Proposed Realization of modified Scrambling using 2D-DWT Based OFDM Transceivers

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Abstract—**Voice communication Protection is possible and may be in the future becomes a preferable to view the problem of security of voice communication in term of the classical producing speech ciphering system. The use of different form of speech scramblers have thus been a common approach to voice security. The main aim of this work is to model and simulation a proposed hybrid structure of speech scrambling system based on 2-Dimenations Discrete Wavelet Transform and best direction of optimal ordering as permutation. The design of scrambling system consists of three main parts, i.e transmitter, receiver and noisy channel. The system investigates 2D-DWT scrambling part and permutation by best direction and inverse 2D-DWT as a hybrid scrambler structure. This processes achieved in transmitter will be use an inverted structure in receiver. The proposed system was examined by using Arabic and English, Analog speech signals. Then for each case the performance evaluation process of the proposed system was taken into consideration via the using of OFDM simulation. The proposed structure with OFDM gave a significant improvement in the BER performance in comxarison with the conventional OFDM when tested for different channel types. The modification OFDM more secures than conventional OFDM structure.**

Index Terms: **2D-DWT/2D-IDWT, OFDM systems, optimal ordering, scrambling, Cryptography.**

I. INTRODUCTION

Secure communication can be considered a very important in both civil and military communication systems. In these systems the possible threats which could attack system in passive or active way are: eavesdropping, modification, replay, masquerading, penetration and repudiation. The methods used to achieve these threats successfully have been considered as highly sophisticated techniques [1]. Cryptography evaluates the security of systems on the following four attributes: authentication, confidentiality, integrity and availability [1,2]. The term scrambling has been, and still used to describe the encryption process to protect voice communication whether archived by digital or analog means [3]. This process is carried out in frequency domain, time-domain as well as two-dimensional (combination of both) [4].

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However, transform-domain speech 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 speech encryption [5].

In secure communication systems the redundancy of the language plays an important role. Higher the redundancy in the language, the easier it is to decrypt the information [4]. That is why many real world cryptographic implementations use a compression program to reduce the size of the signal before scrambling [4]. Two-dimensional scrambling that combines the frequency-domain scrambling with the time-domain scrambling [5]. Besides, there are many other analogue speech encryption methods in the transform domain, e.g., fast Fourier transform, discrete cosine transform and wavelet transform, etc. [2,6]. Recently, some new speech encryption methods including chaotic cryptosystem [7]. In this paper we used hybrid structure of discrete wavelet transform and optimal ordering as permutation and inverse discrete wavelet transform in building of both scrambler and descrambler. The main is to investigate the effectiveness of the proposed new speech ciphering based on hybrid transformation and its application in wireless OFDM Transceiver [8].

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. To overcome the weakness of wavelets in higher dimensions, Candes and Donoho [6, 9] recently pioneered a new system of representations named ridgelets which deal effectively with line singularities in 2-D. The idea is to map a line singularity into a point singularity using the Radon transform [10]. Then, the wavelet transform can be used to effectively handle the point singularity in the Radon domain. Their initial proposal was intended for functions defined in the continuous R2 space. Due to the radial nature of Radon transform, straightforward implementations based on discretization of continuous formulae would require interpolation in polar coordinates, and thus result in transforms that would be either redundant or can not be perfectly reconstructed. In [11], the paper take the redundant approach in defining discrete Radon transforms that can lead to invertible discrete ridgelet transforms with some appealing properties. For example, a recent preprint [10] proposes a new notion of Radon transform for data in a rectangular coordinate such that the lines exhibit geometrical faithfulness. However, the inverse transform is ill-conditioned in the presence of noise and requires an iterative approximation algorithm. In fact, our construction leads to a large family of orthonormal and directional bases for digital 2D-signals, including adaptive schemes. As a result, the inverse transform is numerically stable and uses the same algorithm as the forward transform. Because a basic building block in our construction is the finite Radon transform [11], which has a wrap-around (or aliased line) effect. The properties of the new transform are demonstrated and studied in several applications. 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 [12].

