An Efficient Rate Allocation Scheme with Selective Weighted Function for Optimum Peak-to-Average Power Ratio for Transmission of Image Streams Over OFDM Channels

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Abstract— This paper proposes new scheme for efficient rate allocation in conjunction with reducing peak-to-average power ratio (PAPR) in orthogonal frequency-division multiplexing (OFDM) system. Modification of the set partitioning in hierarchical trees (SPIHT) image coder is proposed to generate four different groups of bit-stream relative to its significance. The significant bits, the sign bits, the set bits and the refinement bits are transmitted in four different groups. The proposed method for reducing the PAPR utilizes twice the unequal error protection (UEP) using the Read-Solomon codes (RS) in conjunction with bit-rate allocation. The output bit-stream from the source code (SPIHT) will be started by the most significant types of bits (first group of bits). The optimal unequal error protection (UEP) of the four groups is proposed. As a result, the proposed structure gives a significant improvement in bit error rate (BER) performance. Performed computer simulations have shown that the proposed scheme outperform the performance of most of the recent PAPR reduction techniques in most cases. Moreover, the simulation results indicate that the proposed scheme provides significantly better PSNR performance in comparison to well-known robust coding schemes.

Index Term— SPIHT coding, unequal error protection (UEP), rate allocation, RS codes, OFDM, PAPR.

I. INTRODUCTION
Orthogonal frequency-division multiplexing (OFDM) scheme [1], [2] is used in most recent wireless communications systems due to its high spectrum efficiency and robustness in multi-path propagation. OFDM is a special form of multi-carrier modulation and mitigate inter symbol interference (ISI) by multiplexing the data on orthogonal property. Moreover, it is, spectrally, more sufficient technique than a conventional signal carrier modulation technique. However, one of major drawbacks of OFDM is the high peak-to-average power ratio (PAPR) of the transmitted signal [3]. The high PAPR of the transmitted signal significantly reduces the average power at the output of the high power amplifier (HPA) used at the transmitter. Indeed, the input signal must lie in the linear region of the HPA, which is well below the saturation power and the increased linear dynamic range requirements impose the use of very expensive HPAs. It is therefore preferable if possible to reduce the PAPR of the signal to avoid the use of back-off. Several methods have been proposed to reduce the PAPR. These methods can be categorized into signal distortion methods and signal scrambling methods [4–8]. Signal distortion methods reduce high peaks directly by distorting the signal prior to amplification. Clipping the signal before amplification is a simple method to limit PAPR. However, the out-of-band and in-band interference due to use these methods will increase the degradation of the system performance. Signal scrambling methods are all variations on how to scramble the codes to decrease the PAPR. Coding techniques can be used for signal scrambling. However, searching for the best code and the overhead associated will be exponentially increased with the increase in the number of carriers. There are three practical solutions of the signal scrambling methods [5]: block coding, selective mapping and partial transmit sequences. The signal scrambling techniques can be classified into schemes with explicit side information and schemes without side information. The scheme of signal scrambling with side information introduces redundancy, so the effective throughput is reduced. At this point it is worth mentioning that increasing redundancy affects on the total transmission rate. So, the maximum redundancy for each data packet must be estimated relative to the packet data significance. As an illustrative method, the joint source and block coding scheme with bit-rate optimization. In this paper, the proposed method for reducing the PAPR utilizes twice the unequal error protection (UEP) using the Read-Solomon codes (RS) [19] in conjunction using selective weighted function with bit-rate allocation. In the following Section, the PAPR problem in conjunction with the optimum UEP will be described.
In OFDM system, a block of N complex symbols is formed with each symbol modulation one of N subcarriers with frequency for The N-subcarrier is chosen as orthogonal. The complex envelope of the transmitted OFDM signal is represented by

\[ x(t) = \frac{1}{N} \sum_{n=0}^{N-1} s_n e^{j2\pi f_n t} \]  

(1)

Where \( s_n \) is the data symbol, N is number of subcarriers and \( f_n \) represents frequency of n-th subcarriers, the OFDM system shown in Fig. 1. In this work, a new scheme combines simply modification of the set partitioning in hierarchical trees (SPIHT) image coding technique followed by an optimum UEP technique is proposed. The modified SPIHT coder will generate four groups of bit-stream. The significant bits, the sign bits, the set bits, and the refinement bits are transmitted in four different groups. The main idea behind this approach is that the output of the SPIHT image coding (source code) will be sent relative to its significant information. The idea of the proposed algorithm can be used with any scalable image coding technique.

The paper is organized as follows: the source code and the PAPR problem in OFDM are discussed in the next section; the proposed algorithm is introduced in Section III. Weighted function are presented in section IV. Selective weighted function are presented in section V. Implementations and computer results are presented in section VI. Finally, conclusions are given in Section VII.

