PAPR Reduction using OFDM Technique with Rate and Power Allocation Employed with JSCC Coding Technique

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ABSTRACT
A robust and an efficient source and channel coding algorithms is proposed in this paper for the purpose of progressive transmission of images over wireless communication systems. This paper presents a modified orthogonal frequency division multiplexing system for robust progressive image transmission. A joint source channel coder is employed in the modified OFDM system. The set Partioning hierarchical trees (SPIHT) used as source code and low density parity check code used as channel coder. The input image is applied with discrete wavelet transforms, by using an wavelet type of biorthogonal wavelet family, in turn then the SPIHT algorithm is applied for the further process, while decoding an IDWT is applied for the reconstruction of the image. The modified OFDM system includes an adaptive clipping technique as a peak to average power ratio reduction technique for the OFDM signal. This proposed PAPR reduction technique is based on adaptive clipping for the amplitude of the input signal, where each of the signals related to the different four groups of the modified SPIHT coder is clipped with a different clipping level according to the group sensitivity, also this work is carried on a 1024*1024 image. Finally this paper demonstrates the efficiency of the modified OFDM system with proposed PAPR reduction technique, when compared with a normal OFDM system without the adaptive clipping technique, and also a CCDF (complementary Cumulative Distributive function) comparison of PAPR is done for the modified OFDM system with and without adaptive clipping over AWGN with QPSK and QAM16 modulation 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, Wavelet, biorthogonal, CCDF, LDPC, Unequal Error Protection (UEP), AWGN channel.

1. INTRODUCTION
Transmission of images over wireless communication systems requires 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. Where in the main drawback is that the progressive organization of the bitstream is highly prone to transmission noise. Channel codes are required to protect the source encoded bitstream. 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 code as well as the conditions of the channel. Forward Error Correction (FEC) scheme [3] is incorporated to increase the transmitted data rate and protect the data prior to transmission. One such FEC scheme 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 based mobile worldwide interoperability for microwave access (mobile WiMAX) based on OFDM access technology [7] and Digital Video Broadcasting (DVB).some of the challenging issues remains 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 PAPR including its distribution and reduction in OFDM systems, in order to utilize the technical features of the OFDM. Some of the techniques that are developed 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. Then the output of the SPIHT image coding will be sent relative to its significant information. An adaptive clipping technique is proposed for the PAPR reduction for 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

One of the best image coding techniques i.e. the SPIHT coder in sense of progressive rate control, decoded image quality and transmission the simplicity of the coding process [1]. In the SPIHT coding algorithm, after the wavelet transmission using 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.

$$S_n(T) = \begin{cases} 0, \text{otherwise} \\ 1, \text{if } \max_{(i,j)\in\tau}\{|Y(i,j) \geq 2^n \end{cases} \quad (1)$$

Where $S_n(\Gamma)$ is the significance of the set of coordinates Γ , and Y(i, j) is the coefficient value at coordinate (i, j).Here the algorithm mainly consists of two passes, 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 consists of nodes that contain single pixels while the LIS contains nodes that have descendants. The maximum number of bits that is required to represent the largest coefficients in the spatial orientation tree is obtained and designed as n_{max} and is given by

$$n_{max}=\left[\log_2(\max_{(i,j)}\{|Y(i,j)|\})\right] \quad (2)$$

During the sorting pass, the coordinates of the pixels that remains in the LIP are tested for significance by using equation (1). Then 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.LIS sets will also have their significance tested and if it is found to be significant it will be added to the LSP, or else they will be added to the LIP. Whereas in the refinement pass, the nth most significant bit of the coefficients in the LSP is output. The value of n will be decreased by 1 and sorting and refinement passes occur again. This process 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 is done. The bit error sensitivity (BES) study is performed by first coding the original image using the SPIHT coder. One of the 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 then 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:

- The significance bit in the bit stream. It decides Whether nodes in the LIP are significant.
- The sign bit of a significant node is transmitted after the significance bit.
- The set bit decides whether the set is significant or not.
- The refinement bits are transmitted during the refinement passes.

