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## Robust Image Transmission with OFDM over an AWGN Channel

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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 (JSC C) is employed in the modified OFDM system. A new scheme approach is proposed for progressive image transmission over coded Orthogonal Frequency Division Multiplexing (OFDM) system with Low Density Parity Check Coding (LDPC). Trigonometric transforms are used in this scheme for improving the performance of the OFDM systems and reducing the Peak to-Average Power Ratio (PAPR) of OFDM signal. It improves the error resilience ability and transmission efficiency for progressive image transmission over Additive White Gaussian Noise (AWGN) channel. The Set Partitioning In Hierarchical Trees (SPIHT) algorithm is used for source coding of the images to be transmitted. In the proposed scheme the transmit data sequence of the OFDM signal after Inverse Fast Fourier Transform (IFFT) is grouped into in-phase and in-quadrature components, then each component is transformed using either the Discrete Cosine Transform (DCT) or the Discrete Sine Transform (DST). The simulation results show that adding the DST to the system improves the visual quality of reconstructed images and reduces the PAPR of OFDM signal more than the DCT.

**KEYWORDS:** OFDM, PAPR, SPIHT, LDPC, Trigonometric transforms.

### I. 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 bit stream is that it is highly prone to transmission noise. Channel codes are required to protect the source encoded bit stream. 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-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.

OFDM modulation has been adopted by several wireless multimedia transmission standards, such as Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB-T), because it provides a high degree of immunity to multipath fading and impulsive noise. High spectral efficiency and efficient modulation and demodulation by

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IFFT/FFT are also advantages of OFDM. In the frequency-selective radio transmission channel, all fading and Inter-Symbol Interference (ISI) result in severe losses of transmitted image quality. OFDM divides frequency-selective channel into several parallel non frequency selective narrow-band channels, and modulates signal into different frequencies. It can significantly improve the channel transmission performance without employing complex equalization schemes. It also has broad application prospect in wireless image and video communications. There are still some challenging issues, which remain unresolved in the design of OFDM systems.

The SPIHT algorithm has been introduced by Said and Pearlman . It is algorithm based on the wavelet transform, and restricts the necessity of random access to the whole image to small sub images. The principle of the SPIHT is partial ordering by magnitude with a set partitioning sorting algorithm, ordered bit plane transmission, and exploitation of self-similarity across different scales of an image wavelet transform. The SPIHT is used for image transmission over the OFDM system in several research works because the SPIHT has a good rate-distortion performance for still images with comparatively low complexity and it is scalable or completely embeddable. To improve the BER performance of the OFDM system, several error correcting codes have been applied to OFDM .

The SPHIT algorithm defines and partitions sets in the wavelet decomposed image using a special data structure called a spatial orientation tree. A spatial orientation tree is a group of wavelet coefficients organized in to a tree rooted in the lowest frequency (coarsest scale) sub band with offspring in several generations along the same spatial orientation in the higher frequency sub band. The SPHIT algorithm consists of three stages: initialization, sorting and refinement. It sorts the wavelet coefficients into three ordered lists: the list of insignificant sets (LIS), the List of Insignificant Pixels (LIP), and the List of Significant Pixels (LSP). At the initialization stage the SPIHT algorithm first defines a start threshold based on the maximum value in the wavelet pyramid, then sets the LSP as an empty list and puts the coordinates of all coefficients in the coarsest level of the wavelet pyramid (Le. the lowest frequency band; LL band) into the LIP and those which have descendants also into the LIS. In the sorting pass, the algorithm first sorts the elements of the LIP and then the sets with roots in the LIS. For each pixel in the LIP it performs a significance test against the current threshold and outputs the test result to the output bit stream.

LDPC codes are a class of linear block codes which provide a reliable transmission for coding performance that is very close to the Shannon's limit and can outperform Turbo codes at long block length but with relatively low decoding complexity. LDPC has been adopted as the DVB-S2 standard. A  $(N, K)$  LDPC code can be represented by a very sparse parity-check matrix having  $M$  rows,  $N$  columns and code rate  $R=K/N$ , where  $K=N-M$  The combination of the high spectral efficiency OFDM modulation technique and LDPC coding will be a good candidate for high speed broadband wireless applications.

