DESIGN OF DWT-SVD BASED AUDIO WATERMARKING USING ANGLE QUANTIZATION

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Abstract: An audio watermark is a unique electronic identifier embedded in an audio signal, typically used to identify ownership of copyright. This thesis considers desired properties and possible applications of audio watermarking algorithms. This thesis describes the different methods involves in process of audio watermarking also it describe the available methods developed by researchers for audio watermarking. This thesis also describes the problems associate with audio watermarking and problems in available work. Proposed work is a new method of audio watermark hiding inside another bigger cover standard audio cover. The method includes 'harr' wavelet based DWT decomposition of frequencies hence the audio samples of watermark gets hidden only those parts of cover audio where human ears are less sensible according to HAS. Proposed method also includes the SVD decomposition which is required for making our method robust against the various communication of processing attacks like compression, filtering, fading or noise addition. Proposed work is also using the concept of angular modulation which initially modifies the audio watermark in to provide extra security and also extra robustness in communication. The design is been develop on MATLAB 2013b version and verification of design o the same.

Keywords: DWT: Discrete Wave Transform, SVD: Singular Value Decomposition , AQ- angle quantization, HAS-human auditory system

I-INTRODUCTION

Audio watermarking is a well-known technique of hiding data through audio signals. It is also known as audio watermarking and has received a wide consideration in the last few years. So far, several techniques for audio watermarking have been discussed in literature by considering different applications and development positions. Perceptual properties of human auditory system (HAS) help to hide multiple sequences of audio through a transferred signal. However, all watermarking techniques face to a problem: a high robustness does not come with a high watermark data rate when the perceptual transparency parameter is considered as fixed. Furthermore, selection of a suitable domain, cover, and considering the problems associated with data-hidden techniques must be considered for designing the path to achieve a data-hidden purpose. The remainder of this chapter is organized as follows: Transmission channel for audio watermarking is discussed. Different audio watermarking attacks are explained. Various audio watermarking techniques are compared. Some basic problem with watermarking as Network surveillance and monitoring systems will not flag messages or files that contain watermarked data. Therefore, if someone attempted to steal confidential data, they could conceal it within another file and send it in an innocent looking email. Another issue is Large amount of data has to be transmitted which arises suspiciousness to the intruder.

The digital watermarking is a technique to embed information of difference from the digital contents in itself so that a human cannot perceive it without almost affecting the quality of contents using perception properties such as the human vision and hearing. In general, audio watermarking methods should satisfy four requirements: inaudibility, robustness, data payload, and blindness. There is a trade-off among these requirements. For example, increasing data payload in a watermarking system results in quality degradation of the watermarked signal and decrease of robustness against signal processing attacks. It is difficult to achieve a good trade-off among inaudibility, robustness, and data payload. Therefore, the solution to this problem is the main purpose to study digital watermarking at present. Moreover there are different type of attacks which reduces the SNR and enhance the MSE because of this attacks BER increases, list of attacks are as follow:-

Filter: some time filter may remove the watermark content form the audio which may cause bad quality watermark after extraction form cover

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Noise: in long distance communication noise may affect watermark content which may cause bad quality watermark after extraction form cover
Lossy compression: compression may remove watermark samples which may cause bad quality watermark after extraction form cover
All above attacks can be resolve with SVD because SVD hide every samples of watermark at singular component of cover which does not changes easily, SVD also hide samples at distributed locations.

II-METHODOLOGY

Proposed work is a new method of audio watermark hiding inside another bigger cover standard audio cover. The ratio of size of the watermark and cover is 1:48, means 1 watermark audio sample will be hidden between 48 samples of cover audio. The method includes 'harr' wavelet based DWT decomposition of frequencies hence the audio samples of watermark gets hidden only those parts of cover audio where human ears are less sensible according to HAS. Proposed method also includes the SVD decomposition which is required for making our method robust against the various communication of processing attacks like compression, filtering, fading or noise addition. Proposed work is also hiding each sample of watermark into SVD decomposed U, S and V elements, hence three copies of watermark samples gets hidden and the SVD decomposition perform on 4x4 blocks of DWT decomposed cover audio so each samples gets hidden at 4x4=16 location and 3 copies of each means total 3x16=48 locations, and in communication if due any kind of attacks some of this watermark samples gets modify still we can reconstruct the original watermark out of maximum unchanged watermark samples. Proposed work is also using the concept of angular modulation which initially modifies the audio watermark in to provide extra security and also extra robustness in communication. It basically converts the audio samples from rectangular to polar formats which need to be reconstruct at the receiver end and it completely modifies the watermark audio hence if somehow any intruder extract the hidden data (i.e watermark) from the cipher audio, still intruder will not have the correct audio watermark. This concept makes proposed method more secure.

