

# SVD Watermarked Video Frame Transmission System Using Chaotic Interleaving

Eman Mohamed Elbakary (✉ [eman\\_elbakary449@yahoo.com](mailto:eman_elbakary449@yahoo.com))

Faculty of Electronic Engineering, Menoufia University <https://orcid.org/0000-0001-5101-9981>

El-Sayed M El-Rabaie

Faculty of Electronic Engineering, Menoufia University

O Zahran

Faculty of Electronic Engineering, Menoufia University

Fathi E Abd El-Samie

Faculty of Electronic Engineering, Menoufia University

---

## Research Article

**Keywords:** Video, Data Hiding, SVD watermarking, Coding, OFDM and Chaotic Map.

**Posted Date:** March 15th, 2021

**DOI:** <https://doi.org/10.21203/rs.3.rs-229267/v1>

**License:** © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

---

# SVD Watermarked Video Frame Transmission System Using Chaotic Interleaving

Eman M. El-Bakary, El-Sayed M. El-Rabaie, O. Zahran, and Fathi E. Abd El-Samie

Faculty of Electronic Engineering, Menoufia University, Menouf, 32952, Egypt

E-mail: [eman\\_elbakary449@yahoo.com](mailto:eman_elbakary449@yahoo.com), [srabie1@yahoo.com](mailto:srabie1@yahoo.com), [osama\\_zahran@el-eng.menofia.edu.eg](mailto:osama_zahran@el-eng.menofia.edu.eg), [fathi\\_sayed@yahoo.com](mailto:fathi_sayed@yahoo.com)

## Abstract

This paper suggests a chaotic Baker interleaving method for minimizing the channel errors on the transmitted data and setting some encryption. The evaluation of the suggested approach is checked by the transmission of various SVD watermarked video frames over Rayleigh fading channels in the presence of additive white Gaussian noise with interleaving by chaotic Baker map. The obtained results indicate that the received SVD watermarked video frames give higher peak signal to noise ratios (PSNRs) using chaotic interleaving compared to other methods.

**Keywords:** Video, Data Hiding, SVD watermarking, Coding, OFDM and Chaotic Map.

## 1. Introduction

SVD watermarked video communication over wireless networks suffers from losses due to either packet dropping or fading-motivated bit errors. Thus, the robustness performance of SVD watermarked video transmission over wireless channels becomes a recent considerable hot issue due to restricted resources and the existence of heavy channel errors [1]. This work suggests a chaotic Baker interleaving technique for efficient transmission of SVD watermarked frame video over (OFDM) wireless systems with convolution code and equalization. Cases of additive white Gaussian noise and Rayleigh fading channels are considered.

SVD watermarking is an attractive technique that used for reliable multimedia transmission. The common use of the SVD watermarked video is utilized in more

applications and become of interest, especially when SVD watermarked is used in cryptography with conjunction. SVD technique is the technique that inserts the hiding secret media. When mixing these methods, the hiding secret data is embedded, authenticated and encrypted. SVD adds hiding secret data which introduce authentication and encryption. The video frame is set to a group of non-overlapping blocks and the watermark is embedded into these blocks [2-3].

The video data is transported over channels mixed with heavy conditions, e.g. burst errors that occur in groups. The burst errors effect should be minimized thus, it is used interleaving on binary data of the SVD watermarked video frames at the side of the transmitter and equalization and convolution code at the side of the receiver [4-7]. To build strong interleavers, chaotic maps scheme that depending on chaotic Baker map can be used for the watermarked SVD video frames in binary format prior to the modulation [8-10]. The advantages of chaotic maps randomization are minimizing the effects of the channel without the need for coding schemes for detecting the error and correcting it [11], achieving encryption in the transmitted data which adds a security to the watermarked SVD video transmission process [12-13].

Using linear equalization and convolution code eliminate the effects of the ISI and MAI [14-16]. While using the joint randomization method, "equalization and convolution code" enhance the robust of the OFDM systems [17]. The randomization is applied on the watermarked SVD video frames and convolution coding before transmission. At the receiver, the equalization and convolution decoding steps are applied. The suggested method estimates the signal to noise ratio (SNR) to measure the efficiency of the received watermarked SVD video frames [18].

This paper is organized as follows. Section 2 explains the background of data hiding. Section 3 explains the hiding and video scheme. Section 4 shows the suggested SVD watermarked scheme. Section 5 explains the OFDM model which used for transmission of watermarked compressed video frame. Section 6 presents the convolution code. Section 7 discusses the linear equalization. Section 8 explains the chaotic map Baker randomization. Section 9 shows the suggested model of OFDM system with the hybrid scheme. Section 10 shows the metric

parameters for system performance evaluation. Section 11 shows the simulation results. At the end, Section 12 presents the conclusions remarks.

## **2. Background of Hiding Secret Data**

Watermarking is an important part of data hiding, which exists to shield copyright content in multimedia. When the multimedia content is shared over the Internet exchange of multimedia content copyright infringement issues are comes into the picture. This paper gives survey of the latest methods that used for the Digital Image watermarking. These techniques can also be used for music files as well as video files. Every digital watermarking technique have certain characteristics such as imperceptibility, and robustness against various image manipulations like compression, filtering, rotation, scaling cropping etc. [19]. Digital video watermarking techniques can be broadly classified into two major categories[20]:

- i) Spatial Domain Watermarking
- ii) Frequency Domain Watermarking

Early watermarking schemes were introduced in the spatial domain, where copyrighted information is added by changing pixel values of the host image. Least Significant Bit insertion is one of the examples of this category. But such algorithms have low payload, they can be easily discovered and quality of image after embedding the copyright information and extracted watermark is not acceptable as pixel strengths are directly changed in these algorithms. Any watermarking algorithm has two parts: embedding algorithm and extraction algorithm.

In the Frequency domain the watermark is embedding into frequency coefficients of the host image. Frequency domain watermarking provides more information hiding capacity and high robustness against various geometrical attacks. Frequency domain watermarking is more robust than spatial domain watermarking due to the embedding of watermark into the altered frequency coefficients of the transformed image [21]. Some well known watermarking transform domain are Fourier Transform (DFT), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT). In transform domain, we have various techniques, Fourier Transform (FT), Short Time Fourier Transform (STFT), and Continuous Wavelet Transform (CWT), Discrete Wavelet Transform (DWT),

Discrete Cosine Transform (DCT) or Combination of DCT and DWT. Digital Image Watermarking Using Discrete Wavelet Transform Concept of DWT is actually very analogous to theoretical model of Human Visual System (HVS). DWT gives multi-resolution representation of an image and DWT [22].

The goal of SVD is embedded data. The objectives of SVD scheme are detectability, robustness and capacity of the hidden data, these advantages made SVD is the important mostly than other techniques such as watermarking and cryptography.

### **3. Hiding and Video Scheme**

Each video contains frames, which are compressed via a changed from the RGB coordinate color to the Y CB CR method [21]. Each part of the Y CB CR is splitted into non-overlapping blocks with size 16 x 16 pixels.

SVD is the technique which made hiding secret objects in invisible manner. The merits of SVD based techniques are robustness, payload, invisibility, and the requirements of the size of the file. At embedding mechanism, the embed data isn't showed, and no one can found it so it is named data hiding. The hidden bits represent the payload which determines the invisibility requirement. The SVD achieves the robustness for data hiding detection. The size of the file after that embedding is unchanged. The suggested method in our work has two processes which are embedding processes and extraction processes [2-3].

### **4. SVD-Based Video Watermarking**

The SVD of video frame is calculated to get orthogonal of two matrices  $U$ ,  $V$  and one diagonal matrix  $S$  [2]. In [1], the  $W$  watermark is added into the matrix  $S$  then a new SVD mechanism is employed on the matrix  $S+kW$  to get  $U_w$ ,  $S_w$  and  $V_w$ , where  $k$  is the factor scale which is controlling the strength of the embedded watermark to the original video frame. Then, the video watermarked frame  $F_w$  is obtained by multiplying the matrices  $U$ ,  $S_w$ , and  $V$ .

#### **4.1 Watermark Embedding:**

The steps of embedding the watermark are as follows:

- 1- Split the video original frame ( $F$  matrix) into non-overlapping blocks.

2- Perform SVD on each block ( $B_i$  matrix) to get the SVs ( $S_i$  matrix) of each block.

Where  $i=1,2, 3,\dots, N$ , and number of blocks is  $N$ .

$$B_i = U_i * S_i * V_i \quad (1)$$

3- Add the video watermark frame ( $W$  matrix) to the  $S$  matrix of each block.

$$D_i = S_i + k * W \quad (2)$$

4- Made SVD on each  $D_i$  matrix to get the SVs of each ( $S_{wi}$  matrix).

$$D_i = U_{w_i} * S_{w_i} * V_{w_i} \quad (3)$$

5- Use the ( $S_{wi}$  matrix) of each block to made the watermarked blocks in the spatial domain.

$$B_{w_i} = U_i * S_{w_i} * V_i \quad (4)$$

6- Combine the watermarked blocks back into one matrix to make the watermarked video frame in the spatial domain ( $F_w$  matrix).

#### 4.2 Watermark Detection:

Having distorted video frame  $F_w^*$  and  $U_{wi}$ ,  $V_{wi}$ ,  $S_i$ , matrices, the steps to get the corrupted watermark are as follow:

1. Split the watermarked video frame ( $F_w^*$  matrix) into blocks which having the same size that used in the embedding process.

2. Made SVD on each none overlapped watermarked block ( $B_{wi}^*$  matrix) to get the SVs of each one ( $S_{wi}^*$  matrix).

$$B_{w_i}^* = U_i * S_{w_i}^* * V_i \quad (5)$$

3. Gets the matrices that contain the watermark using  $U_{wi}$ ,  $V_{wi}$ ,  $S_{wi}^*$ , matrices.

$$D_i = U_{w_i} * S_{w_i}^* * V_{w_i} \quad (6)$$

4. Extract the corrupted watermark ( $W_i^*$  matrix) from the  $D_i$  matrices.

$$\frac{D_i - S_i}{k} = w_i^* \quad (7)$$

#### 5. OFDM System Model

OFDM is communication technology is used in wireless systems of communications. High-speed data that transported via OFDM is changed from series to parallel  $N$  sub channels data [17]. Then modulation, making an inverse fast Fourier transform (IFFT) on the output of data modulated that generate the OFDM multi-carrier signal. Guard intervals inserting inside frames to reduce the inter

symbol interference (ISI) by the multipath fading channels, [17]. The OFDM system block diagram is shown in Fig.1.

