Joint Hybrid Compression Techniques and Convolutional Coding for Wireless Lossy Image Transmissions

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Abstract – This paper demonstrates the effect of color image transmission through AWGN channel using binary phase shift key modulation (BPSK) system and transmission of compressed color image through AWGN. On the other hand, the transmission consumes a large amount of channel and needs the processing, therefore utilizes compression techniques to reduce the size of the original color image to facilitate the transmission compressed color image through AWGN and to obtain the channel optimization. In this paper, a simple hybrid lossy color image compression transmission through AWGN using convolutional coding with Viterbi decoding system is proposed. It is based on combining effective techniques, started by wavelet transform that decompose the image signal followed by polynomial approximation model of linear based to compress approximation image band. The error caused by applying polynomial approximation is coded using bit plane slice coding, whereas the absolute moment block truncation coding exploited to coded the detail sub bands. Then, the compressed information encoded using LZW, run length coding and Huffman coding techniques, the compressed information is entered to the channel coding to coded the information using convolutional coding and modulation using BPSK to transmit through channel and added AWGN, the received signal is demodulated and decoded using Viterbi decoding, the result compressed data passed to source decoding to reconstruct the compressed image. The test results indicated that the proposed system can produce a balance between the compression performance and preserving the image quality, and also simulations results observed that with increase in signal to noise ratio (SNR) values the bit error rate (BER) values decrease.

Keywords – Hybrid lossy image compression, Convolutional coding, Viterbi decoding, AWGN , BPSK.

1. Introduction

Image compression addresses the problem of reducing the amount of information required to represent a digital image [1]. The colour image consists of three primary colours which are red (R), green (G) and blue (B) [22]. Each colour component (R,G,B) is usually specified with 8 bits, so a colour is specified by 24 bits per pixel. To transmit or store a colour image, a huge bandwidth or storage space is needed, to reduce storage space or transmission cost, image compression is the solution [23]. Redundancy is a basic issue in digital image compression [2]. Image compression techniques are categorized into two main types depending on the redundancy removal way, namely Lossless and lossy [3]. Lossless image compression also called information preserving or error free techniques, as their name implicitly indicates, no loss of information, in which the data have been losslessly compressed, in other words, the original data can be reconstructed exactly from the compressed data based on the utilization of statistical redundancy alone (i.e. inter pixel redundancy and/or coding redundancy) with low compression rate, such as Huffman coding, Arithmetic coding, Run Length coding and Lempel-Ziv algorithm [4] , [7]. In lossy image compression that characterized by degrade image quality, in which the data have been lossly compressed, in other words, the original data cannot be reconstructed exactly from the compressed data and there is some degradation on image quality based on utilization of psycho-visual redundancy, either alone or combined with statistical redundancy with higher compression rate, such as Vector Quantization, Fractal, JPEG and Block Truncation coding [8] , [9]. Review on various lossless and lossy techniques can be found in [5] , [20].

Recently, a vast amount of work have been done to improve the performance of image compression techniques, with tools such as Wavelet that become used with an international standards JPEG2000 techniques, where image coder based on wavelet transform the image is decomposed into sub bands images prior to the encoding stage. In other words, wavelet transform tries to isolate different characteristic of a signal in way that collects the signal energy into few component, generally the implementation of wavelet lies in design of filters for sub-band coding [10]. Today, there is trend in the use of predictive coding, where many researchers have exploited to compress images, using a mathematical model that implicitly requires the form of the dependency (causal/ acausal), the order of the model (number of neighbours exploited) and the structure (1-D/2-D). Different modelling structures have been discussed in [6] , [16]. The predictive coding of polynomial based represents an alternative effective way to overcome traditional predictive coding restrictions mentioned above [17] , [10]. In addition, there are traditional simple fast techniques like bit-plane slicing image that sliced the image onto layers [18] , [19] and block truncation coding (BTC) that utilized the first and second moments of each image block [11], [13] and [17] with an improved version that refereed as absolute moment block truncation coding(AMBTC) [14] , [15]. All the efficient standard techniques of hybrid base to increase the efficiency of performance, such as JPEG that exploited the discrete cosine transform (DCT) with predictive coding, review of hybrid techniques can be found in [21]. The rapid growth of wireless communications

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has a request for robust multimedia transmission with high quality, coverage, more power and bandwidth efficiency. Due to restrictions on the wireless communication channels such as limited bandwidth increases the demand for more efficient in performance image communication system that does not consume more bandwidth in order to achieve better image quality [24]. Thus, compression may be required for image transmission over wireless channels, due to compression is used to reduce the size of multimedia data transmitted over the communication channel via data compression techniques such as DWT, and may increase the performance of the communication system [25]. When the redundant bits removed from the image it will be fasting the data processing in the transmitter and receiver side. And as someone knows that any data transmitted through a wireless channel may be corrupted because of the noise effect and other environment effects such as fading, multipath and thermal noise, and to minimize the error in received data there are many techniques used to reconstruct the original transmitted data. One of these techniques use the channel coding and an efficient modulation technique for minimizing the bit error rate BER in the transmitted data [26] , [27]. In the modulation, the digital data need to be converted to waveforms for transmission

over a wireless channel, but in the demodulation the receiver translates the waveforms back into digital data [28]. Several modulation techniques existed, such as binary phase shift keying (BPSK) is the simplest form of modulation. It uses two phases which are separated by 180º [29]. In BPSK system change in phase of the sinusoidal carrier to refer to the information or data, then the phase of sinusoidal will shift by 180 degrees. Phase shift represents the change in state of information [30]. A wireless channel refers to a physical medium that is utilized to send a signal from a transmitter to a receiver. It can be a wire line, optical cable or a wireless radio channel [31]. In a real channel, the signal is modified through transmission in the channel. Signal degradations caused by wireless channels are highly dependent on the specific physical properties of the environment between the transmitter and receiver [32]. The transmitted signal is also corrupted by additive white Gaussian noise (AWGN). Additive white Gaussian noise is a channel in which the only impairment in communication is a linear addition of white noise with a constant spectral density (represented as watts per hertz of bandwidth) and a Gaussian distribution of amplitude as shown in Figure 1 [33].
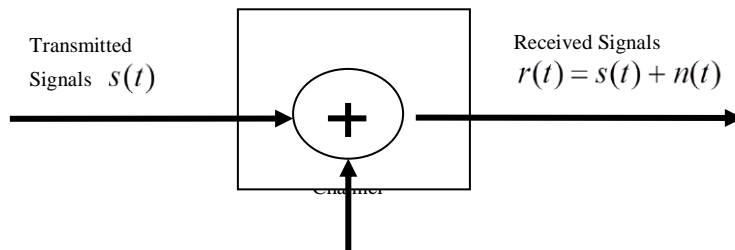
Transmitted Signals $s(t)$

Received Signals $r(t) = s(t) + n(t)$

Channel

Figure 1. AWGN Channel model.

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In this paper, a simple hybrid lossy techniques have been adopted for compressing colour images and transmission through AWGN, based on utilizing the wavelet transform, polynomial representation of linear based along with the bit-plane slicing and AMBTC, and transmission the compressed colour image using convolutional encoding with Viterbi decoding that exploited in an efficient way to improve the compression rate while preserving the image quality in order to reduce bit error rate (BER) through transmission when increase the signal to noise ratio (SNR) . The rest of the paper is organized as follows, section 2 contains error correction techniques applied for the proposed system; section 3 contains comprehensive clarification of the proposed system; the result of the proposed system is given in section 4; the result assessments is given in section 5; the conclusion is given in section 6.

