER RATIO

The high power amplifier (HPA) used at the transmitter section has non-linear characteristics, also it is sensitive to variations in signal amplitudes. These variations in the amplitude of signals at the HPA leads to inter-modulation interference between different subcarriers which results in high PAPR. Consequently Bit Error Rate (BER) at the receiver side will be increased which leads to degradation in the performance of the system. The presence of large PAPR requires analog to digital and digital to analog converters with wide dynamic range at high cost. In order to increase the performance of the overall system, PAPR should be reduced without increasing its BER.

In an OFDM system, the incoming data is modulated to N subcarriers in the frequency domain. The representation of the baseband signal is

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X[k] e^{j2\Pi \Delta f k t/T}, \ t \in [0,T]$$

where Δf = W/N is the spacing of the subcarriers of bandwidth W Hz,

T = 1/Δf is the symbol period

N = number of subcarriers

PAPR is defined as the ratio of peak amplitude of the signal to the average value of the signal

$$\text{PAPR}\{x\} = \frac{\max(x)^2}{E[(x)]}$$

The PAPR of the continuous time signal is approximated using the PAPR of the discrete time signal. The PAPR performance is measured using its complementary cumulative

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distribution function (CCDF). It shows the probability of a PAPR exceeding a specified threshold value. The CCDF is given by

$$P(PAPR>y) = 1- P(PAPR \leq y)$$

where y is the PAPR threshold.

III. DISCRETE COSINE HARMONIC WAVELET PACKETS

Wavelet achieves better frequency localization, bandwidth efficiency. It is used in communication since it provides robustness to fading communication channels and it reduces intersymbol interferences (ISI). Use of wavelet filters allows good side lobe attenuation, flexibility and good side lobe suppression [4]. In wavelet packets, the approximation and detailed coefficients are split at each stage and decimated. WP-OFDM uses inverse WPT to map input data onto orthogonal sub carriers at the transmitter. The wavelet packet is obtained by concatenating the coefficients from the last level of decomposition [12].

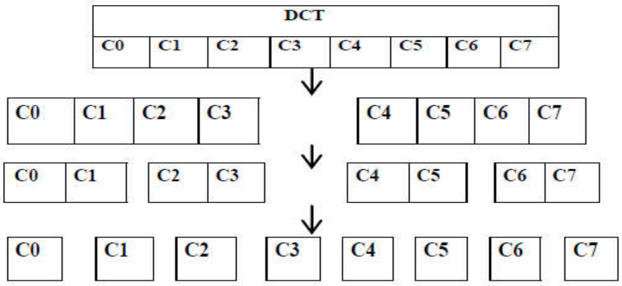

Fig. 1 Discrete cosine harmonic Wavelet packets

In WP-OFDM the signal is split into low pass and high pass components by means of successive filtering [1]. The wavelet packet decomposition to high pass/detail and low pass/coarse forms the wavelet packet full tree structure [2]. On concatenating all the coefficients, the wavelet packet of the original signal is obtained, starting from the last level of decomposition. By using the optimizing technique, PSO optimal wavelet coefficients are selected which forms different tree structures, then their PAPR is calculated, and the one with minimum PAPR is selected for transmission. The formation of scales in DCHWPT for a DCT of size N= 16 is shown in Fig. 1 The coefficients C0-C3 represents the low pass sub band and the coefficients C4 - C7 corresponds to high pass sub band. The final level of decomposition results in scales C0, C1, C2, C3, C4, C5, C6 and C7.

IV. PARTICLE SWARM OPTIMIZING

Particle swarm optimization is one among the evolutionary computation methods [11]. PSO optimizes a problem by improving a candidate solution iteratively with regard to a given measure of quality. This technique is based on researches in swarms such as bird flocking.

PSO is based on a simple concept in which each of the solution is considered as a "bird" in its search space. It is called as a "particle" [10] . Each of the particles have their fitness values evaluated by the fitness functions which are to be optimized. Also, they have velocities that direct the motion of the particle. By following the current optimum particles, the particles fly through the problem space. Initialization of PSO is done with a group of random particles. It then searches for an optimal value by updating generations. Every particle is updated in each iteration following two best values. The first one is called pbest, which is the best solution achieved so far. The other is called global best (gbest), which is the best value tracked so far by any particle in the population. When a particle takes a best value among a particular group, it is termed as local best (lbest). is based on a simple concept and is easy to implement as there are only a few parameters to adjust. In the Particle Swarm Optimization, the bird flocking concept optimizes a certain objective function. Here, each agent knows its best value (pbest) and the best value among the group (gbest). By using the current velocity and distance from the pbest and gbest, each agent tries to modify its position. In PSO particles have velocity, hence it retains part of their previous state.

