Design and Realization of modified Encryption using 2D-DWT and Phase Matrix via OFDM Transceivers

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Abstract

The research study is about the enhancement of Data transmission Protection system. It gives support to integrity of data and information security, message non-repudiation, and key management scheme of the conventional classical producing data ciphering system. The uses of different forms of data Encryption have thus been a common approach to data security. The main aim of this work is to model and simulation a proposed hybrid structure of data Encryption system based on 2-Dimentions Discrete Wavelet Transform 2D-DWT and Phase matrix as permutation 2-Dimentions Fast Fourier Transform 2D-FFT. The design of Encryption system consist a combination of using 2D-FFT to the 2D data signal then enters the 2D frequency spectrum to the permutation by phase matrix and the output to inverse 2D-IDWT. All these combination parts work as a hybrid Encryption structure. This processes achieved in transmitter will be used in an inverted structure in Decryption part in receiver. The Encryption and Decryption parts are used with Orthogonal Frequency Division Multiplexing OFDM to consist the proposed system. the proposed system was examined by transmitting over one million random bits under different channel types. The simulation results show that the system augments the attack-resistant potential and decreases the mistaken rate BER. The proposed Encryption OFDM system gave a significant improvement in the BER performance in comparison with the conventional OFDM.

Index Terms: 2D-DWT/2D-IDWT, OFDM systems, Phase Matrix, Encryption, Cryptography.

الخلاصة:

البحث الحالي هو دراسة لتعزيز منظومة حماية تناقل البيانات. و يعطي دعم لتكامل امنية البينات والمعلومات وعدم نبذ الرسائل ومخطط ادارة المفاتيح لنظام التشفير التقليدي. ان استخدام اشكال مختلفة لتشفير البيانات اصبح طريقة شائعة لحماية البيانات. الهدف الرئيسي لهذا العمل بناء نموذج ومحاكاة لتركيبه هجينة مقترحة لنظام لتشفير البيانات على باستعمال التحويل المويجي المنفصل ثنائي الأبعاد و مصفوفة الطور كقاعدة للنثر. تصميم نظام التشفير المقترح يحتوي على ثلاثة أجزاء هي الإرسال والاستلام والقناة الضوضائية. جزء التشفير الموجود في المرسلة يتشكل من تحويل فورير السريع ثنائي الإبعاد يلحقه جزء النثر بواسطة مصفوفة الطور ثم بعد ذلك معكوس التحويل المويجي ثنائي الأبعاد لتشكل جميعها التركيبة الهجينة للمشفرة. هذه العملية المستخدمة في المرسلة سوف تستخدم بشكل معكوس في جزء حل التشفير في المستلمة. هذا النظام المقترح تم فحصه بإرسال مليون بت من البيانات تحت مختلف أنواع قنوات النقل. نظام التشفير المقترح مع نظام مازج تقسيمات التردد المتعامدة أعطى تحسين مميز في معدل الخطاء في نقل البيانات مقارنة مع نظام مازج تقسيمات التردد المتعامدة العادي. لذلك فنظام مازج تقسيمات التردد المتعامدة المشفر اضافة الى كونه أكثر أمان كذلك أعطى نتائج أفضل من حيث تحسين المواصفات مقارنة بنظام مازج تقسيمات التردد المتعامدة العادي.

I. Introduction

The importance of network security has been significantly increasing in the past few years. With the development of micro-electronics, computer science, computer and internet become one of essential part of life and work, so it is urgent to ensure the security of data of electronics transfer, electronic mail, and office automation. Data encryption among civilians and in the commercial world is increasingly needed [Baig and Mughal, 2007]. The basic idea of cryptology is hiding information [Roberto and García, 2009], the people who has no authorization cannot know the true information. Encryption is to reverse the information with mathematical tools. The original information is called plaintext; the information enciphered is called cipher text. The process which is from plaintext to cipher text is called encryption; the reverse process is called deciphering.

Deciphering is under the control of deciphering key, and the mathematical transformation that is used for deciphering is called data encryption algorithm. Cryptography evaluates the security of systems on the following four attributes: authentication, confidentiality, integrity and availability [Baig and Mughal, 2007,Cheng el at 2009]. The term scrambling has been, and still used to describe the encryption process to protect voice communication whether archived by digital or analog means [Kitming -2002]. This process is carried out in frequency domain, time-domain as well as two-dimensional (combination of both) [Maglogiannis el at 2009]. However, transform-domain data encryption and decryption has sought a significant role in secure communication systems. Among the transform-domain techniques, DCT and DWT have proved to be the best for data encryption [Hombrebueno el at 2009].

Because the data is stored in the computer transmitted through network in the term of cipher text, if the deciphering is leak out, the person who has no authorization won't know the true meaning, and then the data can be secure. Meanwhile, anybody who has no authorization can't forge right cipher text, so the data can't be changed, then the data is surely safe [Maglogiannis el at 2009]. That is why many real world cryptographic implementations use a compression program to reduce the size of the signal before encryption [Maglogiannis el at 2009]. Two-dimensional encryption that combines the frequency-domain encryption with the time-domain encryption [Hombrebueno el at 2009]. Besides, there are many other analogue data encryption methods in the transform domain, e.g., fast Fourier transform, discrete cosine transform and wavelet transform, etc. [Cheng el at 2009,Qinghua el at 2009]. Recently, some new data encryption methods including chaotic cryptosystem [Keita el at 2007]. In this paper we used hybrid structure of discrete wavelet transform and phase matrix as permutation and inverse discrete wavelet transform in building of both Encryption and decryption. The main aim is to investigate the effectiveness of the proposed new data ciphering based on hybrid transformation and its application in wireless OFDM Transceiver [Tafaroji and Falahati, 2007 ,Roberto and García, 2009].