Figure 1 shown below is proposed block diagram for audio watermark hiding inside the cover audio file, steps are as follow:-
Step 1: input Cover audio file and generate its samples into MATLAB environment.
Step 2: DWT decomposing of cover audio file up to two levels
Step 3: convert 1D audio file into 2D audio matrix
Step 4: SVD performed on 4x4 blocks of 2D audio matrix and develop U, V and S which are also with the same 4x4 size
Step 5: input Watermark audio file and generate its samples into MATLAB environment
Step 6: perform logical XOR with the KEY after scaling the samples and then rescale the samples to its original level.
Step 7: perform Angle quantization and generate quantized audio samples
Step 8: quantized watermark hiding for embedding watermark Interchange each sample of quantized audio with any one out of 16 samples of U, S, V The position of the replacing sample is decided based on the key with modulo operation.
Step 9: perform Inverse SVD on the modified U,S and V
Step 10: develop new 4x4 blocks of 2D audio matrix
Step 11: reshape again into the 1D audio file
Step 12: perform 2 level IDWT and finally what we achieve is the cipher audio file which will be similar to cover but watermark will be hidden inside.

Proposed Algorithm watermark hiding: Let X is the cover Audio of Mx2 size, with M number of samples at right ear and M number of samples at left ear. Watermarking process will be same for left and right ear samples.
M/4 is need to be reshape in a perfect square shape for the size of NxN, and it is possible only if M/4 is a perfect square, so number of samples 'M' in the cover must be chosen as M/4 is a perfect square or we can select samples as required and remaining will be add after the watermark hidden.
For example if number of samples in cover audio are M then

$$q = \sqrt{M1}$$
$$q1 = absolute\ of\ (q)$$
$$M2 = 4 * q1^2$$
$$M3 = M - M2$$

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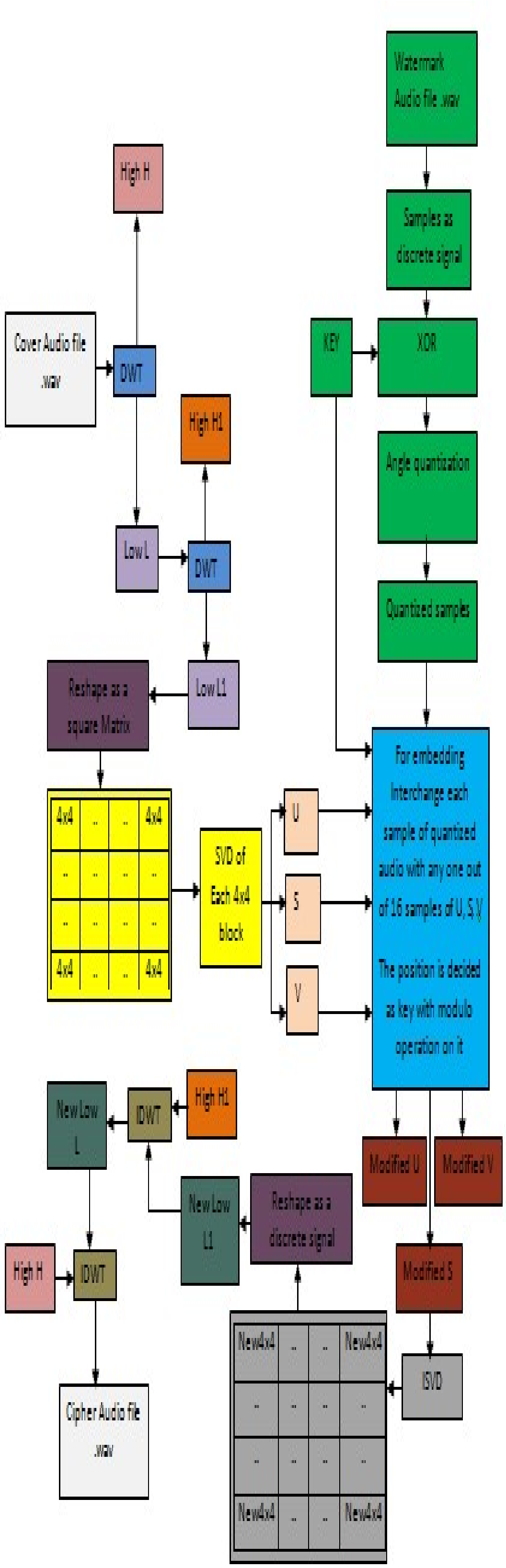