In Figure1, the order of significance is from the most significant types of bits to the least significant for gray(1024X 1024) LENA image (at 0.129 bpp) is as follows: the significance bits > sign bits > set bits > refinement bits.

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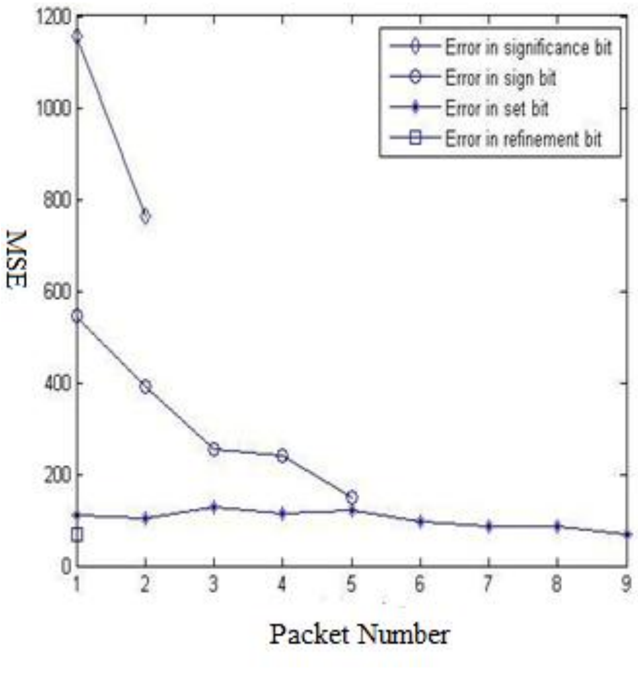

Fig1:Error bit sensitivities within the SPIHT bit stream

The resulted groups that are obtained from the SPIHT coder are unequally protected using the LDPC coder, where the amount of the redundancy which adds the data to each group for protection using the LDPC channel coder depends on the group sensitivity.

Following a wavelet transformation, SPIHT divides the wavelet into *Spatial Orientation Trees* as shown in figure 2. Each node in the tree corresponds to an individual pixel. The offspring of a pixel are the four pixels in the same spatial location of the same subband at the next finer scale of the wavelet. Pixels at the finest scale of the wavelet are the leaves of the tree and have no children. Every pixel is a part of a 2 x 2 block with its adjacent pixels. Blocks are the natural result of the hierarchical trees because every pixel in a block will be shared by the same parent. Also, the upper left pixel of each 2 x 2 block at the root of the tree has no children since there are only 3 subbands at each scale and not four. Figure 2 shows how the pyramid is defined. Arrows points to the offspring of an individual pixel, and the grayed blocks shows that all the descendants for a specific pixel at every scale. SPIHT codes a wavelet by transmitting the information about the significance of a pixel. By stating whether or not a pixel is above some threshold, information about that pixel's value is implied. Furthermore, SPIHT transmits the information stating whether the pixel or any of its descendants is above a threshold. If the statement proves to be false, then all of its descendants are known to be below that threshold level and they do not need to be considered during the rest of the current pass. At the end of each pass the threshold is divided by two and the algorithm continues, By proceeding in this manner, information about the most significant bits of the wavelet coefficients will always precede information on lower order significant bits, which is referred to as bit plane ordering. Within each bit plane data is transmitted in three lists: the list of insignificant pixels (LIP), the list of insignificant sets (LIS) and the list of significant pixels (LSP).