The success of wavelets is mainly due to the good performance for piecewise smooth functions in one dimension. Unfortunately, such is not the case in two dimensions. In essence, wavelets are good at catching zero-dimensional or point singularities, but two-dimensional piecewise smooth signals resembling 2D-signals have one-dimensional singularities. That is, smooth regions are separated by edges, and while edges are discontinuous across, they are typically smooth curves. Intuitively, wavelets in two dimensions are obtained by a tensor-product of one dimensional wavelets and they are thus good at isolating the discontinuity across an edge, but will not see the smoothness along the edge. The properties of the new transform are demonstrated and studied in several applications [Laith 2009]. As an illustration, consider the 2D-signal denoising problem where there exist other approaches that explore the geometrical`regularity of edges, for example by chaining adjacent wavelet coefficients and then thresholding them over those contours [Qadeer el at 2009].

II. Phase Matrix as Permutation in the Encryption

The number of possible permutation of elements is N!. However, all of these permutations cannot be used because some of them do not provide enough security [Yeen and Fettweis -1993]. Let P be a set of permutation, and let P^{-1} be the set of inverse permutations corresponding to the permutation in P. The set S has to satisfy the requirement that any permutation in P must not produce an intelligence Encrypted data. It is difficult to evaluate the intelligibility of the Encrypted data signal and the intelligibility of the deEncrypted data signal by a quantitative criterion because intelligibility is substantially a subjective matter multiplied by a *PHASE MATRIX (PM)* which can be simply generated as in Eq. (1) and Eq. (2) [Yeen and Fettweis -1993, Jameel el at 2007, Yuan. el at 2004]

$$X(n,i)=\sum_{v=0}^{N-1} x(n*N-(N-1)+v,i)\, e^{-j(2\pi/N)i.v} \qquad (1)$$

Where; n is the data bit number, i: is the frequency bin of the FFT or IFFT (from 1 to N), N is the window size of FFT and $x(\ .,.\ )$: is the modulated signal

It can be seen that the Phase Matrix in Eq. (2) is a square matrix with a dimension of N*N points. The phase of this matrix will change as the frequency bin of the FFT changes. If the FFT has 64 points, then the Phase Matrix in Eq. (3) can be formulated in the following fashion:

$$PM=\begin{bmatrix} e^{-j(2\pi/64)*0} & e^{-j(2\pi/64)*1} & e^{-j(2\pi/64)*2} & \ldots\ldots\ldots\ldots & e^{-j(2\pi/64)*63} \\ e^{-j(2\pi/64)*0} & e^{-j(2\pi/64)*2} & e^{-j(2\pi/64)*4} & \ldots\ldots\ldots\ldots & e^{-j(2\pi/64)*126} \\ e^{-j(2\pi/64)*0} & e^{-j(2\pi/64)*3} & e^{-j(2\pi/64)*6} & \ldots\ldots\ldots\ldots & e^{-j(2\pi/64)*189} \\ . & . & . & & . \\ . & . & . & & . \\ . & . & . & & . \\ . & . & . & & . \\ e^{-j(2\pi/64)*0} & e^{-j(2\pi/64)*64} & e^{-j(2\pi/64)*128} & \ldots\ldots\ldots\ldots & e^{-j(2\pi/64)*4032} \end{bmatrix} \qquad (2)$$

And the phase values in degree can be written in the form:

$$\theta_{degree}=\left|\begin{array}{ccccccccc} 0 & -5.625 & -11.25 & -16.8750 & -22.5 & \cdots & 16.875 & 11.25 & 5.625 \\ 0 & -11.25 & -22.5 & -33.7500 & -45 & \cdots & 33.75 & 22.5 & 11.25 \\ 0 & -16.875 & -33.75 & -50.6250 & -67.5 & \cdots & 50.625 & 33.75 & 16.875 \\ \vdots & \vdots & \vdots & \vdots & \vdots & & \vdots & \vdots & \vdots \\ 0 & 5.625 & 11.25 & 16.875 & 22.5 & \cdots & -16.875 & -11.25 & \\ 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \end{array}\right| \qquad (3)$$

If the signal is multiplied by this PM at the transmitter side then it must be multiplied by the *Inverse of Phase Matrix (IPM)* at the receiver side in order to retrieve it, or in other form:

$$y_{receiver-side}=y_{received}\ * IPM \qquad (4)$$

Note that the last equation is a general equation, which means it depends on the location of the received signal that must be processed, and the location depends on the transmitter side, because at the receiver the inverse procedure will be done to process the signal.

The resizing is very important for the purpose of mapping in the next two sections. Since the data must be converted to a suitable two dimensional matrix before the FRAT mapping and then it must be reconverted to a one dimension after mapping to obtain the sub-carrier modulation as seen later. Fig. (1) Illustrates the main procedure of matrix resizing operations for both **1D** vector to **2D** matrix and **2D** matrix to **1D** vector [Laith 2009].

