PROGRESSIVE IMAGE TRANSMISSION OVER OFDM SYSTEM

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ABSTRACT

A modified Orthogonal Frequency Division Multiplexing (OFDM) system for robust progressive image transmission is proposed in this paper. A joint source-channel coder (JSCC) is employed in the modified OFDM system. The set partitioning hierarchical trees (SPIHT) used as source coder, and The Low-Density Parity-Check (LDPC) used as a channel coder. The SPIHT coder is modified to generate four different groups of bit stream relative to its significances. An unequal error protection (UEP) is suggested for data groups with the LDPC coder. Also, the modified OFDM system includes an adaptive clipping technique as a Peak to average power ratio (PAPR) reduction technique for OFDM signal. This proposed PAPR reduction technique is based on adaptive clipping for the amplitude of the input signal, where each of signals related to the different four groups of the modified SPIHT coder is clipped with a different clipping level according to the group sensitivity. To demonstrate the efficiency of the modified OFDM system with proposed PAPR reduction technique, the simulation results are presented based on bit error rate (BER), the Peak-signal-to-noise ratio (PSNR) and PAPR over AWGN channel. Based on the simulation results, the proposed structure provides a significant improvement in BER and PSNR performances and a reduction in PAPR is achieved.

Keywords: OFDM, PAPR, SPIHT, LDPC, UEP, AWGN channel

1. Introduction

Transmission of images over wireless communication systems requires robust and efficient source and channel coding algorithms. The current image coding standard JPEG2000 or SPIHT [1] algorithm provides progressive image compression where the original image can be reconstructed incrementally. The main drawback of progressive organization of the bitstream is that it is highly prone to transmission noise. Channel codes are required to protect the source encoded bitstream. Traditionally, the problems of source coding and channel coding have been addressed independently. However, when the constraints of the communication channel are considered, a joint source/channel coding scheme (JSCC) [2] is found to be the most promising scheme for communication of images over noisy channels. In this method, the channel code rate is carefully chosen to match the properties of source coder as well as the conditions of the channel. Forward Error Correction (FEC) scheme [3] is employed to increase the transmitted data rate and protect the data prior to transmission. One of the FEC schemes is Low-Density Parity-

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Check (LDPC) codes, developed by Gallager [4]. As an attractive technology for wireless communications, Orthogonal Frequency Division Multiplexing (OFDM), which is one of multi-carrier modulation (MCM) techniques, offers a considerable high spectral efficiency, multipath delay spread tolerance, immunity to the frequency selective fading channels and power efficiency [5], [6]. As a result, OFDM has been chosen for high data rate communications and has been widely deployed in many wireless communication standards such as Digital Video Broadcasting (DVB) and based mobile worldwide interoperability for microwave access (mobile WiMAX) based on OFDM access technology [7]. However, some challenging issues remain unresolved in the design of the OFDM systems. One of the major problems is high Peak-to-Average Power Ratio (PAPR) of transmitted OFDM signals. Therefore, the OFDM receiver's detection efficiency is very sensitive to the nonlinear devices used in its signal processing loop, such as Digital-to-Analog Converter (DAC) and High Power Amplifier (HPA), which may severely impair system performance due to induced spectral regrowth and detection efficiency degradation. Therefore, it is important and necessary to research on the characteristics of the PAPR including its distribution and reduction in OFDM systems, in order to utilize the technical features of the OFDM. There are several developed techniques to reduce the PAPR in OFDM systems [8, 9] such as clipping [10], companding [11, 12], Partial Transmit Sequence (PTS) [13], Selected Mapping (SLM) [14] and coding [15]. A simple technique used to reduce the PAPR of OFDM signals is to clip the signal to a maximum allowed value, at the cost of BER degradation and out-of-band radiation. Clipping does not add extra information to the signal and high peaks occur with low probability so the signal is seldom distorted.

The target of this paper is to improve the quality of the reconstructed images over the OFDM system and reduce the PAPR of the OFDM signal. It presents a modified OFDM system with a JSCC scheme, which combines simple modification of the SPIHT image coding technique followed by an UEP process using LDPC. The modified SPIHT coder will generate four groups of bit streams. The significant bits, the sign bits, the set bits, and the refinement bits are transmitted in four different groups. The output of the SPIHT image coding will be sent relative to its significant information. Moreover, an adaptive clipping technique is proposed for PAPR reduction for the OFDM signal. The proposed PAPR reduction technique is based on adaptive clipping for the amplitude of the input signal, where the clipping amplitude for the signal depends on its sensitivity. The simulation results for the modified OFDM system and the proposed PAPR reduction technique are obtained utilizing an image transmission over AWGN communication channel.