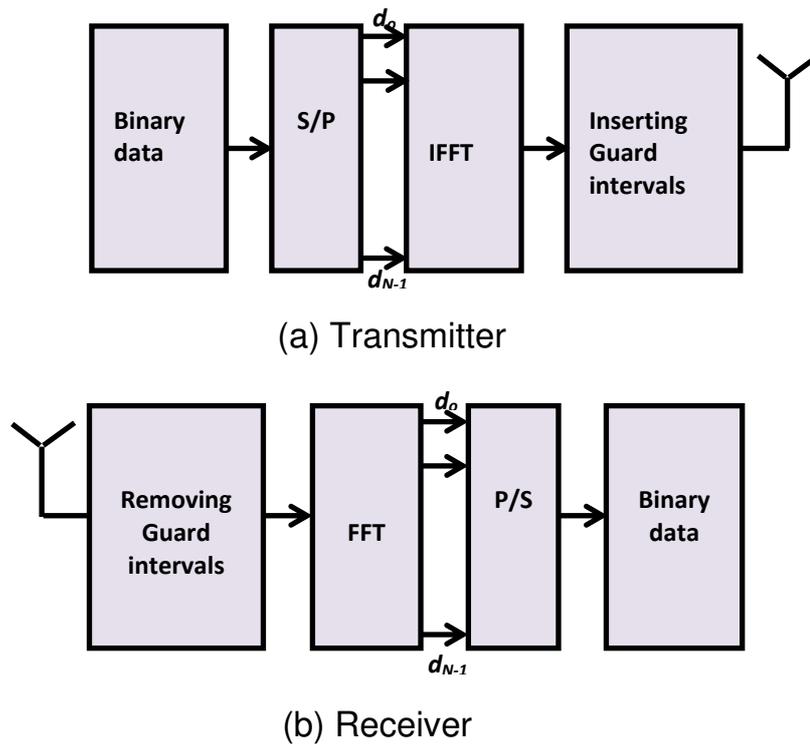


Fig. 1: OFDM system model [17].

The form of guard intervals is added a cyclic prefix (CP) or zeros. The widely-used approach is the addition of a CP. The OFDM use of the fast Fourier transform (FFT) and the inverse fast Fourier transform (IFFT), so that cause low complexity. Using the IFFT/FFT cause an ISI-free channel, a circular convolution is providing by the channel [1,2]. Adding a guard band of at least  $v$  samples between OFDM symbols this cause each OFDM symbol is independent to others OFDM symbols which coming before and after it. If we assume  $T_s$  is the symbol time, and  $T_g$  is the CP time or time guard, the total duration of the symbol is  $T_{total}$  [17]:

$$T_{total} = T_g + T_s. \quad (8)$$

The effect of the ISI can be minimized if the multipath delay or the channel impulse response is lower than the guard interval. This is occurring however, the in-band fading or the inter carrier interference (ICI) is still found. The ratio between the usual symbol duration and the guard interval is dependent, as adding of a guard

interval cause reducing the data throughput [14].The OFDM signal is transmitted through the wireless channel. A multipath fading channel and contaminated by additive white Gaussian noise (AWGN) is applied on the transmitted data.

## 6. Convolutional Codes

The encoder and decoding strategy for convolutional codes based on the Viterbi algorithm [18].The convolution code presents bits which are redundant into the stream of the data through the use of linear shift registers as shown in Fig. 2 [23].

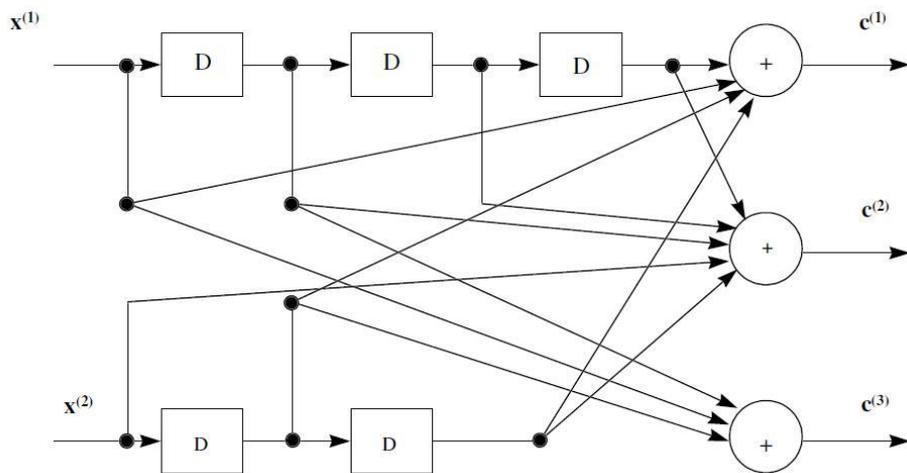


Fig.2: Example of a convolutional encoder, where  $x(i)$  is an input information bit stream and  $c(i)$  is an output encoded bit stream [23].

The bits are inputted into shift registers and the output encoded bits are obtained by modulo-2 addition of the input bits and the contents of the shift registers. The code rate  $r$  for a convolutional code is defined as [23]:

$$r = k/n \quad (9)$$

where  $k$  is the number of parallel input bits and  $n$  is the number of parallel output encoded bits at one time interval.  $K$  is the length for a convolutional code which is explained as:

$$K=m+1 \quad (10)$$

## 7. Linear Equalization

To eliminate the ISI which caused by the multipath fading channel and improvement the performance of the communication system is made by using linear

equalization which is an efficient technique to make that. The linear equalization has different kinds in frequency domain such as the zero forcing (ZF) equalizer and the regularized zero forcing (RZF) equalizer and the linear minimum mean square (LMMSE) equalizer. The solution of ZF is defined as [4-5]:

$$\mathbf{W} = (\mathbf{H}^H \mathbf{H})^{-1} \mathbf{H}^H \quad (11)$$

Where, H is the channel matrix. The advantages of the frequency domain ZF is source data of the equalizer are not required and statistics of the additive noise aren't required too. The disadvantages of the frequency domain ZF equalizer are that, ZF equalizer causes noise enhancement and the computations needed for matrix inversion are time consuming. A new regularization part is added into Eq. (11) for the problem of noise enhancement in the ZF equalizer and become that [14-16]:

$$\mathbf{W} = (\mathbf{H}^H \mathbf{H} + \alpha \mathbf{I})^{-1} \mathbf{H}^H \quad (12)$$

Where,  $\alpha$  is the parameter of regularization. The resulting equalizer is called RZF equalizer. So in the RZF equalizer the additive noise and the statistics of the transmitted data are not required. This causes a better equalizer which eliminates the mean square error (MSE) and removes the ISI. When  $\alpha=1/\text{SNR}$ , this achieve equalizer which is called the LMMSE equalizer. LMMSE equalizer is better than the ZF linear equalizer, as its better treatment to noise. The LMMSE is defined by [7]:

$$\mathbf{W}_{LMMSE} = (\mathbf{H}^H \mathbf{H} + \frac{1}{SNR} \mathbf{I})^{-1} \mathbf{H}^H \quad (13)$$

## 8. Chaotic Interleaving

A chaotic map type which used to make interleaving is called Baker map which generates a square matrix in a permuted version. The Baker map is used to randomize a square matrix of data in its discretized form which represent an  $M \times M$  matrix as follows [8-13]:

The perform of the chaotic interleaving steps explain as

1. The Square matrix  $M \times M$  is divided into vertical rectangles of width  $n_i$  and height  $M$ .

2. Stretch vertical rectangles in the horizontal direction and after that made contracting vertically to obtain a  $n_i \times M$  horizontal rectangle.
3. Mapping stack on horizontal rectangles as shown in Fig. (3-a); where, the right one is put at the top, and the left one is put at the bottom.
4. Divided each output  $n_i \times M$  vertical rectangle into  $n_i$  boxes which its dimensions are  $M=n_i \times n_i$  and exactly containing  $M$  points.
5. Mapped each box column by column into a row as explained in Fig. (3-b).

Fig.3 explains an example of chaotic interleaving of an  $(8 \times 8)$  square matrix which use the secret key,  $S_{key} = (N_1, N_2, N_3) = (2, 4, 2)$ .

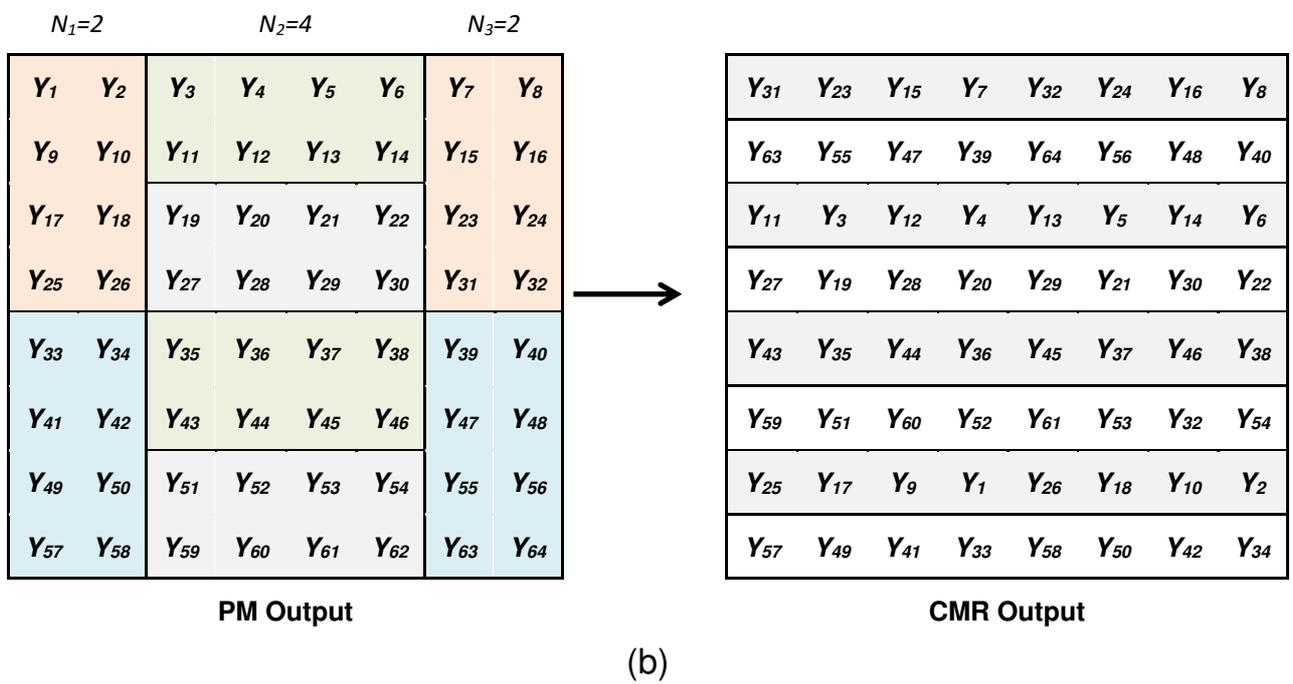
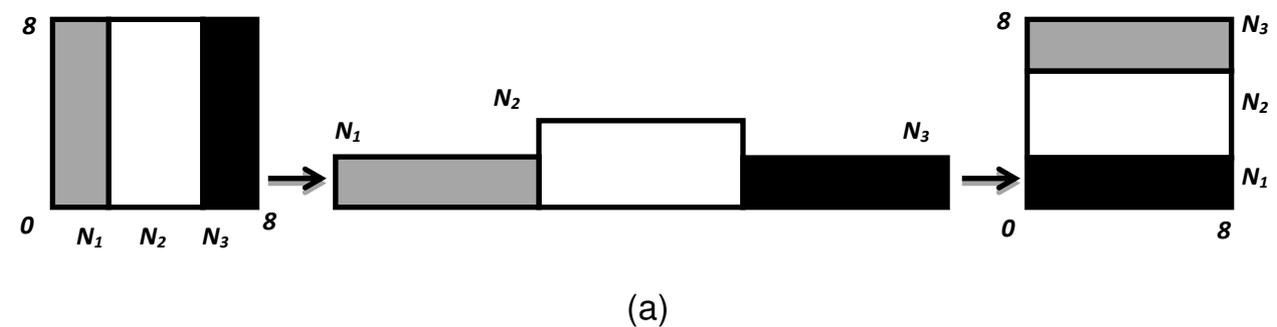


Fig.3: Chaotic Interleaving example using a secret key = (2, 4, 2)

(a) Baker map discretizing form. (b) Randomization matrix of an  $(8 \times 8)$  matrix.