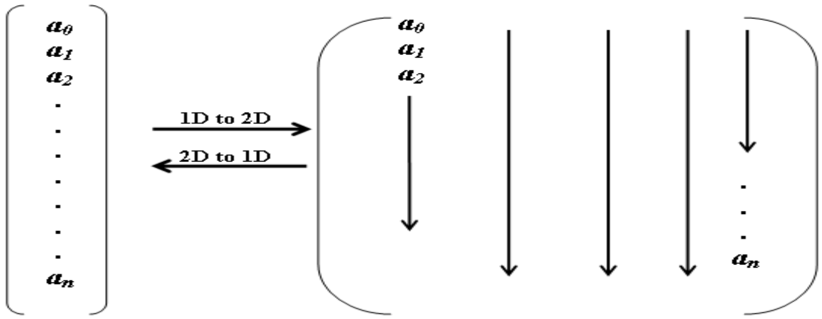

Fig. (1) Graphical illustration of matrix converter operations for both **1D** vector to **2D** matrix & **2D** matrix to **1D** vector

III. Encryption OFDM System Based On Phase Matrix and 2D-DWT

In this section, the phase matrix and 2D-DWT and 2D-FFT which are presented in the previous section are proposed here as a new Encryption technique for the realization of OFDM transceivers. These transform will be used throughout the following sections as a data mapper to obtain a constellated data symbols prior to the sub-carrier modulation. The modified Encryption is proposed as a new Encryption in the communication systems as shown in Fig (2). The basic building blocks in the implementation of OFDM system after some important modification as it can be seen in the next section. In this model each MATLAB function was designed to simulate a specific part of obtaining the modified Encryption of a frame-based input data after achieving the necessary frame resizing according to the algorithm given in the previous section.

The procedure that illustrates the realization steps is shown in Fig. (3), a signal flow diagram that explains the proposed Encryption OFDM transmitter [Jameel el at 2007, Yuan el at 2004].

After converting the input data streams from serial to parallel form to construct a one dimensional vector that contains the data symbols to be transmitted,

$$d = (d_1\ d_2 \ldots\ldots\ldots d_{N^2})^T \qquad (5)$$

where, N^2 is the specified frame length, and N should be power of 2 numbers. Then convert the data packets which are represented by the vector d from one-dimensional vector to an $N \times N$ two dimensional matrix D, according to the matrix resize operation.

Then take the proposed Encryption method to the matrix D to obtain the matrix R of dimensions $N\times N$. The first step in computing the modified Encryption using 2D-DWT is computed 2D-FFT for the matrix D. The procedure of computing 2D-FFT is given in [Yeen and Fettweis -1993, Sadkhan el at 2004]. The output matrix will be dimensions of $N\times N$. Then computing phase matrix of $N\times N$ then multiplying the input matrix by the phase matrix. After this step 2D-DWT will be computed for the matrix, and the procedure of computing 2D-DWT is given in [Sobia el at 2005 , Jameel. el at 2007]. The modification made on data dimensions in the end of calculation the modified Encryption matrix coefficients is R

$$r = (r_1\ r_2 \ldots\ldots\ldots r_{N\times N})^T \qquad (6)$$

At the end of this step, the propose encryption is done and the complex valued symbols are now ready for sub-carrier modulation of OFDM.

After Modified Encryption based on 2D-DWT and phase matrix has been done, a pilot-carrier (training sequence) is generated which is a bipolar sequence {±1}.The receiver will be informed about this sequence previously. The training sequence will be inserted in a parallel with data. The two sequences {data plus training} take the OFDM *Tx* for the vector, (*r*) to obtain the sub-channel modulation [Laith. 2009].

Finally, the two sequences (training plus data) will be converted to one sequence, and P/S converts the signal from parallel form to a serial form (convert the vector(*s*) to serial data symbols):

$s_1, s_2, \ldots\ldots\ldots\ldots\ldots, s_{2(N\times N)}$

The transmitted signal (***S***) will be transferred through the channel to the receiver**.**

Each MATLAB function with this model was designed to perform a specific part of the system.