2. Error Correction Techniques

The main aim of channel coding theory is to find codes which transmit quickly, contain a lot of valid code words and can correct or at least detect many errors. The needed characteristics of this code, mainly depend on the probability of errors happening during transmission. Channel coding is a method of introducing controlled redundancy into transmitted binary data stream in order to increase the reliability of transmission and reduce power transmission requirements. Channel coding is performed by introducing redundant parity bits into the transmitted information stream. The requirement of a channel coding scheme only exists due to the noise introduced in the channel. Simple channel coding schemes allow the receiver of the transmitted data signal to detect errors, while more sophisticated channel coding schemes provide the ability to recover a

limited about of corrupted data. This result in more reliable communication, and in many cases, removes the need for retransmission. The channel decoder will detect and correct the errors [34] , [35].

2.1 Convolutional Coding

Convolutional encoding is one method of performing channel coding. In these methods, redundant bits are used to help determine the occurrence of an error due to noise exists in the channel. Viterbi decoding is a method of performing channel decoding. Convolutional encoder accepts a sequence of message symbols and produces a sequence of code symbols. Its computations based not only on the current set of input symbols, but, on some of the previous input symbols as well. Convolutional encoder is performed on a fixed number of shift registers. Each input bit enters a shift register and the output of the encoder is derived by combining the bits in the shift register. The number of output bits based on the number of modulo- 2 adders used with the shift registers. Convolutional codes are usually specified by the three parameters (n,k,m), where n is the number of output bits, k is the number of input bits and m is the number of shift registers. The quantity k/n called the code rate is a measure of the bandwidth efficiency of code. Convolutional codes can also be specified by the parameters (n,k,L) where, L is known as the constraint length of the code and is defined as the number of bits in the encoder memory that affects the generation of the n output bits. In the convolutional encoder the term generator polynomial (g) distinguishes the encoder connections. The selection of which bits (in the memory registers) are to added (using modulo - 2 adders) to produce the output bits which is called generator polynomials for any m order code. Code polynomials are typically found by trial

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and error through computer simulations [27] , [36].

To understand the working of convolutional encoder, the shift registers store the state information of convolutional encoder, and constrain length (*L*) relates the number of bits upon which the output depends. A convolutional code can become very complex with various code rates and constraint length. A simple convolutional code with *1/2* code rate, it is easy to construct a convolutional encoder A(*2,1,3*). The first step draw *m* boxes representing the shift registers. Then draw *n* modulo -2 adders representing the *n* output bits. Finally, connecting the shift registers to the adders using the bits specifying the generator polynomials. Figure 2 is shown as an example of convolutional encoder A(*2,1,3*). This encoder is going to be used to encode the 3-bit input sequence [*1 0 1*] with the two generator polynomials specified by the bits [*1 1 1*] and [*101*], u_1 represents the input bit, and v_1 and v_2 represent the output bits 1 and 2 respectively. u_0 and u_{-1} represent the initial state of the shift registers which are initially set to zero [37].
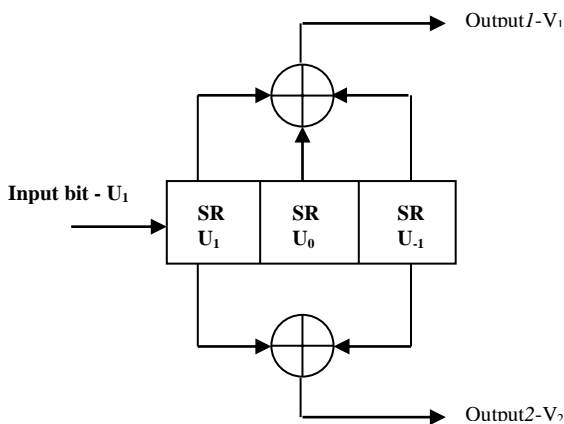

Figure 2. Convolutional encoder A(2,1,3).

2.2 Viterbi Decoding

The main type of convolutional decoder will only accept as input of the direct result of a convolutional encoding algorithm. The more sophisticated types of decoders, including the viterbi decoder will try to correct a certain type of presumed transmission errors. Viterbi decoding, also often referred to as the maximum likelihood decoding [37]. Noisy channels lead to bit errors at the receiver. Viterbi algorithm estimates, actual bit sequence and compute branch metric and path metric from received signal to possible transmitted signal using the trellis diagram [27]. The criterion for decoding between two paths is to select the one that having smaller metric. The viterbi algorithm works on a state machine assumption. That is, at any time the system are modeling in some state. There are a finite number of states, however large, that can be listed. Each state is represented as a node. Multiple sequences of states (paths) can lead to a given state, but one is the most likely path to that state, called "survivor path". This is a fundamental assumption of the algorithm because the algorithm will examine all possible paths that lead to a state and only keep the one most likely. This way the algorithm does not have to keep track of all possible paths, only one per state. A second key assumption is that a transition from a previous state to a new state is marked by an incremental metric, usually a number. This transition is computed from the event. The third key assumption is that the events are cumulative over a path in some sense, usually additive. Thus, the essence of the algorithm is to keep a number for each state. When an event occurs, the algorithm examines moving forward to a new set of states by combining the metric of a possible previous state with the incremental metric of the transition due to

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the event and chooses the best. The incremental metric associated with an event depending on the transition possibility from the old state to the new state [38].

3. The Proposed System

In order to implement the proposed hybrid lossy colour image compression transmission through AWGN using convolutional coding system, following steps are applied and Figure 3 clearly illustrated the system:

<u>Step1:</u> Load the input uncompressed colour RGB image *I* of size *N×N*.

<u>Step 2:</u> Apply two-layered wavelet transform of multiresolution based for each band (R, G and B), by decomposing the image *I* into first layered wavelet of approximation (LL_1) and detail sub bands (LH_1, HL_1, HH_1), then subsequently the LL_1 decomposed into approximation subband (LL_2) and detail sub bands (LH_2, HL_2, HH_2)

<u>Step 3:</u> Perform the polynomial prediction of linear based for the second approximation subband (LL_2) for each band(R, G and b) using the steps below:
1- Partition the LL_2 sub band into non-overlapped blocks of fixed size *n×n*, and performs the polynomial representation to the LL_2 band blocks as shown in Eq. (1,2,3) [12]:

$$a_0 = \frac{1}{n \times n} \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} LL_{2(i,j)} \qquad (1)$$

$$a_1 = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} LL_{2\ (i,j)} \times (j-x_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (j - x_c)^2} \qquad (2)$$

$$a_2 = \frac{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} LL_{2\ (i,j)} \times (i-y_c)}{\sum_{i=0}^{n-1} \sum_{j=0}^{n-1} (i - y_c)^2} \qquad (3)$$

Where $LL_{2(i,j)}$ is the second approximation subband of the original

image block of size *(n×n)* as shown in Eq. (4).

$$xc = yc = \frac{n-1}{2} \qquad (4)$$

2- Apply uniform scalar quantization to quantize the polynomial approximation coefficients, where each coefficient is quantized using different quantization step as shown in Eq. (5,6,7).

$$Q_{a_0} = round\left(\frac{a_0}{SQa_0}\right) \rightarrow Da_0 = Q_{a_0} \times SQa_0 \ (5)$$

$$Q_{a_1} = round\left(\frac{a_1}{SQa_1}\right) \rightarrow Da_1 = Q_{a_1} \times SQa_1 \ (6)$$

$$Q_{a_2} = round\left(\frac{a_2}{SQa_2}\right) \rightarrow Da_2 = Q_{a_2} \times SQa_2 \ (7)$$

Where $Q_{a_0}, Q_{a_1}, Q_{a_2}$ are the polynomial quantized values $SQ_{a_0}, SQ_{a_1}\ SQ_{a_2}$ are the quantization steps of the polynomial coefficients. The quantization step values affect the image quality and the compression ratio, and $D_{a_0}, D_{a_1}, D_{a_2}$ are polynomial dequantized values.