Figure 1: watermark hiding method

$$M1 = \frac{M}{4}$$

M2 are the sample in cover audio, where M2/4 will be a perfect square, and M3 are the extra samples which will not participated in the process of watermark hiding. These samples will be included at the last after watermark hiding.

DWT applied on cover Audio 'A' which has M2x1 samples, Proposed work use simple 'harr' wavelet for decomposition of Cover audio as work is interested in Frequency factorization only and 'harr' wavelet is best in frequency resolution.

Harr filter coefficients for LPF are L0=1 and L1=1

Harr filter coefficients for HPF are H0=1 and H1=-1

$$\mathrm{x(n)_L} = \frac{1}{\sqrt{2}} \sum_{k=1,+2}^{n} x(k) + x(k+1) \qquad (1)$$

$$\mathrm{x(n)_H} = \frac{1}{\sqrt{2}} \sum_{k=1,+2}^{n} x(k) - x(k+1) \qquad (2)$$

Equation (1) and (2) are the level one DWT decomposition

$$\mathrm{x(n)_{L1}} = \frac{1}{\sqrt{2}} \sum_{k=1,+2}^{n} \mathrm{x(k)_L} + \mathrm{x(k+1)_L} \qquad (3)$$

$$\mathrm{x(n)_{H1}} = \frac{1}{\sqrt{2}} \sum_{k=1,+2}^{n} \mathrm{x(k)_L} - \mathrm{x(k+1)_L} \qquad (4)$$

Equation (3) and (4) are the level two DWT decomposition

Size of $\mathrm{x(n)_L}$ is M2/2 size and $\mathrm{x(n)_{L1}}$ is M2/4 and for left and right ear both

$$(\mathrm{x(n)_{RL1}})_{NxN} = Reshape\left(\left(\mathrm{x(n)_{L1}}\right)_{\frac{M2}{4}x\,1} \right) \qquad (5)$$

SVD taken of 4x4 block of $\mathrm{x(n)_{RL1}}$ means will have total (NxN)/16 SVD blocks.

$$maximum\ number\ of\ watermark\ samples\ that\ can\ be\ hide\ in\ cover = \frac{NxN}{16} = \frac{M2/4}{16} = \frac{M2}{64}$$

Here we are explaining the Calculation of SVD for $\mathrm{x(n)_{RL1}}$ only although it is been computed for all 4x4 block of $\mathrm{x(n)_{RL1}}$

Let B1 is the first 4x4 block of $\mathrm{x(n)_{RL1}}$ the singular value decomposition of an 4x4 real matrix B1 is a factorization of the form USV^T , where U is an 4x4 real matrix, S is a 4x4 rectangular diagonal matrix with non-negative real numbers on the diagonal, and V is an 4x4 real or complex unitary matrix. The diagonal entries σ_i of S are known as

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the singular values of B1. The columns of U and the columns of V are called the left-singular vectors and right-singular vectors of B1, respectively.

$$W1 = B1xB1^T$$
$$(W1 - \sigma_i I) = 0 \qquad (6)$$

For a unique set of eigenvalues to determinant of the matrix (W1-σ_i) must be equal to zero. Thus from the solution of the characteristic equation, |W1-σ_i|=0 we obtain eight singular values of σ_i $where\ i = 1,2,3,4$

$$S = \begin{matrix} \sigma1 & 0 & 0 & 0 \\ 0 & \sigma2 & 0 & 0 \\ 0 & 0 & \sigma3 & 0 \\ 0 & 0 & 0 & \sigma4 \end{matrix}$$