II. FINITE RADON TRINSFORM AS PERMUTATION IN THE SCRAMBLER

The number of possible permutation of elements is N!. However, all of these permutations cannot be uwed because some of them do not provide enough security [13]. 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 intelligicne scrambled speech. It is difficult to evaluate the intelligibility of the scrambled speech signal and the intelligibility of the descrambled speech signal by a quantitative criterion because intelligibility is substantially a subjective matter. The finite Radon transform (FRAT) is dmfined for two dimensional 2D-signals in [11,13]. The FT approach will be followed throughout this research due to its suitability for our purposes. The FRAT of a two dimensional square matrix A, with a condition that the size of the matrix, denoted by p, should be prime can be obtained first by taking the 2D-FFT of A:

$$F(r,s)=\sum_{m=0}^{p-1}\sum_{n=0}^{p-1}A(m,n)e^{-j(2\pi/p)rm}\quad e^{-j(2\pi/p)ns} \quad (1)$$

Then the order of the coefficients in the corresponding Fourier slices are controlled by the direction of a set of normal vectors, namely, (a_k, b_k), where $k=0,1,2,....p$.

The optimal ordering of Radon coefficients was suggested first in the work of Minh *et al* [6]. It was shown that the optimum number of FRAT projections is $p+1$, one projection for each column, and the best ordering of the 2D-FFT coefficients in these projections which is controlled by the normal vectors can be achieved if the normal vectors are determined from:

$$(a_k,b_k)=\arg \min_{\substack{(a_k,b_k)\in\{nu_k:1\leq n\leq p\}\\ st.C_p(b_k)\geq 0}} \left\|(C_p(a_k),C_p(b_k))\right\| \qquad (2)$$

Here $C_p(x)$ denotes the centralized function of period p; $Cp(x)=x-p.round(x/p)$.Hence, $\left\|(C_p(a_k),C_p(b_k))\right\|$ represents the distance from the origin to the point (a_k,b_k) on the Fourier plane. The constraint $Cp(b_k) \geq 0$ is imposed in order to remove the ambiguity in deciding between (a,b) and $(-a,-b)$ as the normal vector for the projection. As a result the optimal normal vectors are restricted to have angles in $[0,\pi]$. Now, the matrix F is assigned the symbol $F_{opt.}$, after the reordering [9-12].

Finally, the FRAT can be obtained by taking the 1D-IFFT for each column of the matrix $F_{opt.}$. So, if the columns of the matrix F_{opt} are assigned the symbol f_i, where i take the values of 0, 1, 2, 3, ……….., p, then [6]:

$$r_i(k)=\mathrm{Re}\{\ \frac{1}{p}\sum_{m=0}^{p\text{-}1}f(i)\quad e^{j(2\pi/p)km}\ \}, \qquad (3)$$

Now, the matrix with the r_i columns represents the FRAT of A:

$$R=[r_0\quad r_1\quad r_2..........r_{p-1}] \qquad (4)$$

Also [11] showed that normalization by the square root of the matrix size, p leads for better performance. Note that, reversing the above procedure yields the recovered matrix A, and that is by taking the 1D-FFT, retrieving the original Fourier coefficients ordering, and then taking the 2D-FFT.

On the other hand, this suitability makes the FRAT mapping leads itself with the OFDM structure since it depends on the 1D-IFFT to obtain the required mapping. That increases the orthogonality of the system since it means, IFFT will be used twice, first in the data mapping and secondly in the sub-channel modulation. Fig. (1) Illustrates the main procedure of taking the FRAT and IFRAT, respectively. The objective of the matrix resize block in this Figure is actually to change the dimension of the data to a suitable form to apply the FRAT and IFRAT according to the