## 9. The Proposed Model

The proposed model is based on chaotic map with OFDM, equalization and convolution code. There are 4 stages in this proposed model to transmit SVD watermarked video frames. The first stage is SVD watermarked frame of video data formatting, the second stage is a chaotic interleaving on the binary video data, the third stage is OFDM modulation and the final stage is equalization and convolution code. The proposed system model block diagram given in Fig.4. The proposed model based on OFDM system are explained as follows:

1. The SVD watermarked video frame is converted to the binary matrix form.
2. Reshape the binary matrix which is non-square to an  $M \times M$  square binary matrix format.
3. Apply baker chaotic map randomization to square binary matrix format.
4. Reshape the square binary matrix to its original dimensions.
5. Perform the convolution coding and OFDM modulation on the binary data.
6. Apply the OFDM demodulation at the receiver this process is reversed to obtain channel estimation, assume that the receiver has the secret key of the chaotic map which the same secret key at the transmitter. After that, the received signal is equalized and made convolution decoding process to suppress the ISI, equalizer is called the LMMSE equalizer as follows: [ 4-7 ]

$$\hat{\mathbf{d}} = (\mathbf{H}^H \mathbf{H} + \alpha \mathbf{I})^{-1} \mathbf{H}^H \mathbf{r} \quad (14)$$

7. Reshape binary data to a square matrix and apply a chaotic map derandomization to binary matrix.
8. Reshape the square binary matrix to its original dimensions.
9. Retrieve the SVD watermarked video frame from the binary data.

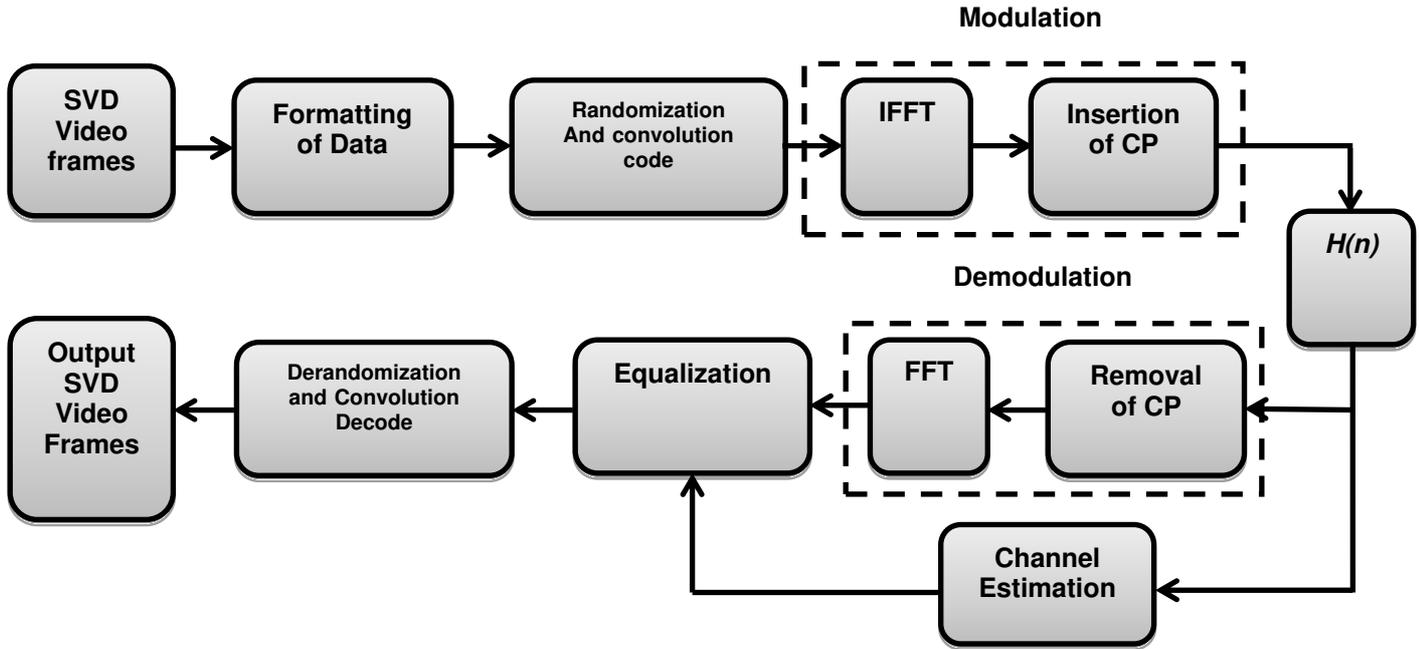


Fig. 4 : Block diagram of the proposed system.

## 10.Metric Parameters for System Performance Evaluation

The performance of the SVD watermark scheme under consideration is determined by using correlation coefficient between blocks and length vector containing histogram counts for correlation coefficient of blocks. It counts the number of values in correlation coefficient of blocks that fall between the elements in the correlation coefficient vector. The normalized correlation is estimated by the following equation, where  $W$  is the original watermark and  $W^*$  is the extracted corrupted watermark. Maximum of correlation coefficient is the maximum of the normalized correlation. To measure the quality of the reconstructed SVD watermarked video frames at the receiver use PSNR the peak signal to noise ratio. PSNR is the ratio between the maximum power of a signal and the power of corrupting noise. The MSE and PSNR are defined as follows [18].

$$NC = \frac{W^* \cdot W}{\|W^*\| \cdot \|W\|} \quad (15)$$

$$C_{rmax} = \max(NC) \quad (16)$$

$$MSE = \frac{1}{MN} \sum_{y=1}^M \sum_{x=1}^N [I(x, y) - \hat{I}(x, y)]^2 \quad (17)$$

$$PSNR = 20 * \log \left( \frac{255}{\sqrt{MSE}} \right) \quad (18)$$

where the original SVD watermarked video frames is  $I(x, y)$ , the reconstruct SVD watermarked video frames is  $I'(x, y)$  and the dimensions of the SVD watermarked video frames are  $M, N$ .

## 10. Simulation Results

To evaluate the performance and efficiency of the proposed scheme system, various monochrome video frames are used for more accuracy such as sat.avi video 256\*256\*3 \* 922 having 256\*256 \*3 pixels. These video frames are used as input to the simulation framework. So we use a chaotic map of size of 256×256 pixel for video frame of size 256×256 and we use a chaotic map of size of 256×256 pixel for video frames of size 256×256.

To test the performance of the proposed scheme carried out many simulation experiments to achieve accuracy. The model of wireless channel which is used is The SUI3 channel. The SUI3 channel is one model of six channel models adopted by the IEEE 802.16a standard. It is used for the evaluating the performance of broadband wireless systems in the 2–11 GHz band [23] from fesa. SUI3 channel has three Rayleigh fading taps at delays of 0, 0.5 and 1ms and relative powers of 0 dB, -5 dB, and -10 dB, respectively [23]. The simulation parameters are summarized in Table (1).

We will explain the important simulation results in two cases. The first case is the transmission of SVD watermarked video frame using OFDM with only equalization and convolution code. In the second case, SVD watermarked video frame is transmitted using OFDM with equalization, convolution code and with chaotic interleaving. The simulation result is explained in the following figures:

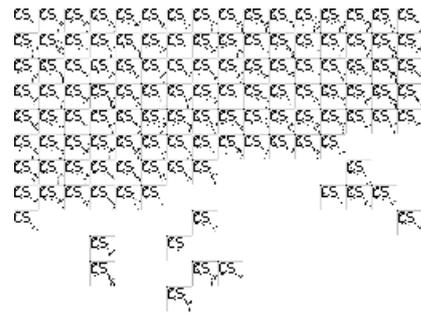
Table (1) Simulation Parameters[ ]

Transmitter	Modulation	BPSK
	video size	256×256×3×921
	Cyclic prefix	20 samples.
	Transmitter IFFT size	M= 256 symbols.
	Chaotic map size	128×128
Channel	Fading	SUI3 channel
	Environment of noise	AWGN
Receiver	Equalization	LMMSE
	Estimation of Channel	Perfect

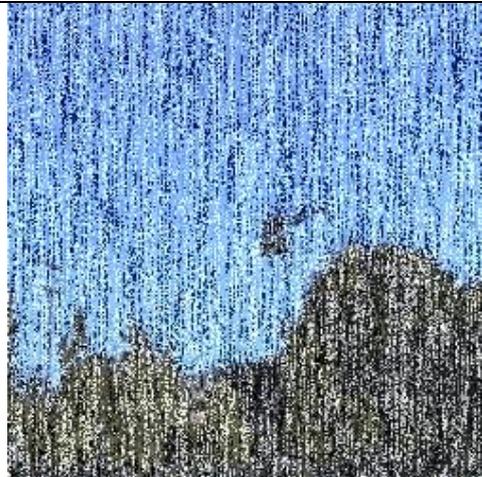




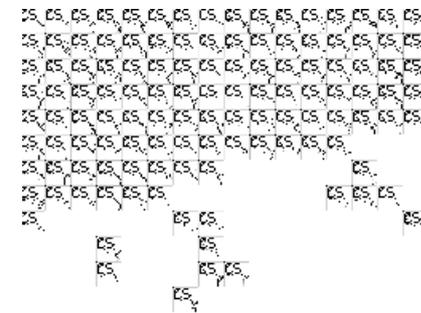
(a) Convolutional coding and LMMSE equalization PSNR=11.7747 dB at SNR=0 dB.