3- Construct the predicted image value $\tilde{I}$ using the dequantized polynomial coefficients for each encoded block representation: as shown in Eq. (8).

$$\tilde{I} = Da_0 + Da_1(j - x_c) + Da_2(i - y_c) \quad (8)$$

4- Find the residual or prediction error as difference between the original *I* and the predicted one $\tilde{I}$, as shown in Eq. (9).

$$R(i,j) = LL_2(i,j) - \tilde{I}(i,j) \qquad (9)$$

5- Mapping the residual image to positive values (i.e., all negative values are mapped to be odd while the positive values will be even) as shown in Eq. (10) to avoid coding complexity due to existence of positive and negative values.

$$X_i = \begin{cases} 2X & if\ X_i \geq 0 \\ -2X_i - 1 & if\ X_i < 0 \end{cases} \qquad (10)$$

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Where X_i is the ith element residual value.

6- Apply the bit plane slicing techniques of the resultant mapped residual image, the technique basically based on slicing the image onto layers, range from layer $_0$ corresponds to the Least Significant Layer (LSB) to layer $_7$ corresponds to the Most Significant Layer (MSB), only the high order layers from layer $_4$ to layer $_7$ are normally used, where the significant details preserved.

7- Perform the scalar uniform quantizer to quantize the slice residual mapped image of high order layers, in other words the sliced residual image from layer $_4$ to layer $_7$ quantized with different quantization step as shown in Eq. (11,12,13,14).

$$Q_{b_4} = round\left(\frac{b_4}{SQb_4}\right) \rightarrow Db_4 = Q_{b_4} \times SQb_4 \quad (11)$$

$$Q_{b_5} = round\left(\frac{b_5}{SQb_5}\right) \rightarrow Db_5 = Q_{b_5} \times SQb_5 \quad (12)$$

$$Q_{b_6} = round\left(\frac{b_6}{SQb_6}\right) \rightarrow Db_6 = Q_{b_6} \times SQb_6 \quad (13)$$

$$Q_{b_7} = round\left(\frac{b_7}{SQb_7}\right) \rightarrow Db_7 = Q_{b_7} \times SQb_7 \quad (14)$$

8- Create the quantized residual mapped image $\tilde{R}(i,j)$ from the dequantized high layers above.

Step 4: For the other detail sub-bands of the first and second layer $(LH_2, HL_2, HH_2, LH_1, HL_1 \text{ and } HH_1)$ for each band (R, G and B) the absolute moment block truncation coding (AMBTC) exploited, the following steps are applied for each subband:

1- Partition the subband into non-overlapped blocks of fixed size $m \times m$ where $m <= n$ (use 2×2 or 4×4).

2- Compute the mean of the partitioned block as shown in Eq. (15).

$$\bar{x} = \frac{1}{m} \sum_{i=1}^{m} x_i \quad (15)$$

Where x_i represents the ith pixel value of the image block and m is the total number of pixels of block.

3- Pixels in the image block are then divided into two ranges of values. The upper range is those gray levels which are greater than the block average gray level $(\bar{x})$ and the remaining brought into the lower range. The mean of higher XH and the lower range XL are computed as shown in Eq. (16 , 17).

$$x_H = \frac{1}{K} \sum_{x_i > \bar{x}}^{m} x_i \quad (16)$$

$$x_L = \frac{1}{number\ of\ pixel\ in\ block - K} \sum_{x_i < \bar{x}}^{m} x_i \quad (17)$$

Where K is the number of pixels whose gray level is greater than $\bar{x}$.

4- Create the Binary image denoted by B, where the 1 corresponds to pixel value greater than or equal to $\bar{x}$, otherwise the 0 used for pixel value smaller than to $\bar{x}$ as shown in Eq. (18).

$$B = \begin{cases} 1 & x_i \geq \bar{x} \\ 0 & x_i < \bar{x} \end{cases} \quad (18)$$

Step 5: Use encoder to code the compress information that composed of binary image if detail subbands layers and the coefficients and quantized residual image, the encoder use LZW, Run Length Coding, which is passed through Huffman Coding for each band(R, G and B).

Step 6: Enter the compressed data in the channel coding. In the channel coding introduced redundancy and the output is a codeword. In the channel coding for the proposed system applying two phases to code the compressed data and each phase produces a transmission system and compared between two phases. The two phases as:

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1. Without using convolutional encoder and the coded data is entered to the next step for digital communication system is modulation.

2. Using convolutional encoder to code the compressed data. The characteristics of the convolutional encoder used in the proposed system is (Rc=1/2, CL=5, dfree=5, generator polynomial=[23 35] and SNR or Eb/No-dB=5). And the coded data is entered to the next step for digital communication system which is modulated.

Step 7: Modulating the coded compressed data to convert the signal to waveform. Using BPSK modulation.

Step 8: Using AWGN channel. The channel can be used to send a signal from the transmitter to the receiver. It usually causes signal dilution and introduces noise, which may lead to severe loss or degradation of the quality of the reconstructed signal if not dealt with appropriately. Where x represents the transmitted signal and n represents the noise channel, therefore the received signal represented as shown in Eq. (19).

$$Y = x + n \qquad (19)$$

Y=Signal after AWGN added.

Step 9: In the receiver side the inverse operation occurs, demodulation of the received signal. In other words, converting a signal from waveforms to digital signal, and can be processed by the channel decoder.

Step 10: The channel decoding used to reconstruct the original information bitstream using the protection bits inserted by the channel encoder. And also two phases occurs for decoding the signal in the proposed system as two steps:

1. In the case of without using convolutional encoder, where the received signal contains noise due to the error in the received bits and needs to compute the bit error rate between the transmitted bits and received bits. After that compute BER and draw the curve for BER.

2. When the received signal is encoding using convolutional encoder, in the decoding using Viterbi decoding

Step 11: After channel decoding, the compressed data is entered to source decoder to reconstruct the compressed image $\hat{\imath}$

Step12: The decoder or reconstruction unit, starts by reconstructing the compressed values then applying the inverse process that reconstruct or rebuild the detail sub bands by replacing the 1 with X_H and 0 with X_L as shown in Eq. (20).

$$X = \begin{cases} X_L & B = 0 \\ X_H & B = 1 \end{cases} \qquad (20)$$

Also the coefficients with the residual utilized to reconstruct the approximation subband of the second layer as shown in Eq. (21)

$$\hat{L}_{L2}(i,j) = \tilde{R}(i,j) + \tilde{I}(i,j) \qquad (21)$$

Lastly by applying the inverse wavelet transform to reconstruct the compressed image $\hat{\imath}$ as shown in Eq. (22).