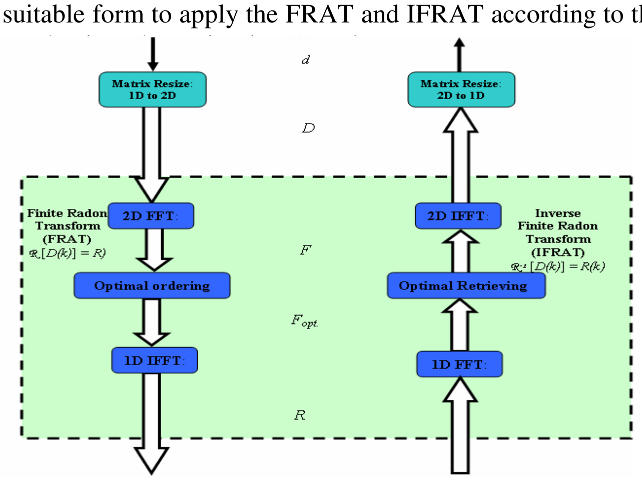


Fig.1. Schematic diagram for the mechanism of the FRAT and IFRAT transform

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. (2) Illustrates the main procedure of matrix resizing operations for both **1D** vector to **2D** matrix and **2D** matrix to **1D** vector.

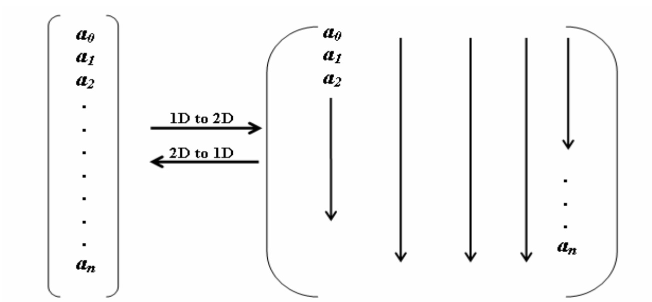


Fig. (2) Graphical illustration of matrix converter operations for both **1D** vector to **2D** matrix & **2D** matrix to **1D** vector

III. SCRAMBLER OFDM SYSTEM BASED ON MODIFIED FRAT USING DWT

In this section, the FRAT which is presented in the previous section is proposed here as a new scrambler technique for the realization of OFDM transceivers. This 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 scrambler is proposed as a new scrambler in the communication systems as shown in Fig (4). The basic building blocks in the implementation of OFDM system after some important modification as it can be seen in the next section. The Block diagram model shown in Fig. (3) will be considered in the implementation of OFDM system after some important modification as can be seen in the next section. In this model each MATLAB function was designed to simulate a specific part of obtaining the modified scrambler 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 scrambler OFDM transmitter [14, 15].

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 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 modified FRAT of the matrix D to obtain the matrix R of dimensions $2N \times p+1$. The first step in computing the modified scrambler using DWT is computed 2D-DWT for the matrix D. The procedure of computing 2D-DWT is given in [13, 16]. The output matrix will be resized to dimensions of $P\times P$ by adding zeros to rows and columns, where p is smallest prime number after N. Optimum Ordering will be taken for the prime matrix to form optimum ordering matrix of dimensions $P\times P+1$.Then resize the optimum ordering dimensions by adding zeros to the columns to make its dimension $2N\times P+1$, these added zeros will be like the zero padding added in the OFDM system. After this step FFT will be computed, and the procedure of computing FFT is given in [9,14]. The modification made on data dimensions in the end of calculation the modified scrambler matrix coefficients R, for a purpose of increasing the bit per Hertz of the mapping before resizing the mapped data and that's by: Construct the complex matrix $\overline{R}$ from the real matrix R such that its dimensions will be $(2N\times(p+1)/2)$ according to:

$$\overline{r}_{l,m} = r_{i,j} + i * r_{i,j+1}\ ,\quad 1 \le i \le 2N,\ 1 \le j \le p+1 \qquad (6)$$

where, $\overline{r}_{l,m}$ refers to the elements of the matrix $\overline{R}$, while $r_{i,j}$ refers to the elements of the matrix R. Converted the matrix $\overline{R}$ to a one dimensional vector r of length $(2N(p+1)/2)$.