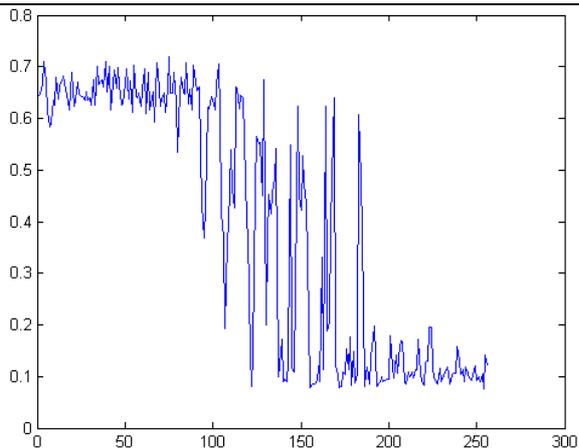
(b) Extracted watermark images.  $C_r$ max = 0.7188 At convolutional coding and LMMSE equalization



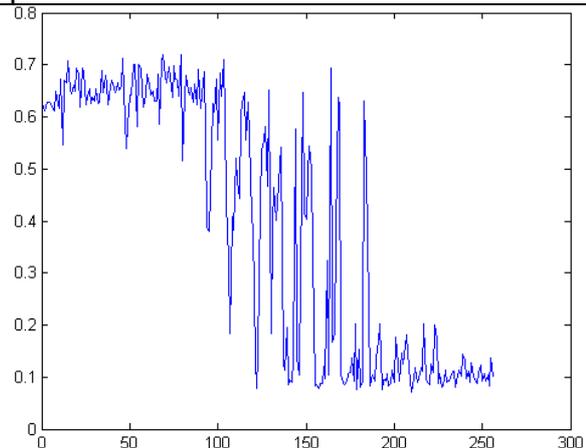
(c) Randomization, convolutional coding, and LMMSE equalization PSNR=12.2241dB at SNR=0dB.



(d) Extracted watermark images.  $c_r$ max = 0.7204 dB at randomization ,convolutional coding, and LMMSE equalization at SNR=0dB .

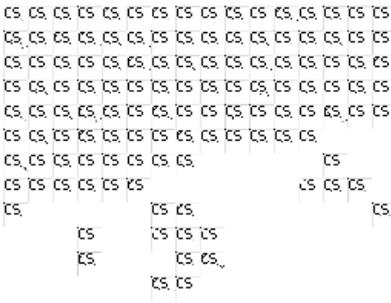
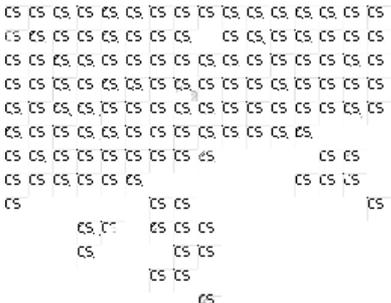
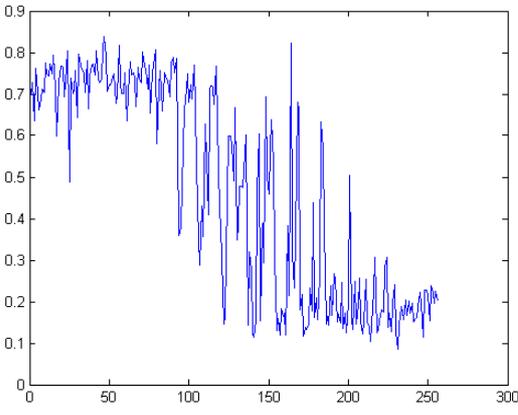
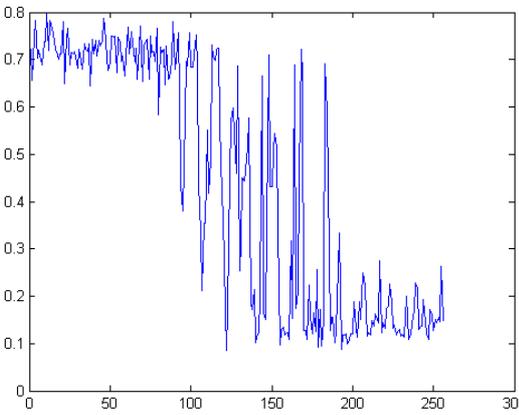


(e) Watermark correlation coefficients ( $C_r$  max. correlation=0.7204) with randomization.



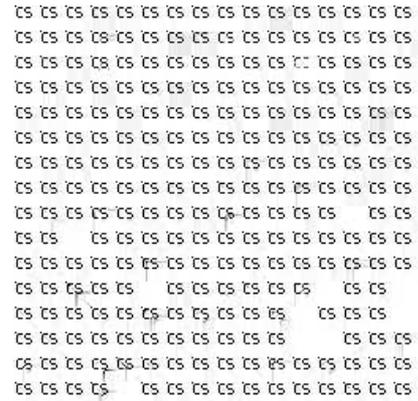
(f) Watermark correlation coefficients ( $C_r$  max. correlation=0.7188 at without randomization.

Fig. 7: The received SVD watermarked Frame 189 and the correlation coefficient between blocks using OFDM in the cases. SUI-3 Raleigh fading channel influenced by AWGN is used. SNR= 0 dB

	
<p>(a) At Convolutional coding and LMMSE equalization PSNR=18.6849 dB at SNR=5dB.</p>	<p>(b) Extracted watermark images. <math>C_r</math> max = 0.7990 At convolutional coding and LMMSE equalization</p>
	
<p>(c) Randomization, convolutional coding, and LMMSE equalization PSNR=22.0329 dB at SNR=5dB.</p>	<p>(d) Extracted watermark images. <math>C_r</math> max = 0.8376 at randomization ,convolutional coding, and LMMSE equalization at SNR=5dB .</p>
	
<p>(e) Watermark correlation coefficients</p>	<p>(f) Watermark correlation coefficients (<math>C_r</math>)</p>

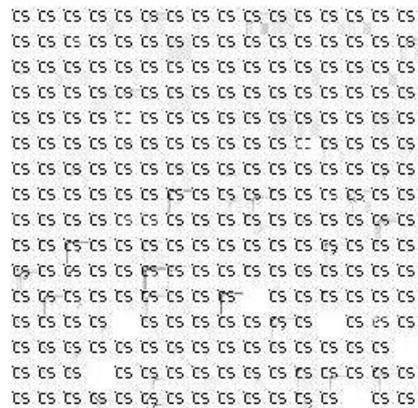
( $C_r$ max. correlation=0.8376) with randomization.	max. correlation=0.7990 at without randomization.
--	---

Fig. 8: The received SVD watermarked Frame 189 and the correlation coefficient between blocks using OFDM in the cases. SUI-3 Raleigh fading channel influenced by AWGN is used. SNR= 5 dB



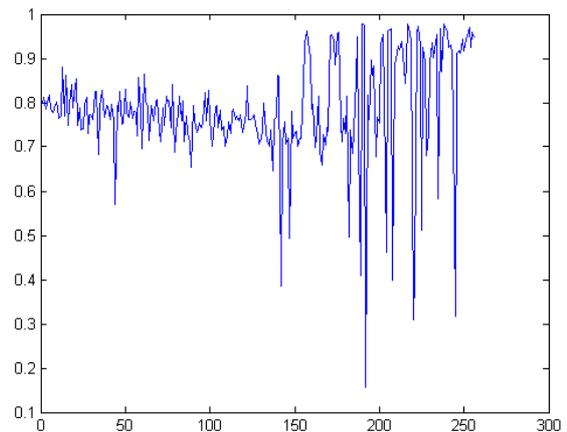
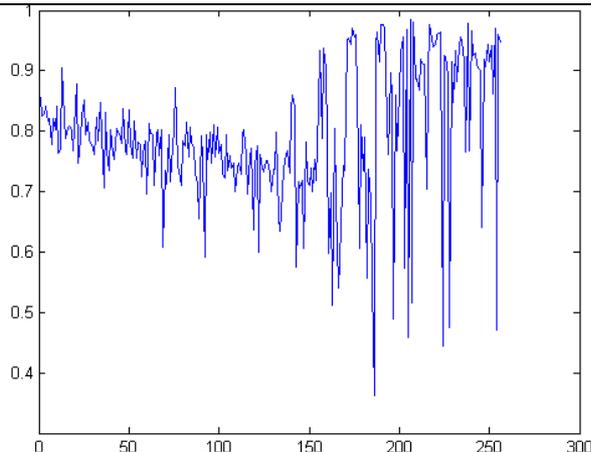
(a) Convolutional coding and LMMSE equalization  
PSNR=39.1199 dB at SNR=20dB.

(b) Extracted watermark images.  $c_r \text{max} = 0.9782$  At convolutional coding and LMMSE equalization



(c) Randomization, convolutional coding, and LMMSE equalization  
PSNR=42.9812dB at SNR=20dB.

(d) Extracted watermark images.  $c_r \text{max} = 0.9832$  at randomization, convolutional coding, and LMMSE equalization at SNR=20dB .



(e) Watermark correlation coefficients (max. correlation=0.9841) with randomization.

(f) Watermark correlation coefficients (max. correlation=0.9782 at without randomization).

Fig. 9: The received SVD watermarked Frame 189 and the correlation coefficient between blocks using OFDM in the cases. SUI-3 Raleigh fading channel influenced by AWGN is used. SNR= 20dB

