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DWT-OFDM for Compressed Image Transmission

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Abstract. *All existing communications systems require high-speed data transmission rates, as all services today demand high transmission speeds and data transmission dependability, and communications are an essential aspect of daily life. One of the most important modulation techniques used in both wired and wireless communication networks is Orthogonal Frequency Division Multiplexing (OFDM). It is a cutting-edge technology for achieving high-speed digital communication. In this work, compression Images by Discrete Wavelet Transform and transmission over DWT-OFDM, and used different baseband modulation schemes such as Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Key (QPSK), Quadrature amplitude modulation (16QAM), and (64QAM) has been considered. From numerical simulation results, it is observed that produced better quality images at the receiver when the Quarter Amplitude Modulation is 16QAM and 64QAM with high SNR.*

Keywords: DWT, OFDM, QAM, SNR.

1. INTRODUCTION

Wireless data transfer has become more popular as the use of multimedia-enabled mobile phones and wireless Internet has grown. People expect higher-quality and more trustworthy transmission of larger and larger volumes of data via these devices, and the type of data transferred via these devices is evolving and changing as well [1]. The ability to communicate such enormous amounts of data is essential. Ways of communicating have had to evolve to reduce the quantity of the data being conveyed, and compression methods are required Image compression involves reducing the quantity of bits needed to represent a picture without significantly decreasing the quality of the visible outcomes. The essential function that becomes one of the fundamental motivations to compress an image is to save storage space as well as reduce transmission time. Other reasons are to reduce the cost of storing and transmitting images and to be able to retrieve or get back the original image. A more significant reason is to preserve visual quality as well as save the raw data. The loss of data is a concern with many types of compression methods; this can result in smaller data volumes, but it can also degrade the information received. This is especially problematic when the data being conveyed includes photos Therefore, compression is a technique in which data is represented in a smaller number of bits or bytes, reducing the memory usage of the device. Image compression must be careful to reduce memory without losing the quality of the image. The decompressed image should be similar to the original image. It is a powerful and compelling technique because it allows for more efficient storage and transmission of data. Images are used in a variety of fields and require a large amount of storage space. Therefore, compressing images without losing quality is important for storage and transmission [2]. Decomposing photos into approximate and detailed parts has the advantage of allowing data with certain attributes to be isolated and manipulated. This allows you to decide whether or not to save more particular details. For example, instead of maintaining all of the horizontal, diagonal, and vertical elements of an image with more vertical aspects, keep more vertical detail. This would allow the image to lose certain horizontal and diagonal characteristics while not affecting how it is perceived by humans [3].

2. 2. BACKGROUND

An effective method for conveying compressed images is DWT-OFDM. Effective image compression and transmission are made possible by the combination of orthogonal frequency division multiplexing and the discrete wavelet transform. This is because the loss of orthogonally between the carriers, which causes inter symbol and intermarried interference, is mitigated by DWT-OFDM. With orthonormal wavelets in place of complicated exponential base functions, DWT-OFDM maintains a significantly greater spectrum efficiency than conventional FFT-OFDM [2]. Furthermore, because of its superior features—such as symmetrical transform, integer-to-integer transform, in-place computation, and progressive image transmission by resolution—DWT has been extensively approved in the JPEG 2000 standard and used as the transform coder in MPEG-4 still texture coding. The adoption of DWT for picture compression also heavily depends on its comprehension of human visual systems because compression is a technique in which data is represented in a smaller number of bits or bytes, reducing the memory usage of the device. Image compression must be careful to reduce memory without losing the quality of the image. The decompressed image should be similar to the original image. It is a powerful and compelling technique because it allows for more efficient storage and transmission of data. Images are used in a variety of fields and require a large amount of storage space. Therefore, compressing images without losing quality is important for storage and transmission [3].