$$r = (r_1\ r_2 \ldots\ldots\ldots\ r_{2N(p+1)/2})^T \qquad (7)$$

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

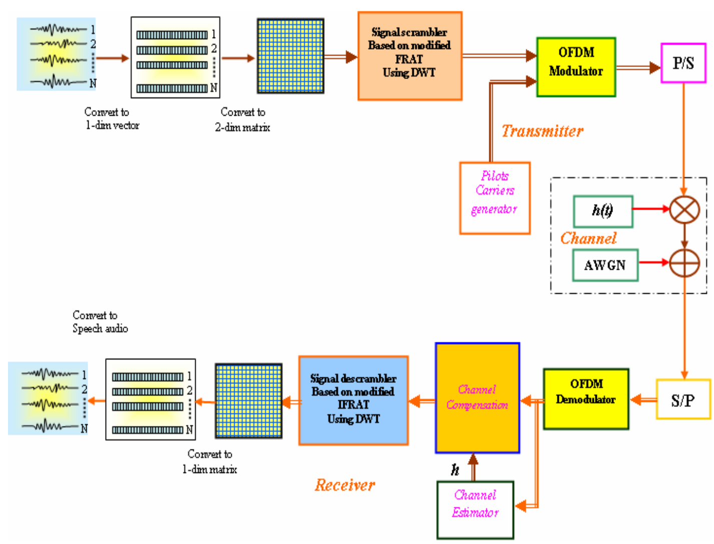


Fig.3. Block Diagram of scrambler OFDM System Based on modified FRAT using DWT

After Modified scrambler based on DWT has been done, a pilot-carrier (training sequence) is generated which is a bipolar sequence $\{\pm 1\}$.The receiver will be informed about this sequence previously. The training sequence will be inserted in a parallel with data. The two sequences {data+training} take the OFDM *Tx* for the vector, (r) to obtain the sub-channel modulation.

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):

$s_1, s_2, \ldots\ldots\ldots\ldots\ldots\ldots, s_{2N(p+1)/2}$

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

It's important here to point out that scrambler achieved in the conventional FFT-based OFDM by QPSK or QAM modulations will be replaced in this proposal by the modified FRAT to get the scrambled data prior to the sub-channel modulation. Each MATLAB function with this model was designed to perform a specific part of the modified FRAT.

Fig.(5) 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+training}. The training sequence will be used to estimate the channel frequency response as follows:

$$H(k) = \frac{\mathrm{Re}ceived\ \ Training\ \ Sample(k)}{Transmitted\ \ Training\ \ Sample(k)}, k = 1,2....,N \quad (8)$$

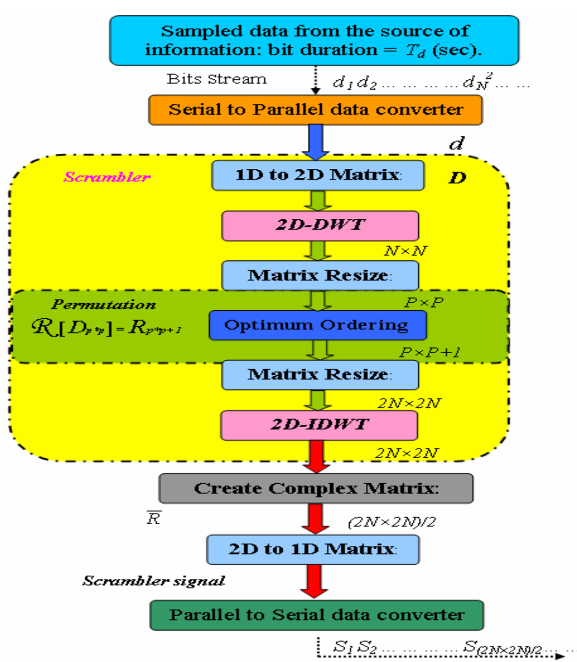
The channel frequency response which is found in the last step will be used to compensate the channel effects on the data, and the estimated data can be found using the following equation:

$$Estimate.data(k) = H^{-1}_{estimate}(k) * \mathrm{Re}\,ceived.data(k) \\ , k = 1,2....,2N \times (P+1)/2 \quad (9)$$

The output of channel compensator will be passed through the signal modified descrambler. The reversed procedure of modified scrambler is used in the transmitter as can be noticed in fig (5). The last step is the P/S which converts the parallel form of the signal to a serial form.