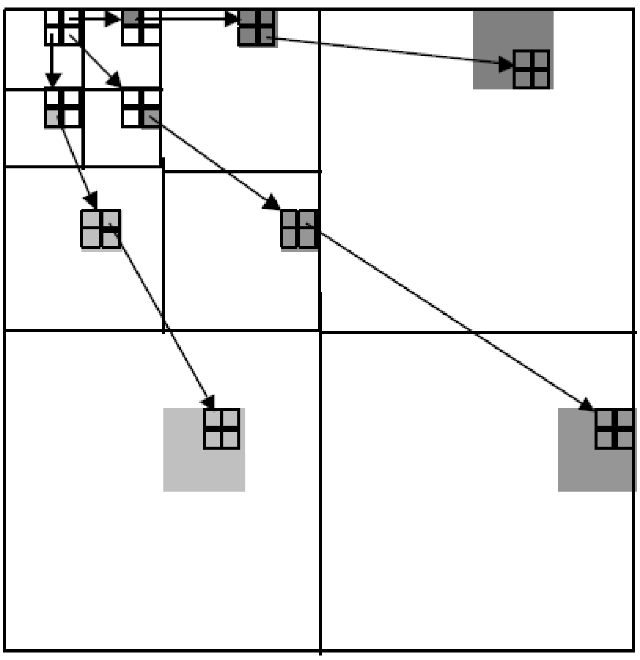

Fig2: Spatial-orientation trees

3. THE MODIFIED OFDM SYSTEM WITH THE PROPOSEDADAPTIVE CLIPPING TECHNIQUE

The block diagram of the proposed modified OFDM system is illustrated in Figure 4. 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 is being mapped by QPSK and QAM 16 mappers, In QPSK mapping mapping is done by multiplexing every two bits into a symbol so as to produce the baseband binary data. Whereas in QAM 16 mapping, mapping is done in such a way that, grouping 4 consecutive bits of the binary baseband stream and selecting one of the 16 waveforms accordingly wherein the resulting waveform occupies one-fourth bandwidth. Then, the transmitted data of each parallel sub-channel is mapped by QPSK or QAM16. Then, the mapped data will be fed into an IFFT circuit, such that the OFDM signal is generated. Finally the modulation is being performed by QPSK or QAM 16,Then the modulated data is passed over the AWGN channel. 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 original image can be reconstructed incrementally. Wherein 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. As shown in figure 4 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 code 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. Wherein the original image can be reconstructed incrementally