2.1 Discrete Wavelet Transform

Wavelets are useful for compressing signals. They can be used to process and improve signals in fields such as medical imaging, where image degradation is not tolerated. It can be used to remove noise in an image [4]. (DWT) is a recently developed data compression technique that is able to provide good compression ratios and high-quality data reconstruction. In using DWT, the input data is transformed into a set of coefficients of representation in a newly formed domain that is defined by the transformed data itself. The DWT possesses the property of dividing data into different frequency components, with each component being an approximate and detailed part. This is done by passing the low-pass and high-pass filters, respectively, across the data to give four sets of different frequency component data.The wavelet transform provides a representation of the time and frequency of the signal [5]. DWT is widely used in several areas, such as engineering, computer science, and mathematics. the way to compress data by using the 2-dimensional DWT (DWT2) to transform an image will produce 4 sets of coefficients: one is a low-pass version of the image (called Approximation Coefficients (A)), and the other 3 sets are high-pass versions (called Details Coefficients: horizontal (H), vertical (V), and diagonal (D)). Most of the information is in the LP version. Hence, we can compress the image by selecting the LP coefficients only prepared to be sent via OFDM system. This method is called sub-band compression [6].

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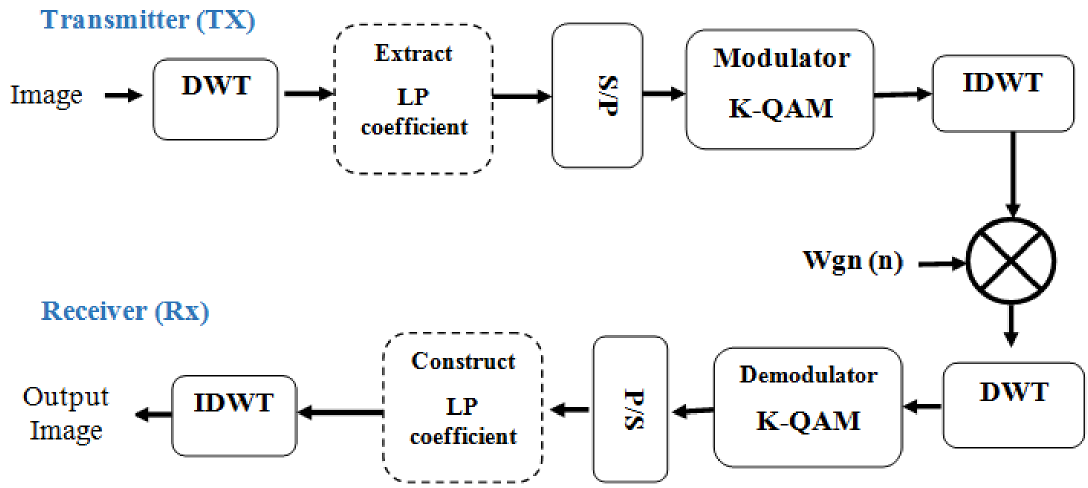

Fig.1. DWT-OFDM transmission system with DWT compression

2.1.1 Transmitter

The OFDM system contains three parts: the first part is the transmitter part which will start the data to pass through clear processes to be configured for transmission. We will just convert the data to 0,1. The second operation of the transmitter part is the serial to parallel converter. The serial input of the data stream is formed into the word size required for transmission operation and converted into parallel form. Then, the data is translated in parallel by assigning each word to a single carrier in the transmission. The third operation in the transmitter part of the OFDM system is the data modulation and in our case, the Rectangular QAM with different degrees 2, 4, 16, 64. This type of modulation is a combination of phase and amplitude together. The fourth operation after data modulation implements IDWT to create the OFDM symbols and transmit them on the channel [6].

2.1.2 Receiver

The DWT receiver consists of a converter used to transform the data from parallel to serial, After passing from the channel that affects the signal by Additive white Gaussian noise AWGN, the signal is reconstructed using reconstruction filters that satisfy the wavelet reconstruction [7] as shown in Figure 3 below[8]. The original signal is obtained by a sequential grouping of the resulting factors (approximate and detailed); therefore, the signal reconstruction, bypassing through low pass filter and high pass filter, do the convolution of the approximate coefficient ya with low pass filter and detail coefficients yd with High pass Filter, then generate a sequence as the output decomposition the signal as shown in the mathematical relation [9] and finally, have an inverse wavelet transform performed. The resulting data was then analyzed by MSE and the correlation between sent and received data.