IV. PERFORMANCE OF MODIFIED FRAT BASED SCRAMBLER OFDM TRANSCEIVERS

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



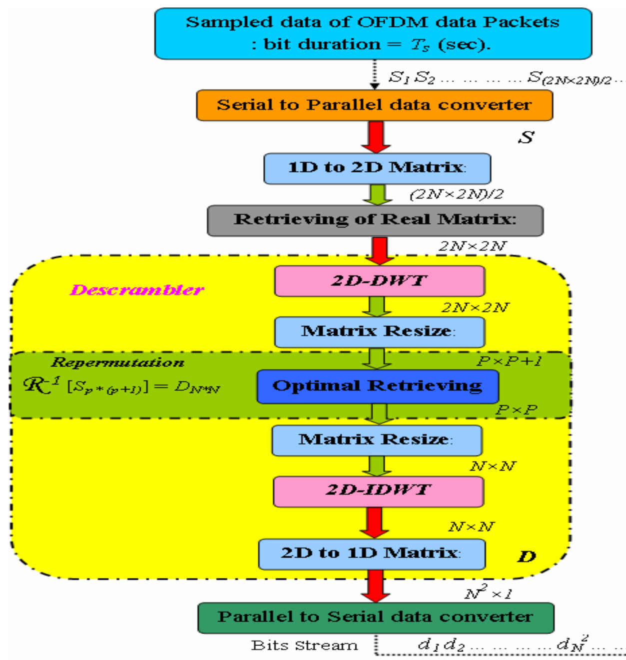


Fig. 5. Schematic diagram for the procedure of the proposed OFDM Receiver

System parameters that will be used through the simulation are; T_d=*0.1µsec*; modified scrambler 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 scrambler 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.(3) 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

We have conducted an extensive exercise of experiments over a long period of time. These experiments including original, scrambled and descrambled speech were carried out using various speech segments of different time periods and genders. Since the residual intelligibility and quality of the recovered speech are largely subjective quantities; the scrambling and descrambling techniques are evaluated on the average results given by the trained listeners. In this regard, many subjective tests were conducted by using the methods adopted by [5,24] with the help of wave files. In a view to make these tests easily understandable for listeners, the wave files of said speech signals were played and heard by the trained listeners. In this exercise, thirty trained listeners who were all listened to these recorded 50 scrambled speech segments. Each segment consisted of the digits 0 to 9 spoken in group of four digits. Further, the tests were not confined to digits only but sentences and conversational segments were also used. In order to make tests stringent and more result-oriented, although it was laborious and time-consuming, all the tests were carried out in English, languages. The repetition of the digits on the same position is strictly avoided. The tests were made more inflexible than carried out by [3,7] by:

(i) Isolating the digits that were spoken by not only male but female as well.

(ii) Tests are not limited to digits only, sentences are also included. These segments are recorded.

(iii) Further, conversational segments are also carried out in three languages by both genders.

Some of the results conducted on proposed system using Matlab-7.4 are demonstrated in this paper. A recorded speech file, containing spoken words ‘‘Zero, One, Two, Three’’ uttered by a male is analyzed. Figs. (6–8) show time-domain representation of original scrambled and descrambled files respectively. On the other hand, Figs.(9–11) exhibit distribution of power as a function of frequency of original encrypted and recovered speech, respectively. The close analysis of these signals and their subsequent transformation into frequency domain leave very remarkable and noteworthy observations. 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.

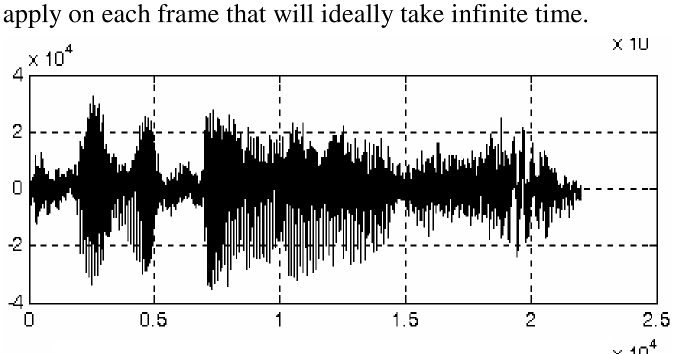
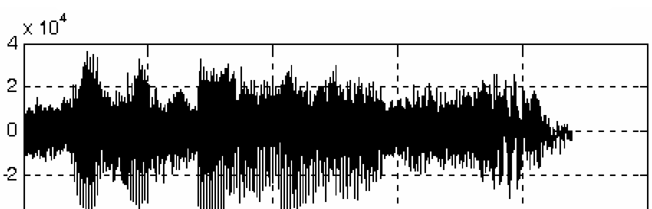


Fig.6. Time-domain representation of original file.