The rest of this paper is organized as follows. Section 2 presents the SPIHT coder and UEP process. The modified OFDM system description with the adaptive clipping technique is explained in section 3. Section 4, introduces the simulation results. Finally, the conclusions followed by the relevant references are included in section 5.

2. SPIHT and UEP

The SPIHT coder is consider as one of the best image coding techniques in sense of decoded image quality, progressive rate control and transmission the simplicity of the coding process [1]. In the SPIHT coding algorithm, after the wavelet transmission using biorthognal 9/7 tap wavelets from Antonini et al. [16] is applied to an image, the main algorithm works by partitioning the wavelet decomposed image into significant partitions based upon the following function.

$$S_n(\Gamma) = \begin{Bmatrix} 0, & \text{otherwise} \\ 1, & \text{if } \max_{(i,j)\in\Gamma}\{|Y(i,j) \geq 2^n|\} \end{Bmatrix} \tag{1}$$

where $S_n(\Gamma)$ the significance of the set of is coordinates Γ, and $Y(i,j)$ is the coefficient value at coordinate (i,j). There are two passes of 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_{max} and is given by

$$n_{max} = \lfloor \log_2\left(\max_{(i,j)}\{|Y(i,j|\}\right) \rfloor \tag{2}$$

During the sorting pass, the coordinates of the pixels which remain in the LIP are tested for significance by using equation (1). The result $S_n(\Gamma)$ 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 wil 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 based on the type of bits and their contribution in the PSNR of the reconstructed image is done. 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, and coded image is decoded and the resultant MES is obtained. The corrupted bit is corrected before proceeding on to the next bit. On analysis, there are four 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 Figure 1, the order of significance from the most significant types of bits to the least significant for gray (512×512) LENA image (at 0.129 bpp) is as follows: the significance bits > sign bits > set bits > refinement bits.

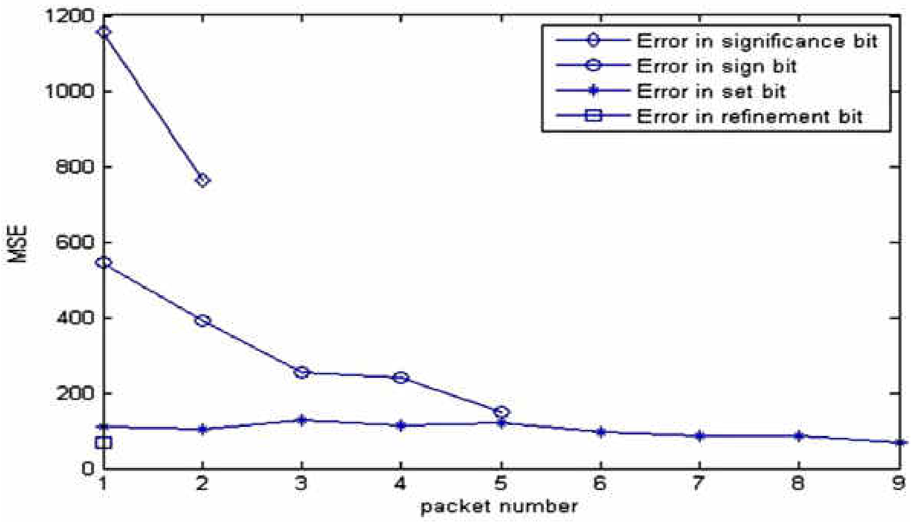

Fig. 1. Error bit sensitivities within the SPIHT coded bit stream

The resulted groups of the SPIHT coder are unequally protected using the LDPC coder, as a channel coder, where the amount of redundancy will be added to data of each group for protection depending on the group sensitivity.

3. The modified OFDM system with the adaptive clipping technique

The block diagram of the proposed modified OFDM system is illustrated in Figure 2. The SPIHT coder is chosen as the source coding technique due to its flexibility of code rate and simplicity of designing optimal system. The modified SPIHT divides the image bit stream into several groups according to its sensitivities. Afterwards the information bits are unequally encoded with the LDPC encoder. The OFDM considered in this work utilizes N frequency tones (number of subcarriers) hence the baseband data is first converted into parallel data of N sub-channels so that each bit of a codeword is on different subcarrier. Then, the transmitted data of each parallel sub-channel is modulated by QBSK or QAM16. Finally, the modulated data are fed into an IFFT circuit, such that the OFDM signal is generated. At the receiver, the OFDM sub-channel demodulation is implemented by using a FFT then the Parallel-to-Serial (P/S) conversion is implemented. This received OFDM symbols are de-modulated at the de-mapper. The demodulated bits are decoded with the LDPC decoder and data bits are restored. These data are converted into image format, such that SPIHT decoder can be obtained.