II. SOURCE CODE PEAK-TO-AVERAGE POWER RATIO PROBLEM

A. Peak-to-Average Power Ratio problem

OFDM consist of many modulated subcarriers. As mentioned in the previous section, this leads to a problem with the peak to average power ratio. If N subcarriers are added up coherently, the peak power is N times the average power in the case of the baseband signal. The PAPR is defined [8], [9] as follows:

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

(2)

It is clear, from Equation (2), that the PAPR reduction techniques are concerned with reducing max . However, since most systems employ discrete-time signals, the amplitude of samples of \( x(t) \) is dealt with in many of the PAPR reduction techniques. Since symbol spaced sampling of Equation (1) sometimes misses some of the signal peaks and results in optimistic results for the PAPR, signal samples are obtained by oversampling (1) by a factor of L to approximate the true PAPR better. The L-times oversampled time-domain samples are obtained by an LN-point inverse discrete Fourier transform (IDFT) of the data block with (L-1) N zero-padding. It was shown in [10] that L=4 is sufficient to capture the peaks.

A large number of OFDM PAPR reduction techniques have appeared in the literature, all having the purpose of reducing the required HPA back-off and the effects of its nonlinearity. Fig. 2 shows a typical AM/AM response for an HPA, with the associated input and output back-off regions (IBO and OBO), respectively.

![Fig. 2. A typical power amplifier response.](image-url)
correcting capabilities) that minimizes the PAPR of the resulting transmitted signal. The PAPR is reduced, but so is the data rate. Other methods use phase manipulations (e.g. Selective Mapping (SLM), Partial Transmit Sequences (PTS), Random Phasor [12-14]). Although these methods are very effective, it has a high complexity and also requires side information coded to be transmitted. This fact raises problems in terms of compliance to standards. Other methods such as Tone Reservation [15] propose inserting anti-peak signals in unused or reserved subcarriers. The method does not cause any in-band distortion, but it reduces the useful data rate. Although suited in some implementations (IEEE 802.16e for example), it is not always standard compliant (the bandwidth sacrifice required by this method is not acceptable in IEEE 802.16d). Another methods proposes altering the QAM constellation in order to reduce high signal peaks. The first method relying on the principle of constellation expansion was Tone Injection [15]. It involves a complex optimization process that makes it scarcely attractive for systems with a high number of carriers. Simpler constellation extension methods were recently developed. Active constellation extension (ACE) [16] allows the corner QAM constellation points to be moved within the quarter planes outside their nominal values. The other border points are allowed to be displaced along rays pointing towards the exterior of the constellation. The interior points are not modified, in order to preserve the minimum distance between the constellation symbols. Recently, a simple non-iterative PAPR reduction method relying on metric-based symbol pre-distortion (MBSP) was proposed in [17]. From all of the algorithms described above, only the last two are suited for a practical implementation in a system compliant to the IEEE 802.16d standard. In this work we use The HighPower Amplifier (HPA) is Rapp’s solid state power amplifier model (SSPA) [34, 35] with the characteristic

\[
\frac{v_{\text{out}}}{v_{\text{in}}} = \left(1 + \frac{v_{\text{in}}}{v_{\text{sat}}}\right)^{1/2p}
\]

where \(v_{\text{in}}, v_{\text{out}}\) are the complex input and output signals, respectively. \(v_{\text{sat}}\) is the output saturation level. The parameter \(p\), often called “knee factor”, controls the smoothness of the characteristic.

The input back-off (IBO) with respect to the saturation values can be defined as,

\[
\text{IBO} = 10 \log_{10} \left( \frac{v_{\text{sat}}^2}{E \left| v_{\text{in}} \right|^2} \right)
\]

where \(E\) is the input power.

In this paper, a rapp model HPA is assumed with knee factor \(p = 2\), IBO = 3.5 dB.

B. Source code (SPIHT) and the UEP process

The SPIHT method is consider the best image coding technique in terms of decoded image quality, progressive rate control and transmission, and the simplicity of the coding process [18]. In the SPIHT coding algorithm, after the wavelet transform using 9/7 tap wavelets from Antonini et al. [20] is applied to an image, the main algorithm works by partitioning the wavelet decomposed image into significant and insignificant partitions based upon the following function

\[
S_n(T) = \begin{cases} 
1, & \max_{(i,j) \in T} \left| b(i,j) \right| \geq 2^n \\
0, & \text{otherwise}
\end{cases}
\]

where \(S_n(T)\) is the significance of the set of coordinates \(T\), and \(b(i,j)\) is the coefficient value at coordinate \((i,j)\). There are two passes to the algorithm, the sorting pass and the refinement pass. The sorting pass is performed on the list of insignificant sets (LIS), list of insignificant pixels (LIP) and the list of significant pixels (LSP). The LIP and LSP consist of nodes that contain single pixels while the LIS contains nodes that have descendants. The maximum number of bits required to represent the largest coefficients in the spatial orientation tree is obtained and designed as \(n_{\text{max}}\) and is given by

\[
n_{\text{max}} = \left\lfloor \log_2 \left( \max_{(i,j)} \left| b(i,j) \right| \right) \right\rfloor
\]

During the sorting pass, those coordinates of the pixels which remain in the LIP are tested for significance by using equation (5). The result \(S_n(T)\) is sent to the output. Those that are significant will be transferred to the LSP as well as have their sign bit output. Sets in the LIS will also have their significance tested and if found to be significant, will removed and partitioned into subsets. Subsets with a single coefficient and found to be significant will be added to the LSP, or else they will be added to the LIP. During the refinement pass, the \(n\)-th most significant bit of the coefficients in the LSP is output. The value of \(n\) is decreased by 1 and the sorting and refinement passes occur again. This continues until either the desired rate is reached or until \(n=0\) and all nodes in the LSP have all their bits output.