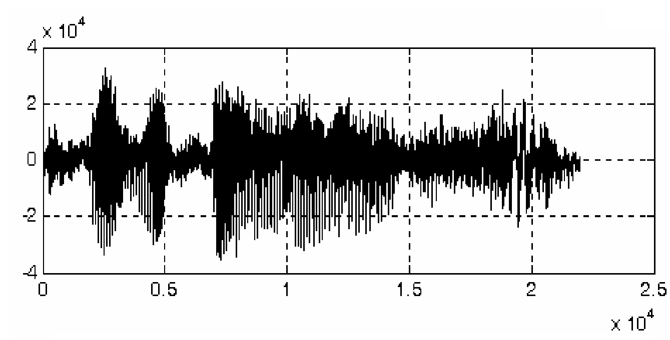


Fig. 8. Time-domain representation of descrambled file

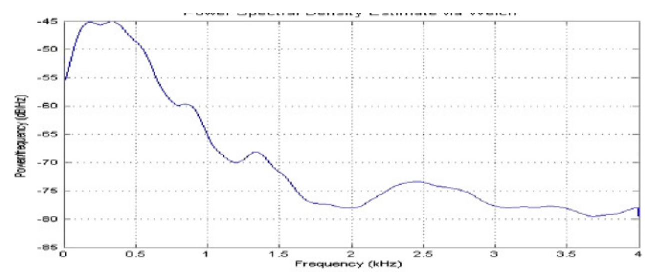


Fig. 9. Power spectral density of original file.

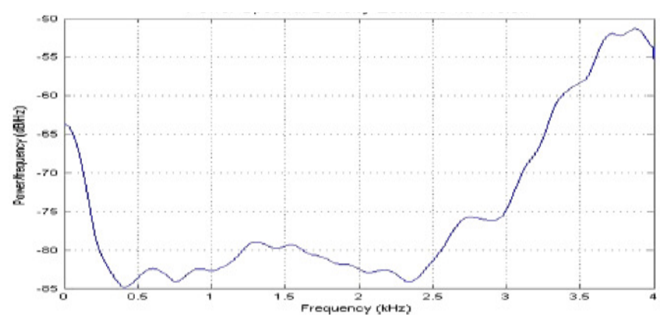


Fig.10. Power spectral density of scrambled file.

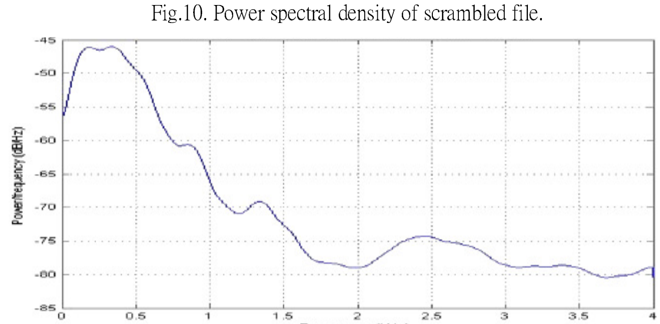


Fig.11. Power spectral density of descrambled file.

A. The scrambler -OFDM in AWGN Channel:

A program of MATLAB V7.4 was used to simulate the proposed modified FRAT-OFDM transceiver shown in Fig. (3). Several MATLAB functions were programmed to simulate the transceiver shown in Fig. (3).These include frame resizing, modified scrambler-descrambler, pilot carriers insertions-removing, etc. the result of the simulation for the proposed scrambler-OFDM system is calculated and shown in Fig.(12), and which gives the BER performance of scrambler-OFDM using DWT and QPSK-OFDM using FFT in AWGN channel. It is shown clearly that the scrambler -OFDM using modified scrambler is much better than QPSK-OFDM using FFT.