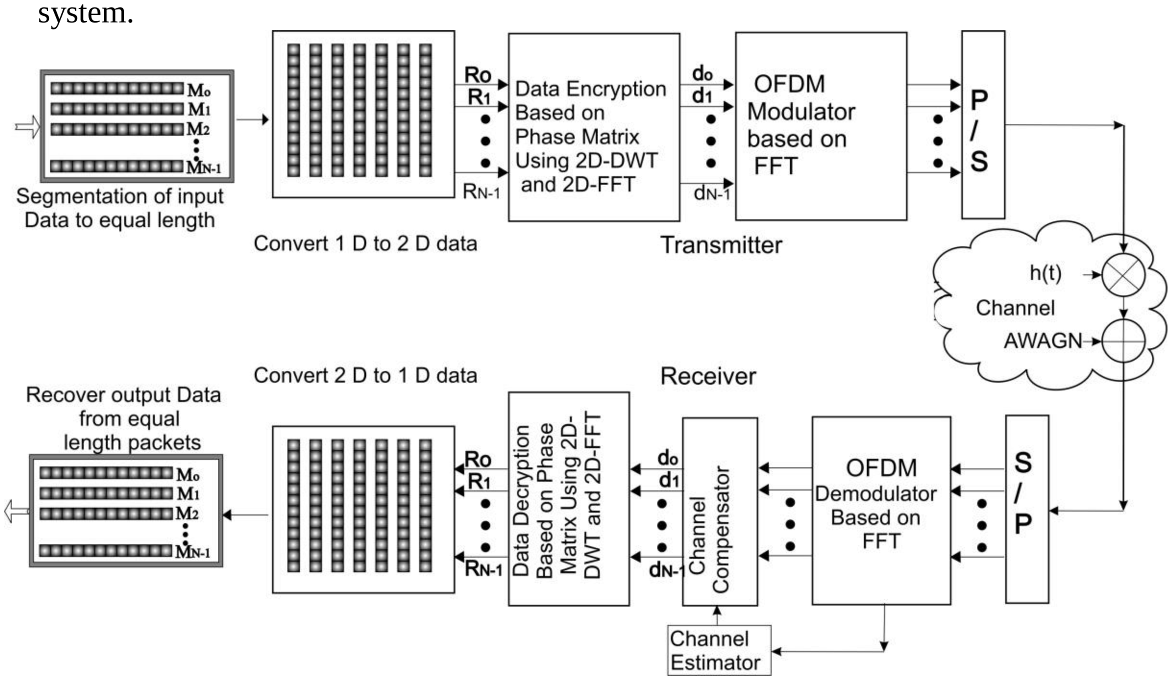

Fig.2 Block Diagram of Encryption OFDM System Based on 2D-DWT and Phase Matrix

Figure (4) represents the procedure for the receiver to retrieve the transmitted data. In the receiver side the procedure is reversed as it can be noticed. Also one can take a close look to see how the data dimensions are changing suitably throughout the blocks. When the signal received in the receiver, S/P converts the received sequence to a parallel form; also the separation of the two sequences will be done. The received signal will be input to the OFDM Demodulator (*S*). After that the values corresponding to the zeros pad are removed, therefore the signal at the output of this step represents {data plus training}. The training sequence will be used to estimate the channel frequency response as follows:

$$H(k) = \frac{Received\ \ Training\ \ Sample(k)}{Transmitted\ \ Training\ \ Sample(k)}, k = 1,2\ldots,N \qquad (7)$$

The channel frequency response which is found in the last step will be used to compensate the channel effects on the data, and the estimated data can be found using the following equation:

$$Estimate.data(k) = H^{-1}_{estimate}(k) * \mathrm{Re}ceived.data(k) \quad , k = 1,2....,N \times N \qquad (8)$$

The output of channel compensator will be passed through the signal modified deEncryption. The reversed procedure of modified Encryptions used in the transmitter as can be noticed in fig (4). The last step is the P/S which converts the parallel form of the signal to a serial form.

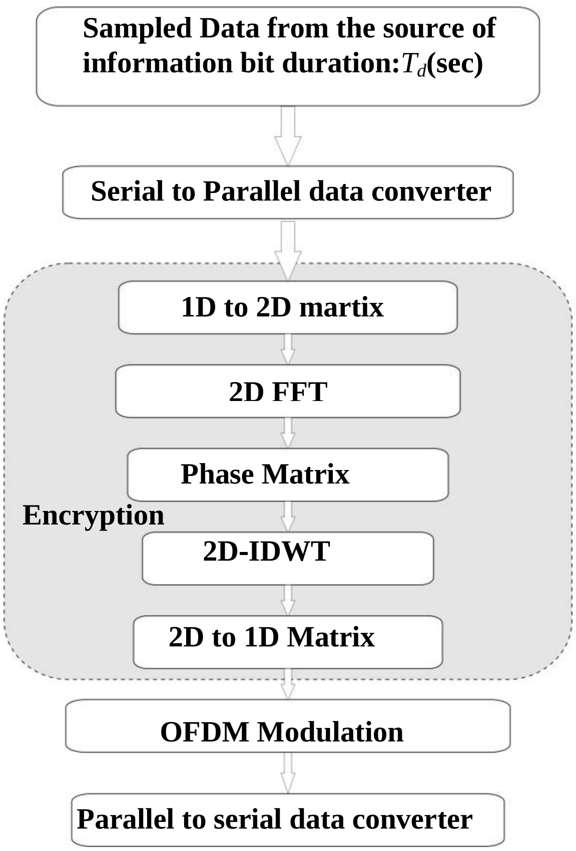

Fig. 3 Schematic diagram for the procedure of the proposed Encryption

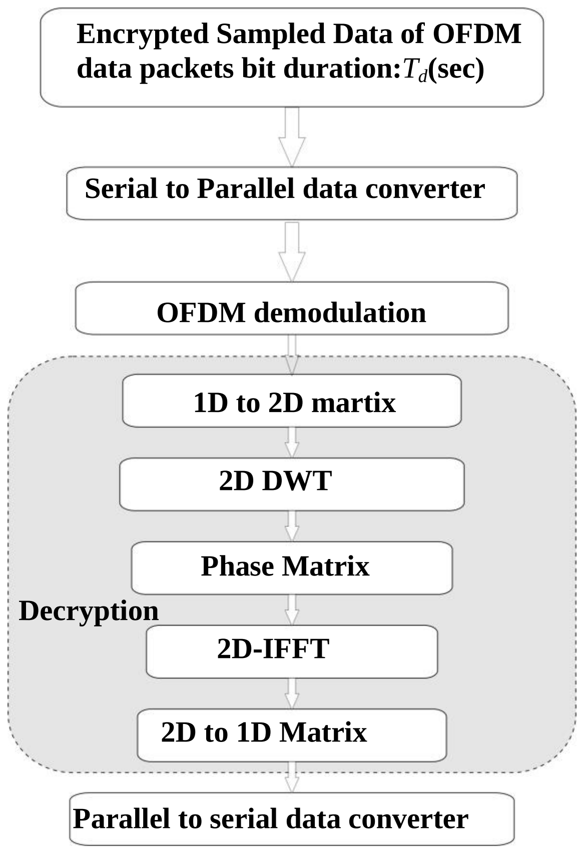

Fig. 4. Schematic diagram for the procedure of the proposed Decryption

IV. Performance of Modified Encryption Based OFDM Transceivers

In this section and the preceding sections, the modified Encryption -based OFDM transceiver which is proposed in the previous section will be simulated, and its performance will be analyzed.