In this work, modification of the output bit-stream of the SPIHT coder is done. The modification process is based on the type of bits and their contribution in the PSNR of the reconstructed image. The bit error sensitivity (BES) study is performed by first coding the original image using the SPIHT coder. One bit in the coded image is corrupted, starting from the first bit to the last bit. Each time a bit is corrupted, the coded image is decoded and the resultant MSE is obtained. The corrupted bit is corrected before proceeding on to the next bit. On analysis, there are 4 major types of bit sensitivities within the SPIHT coded bits. Their description is summarized as follows: (1) the significance bit in the bit stream. It decides whether nodes in the LIP are significant, (2) the sign bit of a significant node that is transmitted after the significance bit, (3) the set bit that decided the set is significant or not, (4) the refinement bits that are transmitted during the refinement passes.
In this work, the problem of FEC using RS codes will be introduced. We assume that the image source is encoded by the SPIHT coder. The generated bitstream is partitioned into a sequence of packets. Let denote the expected decrease in distortion if the ith packet is decoded. The overall distortion can be written as follows:

\[ D(l) = D_0 - \sum_{i=1}^{l} P_i \Delta D_i \]  

(7)

Where \( D_0 \) is the expected distortion when the rate is zero, \( P_i \) is the probability that the \( i^{th} \) packet and its preceding packets are received correctly, and \( l \) is the number of source packets that the transmitter chose to send. The probability \( P_i \) can be written in the form:

\[ P_i = \prod_{j=1}^{l} Q_j(r_j) \]  

(8)

Where \( Q_j(r_j) \) is the probability that the \( j^{th} \) layer of source packet is received correctly when sending by a rate of \( r_j \).

Substituting from equation (8) in equation (7) yields to:

\[ D(r) = D(l) = D_0 - \sum_{i=1}^{l} \left( \prod_{j=1}^{l} Q_j(r_j) \right) \Delta D_i \]  

(9)

With the distortion expression in equation (9), for any rate allocation vector \( \gamma_j \), we can minimize the expected distortion subject to a transmission rate constraint. The problem can be formulated as follows:

\[ \min D(r) \quad \text{subject to} \quad \sum_{j=1}^{l} r_j \leq R \]  

(10)

Where \( R \) is the total transmission rate.

B. Forward Error Correction with RS Codes

Assuming that, the stream is partitioned into coding blocks. Each coding block has \( k \) source packets. For each block of \( k \) source packets, we assume that parity packets are produced using a systematic style erasure correction code. The maximum amount of redundancy that will be needed by the transmitter to protect the source. In this work, we study the signal transmission over BSC and AWGN channel. First, let the packet transmitted through binary symmetric channel with bit error rate \( \epsilon \). Then, the packet loss probability is given by:

\[ S(P) = 1 - (1 - P)^m \]  

(11)

Assuming independent bits and \( m \) is the number of bits in the packet. For AWGN channel packet is transmitted symbol by symbol through the channel, where each MQAM symbol has \( b \) bits in it, modulated using fixed power MQAM. Thus, each packet corresponds to \( L/b = L_g \) MQAM symbols. We assume additive white Gaussian noise (AWGN) at the receiver frontend, and no interference from other signals. The channel is narrowband, so the power spectra of both the received signal and the noise have no frequency dependence, i.e., the channel is characterized by a single path gain variable. For AWGN

\[ S(b, \gamma_j, L) = [1 - P(b, \gamma_j)]^{L/b} \]  

(12)
Where \( \gamma_s \) is the SNR per symbol, \( P_e \) is the symbol error rate where \( P_e \) of MQAM in AWGN channels is (approximately) given by [27].

\[
P_e(b, \gamma_s) = 4(1 - 2^{-b/2}Q(\sqrt{\frac{3}{2} \gamma_s}))
\]

(13)

It is shown in [28] that the output of a linear minimum mean-square error (MMSE) detector is approximated by a Gaussian distribution. After channel decoding with a \((N, K)\) RS code for source layer \( j \), the probability that the \( j^{th} \) layer of source packet is received correctly can be written as follows [29]:

\[
Q_j(\{r_j\}) = \frac{EP(\{r_j, k, S_j(P)\})}{k}
\]

(14)

Where \( EP(\{r_j, k, S_j(P)\}) \) is the expected number of source packets that can be recovered and it can be written as follows:

\[
EP(\{r_j, k, S_j(P)\}) = \sum_{i=0}^{v} \left[ \sum_{j=0}^{v} (I - S_j(P))^{(v - r_j)v} \right] + \sum_{i=0}^{v} \left[ \sum_{j=0}^{v} S_j(P)^{(v - r_j)v} \right]
\]

(15)

Hence, with the expected distortion expression in equations (9), (13) and (14), for any rate allocation vector, we can optimize the rate vector to minimize the expected distortion subject to a transmission rate constraint.