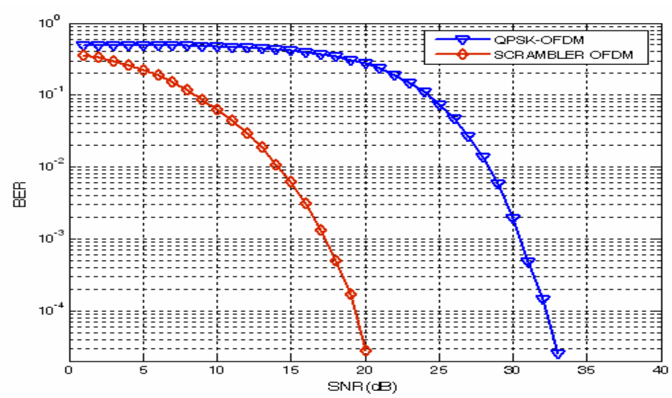


Fig .12. BER performance of scrambler -OFDM using modified scrambler in AWGN channel model

B. The scrambler -OFDM in Flat fading channel

The same MATLAB V7.4 program that simulated the Fig. (3) 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 (13), it can be seen that for BER=10^{-4} the SNR required for scrambler-OFDM using modified scrambler is about 23dB, while in QPSK-OFDM using FFT the SNR is about 34dB, therefore a gain of 11dB for the scrambler -OFDM using modified scrambler against QPSK-OFDM using FFT is obtained. Therefore the scrambler-OFDM using modified scrambler outperforms significantly system for this channel model.

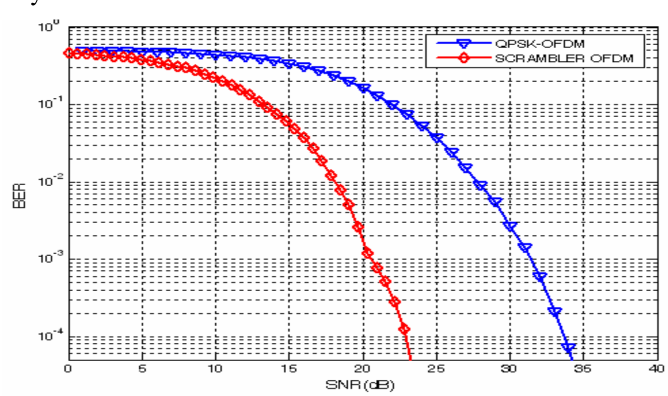


Fig.13. BER performance of scrambler -OFDM using modified scrambler in Flat Fading Channel at Max Doppler Shift=10Hz.

C. The scrambler -OFDM in Frequency Selective fading channel:

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 τ_{max}=*0.1μsec* for several values of SNR. Fig. (14) 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 scrambler -OFDM using DWT is about 29dB, while in QPSK-OFDM using FFT the SNR is about 37.5dB. Therefore a gain of 8.5dB for the scrambler -OFDM using DWT against QPSK-OFDM using FFT 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}).

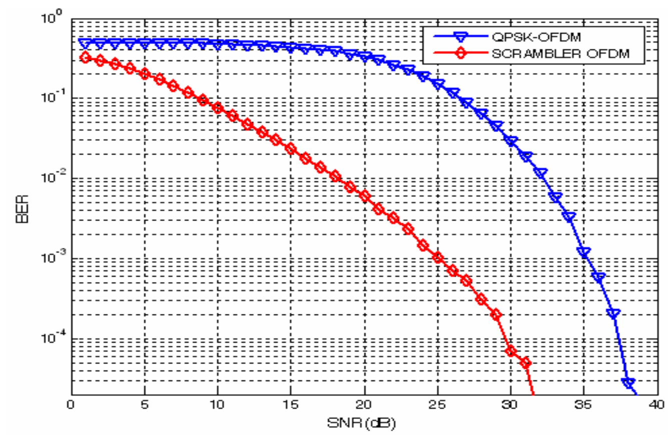


Fig .14. BER performance of scrambler -OFDM using modified scrambler in Selective Fading Channel at Max. Doppler Shift=10Hz.