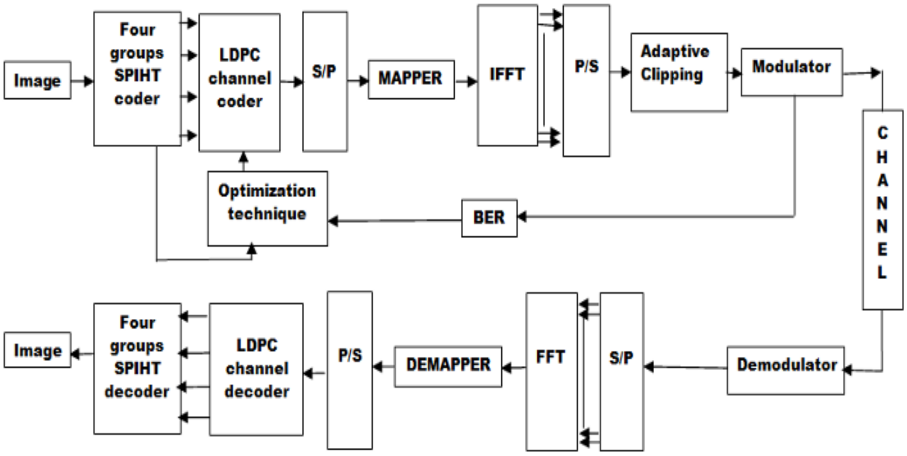

Fig. 2. The modified OFDM system diagram

As shown in figure 2 the modified OFDM system includes an adaptive clipping technique for PAPR reduction. The proposed PAPR reduction technique is sensitivity-based clipping technique based on adaptive clipping for the amplitude of the input signal, where each of signals related to the different four groups of the modified SPIHT coder is clipped with a different clipping level according to the group sensitivity. The problem of the distortion, which is associated with the amplitude clipping will be almost solved using the proposed adaptive clipping technique. Therefore, the modified OFDM system with the proposed adaptive clipping and the JSCC will reduce the PAPR and compensate the resulting distortion and the degradation in the Peak-signal-to-noise ratio PSNR value.

4. Simulation results

4.1. BER performance for the modified OFDM system

The proposed scheme is experimentally evaluated for the transmission of the (512 × 512) 8-bit monochrome test image “LENA” over the modified OFDM system. Scalable bit stream was generated using the modified SPIHT source coder. Then we use LDPC for encoding the output of the SPIHT coder with EEP and UEP schemes, the equal protection code rate REEP = 3/4 and total transmission rate TR = 0.172 bpp. The simulation parameters of OFDM system is N = 256 subcarriers and CP=0.25. Table 1 shows the simulation results. These results have been obtained with transmitting the image over an AWGN channel in two cases: in the first case SNR = 5dB and the mapping format is QBSK, in the second case SNR = 12dB and QAM16 mapping is used.

Table 1
The decoded "LENA" Image for EEP and UEP at TR =0.172bpp

Scheme / Measure	Original OFDM	Modified OFDM (EEP)	Modified OFDM (UEP)
	Mapping=QPSK SNR=5dB Code Rate=3/4		
MSE	4.1937e+003	3.3561e+003	175.1295
PSNR (dB)	11.5670	12.9628	25.7271
	Mapping=QAM16 SNR=12dB Code Rate=3/4		
MSE	3.6295e+003	2.9059e+003	153.1731
PSNR (dB)	12.7586	13.9452	26.5336

Figure 3 shows the PSNR of the reconstructed "LENA" image over AWGN channel with the original OFDM and the modified OFDM systems ,where the used simulation parameters are: code rate = 3/4, the total transmission rate = 0.172 bpp, SNR = 15 dB and QAM16 mapping.

(a)

(b)

(c)

Fig. 3. The decoded LENA image from left to right, (a) original, (b) original OFDM [PSNR= 24.5140 dB], (c) modified OFDM (UEP) [PSNR= 30.4160 dB]

As shown from the simulation results: our proposed modified OFDM system outperforms the original OFDM system. The superior performance of the modified OFDM system is due to employing the JSCC, which based on the modified SPIHT and LDPC. The modified OFDM system achieves an improvement in the PSNR of the reconstructed image over the original system, i.e. approximately 6 dB improvement over AWGN with SNR = 15 dB, QAM16 mapping and TR = 0.172 bpp.