And if values of σ_i again put into equation (20) we obtain x1, x2, x3 and x4 value

$$(W1 - \sigma_i I)x = 0 \qquad (7)$$

$$U = \begin{matrix} x1 & -x2 & -x3 & -x4 \\ x4 & x1 & -x2 & -x3 \\ x3 & x4 & x1 & -x2 \\ x2 & x3 & x4 & x1 \end{matrix}$$

And if

$$W2 = B1^T xB1$$
$$(W2 - \sigma_i I)x = 0 \qquad (8)$$

And if values of σ_i again put into equation (21) we obtain x1, x2, x3 and x4 value

$$V = \begin{matrix} x1 & x2 & x3 & x4 \\ -x4 & x1 & x2 & x3 \\ -x3 & -x4 & x1 & x2 \\ -x2 & -x3 & -x4 & x1 \end{matrix}$$

U, S and V computed for each 4x4 block of $x(n)_{RL1}$, As explain above.

$$U_{x(n)_{RL}}, S_{x(n)_{RL1}} V_{x(n)_{RL1}} = SVD(x(n)_{RL1}) \qquad (9)$$

On the other hand let Y is the watermark Audio with Px2 size with P number of samples at right ear and P number of samples at left ear. Watermarking process will be same for left and right ear samples.

First logical XOR with the 8 bit key 'K'

Z= (Y xor K) (10)

Angle-Quantization is a scheme to embed the watermark information into the angle of signal on polar coordinates using Quantization method. The motive behind the angel quantization is to modify the watermark before actual hiding for extra security, This scheme operation is represented as

Let Z1 and Z2 are any sample of Z

$$\theta1 = \tan^{-1}\left(\frac{Z1}{Z2}\right) \qquad (10)$$

$$r1 = \sqrt{Z1^2 + Z2^2} \qquad (11)$$

Where θ1 is an angle Z2 and Z1, and r1 is radius.

Provided θ1 and r1 gets hidden instead of Z1 and Z2 this scheme has a property which is unchanging against amplitude scaling because it implements polar coordinates transform.

If K is the Key then

T=K mod θ1(degree)

T shows the position of sample in U, S and V which is to be replace with θ1 first then second U, S and V will be replace by r1 and this process keep on until all samples finish of watermark as

$$MU = (U_{(T,T)} = r1)$$
$$MS = (S_{(T,T)} = r1)$$
$$MV = (V_{(T,T)} = r1)$$

$$MU = (U_{(T,T)} = \theta1)$$
$$MS = (S_{(T,T)} = \theta1)$$
$$MV = (V_{(T,T)} = \theta1)$$

ISVD taken as

$$(x(n)_{MRL1}) = MU * MS * MV^T \qquad (12)$$

$$(x(n)_{ML1})_{\frac{M2}{4}x\,1} = Reshape(\ (x(n)_{MRL1})_{NxN}\ ) \qquad (13)$$

IDWT

$$x(k)_{ML} = \frac{x(n)_{ML1} + x(n)_{H1}}{\sqrt{2}} \qquad (14)$$

$$x(k+1)_{ML} = \frac{x(n)_{ML1} - x(n)_{H1}}{\sqrt{2}} \qquad (15)$$

$$x(k)_M = \frac{x(n)_{ML} + x(n)_H}{\sqrt{2}} \qquad (16)$$

$$x(k)_M = \frac{x(n)_{ML} - x(n)_H}{\sqrt{2}} \qquad (17)$$

X(n) is the final ciphered audio file which have the watermark audio hidden in original cover audio.

Figure 2 shown below is proposed block diagram for audio watermark hiding inside the cover audio file, steps are as follow:-

Step 1: input Cipher audio file and generate its samples into MATLAB environment.

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Step 2: DWT decomposing of cipher audio file up to two levels
Step 3: convert 1D cipher audio file into 2D cipher audio matrix
Step 4: SVD performed on 4x4 blocks of 2D cipher audio matrix and develop U, V and S which are also with the same 4x4 size
Step 5: extract watermark samples which ware replaced in U, S and V at the time of watermark hiding, the potion will be obtain with the same KEY at the time of watermark hiding.
Step 6: find maximum match samples in U, S and V and perform acerage of all 48 copies of each samples and the average value will be consider as final sample
Step 7: perform inverse angle quantization and then perform logical XOR with the KEY.
Step 8: the sample remain after all above process are the final recovered watermark audio.