System parameters that will be used through the simulation are; $T_d=0.1\mu sec$; modified Encryption window: 8×8; FFT bins= 64; Guard interval: Cyclic prefix approach with 26 symbol is added to the frame; Pilot-assisted channel estimator. The output of modified Encryption is (16×6), and then the frame that will be sub carrier modulation of length 64×2 after the training is inserted into to the frame before sending through channel, while different types of channel models are taken into account during the simulation. First, an AWGN channel is considered with several SNR values. Then, multi-path Raleigh distributed fading channels are considered with two scenarios; Flat and multi-path selective fading cases. Fig.(2) is schematic block diagrams for the proposed OFDM transceiver. The pilot-assisted channel estimator is proposed here to combat the fading effects as it was explained earlier in the previous section. It was found to be an efficient method especially for slow fading channels.

V. Simulation Results of OFDM with proposed Encryption:

In time-domain they are simply drawn as discrete-time signals but in frequency domain the distribution of energy is not as genuine as before the application of encryption process. Secondly, the spectrum is inverted altogether which flips the distribution of energy level as a function of frequency. Thirdly, signal is multiplied in frequency domain which is tantamount to convolution in time-domain. As the transmitted signal is in time-domain so any unauthorized person who wants to decrypt the signal without the knowledge of scheme, would have to convolve in time-domain which, unquestionably a very time consuming process in real-time systems. Further, he doesn't know the permutation order of the system that's why he would have to apply on each frame that will ideally take infinite time.

A. The Encryption-OFDM in AWGN Channel:

A program of MATLAB R2008a was used to simulate the proposed modified Encryption- OFDM transceiver shown in Fig. (2). Several MATLAB functions were programmed to simulate the transceiver shown in Fig. (2).These include frame resizing, modified Encryption-description, pilot carriers insertions-removing, etc. the result of the simulation for the proposed Encryption-OFDM system is calculated and shown in Fig.(5), and which gives the BER performance of Encryption-OFDM using DWT and QPSK-OFDM using FFT in AWGN channel. It is shown clearly that the Encryption-OFDM using modified Encryption is much better than QPSK-OFDM using FFT and the Encryption of Modified FRAT OFDM present in [Laith -2009].

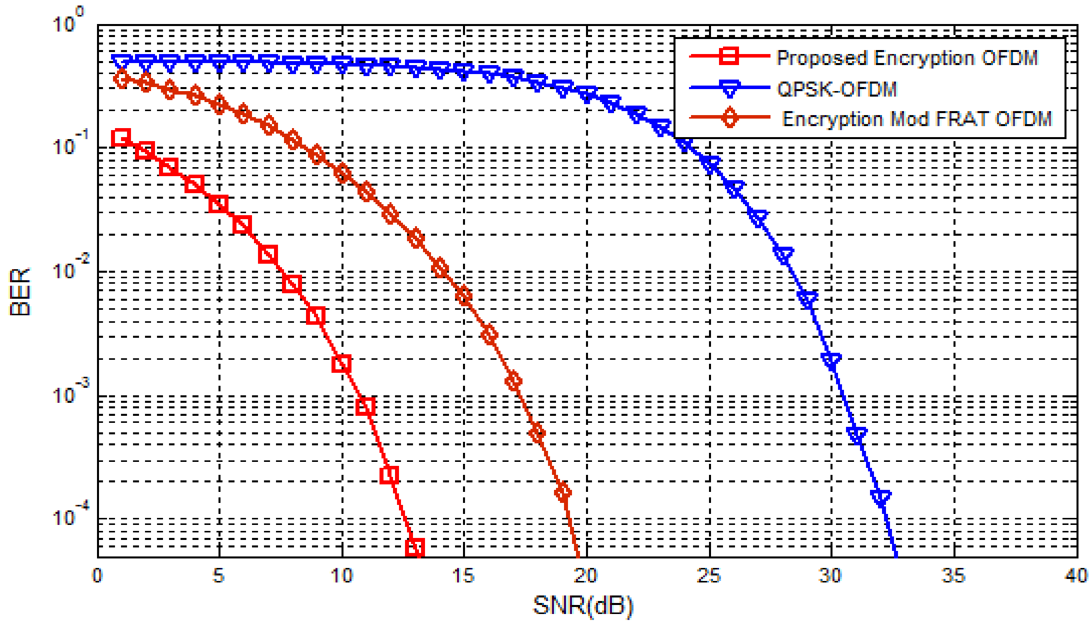

Fig .5. BER performance of Encryption -OFDM using modified Encrypter in AWGN channel model

B. The Encryption-OFDM in Flat fading channel

The same MATLAB R2008a program that simulated in Fig. (2) is used here to simulate the results in flat fading channel with AWGN except a flat fading channel is added to the channel model. In this type of channel, the signal is affected by the flat fading with addition to AWGN; in this case all the frequency components in the signal will be affected by a constant attenuation and linear phase distortion of the channel, which has been chosen to have a Rayleigh's distribution. A Doppler frequency of 10 Hz is used in this simulation. From Fig (6), it can be seen that for BER=10^{-4} the SNR required for Encryption-OFDM using modified Encryption is about 17dB, while in QPSK-OFDM the SNR is about 31dB, therefore from fig.(6)..fig. (8) a gain of 14dB for the Encryption-OFDM using modified Encryption against QPSK-OFDM is obtained. Therefore the Encryption-OFDM using modified Encryption outperforms significantly system for this channel model.