4.2. PAPR performance for the modified OFDM system with the adaptive clipping technique

Simulations are used to clarify the peak power reduction capability and the BER performance with the proposed technique. The modified OFDM system with the proposed adaptive clipping technique was experimentally evaluated for the transmission of the (512 ×512) 8-bit monochrome test image "LENA" over AWGN channel. The simulation results and the values for the maximum PAPR (PAPR_max) and the average PAPR (PAPR_av) are shown in Table 2, where the simulation parameters are: code rate=3/4, TR=0.172 bpp, N = 256 subcarriers, CP=0.25, QPSK and QAM16.

Table 2

The simulation results for the adaptive clipping technique for PAPR reduction over AWGN channel at TR = 0.172bpp

Measure / Scheme	PAPR_max	PAPR_av	PSNR (dB)
Mapping=QPSK SNR=9dB Code Rate=3/4			
Original OFDM	9.7902	7.8173	21.2803
Modified OFDM	11.2442	7.7623	30.4160
Modified OFDM- With adaptive clipping	7.7887	3.0617	30.4160
Mapping=QAM16 SNR=15dB Code Rate=3/4			
Original OFDM	9.8262	7.8394	23.0684
Modified OFDM	10.4304	7.7852	30.4160
Modified OFDM-	7.8309	3.9279	29.9306

Measure / Scheme	PAPR_max	PAPR_av	PSNR (dB)
With adaptive clipping			

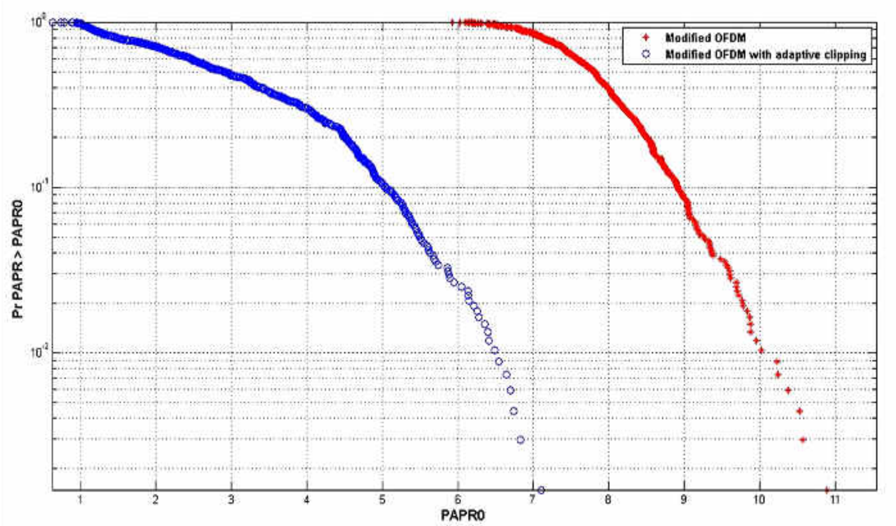

Fig. 4. CCDF comparison of PAPR for the modified OFDM system with and without adaptive clipping over AWGN with QBSK mapping

Figure 4 shows Complementary Cumulative Distribution Function (CCDF) comparison of PAPR for the modified OFDM system with and without adaptive clipping over AWGN with SNR =9dB and with QBSK mapping. Form the CCDF curves we note that the modified OFDM system with the adaptive clipping outperforms the OFDM system without adaptive clipping. Also figure 5 shows the reconstructed “LENA” image over the OFDM system with and without adaptive clipping with the previous simulation parameters at TR = 0.172 bpp.

Figure 6 and Figure 7 shows CCDF comparison of PAPR and the reconstructed “LENA” image for the modified OFDM system with and without adaptive clipping. The simulation carried over the AWGN channel using QAM16 mapping and with SNR = 15dB and TR = 0.172 bpp.