Table (1) the results for all systems

System name	AWGN	Flat Fading	Selective Fading
		f_{Dmax} = 10 Hz	f_{Dmax} = 10 Hz
QPSK-OFDM	32	34	37.5
SCRAMBLER OFDM	18	23	29

VI. CONCLUSION

In this work, we proposed a new modified scrambler using 2D-DWT 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. It was found that parameters of the new structure have physical relationship with the communication system performance characteristics which makes the matching very easy. Also it can be concluded that this structure offers more robust performance in many other high rate communication systems, resisting a wide range of changes in system parameters. As a result of applying the modified scrambler, the BER performance was improved significantly, especially in the existence of multi-path fading channels on the average, an SNR gain of 6.5dB is gained to achieve an error of 10^{-4} in AWGN, flat fading channels respectively. While in multi-path frequency-selective channel SNR gain of 3.5dB is gained to achieve such an error.

VII. REFERENCES

[1] P. Toft, “The radon transform theory and implementation”, Ph.D. dissertation, Department of Mathematical Modeling, Technical University of Denmark, Denmark, June 1996.

[2] Roger J. Sutton, “Secure Communications-Applications and Management” , John Wiley & Sons, Inc., 2002.

[3] W.W. Chang et al., The automated cryptanalysis of DFT-based speech scramblers, IEICE Transactions INF.&SYST. E 83 2107–2112, 2000.

[4] H. Zhang, D. Yuan, M. Jiang and Dalei Wu “Research of DFT-OFDM and DWT-OFDM on Different Transmission Scenarios.” Proceedings of the 2nd International Conference on Information Technology for Application (ICITA), 2004.

[5] A. Jameel, M.Y. Siyal, N. Ahmed, “Transform-domain and DSP based secure speech communication system”, Elsevier Microprocessors and Microsystems 31 pp.335–346, 2007.

[6] N. Minh Do and M. Vetterli, “The finite ridgelet transform for image representation”, IEEE Trans. Image Processing, vol. 12, No. 4, pp. 16.28, Jan. 2003.

[7] J. G. Proakis, “Digital Communications”, Prentice-Hall, 4th edition, 2005.

[8] H. Schulze and C. Lüders “Theory and Applications of OFDM and CDMA Wideband Wireless Communications”, John Wiley& Sons Ltd, 2005.

[9] I. S. Uzun and A. Amira, “Design and FPGA Implementation of Finite Ridgelet Transform” VLSI Architecture for Speech and Signal Processing, pp. 5826-5829, 2005.

[10] S. Foucher, V. Gouaillier, L. Gagnon., “Global Semantic Classification of Scenes using Ridgelet Transform”, R&D Department, Computer Research Institute of Montreal,550 Sherbrooke West, Suite 100, Montreal, Canada, H3A 1B9 ,2005.

[11] C. Patrizio, K. Deepa and N. Alessandro,“Robust digital watermarking in the ridgelet domain”, IEEE Signal Processing Letters, Vol 11, No 10, pp 826-830, October, 2004.

[12] Z. Zhang, X. Liu and Z. Fan “The Performances Analysis of Transformation Methods in Image Watermarking Using Subsampling”, Proceedings of the 6th World Congress on Intelligent Control and Automation, June 21 - 23, pp. 9984-9987, Dalian, China, 2006.

[13] N. Rao, J. Homer, "Speech Compression Using Wavelets", Electrical Engineering Thesis Project, 2001.

[14] A. Jameel, M.Y. Siyal, N. Ikram, " A robust secure speech communication system using G.723.1 and TMS320C6711 DSP", Microprocessors and Microsystems 30 (1), 26–32, 2006.

[15] C. A. Rahman and W. Badawy, “A VLSI Architecture for Finite Ridgelet Transform” IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 26, No. 3, pp. 594-597, 2004.

[16] S.B. Sadkhan, N. Abdulmuhsen, N. F. Al-Tahan “A Proposed Analog Speech Scrambler Based on Parallel Structure of Wavelet Transforms” IEEE 24th National Radio Science Conference, Faculty of Engineering, Ain shams Univ., Egypt pp. 1726-1735, March 2007.

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