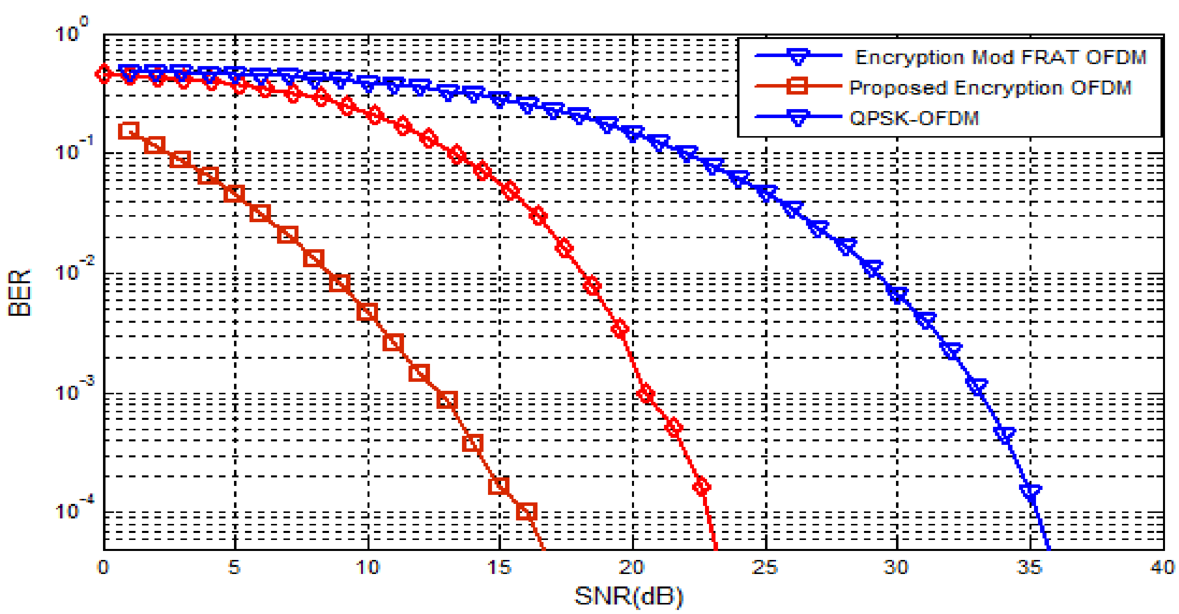

Fig.6. BER performance of Encryption -OFDM using modified Encrypter in Flat Fading Channel at Max Doppler Shift=10Hz.

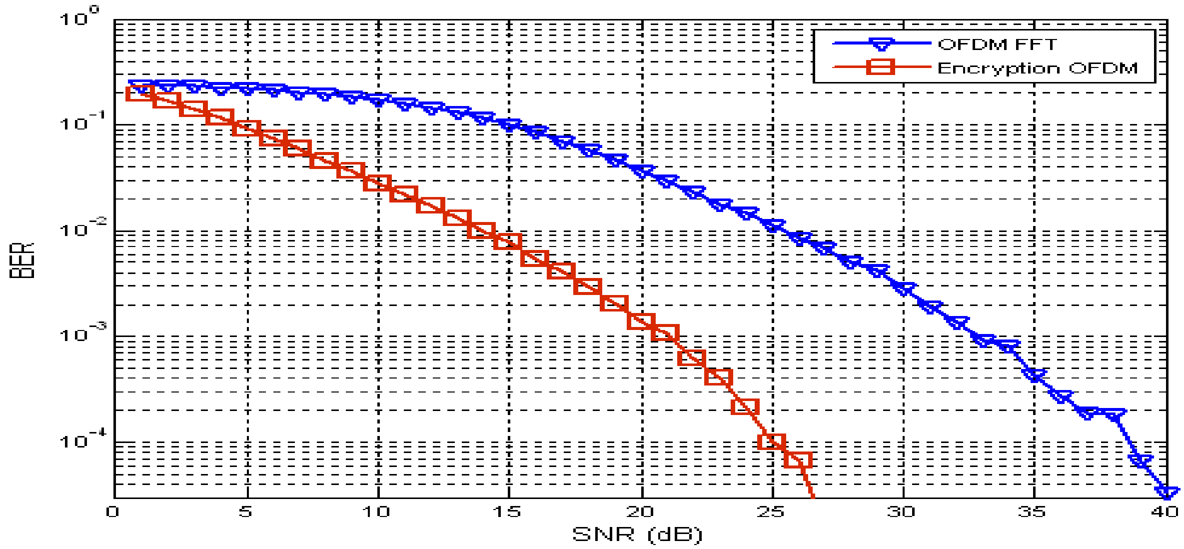

Fig.7. BER performance of Encryption -OFDM using modified Encrypter in Flat Fading Channel at Max Doppler Shift=100Hz.