(a)

(b)

(c)

Fig. 5. The decoded LENA image from left to right, (a) original, (b) modified OFDM [PSNR= 30.4160 dB], (c) Modified OFDM with adaptive clipping [PSNR= 30.4160 dB] over AWGN channel at SNR=9 dB with QBSK

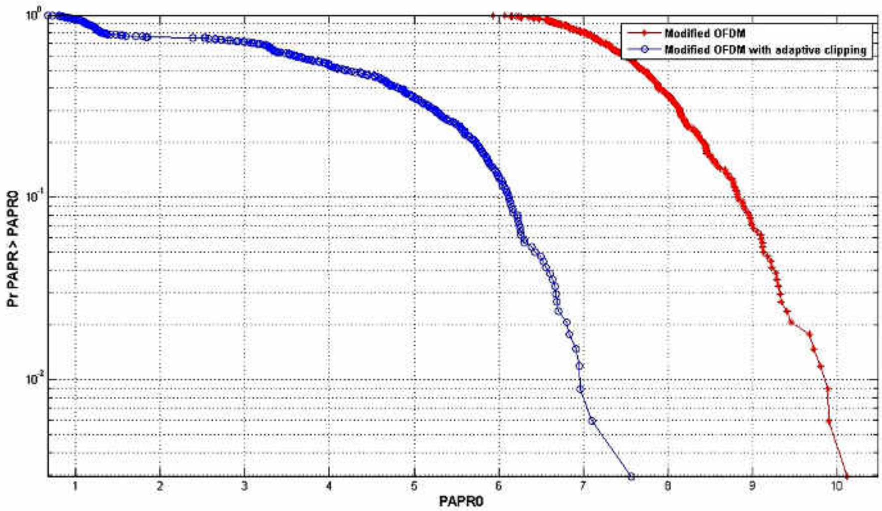

Fig. 6. CCDF comparison of PAPR for the modified OFDM system with and without adaptive clipping over AWGN channel with QAM16 mapping

(a)

(b)

(c)

Fig. 7. The decoded LENA image from left to right (a) original (b) modified OFDM [PSNR= 30.4160 dB] (c) Modified OFDM with adaptive clipping [PSNR= 29.9306 dB] over AWGN channel at SNR=15 dB with QAM16

As shown from the simulation results; the proposed adaptive clipping technique for PAPR reduction achieves good results and reduce the PAPR of the OFDM system with no noticeable effect on the PSNR of the reconstructed image. For example the proposed technique reduce the PAPR by approximately 4 dB over AWGN channel at SNR=9 dB using QBSK mapping and approximately by 2.5 dB over AWGN channel at SNR=12 dB using QAM16 mapping.

5. Conclusions

In this paper, a modified OFDM system was proposed. A JSCC was employed at the modified OFDM system, this JSCC consists of a modified SPIHT as source coder and an LDPC as channel coder. An UEP process was done for data protection based on the data sensitivity. Also an adaptive clipping technique for PAPR reduction was proposed in the modified OFDM system. The performance of the modified OFDM was evaluated with transmitting the modified SPIHT image streams over an AWGN channel. The simulation results indicate that the modified OFDM system scheme provides significantly better PSNR performance in comparison to the original OFDM system. Moreover, the simulation results for the adaptive clipping technique showed that the proposed technique achieved good results and reduced the PAPR value of the modified OFDM system without noticeable degradation in the PSNR the reconstructed image.

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النقل التدريجى للصور فى نظم الترددات المتعامدة ذات التقسيم المتعدد

ملخص:

يقدم فى هذا البحث مقترح تعديل نظام الترددات المتعامدة ذات التقسيم المتعدد (OFDM) لنقل الصور بنظام النقل التدريجى بطريقة متينة. فى هذا النظام المعدل تتم عملية التشفيرلكل من مصدر الصورة والقناة بطريقة مرتبطة حيث انه يستخدم النظام المسمى "تقسيم الأجزاء بطريقة الشجرة الهرمية" (SPIHT) لتشفير المصدر و يستخدم (LDPC) كنظام لتصحيح الأخطاء عبر قناة الإتصال فى الصورة المرسلة. وتم تعديل نظام (SPIHT) بحيث يتم تصنيف النبضات أثناء عملية التشفير وتقسيمها إلى أربع مجموعات طبقا لأهميتها. وتتم طريقة حماية الخطأ غير المتساوية (UEP) لتلك المجموعات. وأيضا يحتوى ذلك النظام المعدل على تقنية القص المتغيرة للإشارة وذلك لتقليل نسبة معامل "أقصى قرة إلى متوسط القدرة" (PAPR), حيث انه تختلف قيمة مستوى القص من إشارة إلى أخرى وذلك حسب أهميتها. للتدليل على كفاءة النظام المقترح تم عرض نتائج المحاكاة على أساس معدل خطأ النبضة (BER) و نسبة ذرة الإشارة إلى الضوضاء (PSNR) و نسبة معامل "أقصى قرة إلى متوسط القدرة" (PAPR) . وأثبتت هذه النتائج كفاءة النظام المقترح بالنسبة للمعاملات المذكورة.