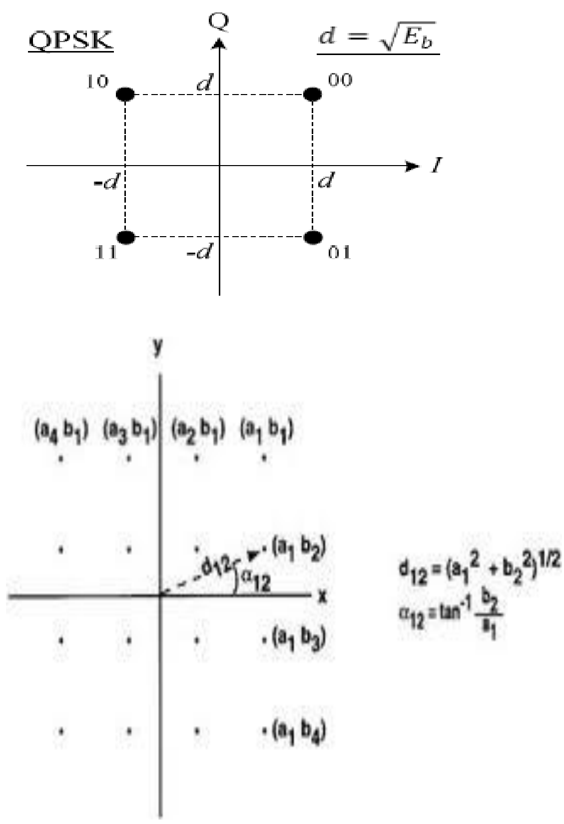

Fig 3:QPSK and QAM 16 constellation diagram

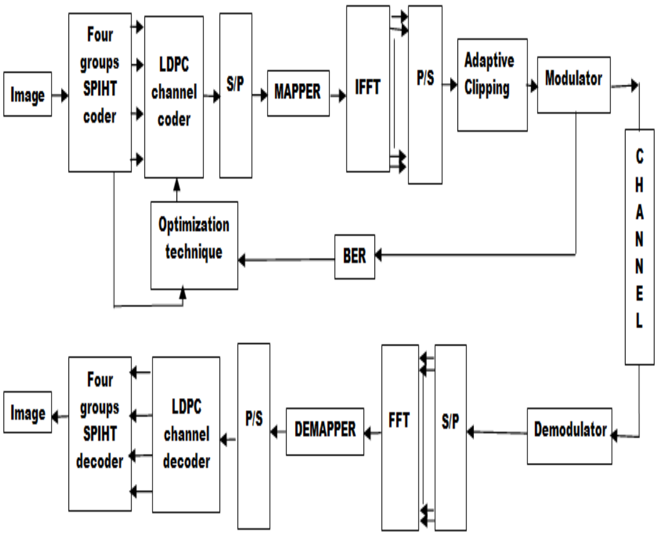

Fig 4: Modified OFDM Block Diagram

4. SIMULATION RESULTS

4.1. BER Performance for the Modified OFDM System

The proposed scheme is experimentally evaluated for the transmission of the (1024 X 1024) 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 RT = 0.180bpp. 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" for eep and uep at RT =0.180bpp

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 5 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 =0.180bpp, SNR = 15 dB and QAM16 mapping.

Fig 5:The decoded "LENA" 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 the technique employing JSCC, which is 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 RT = 0.180bpp

4.2. Performance of 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 (1024 X 1024) 8-bit monochrome test image "LENA" over AWGN channel.

TABLE 2:Performance of the adaptive clipping over the AWGN channel at RT=0.180bpp

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	29.5970
Modified OFDM-With adaptive clipping	7.7887	3.0617	30.4160
Mapping=QAM16 SNR=15dB Coate=3/4			
Original OFDM	10.8262	7.8394	23.0684
Modified OFDM	10.4304	7.7852	30.4160
Modified OFDM-With adaptive clipping	7.8309	3.9279	29.9306

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, RT=0.180 bpp, N = 256 subcarriers, CP=0.25, QPSK and QAM16.

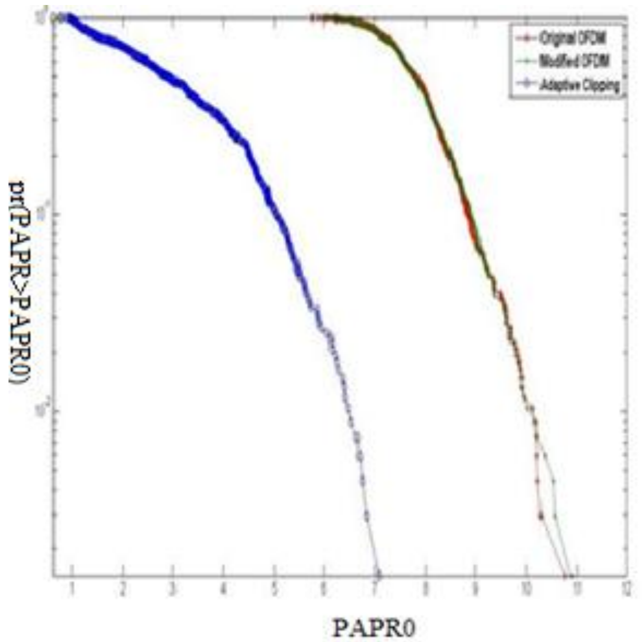

Fig6:CCDF comparison of PAPR for the modified OFDM system with and without adaptive clipping over AWGN with QPSK mapping

Figure 6 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. Form the CCDF curves we note that the modified OFDM system with the adaptive clipping outperforms the OFDM system without adaptive clipping. Also figure 7 shows the reconstructed "LENA" image over the OFDM system with and without adaptive clipping with the previous simulation parameters at RT= 0.180bpp

Fig7:The decoded "LENA" from left to right, (a) original, (b) modifiedOFDM [PSNR= 30.4160 dB], (c) Modified OFDM with adaptive clipping[PSNR= 29.5970 dB] over AWGN

Figure 8 and Figure 9 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 QAM16mapping and with SNR = 15dB and RT = 0.180bpp.