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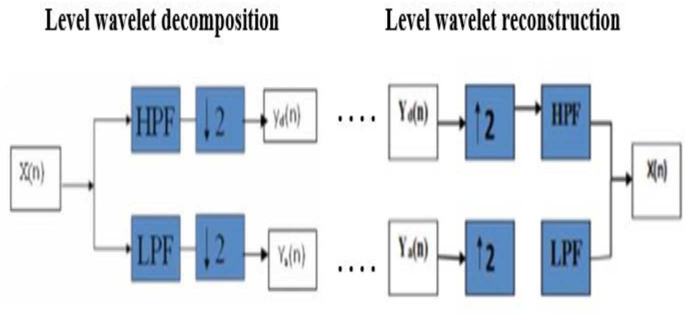

Fig. 2. The Diagram of Decomposition and Reconstruction Wavelet[6]

2.2 Mean Squared Error

The mean square error (MSE) is the simplest and most widely used quality metric computed by averaging the squared intensity differences of distorted and reference image pixels [10]. It is from standard quality metrics used in the past for normal luminance images [11]; the MSE is a signal fidelity measure. The goal of the signal fidelity measure is to compare two signals by providing a quantitative score that describes the degree of similarity/ fidelity or, conversely, the level of error/distortion between them [12]. The MSE is lower-bounded at zero (when the two images are identical) and has no upper bound [13]; MSE greater values indicate lower image /similarity [14].

Mathematical format for two images and, of size N×M [15].

$$MSE(X, Y) = \frac{1}{M \times N} \sum_j [xij - yij]$$

3. RESEARCH METHOD

MATLAB simulation was used to create the system in Figure 1 that was employed in this study. The initial image sent was a 256 x 256-pixel MATLAB image of a Cameraman. At the transmitter, the data signals (image) that were compressed way Discrete Wavelet Transform and transmitted using the DWT-OFDM technique the DWT length is equal to 8 and the modulation technique is (2-4-16-64) QAM, with SNR range from -40:40 under Gaussian noise. For this simulation, used wavelet (db2) with a degree of decomposition equal to two was used. There are many levels of image compression, but the second level is very appropriate for image compression and the increase in the level does not affect the compression ratio, data are converted from serial to parallel and then converted from the frequency domain to the time domain by using IDWT and then converted from parallel to serial. The OFDM signal is ready for transmission. At the receiver, all stages of the transmitter will be reversed, which include analog to digital converter, converting from serial to parallel, converting the data from the time domain to the frequency domain by using DWT, applying demodulation of rectangular modulation, and converting from parallel to serial, at last, contract Lp coefficient by implement inverse Discrete Wavelet Transform. After these stages, Mean squared error (MSE) measures are applied to know which properties of signals have been affected by the transmission process through the noisy OFDM system.

Al-Furat Journal of Innovations in Electronics and Computer Engineering (FJIECE)
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4. RESULTS AND DISCUSSION

Using MATLAB, compressed image DWT2 by extracting approximation coefficient (LP) because has the most necessary information while not allowing the image to deteriorate as shown in figure 2, and then implemented DWT-OFDM with Four different types of modification (BPSK, QPSK, 16QAM, 64QAM) as shown in figure 3, where the signal to noise ratio,(SNR) ranges from -40 dB to 40 dB; assuming a wired communication system, the compressed signal is passed on only via one path. After compressed signals are received from DWT-OFDM, The mean squared error (MSE) of the sent and received image is calculated. Figures 1-2 show.