PSO algorithm works on the following steps:

1. Initialise particles with random position and velocity vectors and initialise the number of iterations.
2. Evaluate fitness for each particle's position.
3. If fitness (P) better than fitness (pbest) then pbest = P.
4. Set best of pbest's as gbest.
5. Update particle velocity and position.
6. Repeat steps [2-5] iteratively.
7. Optimal solution is obtained.

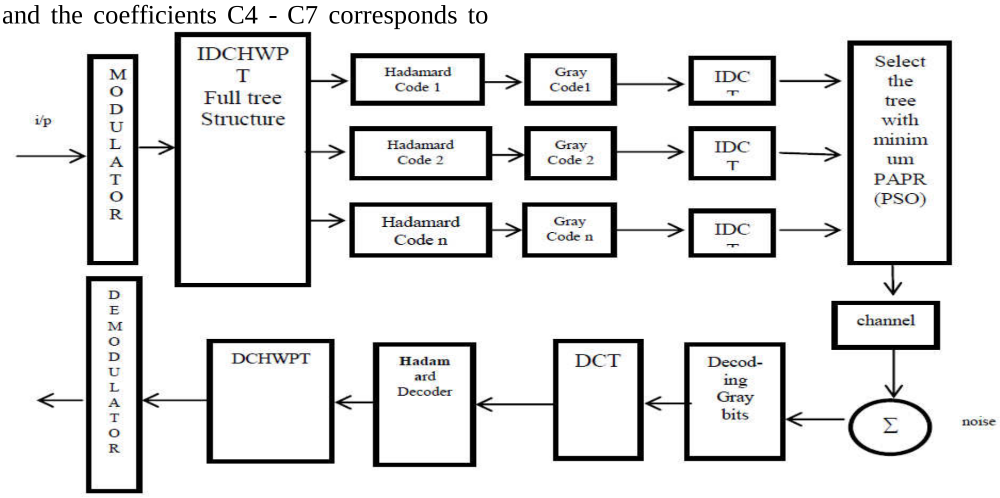

Fig.2 Block diagram for DCHWP-OFDM

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V. DCHWP-OFDM SYSTEM

The block diagram for the proposed system is shown in Fig. 2. The incoming data is modulated using Binary Phase Shift keying Modulation. On applying IDCHWPT, wavelet packet full tree structure has been formed. From the full tree structures are formed by applying the optimizing technique named Particle Swarm Optimization (PSO). It selects the optimal wavelet packet tree coefficients from the fully decomposed tree structure. The different trees formed are multiplied by Hadamard code words which are used for error correcting purposes. In order to identify the trees at receiver side they are added with Gray codes at the beginning [8]. Subsequently, apply IDCT to each of the tree structures and then PAPR is computed on each of it and the tree with minimum amount of PAPR is selected and transmitted. Gray codes are sent as side information to the receiver. At the receiver, the Gray code words are extracted in order to identify the the transmitted tree structures at the receiver. DCT is applied further, then decoding is done using Hadamard code. Afterwards, DCHWP decomposition is done, for splitting the sub bands in DCT domain. Then BPSK demodulation is done finally in order to estimate the transmitted data.

VI. ALGORITHM

Step 1: The incoming bit streams are mapped into Binary Phase Shift keying (BPSK). By using IDCHWPT, the fully decomposed tree structures will be formed. The optimal wavelet packet tree coefficients are selected from the full tree structure by using PSO algorithm.

Step 2: Each of the set of coefficients is multiplied by one of the Hadamard code words. The transformation for the input sequence is U=HV, where H is a (n*n) Hadamard matrix, X is the input vector and Y is the output vector.

Step 3: The above resulting sequences is added with Gray codes for the purpose of identifying the tree structures at the receiver. Subsequently, IDCT is applied for the coded sequences. The PAPR is computed for the different set of sequences and the one with lowest PAPR is selected for transmission.

Step 4: At the receiver, the Gray codes are extracted from the transmitted sequences to identify the transmitted sequences. Then DCT is applied to obtain the time domain data.

Step 5: The coded sequences are decoded at the receiver by using corresponding Hadamard code which is used at the transmitter. It is done by taking the inverse Hadamardtransform of the signal V to get the estimate of $\hat{U} = H^T V$.