The BER performance of the Low Density Parity Check Coding- Coded Orthogonal Frequency Division Multiplexing system (LDPC-COFDM) is influenced by the sub channels which have deep fade due to frequency selective fading. According to this combination, several algorithms were introduced into LDPC-COFDM system to improve the BER by adaptive bit loading and power allocation of each subcarrier. The paper concentrates on two targets reducing the PAPR of the OFDM signal and improving the quality of the reconstructed images. It considers the trigonometric transforms as a way for reducing the PAPR by using the character of the DCT/DST energy focused in the low component.

The data of OFDM signal is modulated by IFFT then using DCT/DST, which can reduce the PAPR. Compared with the means of SLM-OFDM and PTS-OFDM, OFDM system modified by DCT/DST maintain the system orthogonal properties, which will not result in additional noise and need not transmit side information. At the same time, the proposed method reduces the PAPR greatly and the system has character of low complexity hardware.

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 represents a modified OFDM system with a JSCC scheme, which combines simple modification of the SPTHT image coding technique followed by an UEP process using LDPC. The modified SPTHT coder will generate four groups of bit streams. The significant bits, the sign bits, the set bits, and the refinement bits are

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transmitted in four different groups. The output of the SPTHT 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 A WGN communication channel. The rest of this paper is organized as follows. Section 2 presents the SPIHT coder and UEP process.

## a. Motivation

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 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.

There are still some challenging issues, which remain unresolved in the design of OFDM systems. One of the major problems is high PAPR of transmitted OFDM signals. Therefore, the OFDM receiver 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. All fading and Inter-Symbol Interference (ISI) result in severe losses of transmitted image quality. The aim of this project is reduce the PAPR of transmitted OFDM signals, improve the transmitted image quality & The SPIHT coder is chosen as the source coding technique due to its flexibility of code rate and simplicity of designing optimal system.

## b. Project Objective

The project concentrates on two targets reducing the PAPR of the OFDM signal and improving the quality of the reconstructed images. It considers the trigonometric transforms as a way for reducing the PAPR by using the character of the DCT/DST energy focused in the low component. The data of OFDM signal is modulated by IFFT then using DCT/DST, which can reduce the PAPR. Compared with the means of SLM-OFDM and PTS-OFDM, OFDM system modified by DCT/DST maintain the system orthogonal properties, which will not result in additional noise and need not transmit side information. At the same time, the proposed method reduces the PAPR greatly and the system has character of low complexity hardware.

Simulation:

Software Tools Used :- MATLAB 2010a  
MATLAB Simulation are carried to study the transmission of SPIHT coded images on LDPC COFDM modified by Trigonometric transforms over AWGN channel

## II. LITERATURE SURVEY

There are several developed techniques to reduce the PAPR in OFDM systems[3,4] such as clipping[5], companding[6,7], Partial Transmit Sequence[8], (PTS) Selected Mapping (SLM)[9], and coding [10]. The clipping technique is the simplest one that can be used in OFDM systems, but it causes additional clipping noise, which degrades the system performance. An alternative technique to mitigate the PAPR problem is based on signal transformations. This technique involves a signal transformation prior to amplification, then an inverse transformation at the receiver prior to demodulation. In [11] trigonometric transforms were suggested as alternatives for the FFT to reduce the PAPR. The authors in concluded that OFDM systems with trigonometric transforms provide higher PAPR reduction than the standard FFT based system. However, they modified the OFDM symbols before transmission using

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the PTS. Their results reveal that without PTS, the distribution of PAPR is the same for that conventional one such that the reduction depends on PTS, which makes redundancy in the system.

The SPIHT is used for image transmission over the OFDM system in several research works[13,14] because the SPIHT has a good rate-distortion performance for still images with comparatively low complexity and it is scalable or completely embeddable.

Y. Sun, X. Wang and Liu proposed the paper[13] "A Joint Channel Estimation and Unequal Error Protection Scheme for Image Transmission in Wireless OFDM Systems" in "Multimedia Signal Processing" Journal, IEEE, pp. 380 - 383, 2002 - This orthogonal frequency division multiplexing (OFDM) modulation, adopted by the digital video broadcasting (DVB-T) standard, has been recognized for its good performance for high data rate wireless communications. Therefore, the study of the robust transmission of multimedia data over OFDM systems has attracted extensive research interests. In the past, channel estimation, which is an important aspect in OFDM systems, has not been exploited for multimedia transmission. When using the block training based channel estimation, OFDM data blocks experience unequal decoding error rate due to the imprecision of channel estimation. We use this property to provide unequal error protection (UEP) for transmission of SPIHT coded images. Compared with the systems using pilot training channel estimation schemes, which are recommended in the DVB-T standard, the proposed scheme improves the PSNR of reconstructed images by up to 2 dB.