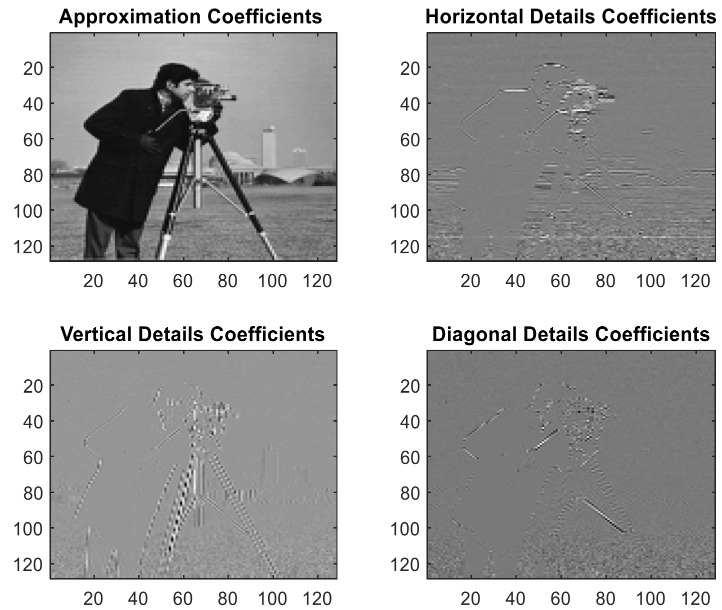

Fig. 3. Approximation Coefficients and the three sets from Details Coefficients

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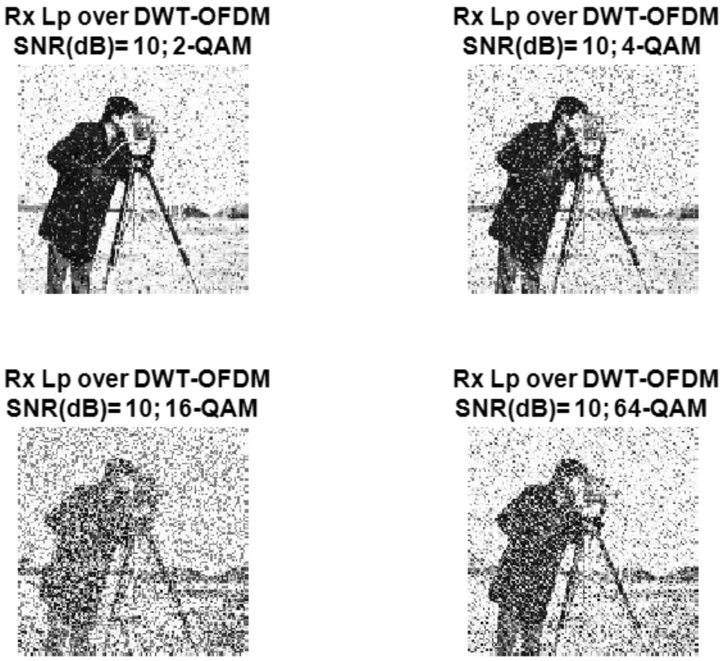

Fig. 4. Transmission of the LP coefficient (ApproximationCoefficients) of Image with Different QAM Degrees over DWT-OFDM with SNR=10.

We note in Figure 5 that the higher the QAM degree, the greater the parallelism; i.e. the higher the transmission speed is the greater the error rate for the same value SNR is going to be.

Most wavelets used for compression are Haar, Daubechies (db1, ... and db9), Symlets, and Coiflets. The best waves that give the main square error few, under the same compression ratio and SNR ratio, as shown in Table 4.1 below.

Table 1. Using Different Wavelets with SNR=10 in dB to Obtain Less MSE

Wave	SNR in dB	MSE
Db1	10	1.014863389593656e-04
Db3	10	3.648817350835901e-05
Db9	10	4.806680438095340e-05
Haar	10	1.014863389593656e-04
bior1.1	10	1.014863389593656e-04
bior3.9	10	6.098786061378556e-05
Sym2	10	3.463067090813115e-05
Coif1	10	3.545801902837883e-05
Coif3	10	4.173398487181658e-05

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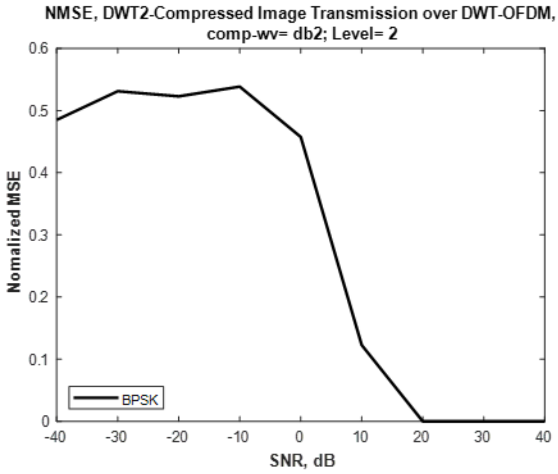

Fig. 5. WT2-Compressed Image Transmission over DWT-OFDM with BPSK.