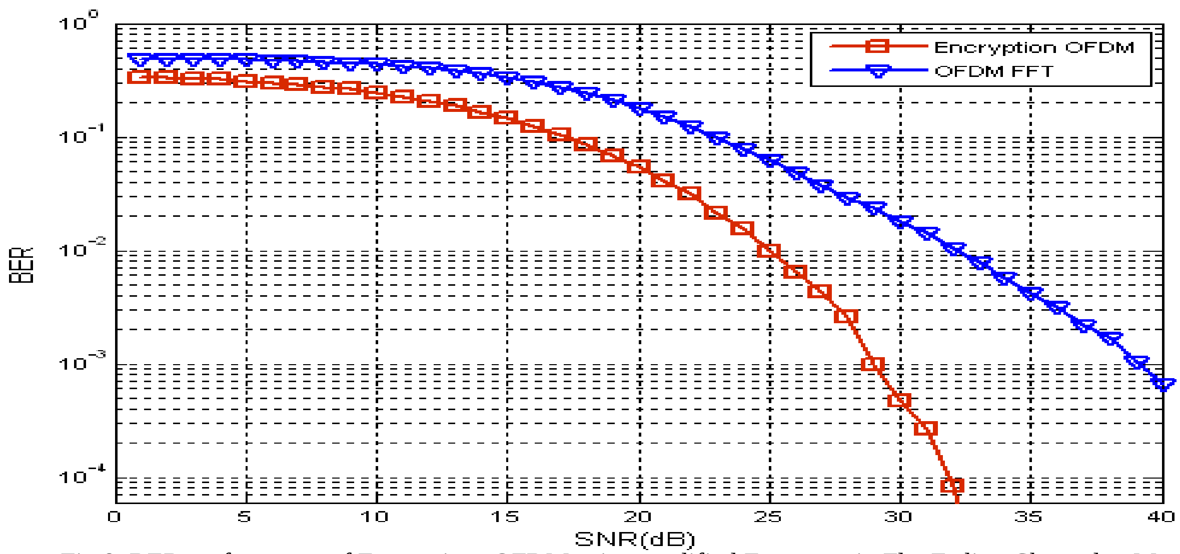

Fig.8. BER performance of Encryption -OFDM using modified Encrypter in Flat Fading Channel at Max Doppler Shift=500Hz.

In this section, BER performances of modified FRAT-OFDM using DWT are simulated in a multi-path frequency selective Rayleigh distributed channels with AWGN. Two ray channel is assumed here with a second path gain of -8dB, at a maximum delay from the second path of $\tau_{max}=0.1\mu sec$ for several values of SNR. Fig. (9) Shown simulation results at maximum Doppler shift, f_{Dmax} =10Hz. It's clearly seen from this figure the performance for BER=10^{-4} the SNR required for Encryption-OFDM using DWT is about 19dB, while in QPSK-OFDM using FFT the SNR is about 37dB. Therefore from fig.(9)…fig.(11) a gain of 18dB for the Encryption-OFDM using DWT against QPSK-OFDM is obtained. The results present in this paper summarized in Table (1), and these results were computed after test the system by transferring about 1M symbols. The table present the SNR that get BER of (10^{-4}).

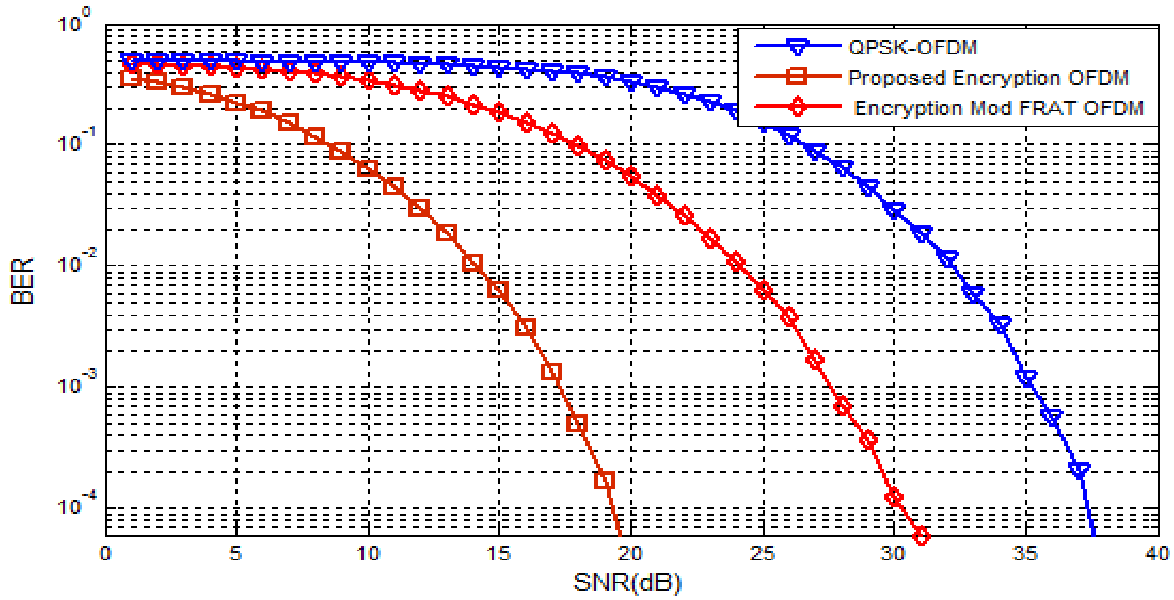

Fig .9. BER performance of Encryption -OFDM using modified Encrypter in Selective Fading Channel at Max. Doppler Shift=10Hz.