Gusmo, R. Dinis and N. Esteves[2] proposed the paper "On Frequency Domain Equalization and Diversity Combining for Broadband Wireless Communications" in IEEE Commun. Lett., Vol.51, No.7, 2003. This is concerned with the use of frequency-domain equalization (FDE) and space diversity within block transmission schemes for broadband wireless communications. The expected performance with both multicarrier (MC) and single-carrier (SC) modulations is emphasized, when a cyclic prefix, long enough to cope with the maximum relative channel delay, is appended to each transmitted block. A set of numerical results is presented and discussed, with the help of appropriate, analytical performance bounds which are conditional on a given channel realization. These bounds are used to explain the performance advantage of the SC/FDE option, the benefits of space diversity, and the impact of the criterion for computing the FDE parameters.

C. Yuan Yang and M. Kai Ku[18] proposed the paper, "LDPC Coded OFDM Modulation for High Spectral Efficiency Transmission" Proceedings in ECCSC 2008, 2008. This paper investigates efficient low-density parity-check (LDPC) coded orthogonal frequency division multiplexing (OFDM) modulation schemes for fixed wireless application. We use partially LDPC coded with double gray code labeling technique and Reed-Solomon code with LDPC Coded Modulation (RS-LCM) to achieve better performance than the conventional LDPC bit-interleaved coded modulation (BICM) scheme. RS-LCM scheme outperforms BICM scheme by 0.4 dB at a BER of  $10^{-5}$ .

S. Wang, J. Dai, C. Hou and X. Liu[14] proposed the paper, "Progressive Image Transmission over Wavelet Packet Based OFDM" Proceedings in Electrical and Computer Engineering 2006 Canadian Conference 2006. A new scheme for progressive image transmission over wavelet packet based orthogonal frequency division multiplexing (WP-OFDM) system is proposed. First, the BER performances of WP-OFDM systems with different Daubechies wavelet as orthogonal basis functions in multipath fading channel are investigated. The results show that there are error floors in the BER curves, so an equalization method is applied to eliminate the error floor. Then in the WP-OFDM system with the equalization method, a joint source channel coding (JSCC) method is introduced to give image encoder output bit streams with different perception importance unequal error protection. Simulation results confirm the effectiveness of our proposed image transmission scheme.

A. Rushdi and J. Tuqan [11] proposed paper, "Peak reduction in Trigonometric Based OFDM System" Proceedings in ACSSC. 2007. A key building block in any OFDM transceiver is the Fast Fourier Transform (FFT) and its inverse. A number of researchers have recently proposed the use of the discrete cosine transform (DCT) and the discrete sine transform (DST), and their inverses as alternative modulating/demodulating bases to improve the BER performance of OFDM schemes while maintaining a low implementation cost. In this paper, we consider the open problem of reducing the peak-to-average power ratio (PAPR) in OFDM systems that deploy these trigonometric transforms. In specific, we show that similar to the FFT case, the complex envelope of a band limited DCT/DST-OFDM signal has a chi-square distribution with one degree of freedom and hence converges weakly to a Gaussian random process as the number of sub-carriers becomes large. Using this result, we then derive closed form expressions for the complementary

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cumulative distribution functions (CCDF) of each system and show that OFDM systems with trigonometric transforms provide higher PAPR reduction than the standard FFT-based system. Simulation results that compare the CCDFs of the different transforms using the partial transmit sequences (PTS) technique confirm our theoretical findings.

T. Jiang and Y. Wu[3] proposed paper, "An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals"2008. One of the challenging issues for Orthogonal Frequency Division Multiplexing (OFDM) system is its high Peak-to-Average Power Ratio (PAPR). In review and analysis different OFDM PAPR reduction techniques, based on computational complexity, bandwidth expansion, spectral spillage and performance. And [4, 5, 6] also some methods of PAPR reduction for multiuser OFDM broadband communication systems.

### III. OFDM SYSTEM DESCRIPTIONS WITH PROPOSED MODIFICATION

The block diagram of the proposed LDPC-COFDM system is illustrated in Fig. 1. As will be shown in the next sections, the proposed modifications will be in the transform and replacement block. The SPIRT coder is chosen as the source coding technique due to its flexibility of code rate and simplicity of designing optimal system. The SPHIT divides the image stream into several layers according to the importance of progressive image stream. Then the image stream is converted to a binary format. Afterwards the information bits are LDPC encoded at the LDPC encoder. The OFDM considered in this paper 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 code word is on different subcarrier.