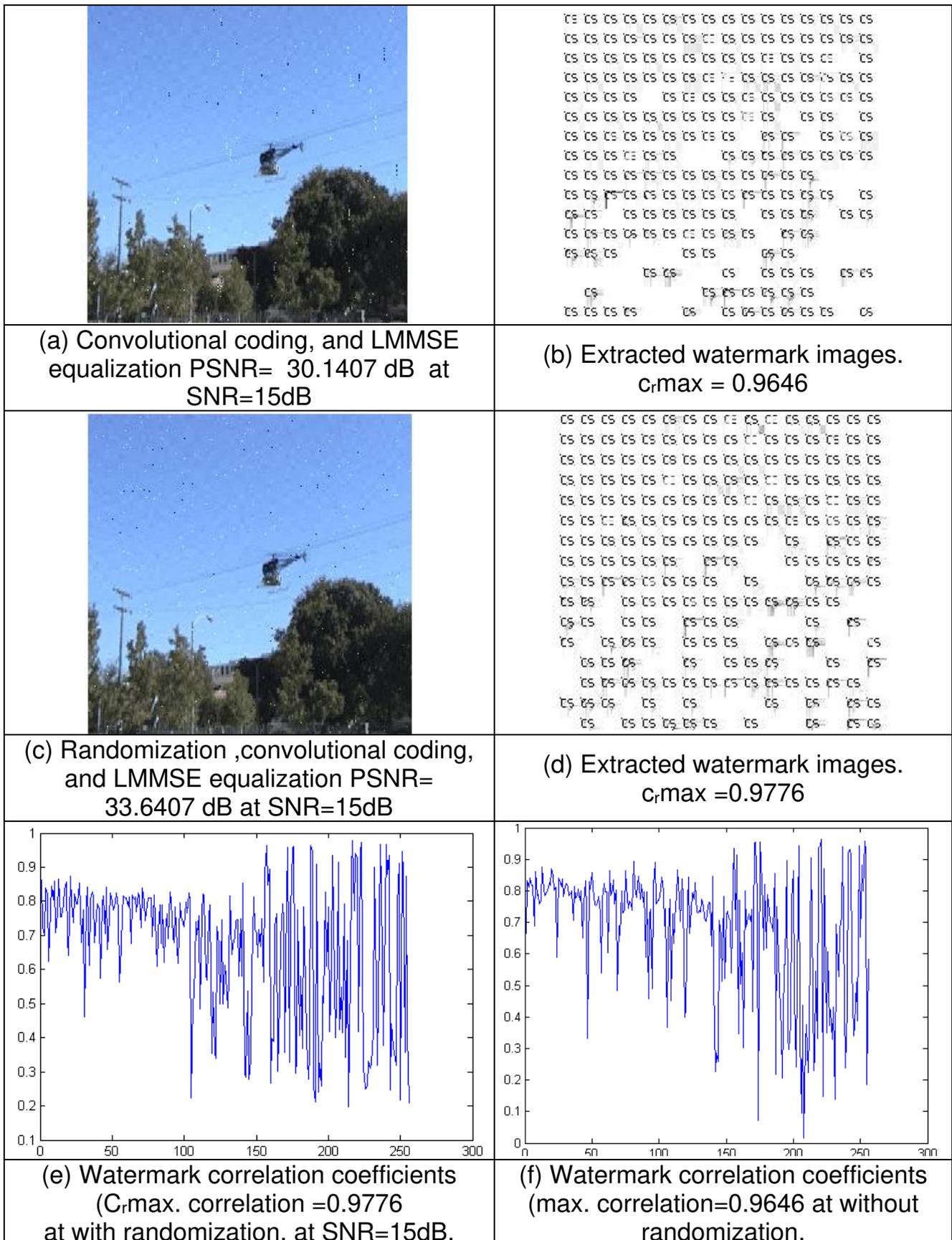


Fig.10: The received SVD watermarked Frame 189 and the correlation coefficient between blocks using OFDM in the cases. SUI-3 Raleigh fading channel influenced by AWGN is used. SNR= 15 dB

It is found from the simulation result that, PSNR and  $c_r$  max are increased when the SNR is increased. It is found from the simulation result that the case of using OFDM with equalization, chaotic interleaving and convolution code is better than the case of using OFDM with only equalization and convolution code. The better case gives high PSNR and high maximum correlation coefficient than the other case so that the proposed case is more efficiency than other case. The chaotic map for this case reduces the noise and increase the maximum correlation coefficient between extracted watermarked blocks. Table 2 is explaining the simulation results in all cases.

**Table (2) The received SVD watermarked Frame 189 and the correlation coefficient between blocks using OFDM in the cases. SUI-3 Raleigh fading channel influenced by AWGN is used.**

SNR	PSNR Convolutional coding and LMMSE equalization	PSNR Randomization, convolutional coding and LMMSE equalization	$C_r$ max Convolutional coding and LMMSE equalization	$C_r$ max Randomization, convolutional coding, and LMMSE equalization
0	11.7747 dB	12.2241dB	0.7188	0.7204
5	18.6849 dB	22.0329 dB	0.7990	0.8376
15	30.1407 dB	33.6407 dB	0.9646	0.9776
20	39.1199 dB	42.9812dB	0.9782	0.9832

## 12. Conclusion

This work introduced an efficient watermarked video frame communication system over wireless channels wireless via chaotic Baker map that performed with linear equalization and convolutional coding. This proposed model improves the PSNR and the maximum correlation coefficient. The chaotic map adds security and encryption to the watermarked data. Simulation results show high correlation between subjective fidelity metrics (human visual perception) and objective performance metrics. To sum up, this work proves that chaotic map with linear equalization, convolution coding and OFDM can be used for efficient wireless communication.

## Reference

- [1] J. M. Shieh, D. C. Lou, and M. C. Chang, "A Semi-Blind Watermarking Scheme Based on Singular Value Decomposition", *computer standards & interface* 28, 428-440, 2006.
- [2] R. liu and T. Tan, "An SVD-Based Watermarking Scheme for Protecting Rightful Ownership", *IEEE Trans. on multimedia*, Vol. 4, no. 1 March 2002.
- [3] R. A. Ghazy, N. A. El-Fishawy, M. M. Hadhoud, M. I. Dessouky, and F. E. A. El-Samie, "An Efficient Block-by-Block SVD-Based Image Watermarking Scheme", *National Radio Science Conference*, 13-15 March, Cairo, Egypt, 2007.
- [4] I. Martoyo, T. Wesis, F. Capar, and F. Jondral, "Low Complexity CDMA Downlink Receiver Based on Frequency Domain Equalization," in *Proc. of IEEE VTC*, vol.2, pp. 987-991, 6 - 9 Oct. 2003.
- [5] F. S. Al-Kamali, M. I. Dessouky, B. M. Sallam, and F. E. El-Samie "Regularized Zero Forcing Equalizer with Soft Decision PIC for Multi-rate Downlink CDMA Systems," *International Conference on Engineering and Mathematics, ENMA 2007*, Bilbao, Spain, pp. 133-140, 9-11 July 2007.
- [6] F. Adachi, D. Garge, S. Takaoka, and K. Takeda, "Broadband CDMA Techniques," *IEEE Wireless Commun.*, Vol. 12, Issue 2, pp. 8-18, April 2005.
- [7] D. Falconer et al., "Frequency Domain Equalization for Single-Carrier Broadband Wireless Systems," *IEEE Commun. Mag.*, vol. 40, pp. 58–66, April 2002.
- [8] F. Han, X. Yu, . and S. Han, " Improved Baker Map for Image Encryption", *Proceedings of the First International Symposium on Systems and Control In Aerospace and Astronautics, ISSCAA 2006*, pp.1273-1276.

- [9] J. Fridrich, "Image Encryption Based on Chaotic Maps", Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics, 1997, pp. 1105-1110.
- [10] Q. Qian, Z. Chen, Z. Yuan, "Video Compression and Encryption Based-on Multiple Chaotic System", Proceedings of The 3rd International Conference on Innovative Computing Information and Control (ICICIC'2008).
- [11] F. Huang, F. Lei, "A Novel Symmetric Image Encryption Approach Based on a New Invertible Two-dimensional Map", Proceedings of the International Conference on Intelligent Information Hiding and Multimedia Signal Processing IIHMSp 2008, pp. 1340-1343.
- [12] S. C. Koduru and V. Chandrasekaran, "Integrated Confusion-Diffusion Mechanisms for Chaos Based Image Encryption", IEEE 8th International Conference on Computer and Information Technology Workshops, 2008, pp. 260-263.
- [13] K. Usman, H. Juzojil and I. Nakajimal, "Medical Image Encryption Based on Pixel Arrangement and Random Permutation for Transmission Security" Proceedings of the 9th International Conference on e-Health Networking, Application and Services, 2007, pp. 244-247.
- [14] F. S. Al-kamali, M. I. Dessouky, B. M. Sallam, and F. E. El-Samie, "Frequency Domain Interference Cancellation for Single Carrier Cyclic Prefix CDMA Systems," Progress In Electromagnetics Research B, PIERB 3, pp. 255-269, 2008.
- [15] F. S. Al-kamali, M. I. Dessouky, B. M. Sallam, and F. E. El-Samie, "Performance Evaluation of Cyclic Prefix CDMA Systems with Frequency Domain Interference Cancellation," Digital Signal Processing Journal, Elsevier Inc., Volume 19, Issue 1, pp. 2-13, January 2009.
- [16] A. Klein, "Data Detection Algorithms Specially Designed for The Downlink of CDMA Mobile Radio Systems," in proc. of IEEE VTC, vol. 1, pp. 203–207, 4-7 May 1997.
- [17] T. Athanasiadis, K. H. Lin, and Z. M. Hussain, " Multimedia Transmission over Wireless Space-Time-Frequency coded OFDM Systems with Adaptive Beamforming", Proceedings of the IEEE Asia-Pacific Conference on Communications (APCC), 2006.
- [18] Harada H, Prasad R (2002) Simulation and Software Radio for Mobile Communications. Artech House Publishers.
- [19] S. Kikan, and V. R. Singh, "Video Watermarking Techniques for Digital Right Management: A Review tour", American International Journal of Research in Science,

Technology, Engineering & Mathematics , 13(2), December, 2015-February, 2016, pp. 111-117.

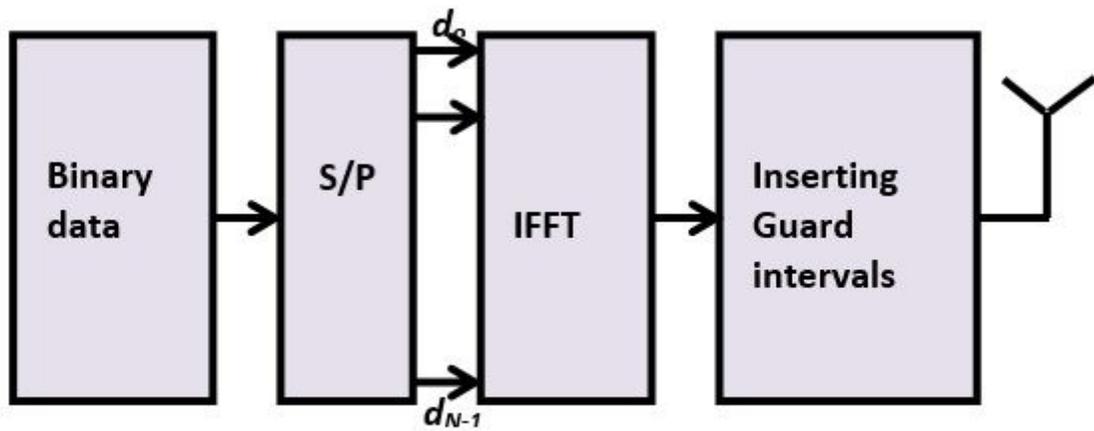
[20] Krishnamoorthi, A. Devi, M. Z. Kurian, and K. V. Reddy, "Pseudo 3D-DCT Approach of Digital Watermarking for Video Sequences", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 4, April 2014

[21] N. Kumar, and R. D. Shivanand, "A 3D-DCT based robust and perceptual video watermarking scheme for variable temporal length video sequence", World Journal of Science and Technology 2012, ISSN: 223, pp:65-69, 2012

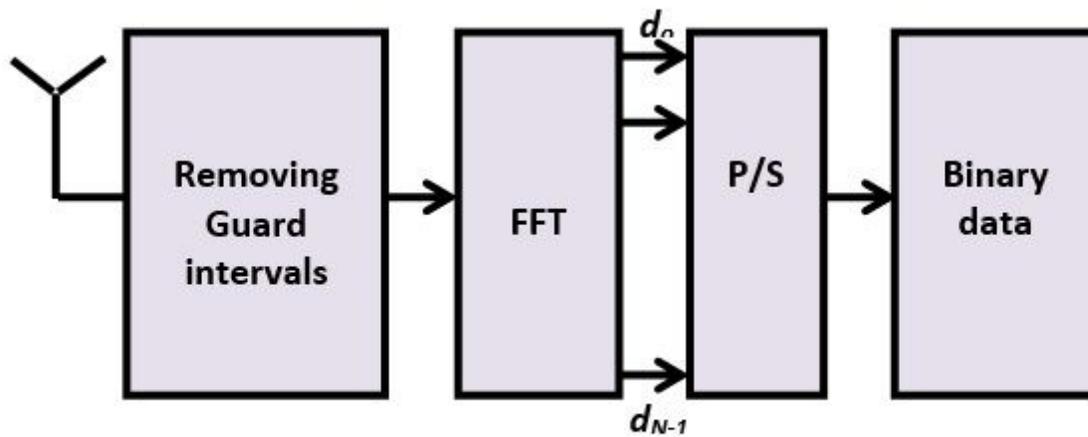
[22] B. Ram, "Digital Image Watermarking Technique Using Discrete Wavelet Transform And Discrete", Journal of Advancements in Research & Technology, Volume 2, Issue4, Apr. 2013.