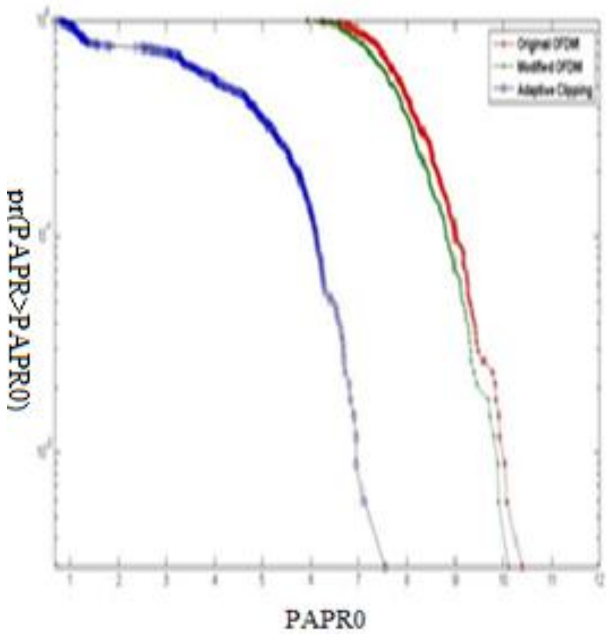

Fig8:CCDF comparison of PAPR for the modified OFDM system withand without adaptive clipping over AWGN channel with QAM16 mapping

Fig9: The decoded "LENA" from left to right (a) original (b) modifiedOFDM [PSNR= 30.4160 dB] (c) Modified OFDM with adaptive clipping [PSNR= 29.9306 dB] over AWGN channel at SNR=15 dB with QAM16

Figure 10 shows the comparison of PAPR's CCDF curves for both adaptive clipping technique and SLM method with a different number of phase sequences (U=4 and U=16). In Figure 10 it is clear that the adaptive clipping technique provides better PAPR reduction performance than the SLM method.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. Relative to the original OFDM system, the SLM method with U= 4 reduce the PAPR by about 1.7 dB, the SLM method with U= 16 reduce the PAPR by about 2.3 dB and the adaptive clipping technique reduce the PAPR by about 2.5 dB.

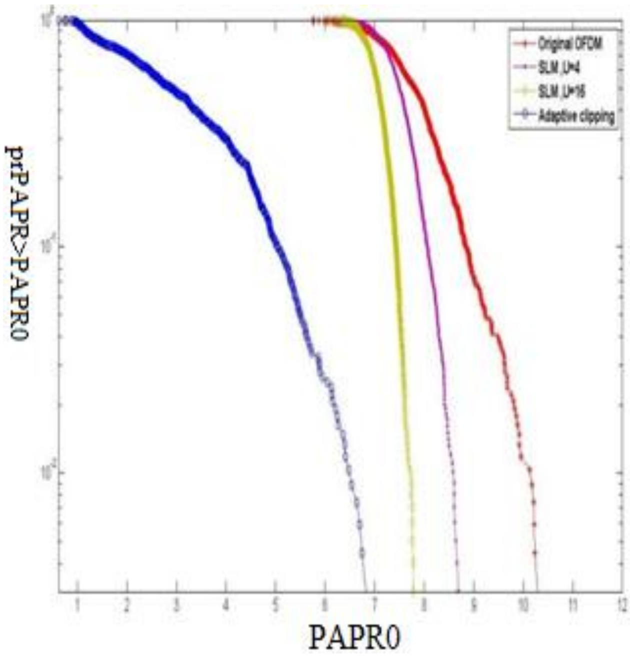

Fig 10:PAPPR's CCDF using SLM and Adaptive clipping with N=256

5. CONCLUSION

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 of the reconstructed image. Furthermore, the simulation results showed that the adaptive clipping technique outperforms the SLM method for PAPR reduction.

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