Step 6: BPSK demodulation is performed in order to estimate the transmitted bits.

VII. SIMULATIONS AND RESULTS

a. PAPR Performance of DCHWP OFDM for SISO System

The PAPR performance of DCHWP-OFDM for SISO System using tree pruning method to select the wavelet packet tree structure from the fully decomposed tree structure is shown in Fig. 3 Tree pruning method refers to the joining of successive nodes from the last level of decomposition to obtain the different tree structures. The performance for six level of decomposition is compared with conventional OFDM.

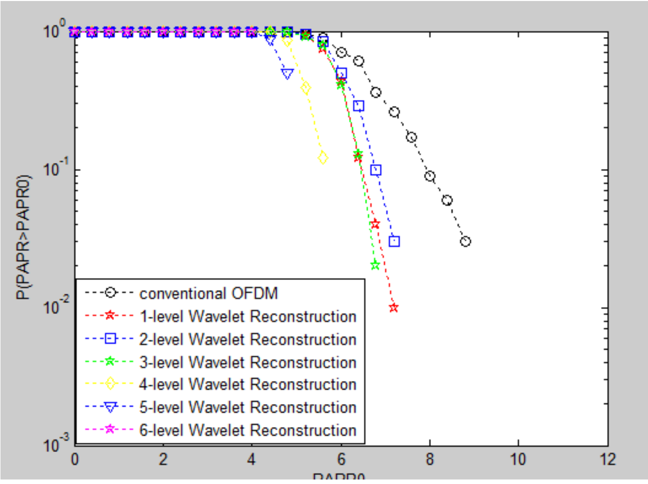

Fig.3 PAPR Performance of DCHWP-OFDM for SISO

b. PAPR Performance of Proposed System

The PAPR performance of DCHWP-OFDM for MIMO OFDM is shown in Fig. 4. The optimal coefficients are selected using PSO. PAPR performance for different level of wavelet decomposition is simulated. As the level of decomposition increases, there occurs a considerable reduction in PAPR. Performance upto sixth level is plotted.

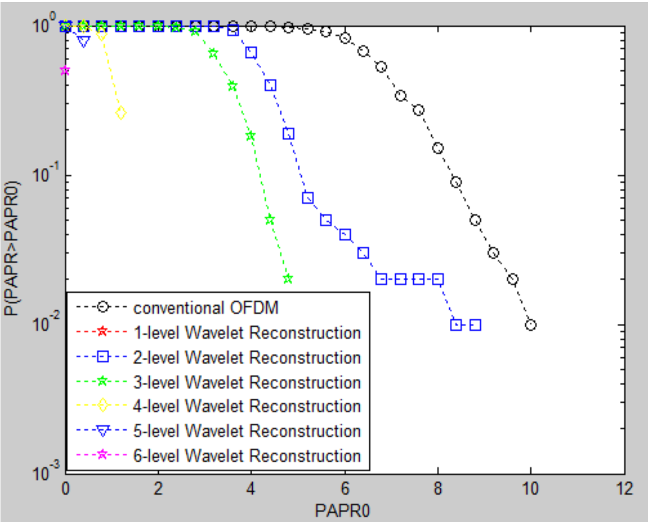

Fig.4 PAPR Performance of DCHWP-OFDM for MIMO Systems using PSO

c. Comparison of proposed system with DCHWP OFDM for SISO System

The proposed system based on Particle Swarm Optimization for MIMO OFDM gives better result than DCHWP SISO OFDM.

Table1: Comparison of proposed system with DCHWP OFDM for SISO System

Wavelet decomposition level	Existing method	Proposed method
1	0.5069	0.3895
2	0.4923	0.3408
3	0.4813	0.2904

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4	0.4619	0.2010
5	0.3786	0.1298
6	0.3471	0.057

VIII. CONCLUSION

A new PAPR reduction method which utilizes Particle Swarm Optimization (PSO) based on DCHWP for MIMO OFDM was proposed. DCHWP utilizes the desirable properties of DCT and harmonic wavelet packets in reducing PAPR. The PAPR has been reduced considerably and the performance increases with increase in decomposition level. The improvement in performance is achieved by the reduced leakage effect of DCT. Use of Gray codes for identification of trees provides computational improvement. As no cyclic prefix employed, bandwidth efficiency is better than DFT-OFDM. The proposed DCHWP method for MIMO OFDM is simple compared to the time domain WP-OFDM as they do not involve any additional processing.

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