C. The Optimization Technique.

Equation (10) can be solved by finding the rate allocation vector \( r \) that minimizes the Lagrangian equation.

\[
J(r, \lambda) = D(r) + \lambda \sum_{i=0}^{v} r_i
\]

OR

\[
J(r, \lambda) = D_o + \sum_{i=0}^{v} I(l - \prod_{j=0}^{v} Q_j(\{r_j\})) \Delta D + \lambda r_i
\]

(16)

The solution of this problem is characterized by the set of distortion increment \( \Delta D \), and \( Q_j(\{r_j\}) \) with which the \( j^{th} \) layer source packet is recovered correctly. In this work, the problem is solved by using an iterative approach that is based on the method of alternating variables [30]. The objective function \( J(\{r_1, \ldots, r_l\}) \) in equation (16) is minimized one variable at a time, keeping the other variables constant, until convergence. To be specific, let \( r^{(0)} \) be any initial rate allocation vector and let \( r^{(t)} = (r^{(t)}_1, \ldots, r^{(t)}_l) \) be determined for \( t = 1, 2, \ldots \) as follows: select one component \( x \in \{r_1, \ldots, r_l\} \) to optimize at step \( t \). This can be done in a round-robin style. Then, for \( x = r_i \) we can perform the following rate optimization:

\[
r_i^{(t)} = \arg \min_{r_i} J(r^{(t-1)}_1, \ldots, r^{(t-1)}_i, r^{(t)}_{i+1}, \ldots, r^{(t)}_l)
\]

\[
= \arg \min_{r_i} \prod_{j=0}^{v} Q_j(\{r_j\}) \Delta D + \lambda r_i
\]

(17)

For fixed \( \lambda \), the minimization problem can be solved using standard non-linear optimization procedures, such as gradient-descent type algorithm [30]. In our simulation results, we always start with the initial rate allocation vector \( r = (1, 1, \ldots, 1) \).

D. The proposed scheme

In the beginning as shown in Fig. 4, the SPIHT coder output bitstream modification has been done. The modification process is based on the type of bits and their contribution in the PSNR of the reconstructed image. The bit error sensitivity (BES) study is performed by first coding the original image using the SPIHT coder. One bit in the coded image is then corrupted, starting from the first bit to the last bit. Each time a bit is corrupted, the coded image is decoded and the resultant MSE is calculated. The corrupted bit is corrected before proceeding on to the next bit. On analysis, the resultant BES study is carried out on a 256×256×8 image of Lena coded at source rate code rate of 0.5 bpp using the SPIHT algorithm. On analysis, there are 4 major types of bit sensitivities within the SPIHT coded bits, as shown in Fig. 3.

The output bitstream will be started by the most significant types of bits (first group of bits). The proposed scheme can be summarized as follows: (1) the SPIHT image coding technique is modified to generate 4 groups of bitstream related to the order of significance, (2) the output data is partitioned into a sequence of packets, (3) the changing in MSE is calculated and the expected decrease in distortion \( \Delta D \) is then approximately estimated, (4) the optimization algorithm is applied to generate the optimum bit rate for each group of bits. The inputs to the optimization algorithm are the packet length, the bit error rate (BER), and expected distortion \( \Delta D \), (5) the output are the rate allocation vectors used with RS codes to generate the transmitted bitstream, (6) the receiver will decode the receiving bitstream by using RS decoder and the modified SPIHT decoder.

E. Image Transmission over OFDM system with RS channel coding (FEC)

0.01 and 0.001, for 256×256 gray-scale Lena image.

Firstly the wavelet transform using 9-tap low pass filter and 7-tap high-pass filter are applied to the original image to decompose it into sub-images. Only 6-layer is used in our test. The modified SPIHT coder is then applied to the wavelet coefficients to generate the source bitstream with a bit rate of 0.5 bpp. The source bitstream is divided into packets of length 80 bits. This means that each block has 10 symbols of one byte for each. In the simulation results, the total bitstream of the Lena image is divided into 17 packets. These 17 packets are divided into 4 groups of packets as follows: (1) 2 packets for the significant information, (2) 5 packets for the
sign bit, (3) 8 packets for the set bit, (4) 2 packets for the refinement bits.

In the beginning, we tried to put the results of the UEP method in a comparison form with the result of the equal error protection (EEP) method. In the case of EEP, the number of RS symbols is selected to be 8-symbol for each row of packet that make the total symbols per packet are 450 symbol per packet. In the case of UEP, the total symbols per packet (R in Eq.9) is selected to be no more than 450 symbol per packet and the optimization algorithm is used to determine the number of RS symbols for each column and row of packets. The result of this step is shown in Fig.5. It is clear from Fig. 5 that the significance and sign packets are protected by 8-symbol for column and row, the set packets are protected by 2-symbol for column and row, and the refinement packets are protected by 8-symbol for row and zero for column.