[23] Conti A, Dardari D, Paolini G, Andrisano O (2003) Bluetooth and IEEE 802.11b coexistence: analytical performance evaluation in fading channels. IEEE Journal on Selected Areas in Communications, 21(2):259-269.

# Figures



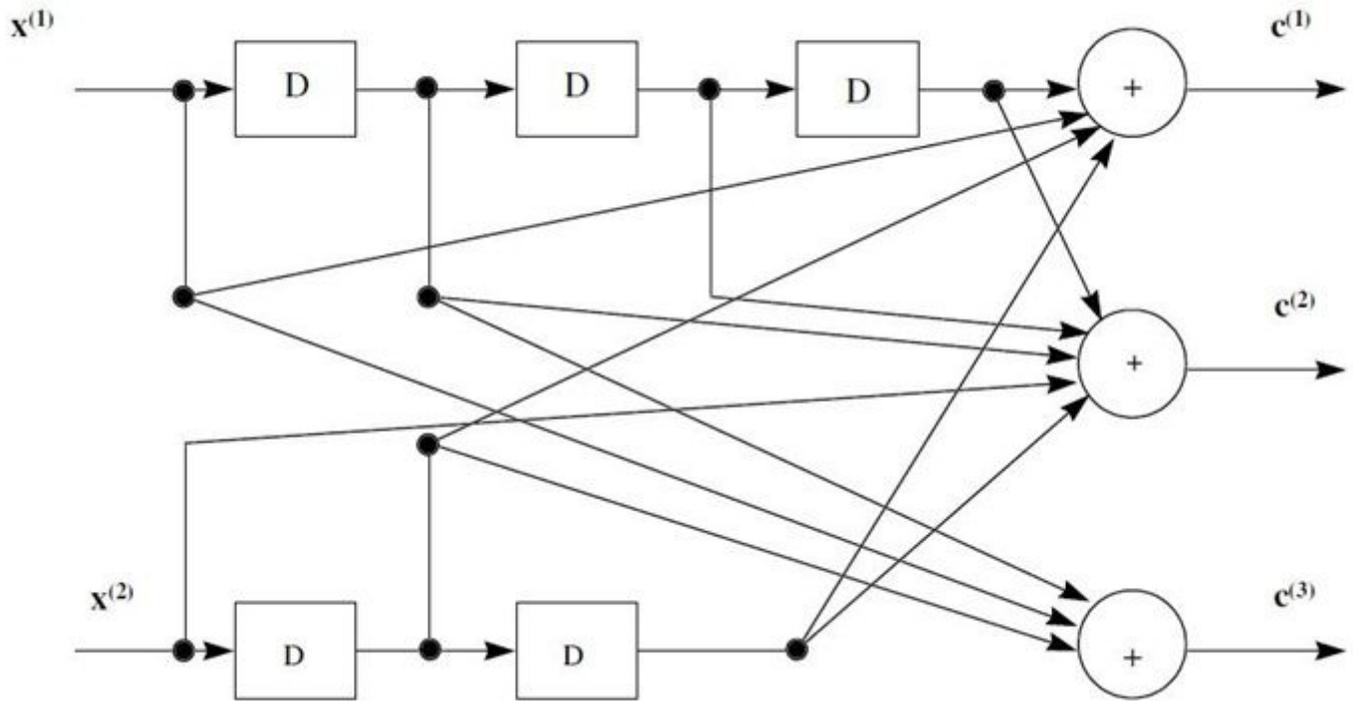
(a) Transmitter



(b) Receiver

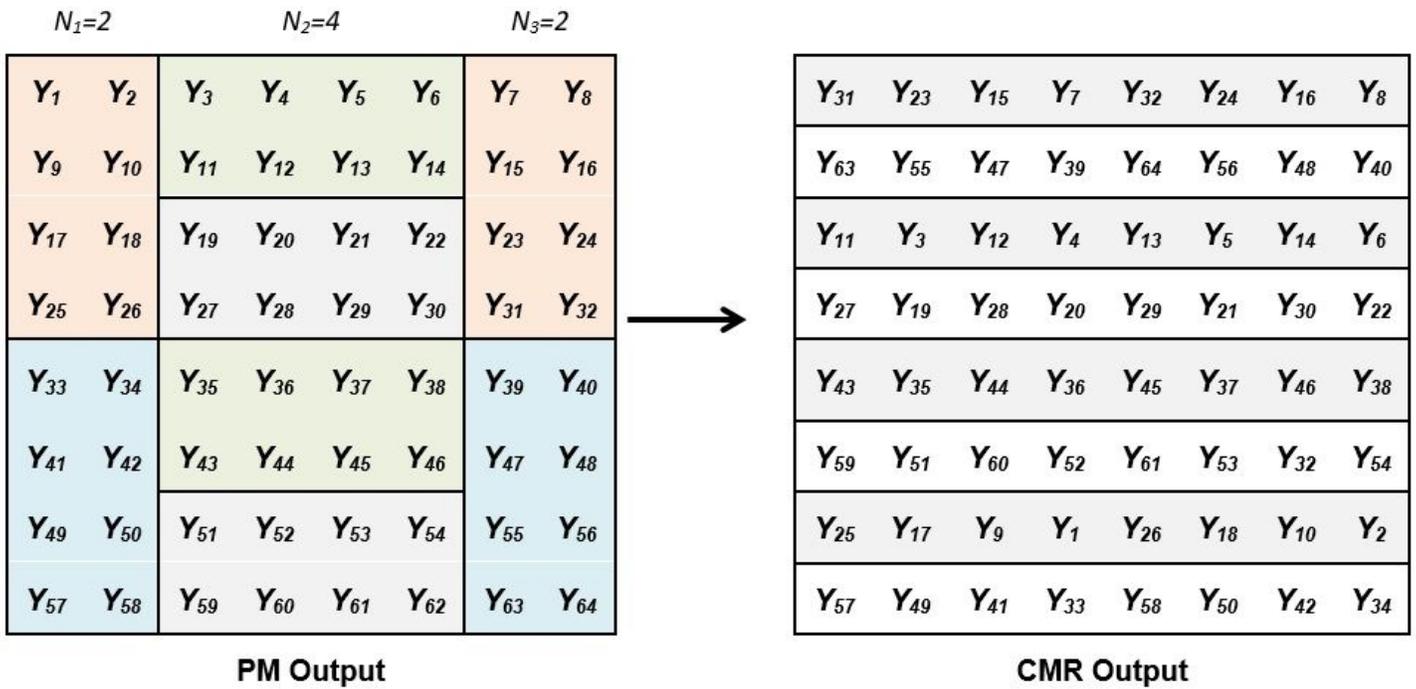
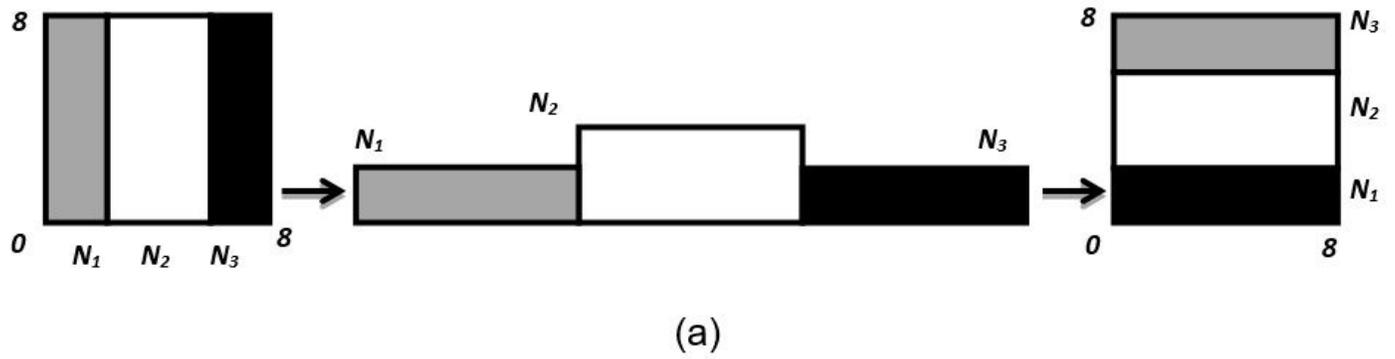
Figure 1

OFDM system model [17].



**Figure 2**

Example of a convolutional encoder, where  $x(i)$  is an input information bit stream and  $c(i)$  is an output encoded bit stream [23].



**Figure 3**

Chaotic Interleaving example using a secret key = (2, 4, 2) (a) Baker map discretizing form. (b) Randomization matrix of an (8x8) matrix.