The output of IFFT is split into two components; in-phase and in-quadrature. Then, either the DCT or the DST is applied to both components, separately. The first half of samples of the in-phase component after the transform ( $L_i$ ) is concatenated with the first half of samples of the in-quadrature component after the transform ( $L_q$ ) to form the new in-phase component. Similarly, the second half of samples of the in-phase component after the transform ( $H_i$ ) is concatenated with the second half of samples of the in-quadrature component after the transform ( $H_q$ ) to form the new in-quadrature component. Finally, the new components are added to produce the OFDM signal as shown.

$$x(t) \cong x[n] = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi f_n t}, 0 \leq t \leq T$$

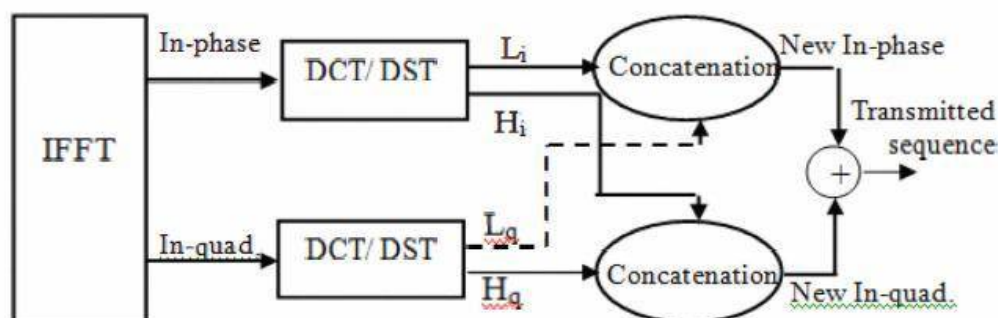


Fig. 1: The trigonometric transform and replacement process.

This sequence after this process can be called  $x_{in}$  with the subscript d referring to the trigonometric transformation process. Each data block is padded with a cyclic prefix (CP) of a length longer than channel impulse response to mitigate the Inter-Block Interference (IBI). The continuous COFDM signal  $x_c(t)$  is generated at the output of the digital to analog (D/A) converter. According to [1], the PAPR of transmitted analog signal can be expressed as follows:

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

where  $E[.]$  is the average power. Generally, the PAPR is considered for a single OFDM symbol, which has a time duration  $T$ . This duration comprises a number of samples equal to  $(N_f + N_g)$ , where  $N_g$  is the guard interval length. At the receiver, the guard interval is removed and the time interval  $[0, T]$  is evaluated. The replacement and inverse transform are then applied to the received samples. Afterwards, 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 demodulated at the demodulator. The demodulated bits are decoded with each LDPC encoded block and data bits are restored. These data are converted into image format, such that SPIHT decoder can be obtained.

### IV. EXPERIMENTAL SET UP

Table 1: The Decoded "LENA" Image for EEP and UEP at R = 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

The proposed scheme is experimentally evaluated for the transmission of the (512 x 512) 8-bit monochrome test image "LENA" over the modified OFDM system. The resulted scalable bit stream which generated using the modified SPIHT source coder is encoded using LDPC coder with an equal error protection (EEP) and an unequal error protection (UEP) schemes. The used simulation parameters are: the equal protection code rate is  $R_{EEP} = 3/4$ , the total transmission rate is  $R = 0.172$  bpp, the number of subcarriers is  $N = 256$  subcarriers and the cyclic prefix is  $CP=0.25$ . Table 1 shows the simulation results for transmitting the "LENA" image over an AWGN channel in two cases: in the first case  $SNR = 5$  dB and the mapping format is QPSK, in the second case  $SNR = 12$  dB and QAM16 mapping is used.

Figure 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,  $R = 0.172$  bpp,  $SNR = 15$  dB and QAM16 mapping.

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Fig. 2: 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 is based on the modified SPTHT 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 R = 0.172 bpp.

### B. 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 x512) 8-bit monochrome test image "LENA" over AWGN channel and calculating the PAPR for each transmitted OFDM symbol. Table 2 shows the PSNR of the reconstructed image and the maximum and average values (PAPR<sub>max</sub> and PAPR<sub>av</sub>) of transmitted OFDM symbols PAPR's for the original OFDM system, the modified OFDM system and the modified OFDM system with the adaptive clipping technique, where the simulation parameters are: code rate=3/4, R = 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 R = 0.172bpp

Measure	PAPR <sub>max</sub>	PAPR <sub>av</sub>	PSNR (dB)
Scheme			
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	29.5970
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-With adaptive clipping	7.8309	3.9279	29.9306

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Figure 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 QPSK mapping. From the CCDF curves we note that the modified OFDM system with the adaptive clipping outperforms the OFDM system without adaptive clipping.