Fig. 5. Channel rates for the protection of “Lena” as determined using the UEP algorithm

In the beginning, we tried to put the results of the UEP method in a comparison form with the result of the equal error protection (EEP) method. In the case of EEP, the number of RS symbols is selected to be 8-symbol for each row of packet that make the total symbols per packet are 450 symbol per packet. In the case of UEP, the total symbols per packet (R in Eq.9) is selected to be no more than 450 symbol per packet and the optimization algorithm is used to determine the number of RS symbols for each column and row of packets. The result of this step is shown in Fig.5. It is clear from Fig. 5 that the significance and sign packets are protected by 8-symbol for column and row, the set packets are protected by 2-symbol for column and row, and the refinement packets are protected by 8-symbol for row and zero for column.

Fig. 6 depicts the average PSNR of the decoded Lena image as a function of the transmission rate for the EEP and the UEP coding method. In particular, our proposed scheme for UEP outperforms the system of EEP by 4.2 dB.

IV. WEIGHTING FUNCTION

This method addresses the PAPR reduction of OFDM by combination of both signal scrambling and signal distortion techniques [31]. The PAPR is to be reduced by both amplitude weighting and random phase updating. The OFDM signal for one symbol interval $0 \leq t \leq T$ is written as

$$s(t) = \sum_{m} \tilde{b}_m W_m e^{j2\pi m\frac{t}{T}}$$

(18)

Where $M$ is number of subcarriers, $\tilde{b}_m$ is modulation data of the $m^{th}$ subcarriers, $T$ is the OFDM symbol period, and $W_m$ is a complex factor defined as

$$W_m = \alpha_m e^{j\varphi_m} \quad m = 0, 1, 2, \ldots, M - 1$$

(19)

Where $\alpha_m$ a positive real value and $\varphi_m$ is the phase of $m$-th subcarriers. The block diagram of an OFDM modulator with complex weighting factors is shown in Fig. 7. To calculate PAPR, first we obtain the instantaneous power of OFDM signal from Eq(18).

[Diagram of OFDM modulator with complex weighting factors]

Fig. 6. the average PSNR of the decoded Lena image as a function of the channel BER for the RS (EEP & UEP) channel coding.
Fig. 7. Block diagram of complex-weighted OFDM modulator.

\[ P(t) = |x(t)|^2 = \sum_{n=0}^{N-1} \sum_{m=0}^{N-1} b_n w_n(b_m w_m)' e^{j \theta(n-m)} \]

(20)

Which can be written as

\[ P(t) = \sum_{n=0}^{N-1} |b_n|^2 |w_n|^2 + \sum_{n=0}^{N-1} \sum_{m \neq n} b_n w_n(b_m w_m)' e^{j \theta(n-m)} \]

(21)

The average power \( P(t) \) over a symbol period of \( T \), we obtain

\[ E[P(t)] = \sum_{n=0}^{N-1} |b_n|^2 |w_n|^2 \sum_{m=0}^{N-1} \sum_{m \neq n} E[b_n b_m'] w_n w_m e^{j \theta(n-m)} \]

(22)

We can say

\[ E[P(t)] = \sum_{n=0}^{N-1} |w_n|^2 \]

(23)

Where \( b_n \) on different carriers are assumed to be independent \( E[b_n b_n'] = \delta(m-n) \). Therefore, the second term in Eq.(22) is zero. The variation of the instantaneous power of OFDM signal from the average is.

\[ \Delta P(t) = P(t) - E[P(t)] = \sum_{n=0}^{N-1} \sum_{m \neq n} \sum_{m \neq n} |b_n|^2 |w_n|^2 |w_m|^2 e^{j \theta(n-m)} \]

(24)

The variance is obtained by averaging of \((\Delta P(t))^2\) over a symbol period of \( T \)

\[ \rho = \frac{1}{T} \int_0^T (\Delta P(t))^2 \, dt = \sum_{n=0}^{N-1} |R_{cc}(i)|^2 \]

(25)

Where \( R_{cc}(i) \) is the autocorrelation function of the complex sequence

\[ R_{cc}(i) = \sum_{n=0}^{N-1} c_n e^{j n i} \]

(26)

The parameter \( \rho \) is the power variance of the OFDM signal and it has been shown that is a good measure of the PAPR. now we consider different weighting functions in this work. In order to be able to compare them with each other we assume the power of all weighting factors be constant.

\[ \sum_{n=0}^{N-1} |W_n|^2 = 1 \]

(27)

the PAPR of OFDM signal can be written as

\[ \text{PAPR} = \frac{\text{Max} \{ P(t) \} \text{ Mean} \{ P(t) \} = \text{Max} \{ P(t) \} = P_{\text{max}} \]

(28)

Weighting function:

1. Bartlett: This weighting function has triangular shape and expressed by

\[ w_m = \begin{cases} A \left(1 - \frac{|m-N/2|}{N/2} \right) & 0 \leq m \leq N-1 \\ 0 & \text{otherwise} \end{cases} \]

(29)