$$x_i = \begin{cases} x/2 & if\ x_i \geq 0 \\ (x+1)/2 & if\ x_i < 0 \end{cases} \qquad (22)$$
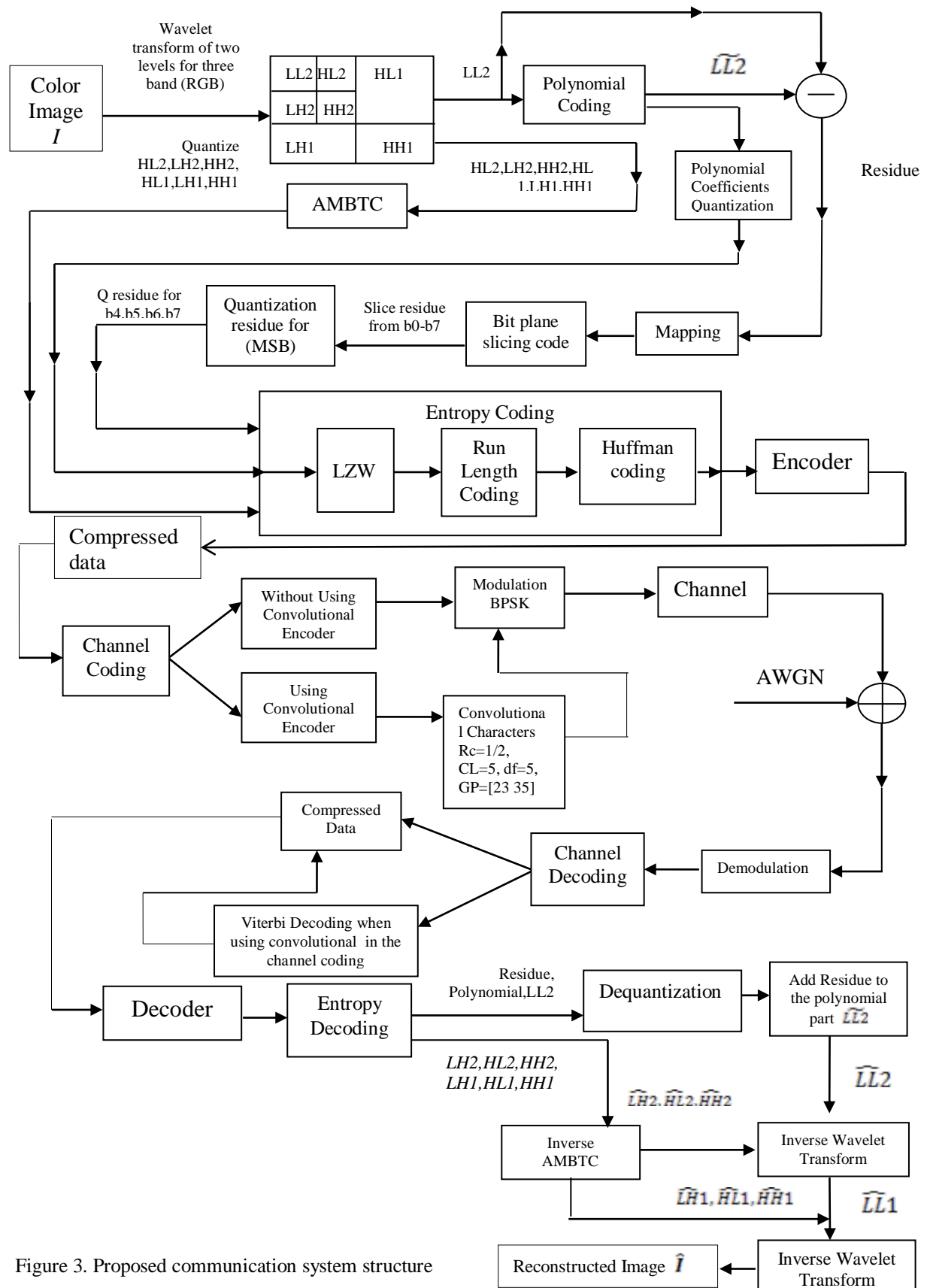
Figure 3. Proposed communication system structure

4. Experiments and Results

For testing the proposed system performance; four standard color images are selected, the images of 256 gray levels(8 bits/pixel) of size 256×256(see Figure 4 for an overview for images House, Airplane, Sailboat on lake respectively). To evaluate the compression efficiency and image quality based on the compression ratio(CR), which is the ratio of the original image size to the compressed size, peak signal to noise ratio(PSNR) a large value implicitly means high image quality and close to the original image and vice versa with normalizes mean square error (NRMSE) where the range of the values between 0 and 1, if the value is close to zero refers to high image quality and vice versa as shown in Eq. (23,24).

$$PSNR = 10 \log_{10} \left[\frac{(255)^2}{\frac{1}{N \times N} \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} [\hat{I}(x,y) - I(x,y)]^2} \right] \quad (23)$$

$$NRMSE(I, \hat{I}) = \sqrt{\frac{\sum_{x=0}^{N-1} \sum_{y=0}^{N-1} [\hat{I}(x,y) - I(x,y)]^2}{\sum_{x=0}^{N-1} \sum_{y=0}^{N-1} I(x,y)^2}} \quad (24)$$

The result of the proposed system for the compression illustrates that the high compression rate is achieved because of utilization of effective multiresolution along with the efficient linear polynomial model of quantize three coefficients(a_0, a_1, a_2) and quantize the high order layer of residual image in which no need to extra information to be used. Implicitly meaning that the compression rate is directly affected by coefficients size compared to residual size, also the other detail subbands consumption of bytes compared to the linear polynomial part. And also reduce the size of the original tested image in order to transmit through AWGN, therefore, this is the main reason for applying the hybrid lossy color image compression before transmission through AWGN.

Certainly, the quality of the compressed image improves the number of quantization levels of both the approximation representation coefficients and for the high order layer of residual image increase. The higher the quality required the larger the number of quantization level that must be used.

Figure 4. Overview of the tested color images (a)House image, (b) Airplane image, and (c) Sailboat on lake image respectively, all images of size 256×256, color images.

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The result are shown in Table 1 and Table 2 which lists the results for different values of the quantization step for the polynomial coefficients and for the high order layer of residual image, and were selected to be between 16 to 64 levels for block size (2×2) and (4×4) to polynomial coefficients and absolute moment block truncation coding (AMBTC), also block size plays an essential role in the process, the block size of (2×2) gives high image quality, while increases the block size to (4×4) the image quality become less(see Figures 5, 6 and 7) for all tested color image respectively and overview the result for one level where Coefficients Quantization level, Qa0,Qa1,Qa2={64,64,64} and Quantization Residual steps for Most Significant Bit (MSB), Rb4, Rb5, Rb6, Rb7 ={32,32,32,32} respectively.

Where compression ratio becomes higher and produces the trade-off between the quality desired and compression ratio.
 In other words , increasing the block size gets bigger the higher compression ratio with higher error and vice versa.
The quality of the compressed image is directly uninfluenced by using different quantization levels of the polynomial coefficients because of dominating the quantize high order layer of residual image, and also the other detail subbands are quantized based on two levels.

Also the result demonstrates that the compression rates are directly affected by the size of polynomial approximation coefficients not the size of residual.

To evaluate the performance of transmission system based on the bit error rate (BER), which is the number of bit errors divided by the total number of transmitted bit during time interval. The relation describing BER as shown in Eq. (25).

Signal to noise ratio(SNR) is the ratio of the bit energy(E_b) to the noise power spectral density(N_o) and it is measured in decibels(dB) as shown in Eq. (26).