Also figure shows the reconstructed "LENA" image over the OFDM system with and without adaptive clipping with the previous simulation parameters at R = 0.172 bpp.

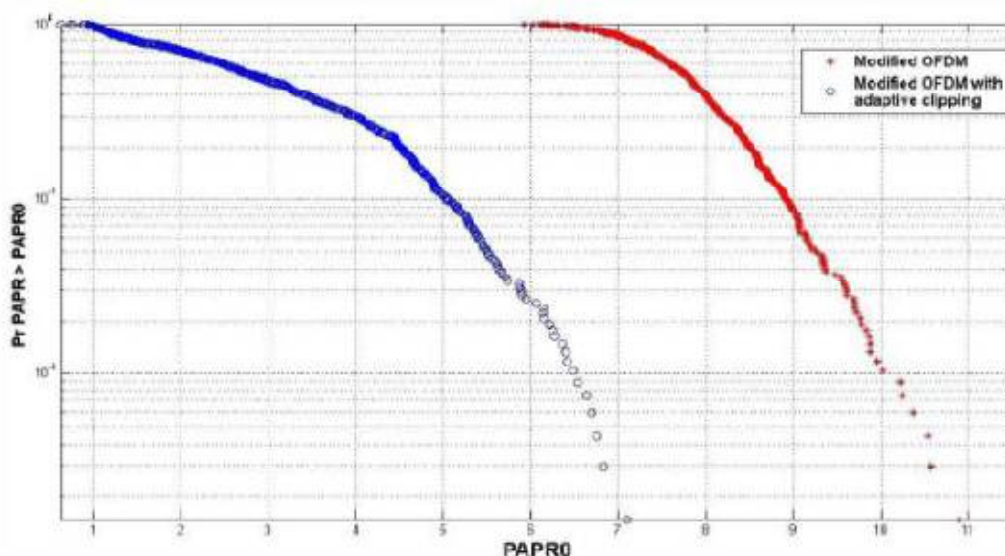


Fig. 3: CCDF comparison of PAPR for the modified OFDM system with and without adaptive clipping over A W GN with QPSK mapping



Fig. 4: The decoded LENA image from left to right, (a) original, (b) modified OFDM [PSNR= 30.4160 dB], (c) Modified OFDM with adaptive clipping [PSNR= 29.5970 dB] over A W GN channel at SNR=9 dB with Q BSK

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.



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For example the proposed technique reduce the PAPR by approximately 4 dB over AWGN channel at SNR=9 dB using QPSK mapping and approximately by 2. 5 dB over AWGN channel at SNR=12 dB using QAMI6 mapping

SNR With Different SPHIT rate		
Sr No	SPIHT Rate	SNR values in dB
1	r=0.2 bpp	11.36
2	r=0.172bpp	10.7027
3	r=0.5 bpp	15.3091
4	r=0.75 bpp	18.0969
5	r=1.0 bpp	21.0284

Table 3: SNR With Different SPHIT rate

## V. CONCLUSION

The combination of the high spectral efficiency OFDM modulation technique and LDPC coding will be a good candidate for high speed broadband wireless applications. The BER performance of the Low Density Parity Check Coding- Coded Orthogonal Frequency Division Multiplexing system (LDPC-COFDM) is influenced by the sub channels which have deep fad due to frequency selective fading. According to this combination, several algorithms were introduced into LDPC-COFDM system to improve the BER by adaptive bit loading and power allocation of each subcarrier. The efficient LDPC coded OFDM system with trigonometric transforms supporting image transmission using SPIHT compression technique is presented and studied. The effectiveness of the proposed system is investigated through simulations over AWGN channel. It is found that the proposed system must be designed carefully in order to achieve a reduction in the PAPR without degrading the PSNR performance. For LDPC COFDM with rate (R=0.5) and rate of SPIHT rate (r = 1) the OFDM signal can be reduced by nearly 7dB or 7.25dB by adding the DCT or DST respectively. We also try to obtain the PSNR for the received standard image through internet at different rates. This work will give the performance of the system model using any realtime 256x256 grayscale images.

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