2. Rectangular: This weighting function has a rectangular shape

\[ w_m = \begin{cases} A & 0 \leq m \leq N-1 \\ 0 & \text{otherwise} \end{cases} \]

(30)

3. Raised cosine: this weighting function is explained by

\[ w_m = A \sin \left( \frac{\pi m}{N} \right), \quad 0 \leq m \leq N-1 \]

(31)

4. Half-sine the shape of this weighting function is described by

\[ w_m = \begin{cases} A \sin \left( \frac{\pi m}{N} \right) & 0 \leq m \leq N-1 \\ 0 & \text{otherwise} \end{cases} \]

(32)

5. Shannon: the shape of these weighting factors is the sinc function defined by

\[ w_m = A \sin \left( \frac{\pi m}{N} \right), \quad 0 \leq m \leq N-1 \]

(33)

6. Gaussian: these factor are generated based on the Gaussian function

\[ w_m = A e^{-\frac{(m-N/2)^2}{2\sigma^2}}, \quad 0 \leq m \leq N-1 \]

(34)

7. Chebyshev: the shape of this weighting function is exponentially increasing,

\[ w_m = \begin{cases} A \sin \left( \frac{\pi m}{N} \right) & 0 \leq m \leq N-1 \\ 0 & \text{otherwise} \end{cases} \]

(35)

The modulated signal will have distortion due to in band and out of band distortion and PAPR reduction using weighted function make the system more sensitive for noise of channel.

V. Selective Weighting Function

The weighted function method for PAPR has high distortion due to channel noise that will effect on signal recover. In this work, we don’t added weighted function to all
The weighted function method for PAPR has high distortion due to channel noise that will effect on signal recover. In this work, we don’t added weighted function to all transmission frame. As shown in Fig.8, the frame pass through PAPR reduction block test.

The PAPR reduction block test flowchart shown in Fig. 9. If the PAPR larger than PAPR_o (peak-to-average power ratio threshold) we make fram pass through multiple weighted function then test PAPR of each fram and select one which gave minimum PAPR and transmit side information.

Fig. 9. Selective weighted PAPR reduction method flowchart

VI. COMPUTER RESULTS

We compare between the result of data transmit over original and modified OFDM systems using Barlett weighting function PAPR reduction method, Compound method PAPR reduction method [32], and PAPR reduction using selective weighting function.

A. Barlett Weighting function with original and modified OFDM system

We use the Barlett weighting function method and compare the simulation result for original and modified OFDM system. Data transmission over two type of channel, binary symmetric channel and AWGN Chennal.

1) Binary symmetric channel:

Here the data transmit over binary symmetric channel. Table I. show simulation result when use this method throw systems with and without UEP at Different kinds of sources transmitted over BSC. Fig. 10 show received Lena image transmit over original and modified OFDM system with channel BER=0.01, and Fig. 11 show received Lena image transmit over original and modified OFDM system with channel BER=0.001, Fig12 show Channel rate protection as determined using the UEP algorithm when use Barlett weighting function method.
TABLE I
SIMULATION RESULT WHEN USE BARLETT WEIGHTING METHOD THROWS SYSTEMS WITH AND WITHOUT UEP OVER BSC

<table>
<thead>
<tr>
<th>Source data type</th>
<th>MSE</th>
<th>transmission rate</th>
<th>Max (PAPR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel BER=0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>1.08224e+004</td>
<td>122880 bps</td>
<td>10.683 dB</td>
</tr>
<tr>
<td>Image data source over Original OFDM</td>
<td>1.0364e+004</td>
<td>122880 bps</td>
<td>9.8068 dB</td>
</tr>
<tr>
<td>Image data source over Modified OFDM</td>
<td>4.9676e+003</td>
<td>121600 bps</td>
<td>10.2945 dB</td>
</tr>
<tr>
<td>Channel BER=0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>1.0582e+004</td>
<td>122880 bps</td>
<td></td>
</tr>
<tr>
<td>Image data source over Original OFDM</td>
<td>4.017e+003</td>
<td>122880 bps</td>
<td>9.915 dB</td>
</tr>
<tr>
<td>Image data source over Modified OFDM</td>
<td>2.0714424+003</td>
<td>121600 bps</td>
<td>9.963 dB</td>
</tr>
</tbody>
</table>

Fig. 10. the received Lena image transmit over original and modified OFDM system over BSC channel with BER=0.01 (PSNR result is proposed in dB), (a) original OFDM (PSNR = 7.975), (b) modified OFDM (PSNR = 11.1693)

Fig. 11. the received Lena image transmit over original and modified OFDM system over BSC channel with BER=0.001 (PSNR result is proposed in dB), (a) original OFDM (PSNR = 12.09), (b) modified OFDM (PSNR = 14.968)

Fig. 12. Channel rate protection as determined using the UEP algorithm for Lena image for BSC with BER=0.01

2) AWGN channel: The transmitted bit stream transmit over AWGN channel, Table II show simulation result when use this method throw systems with and without UEP at different source data type transmit over AWGN channel. Fig. 13 show received Lena image transmit over original and modified OFDM system with channel BER=0.01, Fig. 14 show received Lena image transmit over original and modified OFDM system with channel BER=0.001. Fig 15 show Channel rate protection as determined using the UEP algorithm when use Barlett weighting function method.