 BER is inversely related to SNR, as SNR increases then the BER decreases and vice versa.

$$BER = \frac{ErrorBits}{TotalNumberofTransmittedBits} \quad \textbf{(25)}$$
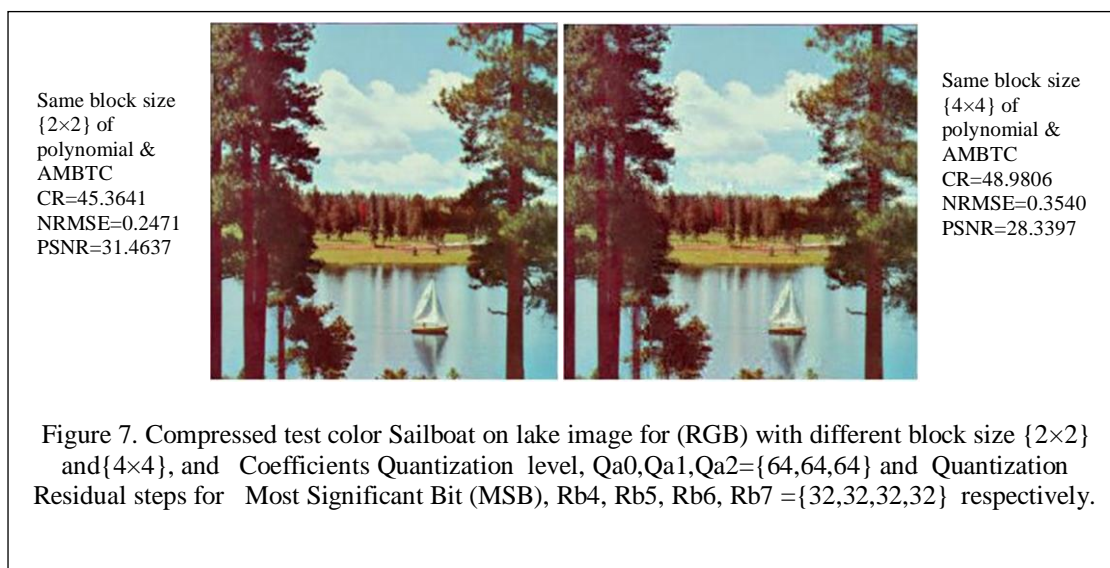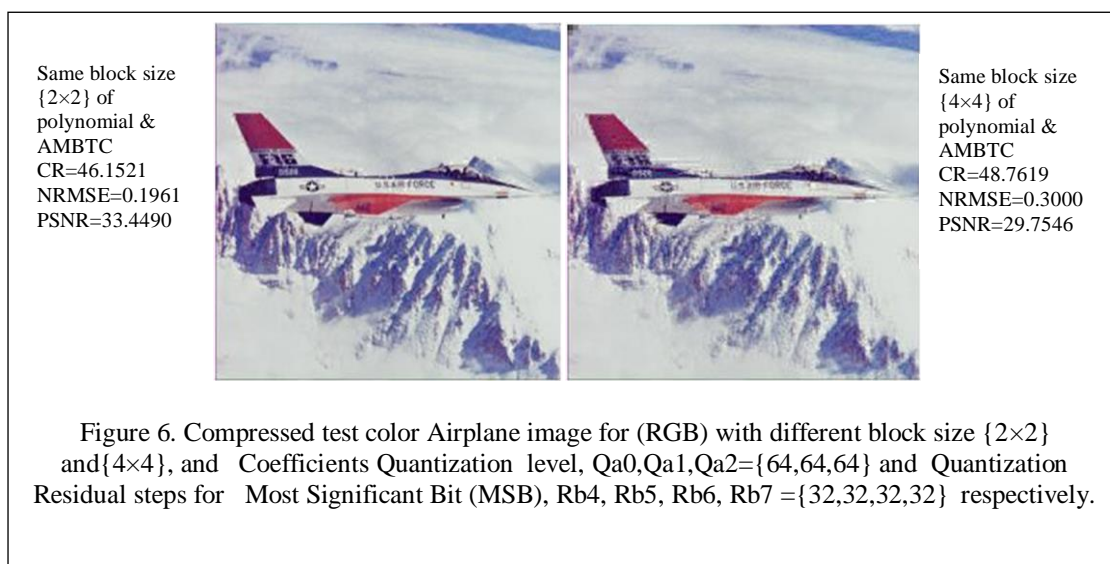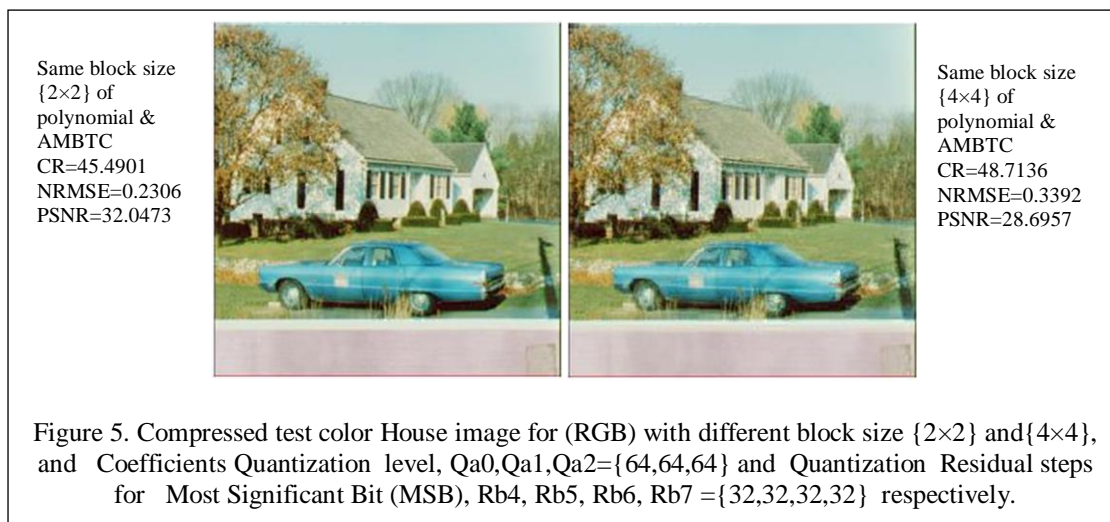
$$SNR = E_b/N_O \quad (26)$$

Table 1. Lists the Results for Different Values of the Block Size {2*2}

Test image	Orig. Size image	Same Coefficients Quantization levels & steps for color image RGB			Same Quantization Residual steps for Bit Plane slicing to Most Significant Bit (MSB), b4,b5,b6,b7 to color image RGB				Block size {2*2}			
		Q a0	Q a1	Q a2	R b4	R b5	R b6	R b7	Comp. Size	NRMS	PSNR	CR
House	196608	32	32	64	16	32	8	16	4226	0.2358	31.8513	46.5234
	196608	32	32	32	16	16	16	16	4212	0.2804	30.3472	46.6781
	196608	32	16	32	32	32	32	32	4180	0.3045	29.6320	47.0354
	196608	16	32	32	16	32	16	16	4164	0.2800	30.3606	47.2161
	196608	64	32	64	16	16	8	16	4292	0.2358	31.8521	45.8080
	196608	64	64	64	32	32	32	32	4322	0.2306	32.0473	45.4901
	196608	64	64	32	64	16	32	64	4302	0.2379	31.7753	45.7015
Airplane	196608	32	32	64	16	32	8	16	4198	0.1996	33.2925	46.8337
	196608	32	32	32	16	16	16	16	4186	0.2223	32.3589	46.9680
	196608	32	16	32	32	32	32	32	4158	0.2421	31.6179	47.2843
	196608	16	32	32	16	32	16	16	4142	0.2232	32.3232	47.4669
	196608	64	32	64	16	16	8	16	4254	0.1995	33.2990	46.2172
	196608	64	64	64	32	32	32	32	4260	0.1961	33.4490	46.1521
	196608	64	64	32	64	16	32	64	4254	0.1969	33.4103	46.2172
Sailboat on lake	196608	32	32	64	16	32	8	16	4256	0.2618	30.9618	46.1955
	196608	32	32	32	16	16	16	16	4226	0.2732	30.5901	46.5234
	196608	32	16	32	32	32	32	32	4200	0.2981	29.8320	46.8114
	196608	16	32	32	16	32	16	16	4168	0.2742	30.5599	47.1708
	196608	64	32	64	16	16	8	16	4296	0.2614	30.9745	45.7654
	196608	64	64	64	32	32	32	32	4334	0.2471	31.4637	45.3641
	196608	64	64	32	64	16	32	64	4310	0.2477	31.4426	45.6167