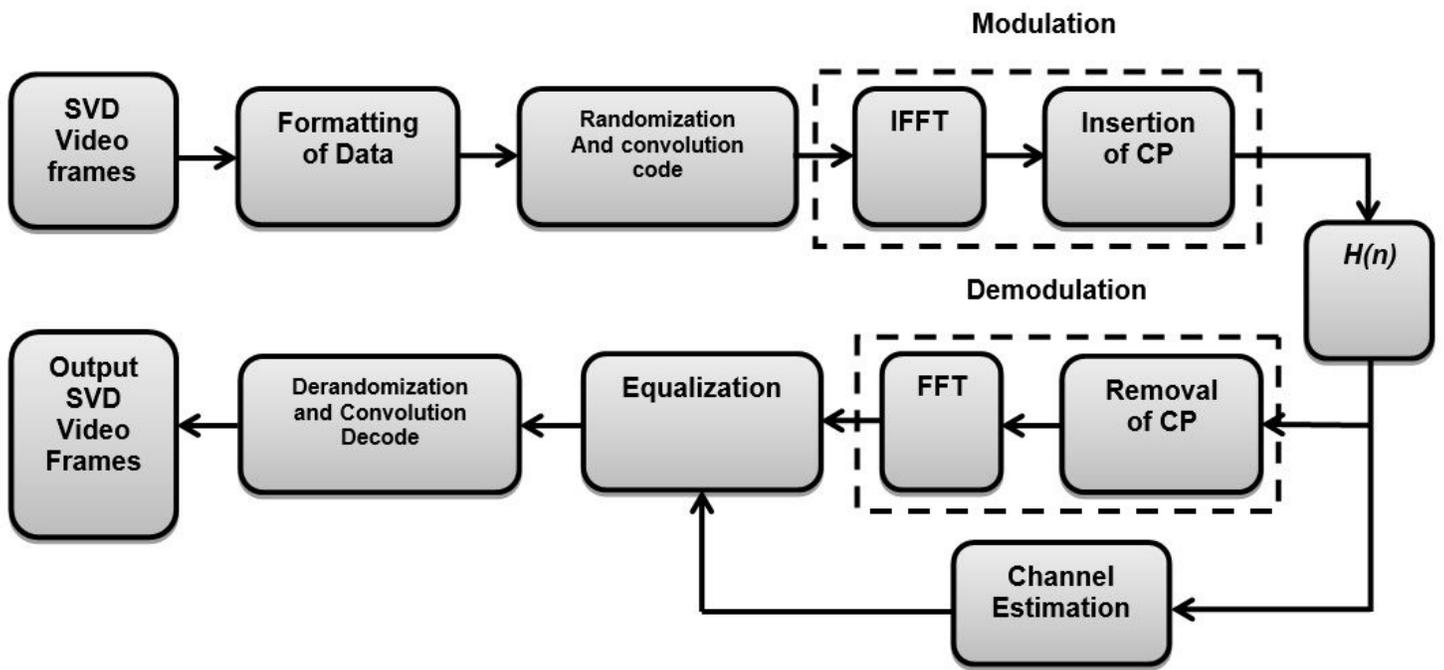


Figure 4

Block diagram of the proposed system.

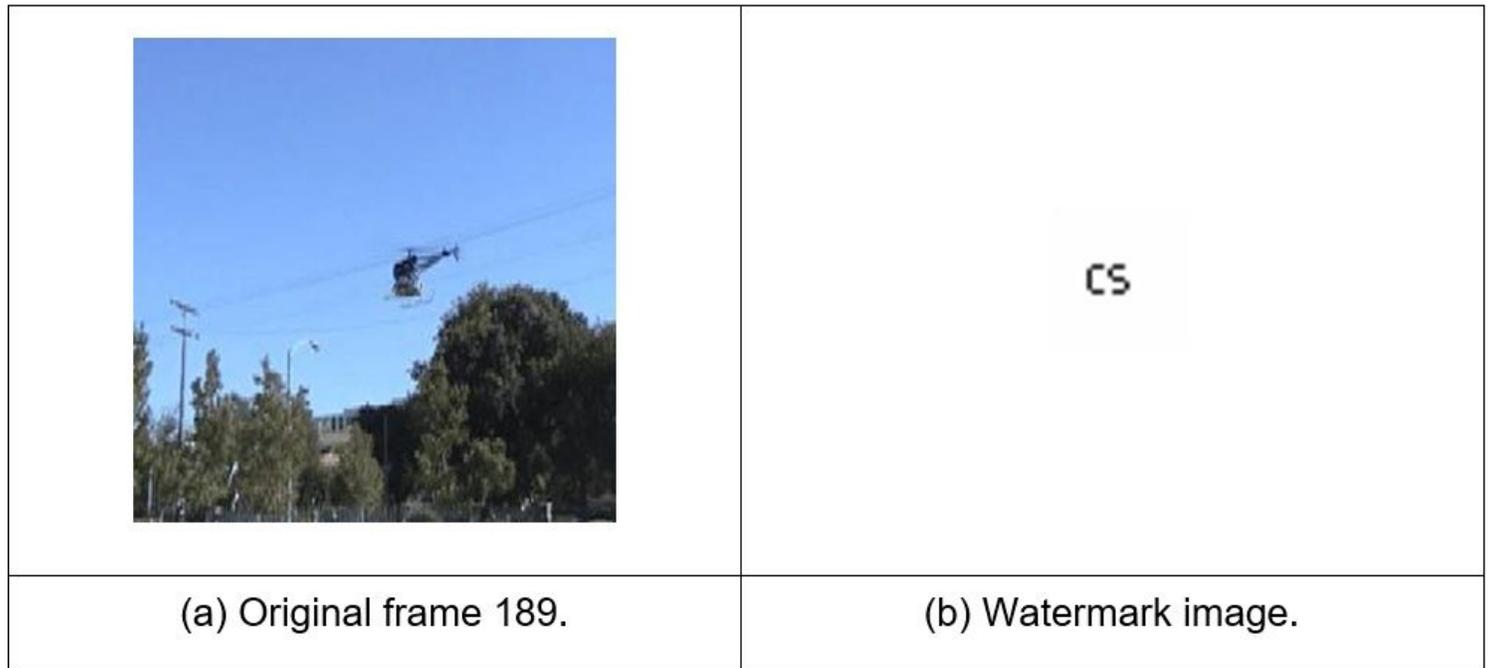


Figure 5

Original frame 189 and the watermark image



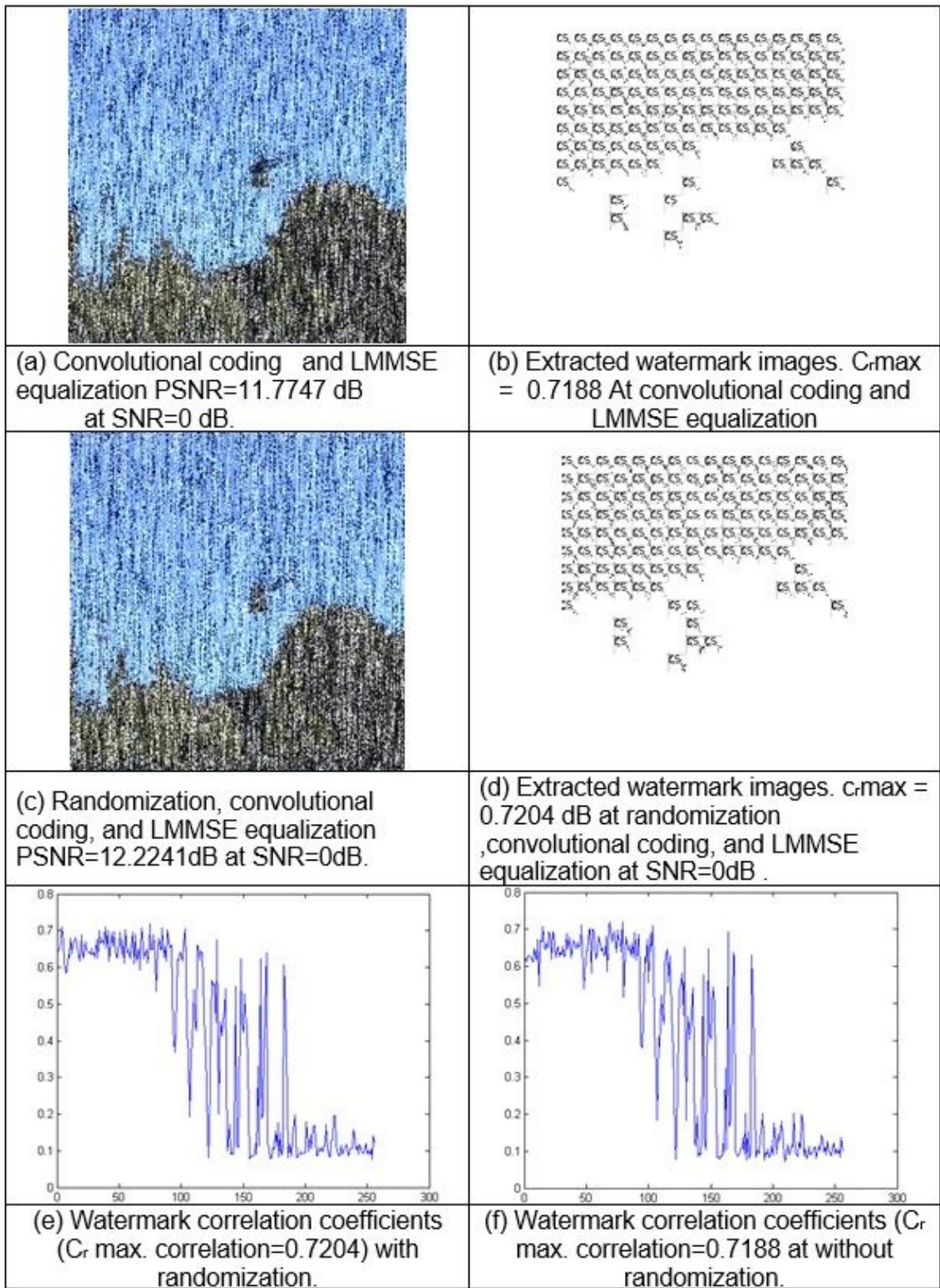
CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS  
CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS CS