TABLE II
SIMULATION RESULT WHEN USE BARLETT WEIGHTING METHOD THROWS SYSTEMS WITH AND WITHOUT UEP OVER AWGN CHANNEL

<table>
<thead>
<tr>
<th>Source data type</th>
<th>MSE</th>
<th>transmission rate</th>
<th>Max (PAPR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel BER=0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>9.8499e+003</td>
<td>30720 syps</td>
<td>10.68 dB</td>
</tr>
<tr>
<td>Image data source over Original OFDM</td>
<td>9.433e+003</td>
<td>30720 syps</td>
<td>9.8 dB</td>
</tr>
<tr>
<td>Image data source over Modified OFDM</td>
<td>1.353e+003</td>
<td>30080 syps</td>
<td>9.5 dB</td>
</tr>
<tr>
<td>Channel BER=0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>9.559 +003</td>
<td>30720 syps</td>
<td>10.68 dB</td>
</tr>
<tr>
<td>Image data source over Original OFDM</td>
<td>8.6 +003</td>
<td>30720 syps</td>
<td>9.8 dB</td>
</tr>
<tr>
<td>Image data source over Modified OFDM</td>
<td>5.327e+002</td>
<td>30080 syps</td>
<td>10.13 dB</td>
</tr>
</tbody>
</table>

Fig. 13. the received Lena image transmit over original and modified OFDM system over AWGN channel with BER=0.01 (PSNR result is proposed in dB), (a) original OFDM (PSNR = 8.384), (b) modified OFDM (PSNR = 15.0815)

Fig. 14. the received Lena image transmit over original and modified OFDM system over AWGN channel with BER=0.001 (PSNR result is proposed in dB), (a) original OFDM (PSNR = 18.785), (b) modified OFDM (PSNR = 20.865)

Fig. 15. Channel rate protection as determined using the UEP algorithm for Lena image for BSC with BER=0.01
B. compound method simulation result

We use the compound method [32] for original and modified OFDM system the data will pass over two type of channel BSC and AWGN.

1) BS Channel: Data transmit over BSC, Table 3 show simulation result when use compound method throw systems with and without UEP at different source data type over BSC. Fig 16 show received Lena image transmit over original and modified OFDM system with channel BER=0.01, Fig 17 show received Lena image transmit over original and modified OFDM system with channel BER=0.001. Fig 18 show Channel rate protection as determined using the UEP algorithm when use compound method.

<table>
<thead>
<tr>
<th>Source data type</th>
<th>MSE</th>
<th>transmission rate</th>
<th>Max (PAPR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel BER=0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>1.03324e+004</td>
<td>122880 bps</td>
<td>7.739 dB</td>
</tr>
<tr>
<td>Image data source</td>
<td>1.166778e+004</td>
<td>122880 bps</td>
<td>8.5378 dB</td>
</tr>
<tr>
<td>over Original OFDM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Image data source</td>
<td>4.0651e+003</td>
<td>121600 bps</td>
<td>7.5253 dB</td>
</tr>
<tr>
<td>over Modified OFDM</td>
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<td></td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Source data type</th>
<th>MSE</th>
<th>transmission rate</th>
<th>Max (PAPR)</th>
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</thead>
<tbody>
<tr>
<td>Channel BER=0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>1.006e+004</td>
<td>122880</td>
<td>7.739 dB</td>
</tr>
<tr>
<td>Image data source</td>
<td>1.03695e+003</td>
<td>122880 bps</td>
<td>8.5378 dB</td>
</tr>
<tr>
<td>over Original OFDM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Image data source</td>
<td>5.47694e+002</td>
<td>117760 bps</td>
<td>8.6578 dB</td>
</tr>
<tr>
<td>over Modified OFDM</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) AWGN channel: Here we use compound method and AWGN channel, Table 4V show simulation result when use compound method throw systems with and without UEP at different source data type over AWGN channel. Fig 19 show received Lena image transmit over original and modified OFDM system with channel BER=0.01, Fig 20 show received Lena image transmit over original and modified OFDM system with channel BER=0.001. Fig 21 show Channel rate protection as determined using the UEP algorithm when use compound method.
TABLE IV
SIMULATION RESULT WHEN USE COMPOUND METHOD THROW SYSTEMS WITH AND WITHOUT UEP, OVER AWGN CHANNEL

<table>
<thead>
<tr>
<th>Source data type</th>
<th>MSE</th>
<th>transmission rate</th>
<th>Max (PAPR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel BER=0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>9.8069e+003</td>
<td>30736 syps</td>
<td>7.739 dB</td>
</tr>
<tr>
<td>Image data source over Original OFDM</td>
<td>4.3469e+003</td>
<td>30736 syps</td>
<td>7.6733 dB</td>
</tr>
<tr>
<td>Image data source over Modified OFDM</td>
<td>1.55262e+003</td>
<td>29455 syps</td>
<td>7.6733 dB</td>
</tr>
<tr>
<td>Channel BER=0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>9.45e+003</td>
<td>30736 syps</td>
<td>7.74 dB</td>
</tr>
<tr>
<td>Image data source over Original OFDM</td>
<td>4.40144 e+002</td>
<td>30736 syps</td>
<td>8.5378 dB</td>
</tr>
</tbody>
</table>

C. Selective Weighting function with original and modified OFDM system

Here we use our proposed method (selective weighting function) and compare the simulation result for original and modified OFDM system, the data will pass over two type of channel BSC and AWGN channel compare the result with result of compound method and the Barlett PAPR method.