Table 2. Lists the Results for Different Values of the Block Size {4*4}

Test image	Orig. Size image	Same Coefficients Quantization levels & steps for color image RGB			Same Quantization Residual steps for Bit Plane slicing to Most Significant Bit (MSB), b4,b5,b6,b7 to color image RGB				Block size {4*4}			
		Q a0	Q a1	Q a2	R b4	R b5	R b6	R b7	Comp. Size	NRMSE	PSNR	CR
House	196608	32	32	64	16	32	8	16	4004	0.3391	28.6968	49.1029
	196608	32	32	32	16	16	16	16	3996	0.3396	28.6852	49.2012
	196608	32	16	32	32	32	32	32	3992	0.3406	28.6588	49.2505
	196608	16	32	32	16	32	16	16	3978	0.3395	28.6861	49.4238
	196608	64	32	64	16	16	8	16	4016	0.3390	28.6987	48.9562
	196608	64	64	64	32	32	32	32	4036	0.3392	28.6957	48.7136
	196608	64	64	32	64	16	32	64	4024	0.3393	28.6923	48.8588
Airplane	196608	32	32	64	16	32	8	16	4006	0.3000	29.7541	49.0784
	196608	32	32	32	16	16	16	16	3994	0.3001	29.7524	49.2258
	196608	32	16	32	32	32	32	32	3982	0.3028	29.6751	49.3742
	196608	16	32	32	16	32	16	16	3978	0.3001	29.7526	49.4238
	196608	64	32	64	16	16	8	16	4016	0.3000	29.7540	48.9562
	196608	64	64	64	32	32	32	32	4032	0.3000	29.7546	48.7619
	196608	64	64	32	64	16	32	64	4022	0.3001	29.7524	48.8831
Sailboat on lake	196608	32	32	64	16	32	8	16	3996	0.3561	28.2900	49.2012
	196608	32	32	32	16	16	16	16	3984	0.3576	28.2538	49.3494
	196608	32	16	32	32	32	32	32	3974	0.3634	28.1122	49.4736
	196608	16	32	32	16	32	16	16	3970	0.3570	28.2680	49.5234
	196608	64	32	64	16	16	8	16	4002	0.3559	28.2933	49.1274
	196608	64	64	64	32	32	32	32	4014	0.3540	28.3397	48.9806
	196608	64	64	32	64	16	32	64	4006	0.3553	28.3089	49.0784

Same block size {2×2} of polynomial & AMBTC
CR=45.4901
NRMSE=0.2306
PSNR=32.0473

Same block size {4×4} of polynomial & AMBTC
CR=48.7136
NRMSE=0.3392
PSNR=28.6957

Figure 5. Compressed test color House image for (RGB) with different block size {2×2} and{4×4}, and Coefficients Quantization level, Qa0,Qa1,Qa2={64,64,64} and Quantization Residual steps for Most Significant Bit (MSB), Rb4, Rb5, Rb6, Rb7 ={32,32,32,32} respectively.

Same block size {2×2} of polynomial & AMBTC
CR=46.1521
NRMSE=0.1961
PSNR=33.4490

Same block size {4×4} of polynomial & AMBTC
CR=48.7619
NRMSE=0.3000
PSNR=29.7546

Figure 6. Compressed test color Airplane image for (RGB) with different block size {2×2} and{4×4}, and Coefficients Quantization level, Qa0,Qa1,Qa2={64,64,64} and Quantization Residual steps for Most Significant Bit (MSB), Rb4, Rb5, Rb6, Rb7 ={32,32,32,32} respectively.