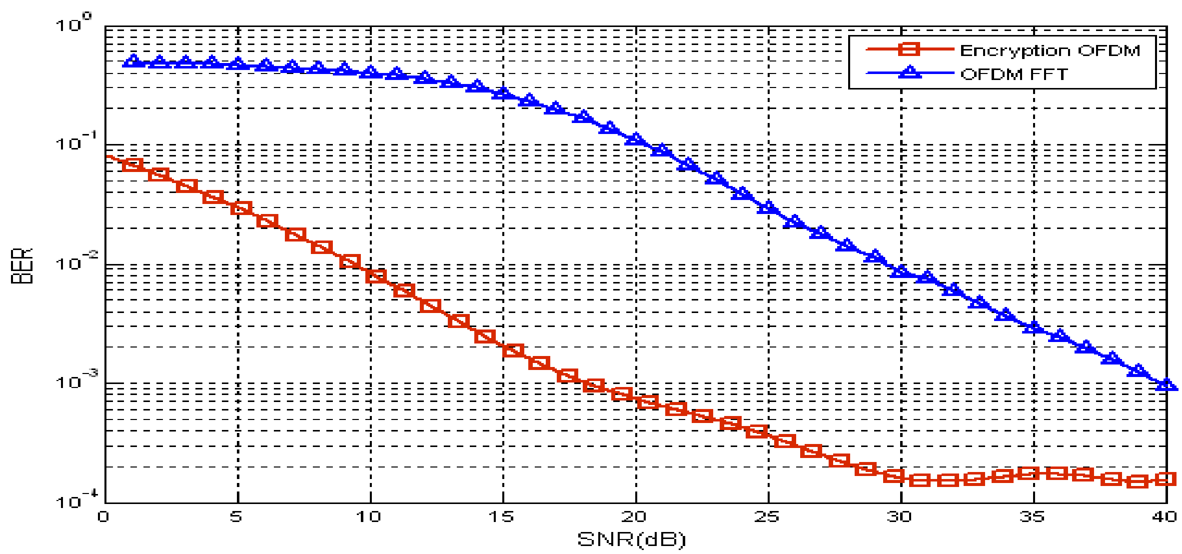

Fig .10. BER performance of Encryption -OFDM using modified Encrypter in Selective Fading Channel at Max. Doppler Shift=100Hz.

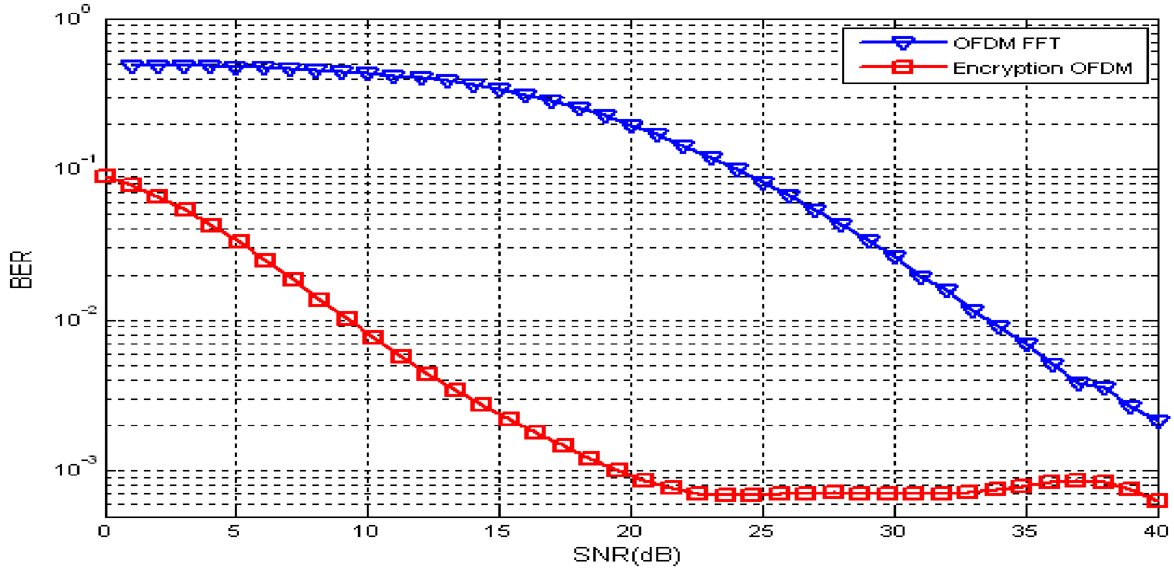

Fig .11. BER performance of Encryption -OFDM using modified Encrypter in Selective Fading Channel at Max. Doppler Shift=500Hz.

Table (1) the results for all systems

System name	AWGN	Flat Fading Max. Doppler Shift 10 Hz	Flat Fading Max. Doppler Shift 100 Hz	Flat Fading Max. Doppler Shift 500 Hz	Selective Fading Max. Doppler Shift 10 Hz	Selective Fading Max. Doppler Shift 100 Hz	Selective Fading Max. Doppler Shift 500 Hz
QPSK-OFDM	24	31	39	non	35	non	non
ENCRYPTION-OFDM	13	17	25	32	19	non	non

Vi. Conclusion

In this work, the encryption system based on combination of 2D-DWT, phase matrix and 2D-FFT can be widespread used in security domain, such as the right authentication on user identification and the secret of information. We proposed a new modified Encryption with OFDM system that is easy to configure since it does not require a complex digital signal processing of 2D-DWT algorithms which are available in all common DSP processors. As well it was successfully extended in the implementation of OFDM system. So the proposed system can be applied in real encryption applications. In addition, it was found that new structure has physical relationship channel effects (inter symbols interference (ISI)) which decreases the Bit error rate (BER) and strong robustness of changeable and limited in the communication system. From simulation results, the applying of the proposed Encrypter improved significantly the BER performance AWGN and flat fading channels on the average SNR of 14dB is gained to achieve BER of 10^{-4} compare with conventional OFDM. Better results gained in multi-path frequency-selective channel so to achieve such an error only SNR of 13.5dB was required.

Acknowledgment

The author acknowledges Dr. Laith A. Abdul-Rahaim for discussions on the topic presented in the paper and offers his simulation results to compare them with my simulation results.

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