1) BS Channel: Data transmit over BSC. Table. V show simulation result when use this method throw systems with and without UEP at different source data type and BSC. Fig. 22 show received Lena image transmit over original and modified OFDM system with channel BER=0.01. Fig. 23 show received Lena image transmit over original and modified OFDM system with channel BER=0.001.Fig. 24 show Channel rate protection as determined using the UEP algorithm.

TABLE V
SIMULATION RESULT WHEN USE SELECTIVE WEIGHTED METHOD THROW SYSTEMS WITH AND WITHOUT UEP, OVER BSC CHANNEL

<table>
<thead>
<tr>
<th>Source data type</th>
<th>MSE</th>
<th>transmission rate</th>
<th>Max (PAPR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel BER=0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>1.0022e+004</td>
<td>122944 bps</td>
<td>8.738 dB</td>
</tr>
<tr>
<td>Image data source over Original OFDM</td>
<td>1.87672e+003</td>
<td>122944 bps</td>
<td>8.75 dB</td>
</tr>
<tr>
<td>Image data source over Modified OFDM</td>
<td>8.873685 e+002</td>
<td>120380 bps</td>
<td>8.7263 dB</td>
</tr>
<tr>
<td>Channel BER=0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>9.8e+004</td>
<td>122944 bps</td>
<td>8.738 dB</td>
</tr>
<tr>
<td>Image data source over Original OFDM</td>
<td>4.27316e+002</td>
<td>122944 bps</td>
<td>8.7263 dB</td>
</tr>
</tbody>
</table>

Fig. 22 the received Lena image transmit over original and modified OFDM system over BSC with BER=0.01 (PSNR result is proposed in dB), (a) original OFDM (PSNR= 18.384) , (b) modified OFDM (PSNR= 21.6948)
Fig. 23 the received Lena image transmit over original and modified OFDM system over BSC with BER=0.001 (PSNR result is proposed in dB), (a) original OFDM (PSNR= 21.6948), (b) modified OFDM (PSNR= 26.13)

(b)

(a)

Fig. 25 the received Lena image transmit over original and modified OFDM system over AWGN channel with BER=0.01 (PSNR result is proposed in dB), (a) original OFDM (PSNR= 18.384), (b) modified OFDM (PSNR= 19.815)

(b)

(a)

Fig. 26. The received Lena image transmit over original and modified OFDM system over AWGN channel channel BER=0.001 (PSNR result is proposed in dB), (a) original OFDM (PSNR=22.53), (b) modified OFDM (PSNR=29.7)

(b)

(a)

3) **AWGN Channel:** Here data transmit over AWGN channel, Table VI show simulation result when use this method throw systems with and without UEP at different source data type and transmit over AWGN channel. Fig. 25 show received Lena image transmit over original and modified OFDM system with channel BER=0.01. Fig. 26 show received Lena image transmit over original and modified OFDM system with channel BER=0.001. Fig. 27 show Channel rate protection as determined using the UEP algorithm.

4) **TABLE VI**

<table>
<thead>
<tr>
<th>Source data type</th>
<th>MSE transmission rate</th>
<th>Max (PAPR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel BER=0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random data source</td>
<td>9.6638e+003</td>
<td>30736 syps</td>
</tr>
<tr>
<td>Image data source over Original OFDM</td>
<td>1.16e+003</td>
<td>30736 syps</td>
</tr>
<tr>
<td>Image data source over Modified OFDM</td>
<td>6.793e+002</td>
<td>30407 syps</td>
</tr>
<tr>
<td>Channel BER=0.001</td>
<td></td>
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</tr>
<tr>
<td>Random data source</td>
<td>9.006e+003</td>
<td>30736 syps</td>
</tr>
<tr>
<td>Image data source over Original OFDM</td>
<td>3.62e+002</td>
<td>30736 syps</td>
</tr>
<tr>
<td>Image data source over Modified OFDM</td>
<td>0.6964e002</td>
<td>30403 syps</td>
</tr>
</tbody>
</table>

Fig. 27. Channel rates protection as determined using the UEP algorithm when data transmit over AWGN with BER=0.01.

Fig. 28. CCDF Comparison of the proposed algorithm with Slm u=4,Huffman coder,clipping,compound and Barlett weighting function

Fig.28 show the power Complementary Cumulative Distribution Function (CCDF) curves provide critical information about the signal encountered in proposed algorithm and the another PAPR reduction method.
REFERENCES


[31] Kusha Raj Panta a