Same block size {2×2} of polynomial & AMBTC
CR=45.3641
NRMSE=0.2471
PSNR=31.4637

Same block size {4×4} of polynomial & AMBTC
CR=48.9806
NRMSE=0.3540
PSNR=28.3397

Figure 7. Compressed test color Sailboat on lake image for (RGB) with different block size {2×2} and{4×4}, and Coefficients Quantization level, Qa0,Qa1,Qa2={64,64,64} and Quantization Residual steps for Most Significant Bit (MSB), Rb4, Rb5, Rb6, Rb7 ={32,32,32,32} respectively.
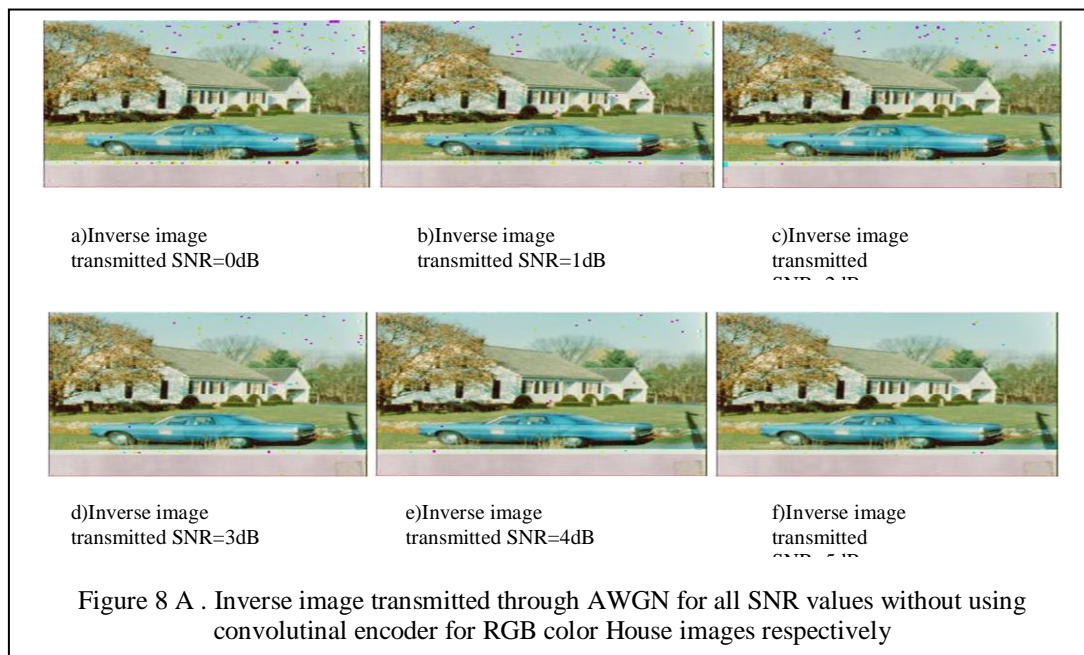
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Simulations are implemented for different signal to noise ratios (SNR) and for each value of the bit error rate (BER) is calculated. the compressed data is used to enter in the channel coding. In the channel coding the proposed system for transmission through AWGN is applied in two cases, firstly the transmission without using convolutional coding, secondly, with using convolutional coding and comparison between them. Figure 8 A illustrates the inverse color image for all SNR values and show the effect of noise in the channel and AWGN for all inverse color House images, where SNR=0 the BER=8×10^{-2} and SNR=5 the BER=6×10^{-3}, when increasing SNR the BER decreased. Figure 8 B also illustrates the inverse color Airplane image for all SNR values, where SNR=0 the BER=8×10^{-2} and SNR=5 the BER=6×10^{-3}. Figure 8 C illustrates the inverse color Sailboat on lake image for all SNR values, where SNR=0 the BER=8×10^{-2} and SNR=5 the BER=6×10^{-3},
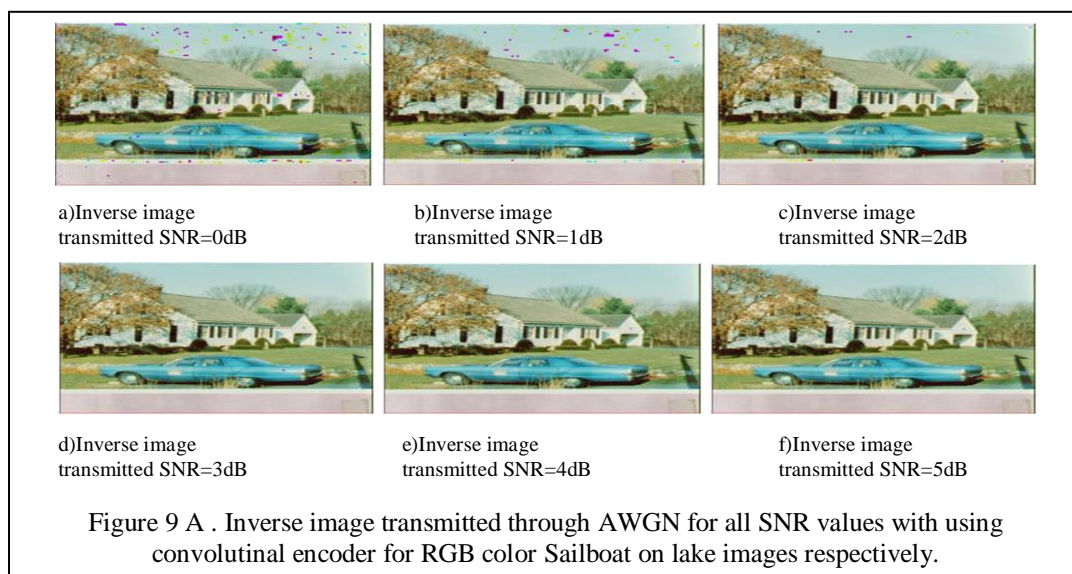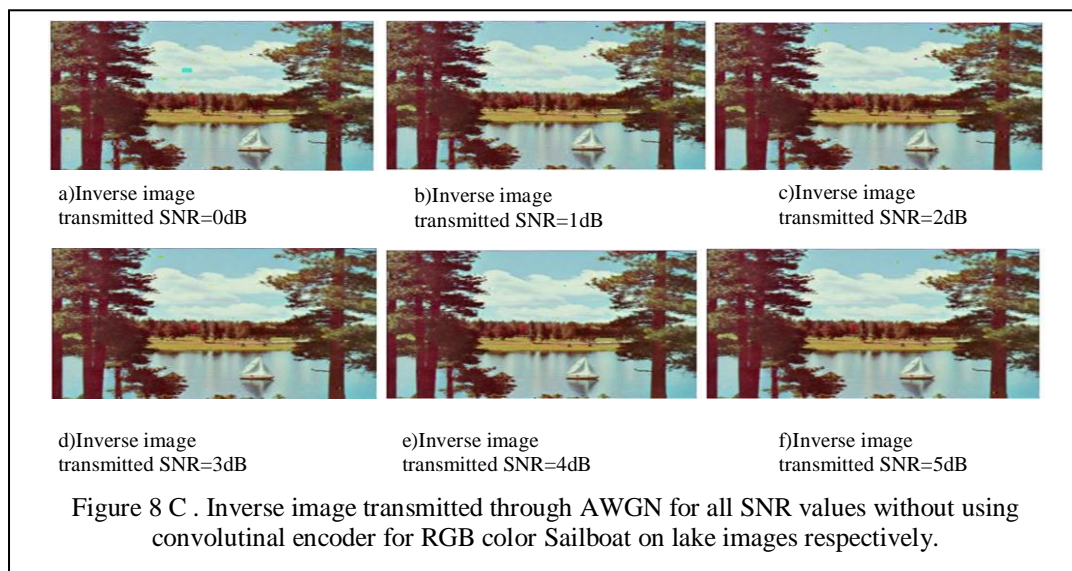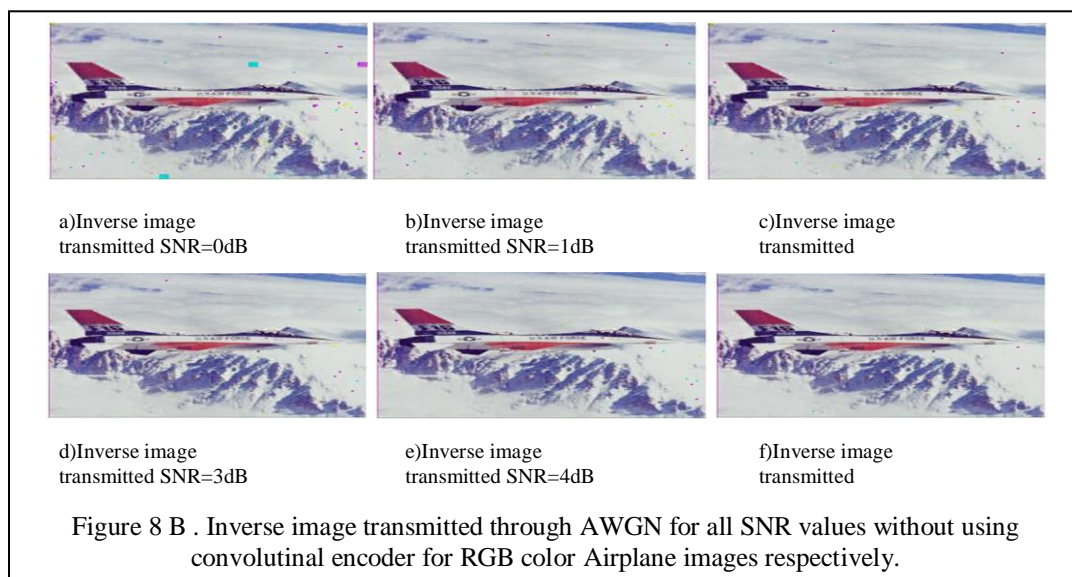
these values for BER is the simulations without using convolutional coding for all tested colour images.

Figure 9 A illustrates the inverse image for all SNR values and shows the effect of noise in the channel and AWGN for all inverse colour House images, where SNR=0 the BER=1.5×10^{-1} and SNR=5 the BER=9×10^{-6}.
Figure 9 B illustrates the inverse image for all SNR values for colour Airplane image, where SNR=0 the BER=1.5×10^{-1} and SNR=5 the BER=9×10^{-6}.

Figure 9 C illustrates the inverse colour Sailboat on lake image for all SNR values, where SNR=0 the BER=1.5×10^{-1} and SNR=5 the BER=9×10^{-6}, these values for BER is the simulations with using convolutional coding for all tested colour images.

a)Inverse image transmitted SNR=0dB

b)Inverse image transmitted SNR=1dB

c)Inverse image transmitted SNR=2dB

d)Inverse image transmitted SNR=3dB

e)Inverse image transmitted SNR=4dB

f)Inverse image transmitted SNR=5dB

Figure 8 A . Inverse image transmitted through AWGN for all SNR values without using convolutinal encoder for RGB color House images respectively

a)Inverse image transmitted SNR=0dB

b)Inverse image transmitted SNR=1dB

c)Inverse image transmitted

d)Inverse image transmitted SNR=3dB

e)Inverse image transmitted SNR=4dB

f)Inverse image transmitted

Figure 8 B . Inverse image transmitted through AWGN for all SNR values without using convolutinal encoder for RGB color Airplane images respectively.

a)Inverse image transmitted SNR=0dB

b)Inverse image transmitted SNR=1dB

c)Inverse image transmitted SNR=2dB

d)Inverse image transmitted SNR=3dB

e)Inverse image transmitted SNR=4dB

f)Inverse image transmitted SNR=5dB

Figure 8 C . Inverse image transmitted through AWGN for all SNR values without using convolutinal encoder for RGB color Sailboat on lake images respectively.