(a) Original SVD watermarked frame 189

(b) Extracted watermarks.  $C_r, \max = 0.9832$

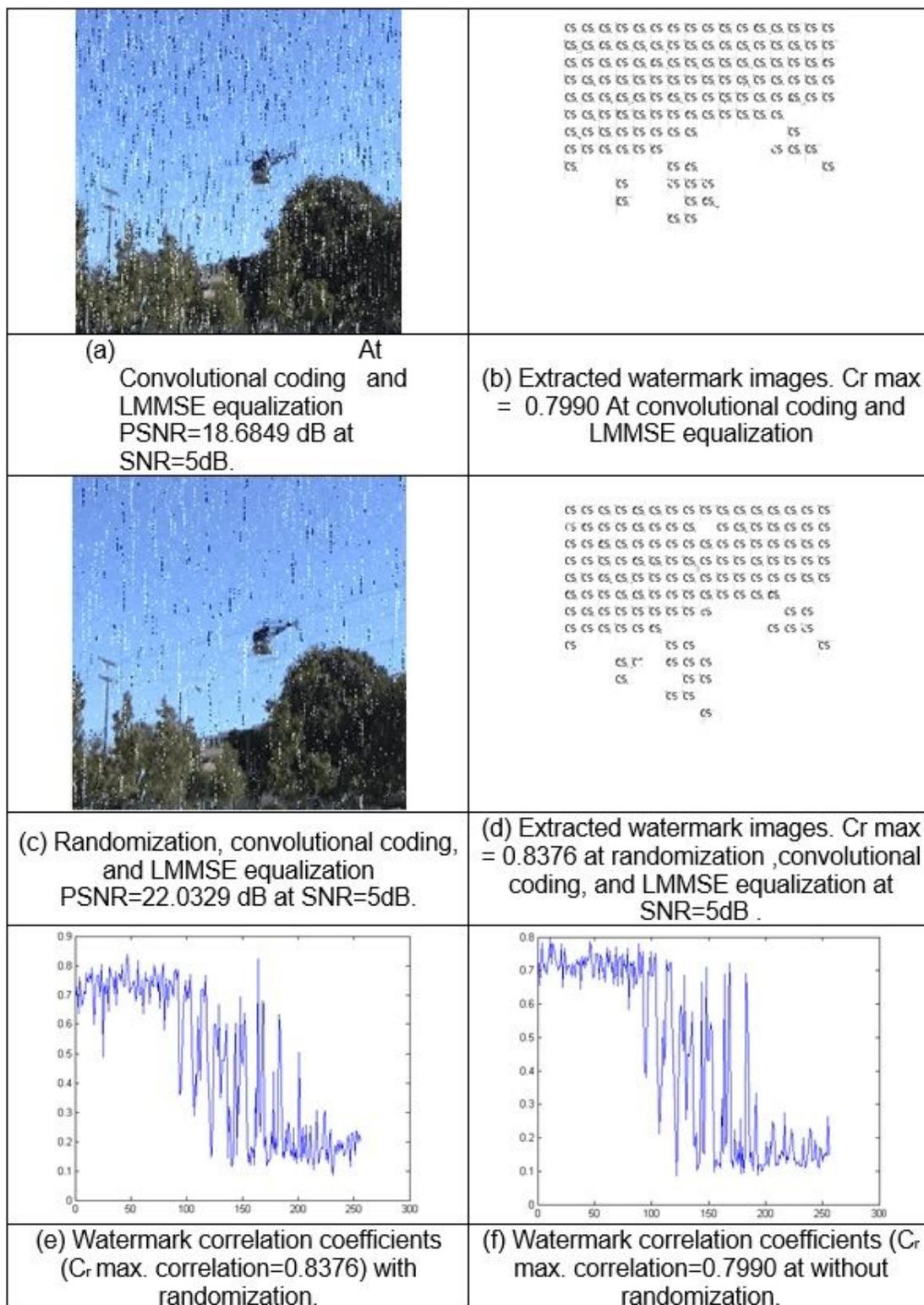
**Figure 6**

SVD watermarked frame 189 and Extracted watermarks.



**Figure 7**

The received SVD watermarked Frame 189 and the correlation coefficient between blocks using OFDM in the cases. SUI-3 Raleigh fading channel influenced by AWGN is used. SNR= 0 dB



**Figure 8**

The received SVD watermarked Frame 189 and the correlation coefficient between blocks using OFDM in the cases. SUI-3 Raleigh fading channel influenced by AWGN is used. SNR= 5 dB

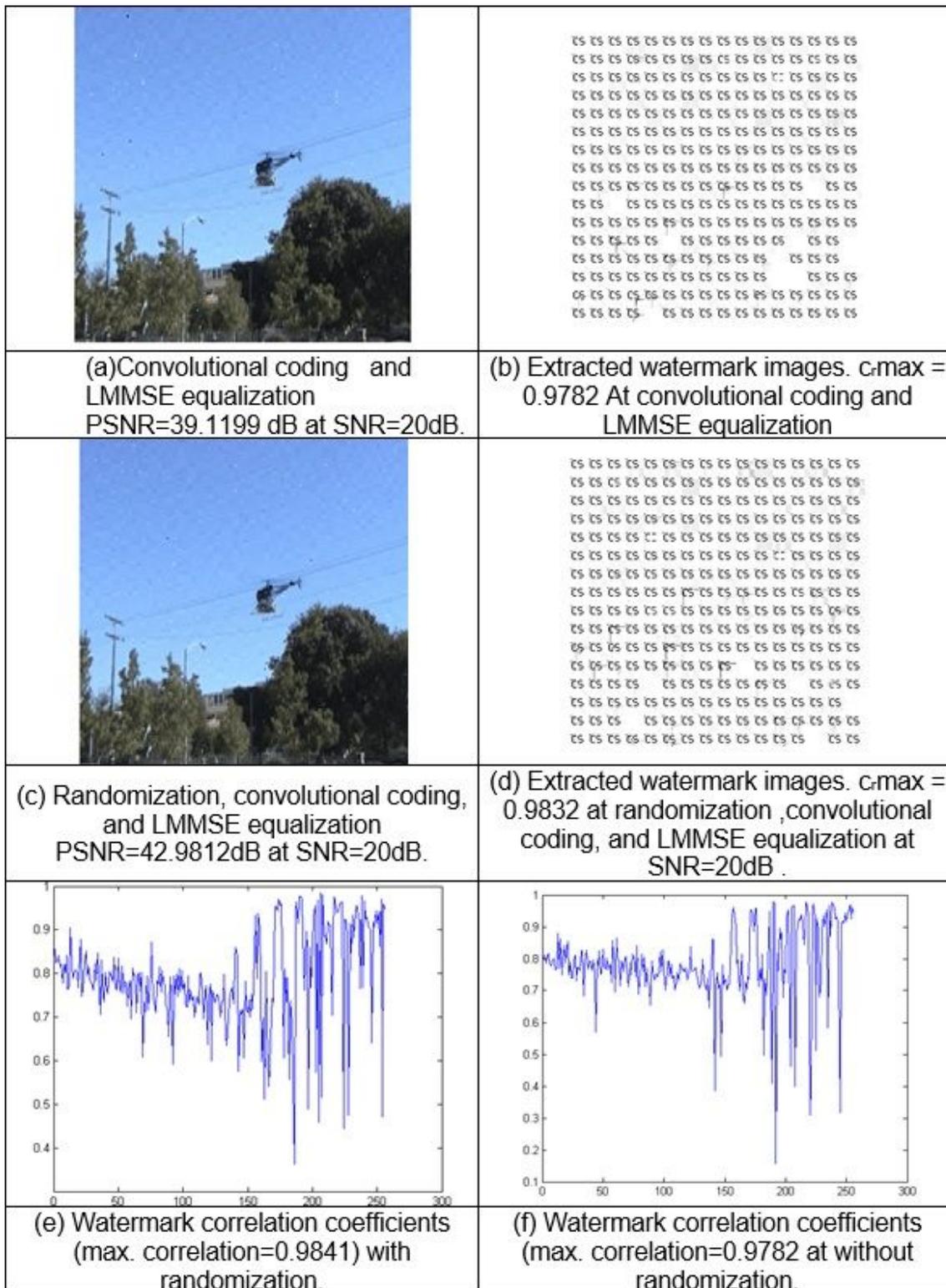
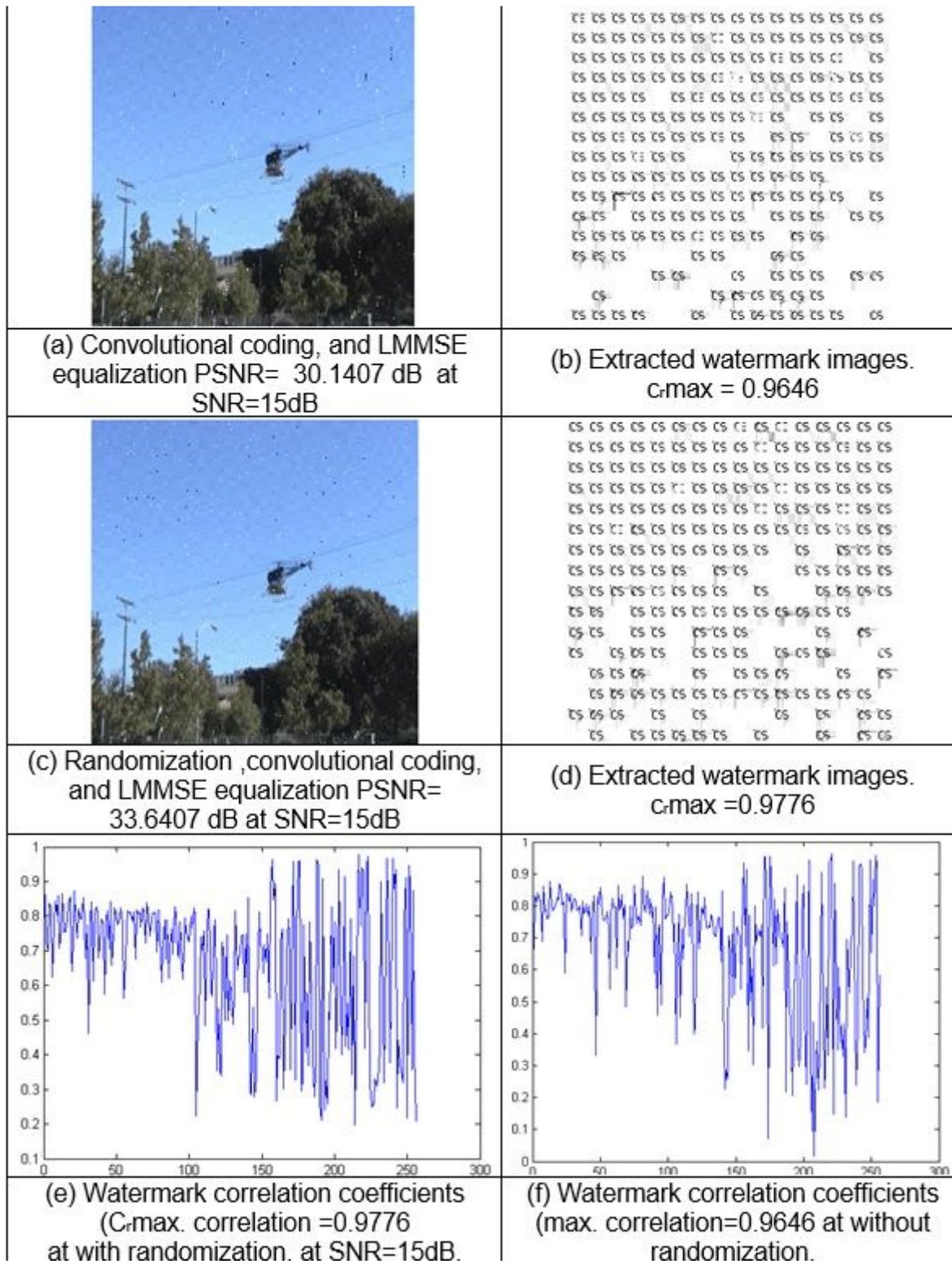


Figure 9

The received SVD watermarked Frame 189 and the correlation coefficient between blocks using OFDM in the cases. SUI-3 Raleigh fading channel influenced by AWGN is used. SNR= 20dB



**Figure 10**

The received SVD watermarked Frame 189 and the correlation coefficient between blocks using OFDM in the cases. SU-3 Raleigh fading channel influenced by AWGN is used. SNR= 15 dB