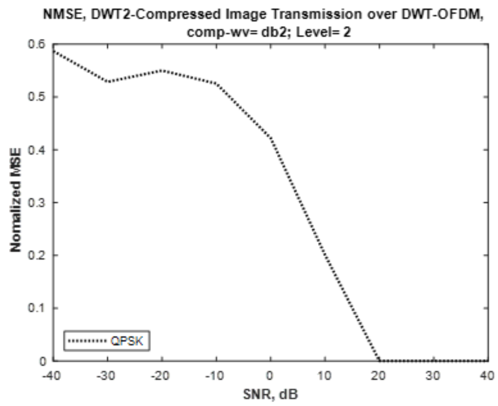

Fig. 6. DWT2-Compressed Image Transmission over DWT-OFDM with QPSK.

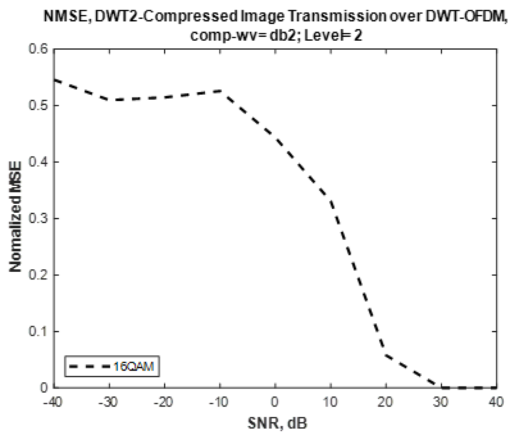

Fig. 7. DWT2-Compressed Image Transmission over DWT-OFDM with 16QAM.

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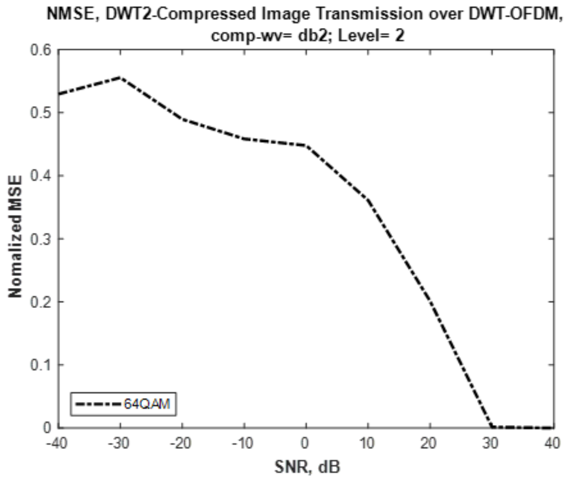

Figure 8. DWT2-Compressed Image Transmission over DWT-OFDM with 64QAM.

5. CONCLUSIONS

The goal of this essay has been to identify and explore the potential of using DWT in still image compression. In doing so, we have broken down the image compression process and explained how the DWT can be used in its place. Having discussed the benefits of the DWT in comparison to traditional image compression techniques, we have also identified how the method can be used to achieve a greater level of compression with little loss of image quality. Lastly, we discussed an application of DWT which can be used to compress image to a desired quality, demanding different compression rate within a single image. In this paper, we used DWT-OFDM to transfer compressed images in the DWT2 way under white Gaussian Noise with BPSK, QPSK, 16QAM, and 64QAM modulation and show the following: extract Lp coefficient and send over the system, leading to fast transmission of another side, Avoiding cyclic prefix in DWT-OFDM leads to the utilization of Bandwidth and a low Mean Square Error (MSE) When the quarter-amplitude modulation is PSK and BPSK, the signal ratio ranges from 20 to 40, except for 16QAM and 64QAM SNR, which begin from 30 to 40. Now that we have confirmed through testing that DWT indeed allows for significant image compression with little quality loss, we conclude that wavelet based compression is the best known method for image compression to date.

Al-Furat Journal of Innovations in Electronics and Computer Engineering (FJIECE)
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