a)Inverse image transmitted SNR=0dB

b)Inverse image transmitted SNR=1dB

c)Inverse image transmitted SNR=2dB

d)Inverse image transmitted SNR=3dB

e)Inverse image transmitted SNR=4dB

f)Inverse image transmitted SNR=5dB

Figure 9 A . Inverse image transmitted through AWGN for all SNR values with using convolutinal encoder for RGB color Sailboat on lake images respectively.

a)Inverse image transmitted SNR=0dB

b)Inverse image transmitted SNR=1dB

c)Inverse image transmitted SNR=2dB

d)Inverse image transmitted SNR=3dB

e)Inverse image transmitted SNR=4dB

f)Inverse image transmitted SNR=5dB

Figure 9 B . Inverse image transmitted through AWGN for all SNR values with using convolutinal encoder for RGB color Airplane images respectively.

a)Inverse image transmitted SNR=0dB

b)Inverse image transmitted SNR=1dB

c)Inverse image transmitted SNR=2dB

d)Inverse image transmitted SNR=3dB

e)Inverse image transmitted SNR=4dB

f)Inverse image transmitted SNR=5dB

Figure 9 C . Inverse image transmitted through AWGN for all SNR values with using convolutinal encoder for RGB color Sailboat on lake images respectively.
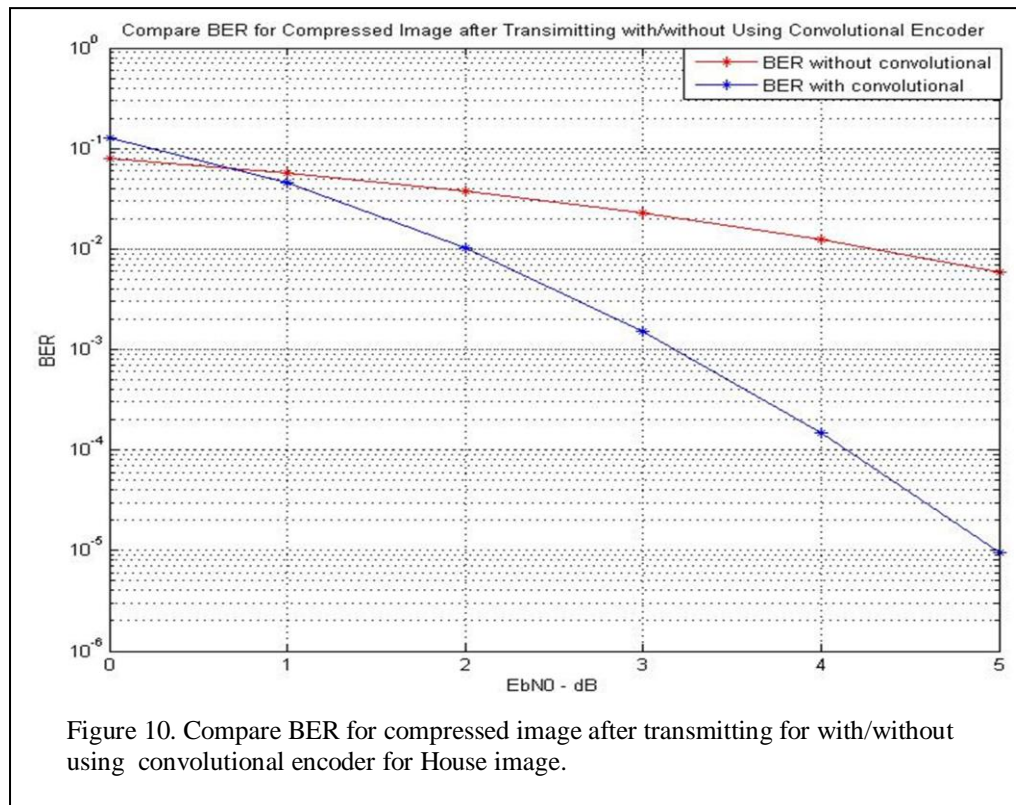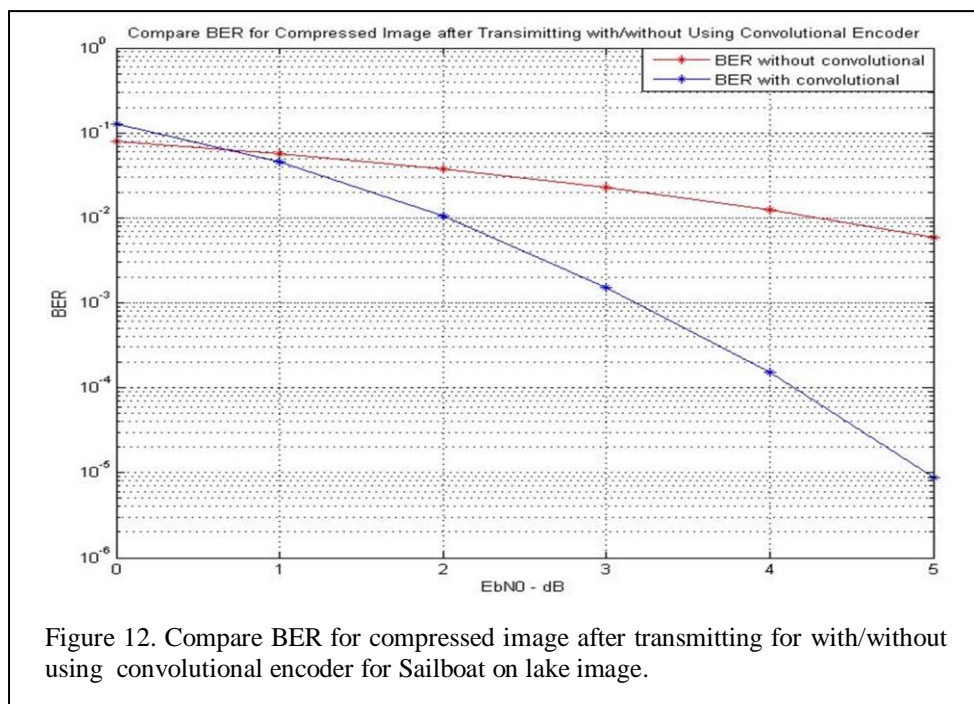
Figure 10, Figure11 and Figure 12 show comparison between BER for transmitted compressed image through AWGN with/without using convolutional encoder for House, Airplane and Sailboat on lake images respectively, and show in the using covolutional gives less BER than without using convolutional.

Figure 10. Compare BER for compressed image after transmitting for with/without using convolutional encoder for House image.

Figure 11. Compare BER for compressed image after transmitting for with/without using convolutional encoder for Airplane image.

Figure 12. Compare BER for compressed image after transmitting for with/without using convolutional encoder for Sailboat on lake image.

5. Results Assessments

Convolutional coding is used as a channel coding, while the proposed hybrid compression system is used as a source coding scheme. Simulation results show that the coding is a simple scheme yet fast method for image transmission over wireless channels. It can also be seen that SNR value increases as the BER value decreases and reduces distortion (i.e., preserving image quality) and vice versa.

6. Conclusion

A joint source-channel coding for the transmission hybrid image compression techniques have been proposed. This proposed focuses around introducing robustness by combining source code modifications and explicit forward error correction (FEC). FEC has been implemented using convolutional encoding with Viterbi decoding. Information transmission has a tradeoff between compression ratio and received quality of image. The compressed stream is more susceptible to channel errors, thus error control coding techniques are used along with images to minimize the effect of channel errors. But there is a clear tradeoff between channel coding redundancies versus source quality. The main factor that affect the performance of the FEC technique is the SNR value, when SNR value increases, thus, the performance of the FEC technique improves or the BER decreases and maintaining the image quality and vice versa. The simulation results indicate that the transmission system using convolutional coding gives less BER than without convolutional coding according to the SNR value.

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