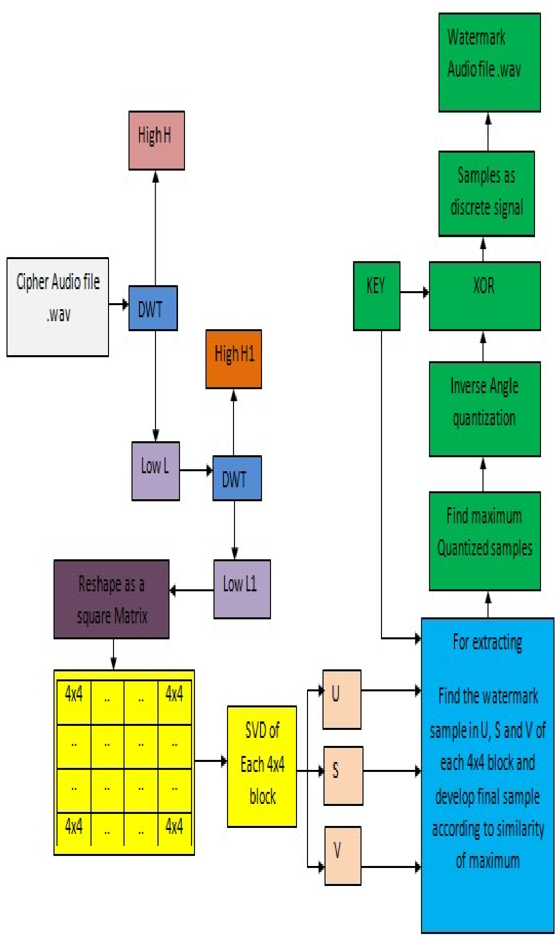

Figure 2: watermark de-hiding method

Proposed Algorithm watermark extraction: Let X is the cipher Audio of Mx2 size, with M number of samples at right ear and M number of samples at left ear. DWT applied on cipher Audio 'X' which has Mx1 samples, Proposed work use simple 'harr' wavelet for decomposition of Cipher audio.

$$x(n)_L = \frac{1}{\sqrt{2}} \sum_{k=1,+2}^{n} x(k) + x(k+1) \qquad (18)$$

$$x(n)_H = \frac{1}{\sqrt{2}} \sum_{k=1,+2}^{n} x(k) - x(k+1) \qquad (19)$$

Equation (1) and (2) are the level one DWT decomposition

$$x(n)_{L1} = \frac{1}{\sqrt{2}} \sum_{k=1,+2}^{n} x(k)_L + x(k+1)_L \qquad (20)$$

$$x(n)_{H1} = \frac{1}{\sqrt{2}} \sum_{k=1,+2}^{n} x(k)_L - x(k+1)_L \qquad (21)$$

Equation (3) and (4) are the level two DWT decomposition
Size of $x(n)_L$ is M/2 size and $x(n)_{L1}$ is M/4 and for left and right ear both

$$(x(n)_{RL1})_{NxN} = Reshape\left((x(n)_{L1})_{\frac{M}{4}x\,1} \right) \qquad (22)$$

SVD taken of 4x4 block of $x(n)_{RL}$ means will have total (NxN)/16 SVD blocks.
U, S and V computed for each 4x4 block of $x(n)_{RL1}$, As explain above.

$$U_{x(n)_{RL1}}, S_{x(n)_{RL1}} V_{x(n)_{RL}} = SVD(x(n)_{RL1}) \qquad (23)$$

If K is the Key then

T=K mod θ1(degree)

T shows the position of sample in U, S and V which is to be replace with θ1 first then second U, S and V will be replace by r1 and this process keep on until all samples finish of watermark as

$$r1t1 = U_{(T,T)}$$
$$r1t2 = S_{(T,T)}$$
$$r1t3 = V_{(T,T)}$$

$$r1 = \frac{r1t1 + r1t2 + r1t3}{3}$$

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$$\theta1t1 = U_{(T,T)}$$
$$\theta1t2 = S_{(T,T)}$$
$$\theta1t3 = V_{(T,T)}$$

$$\theta1 = \frac{\theta1t1 + \theta1t2 + \theta1t3}{3}$$

Inverse Angle-Quantization performed on r1 and θ1

Let Z1 and Z2 are any sample of Z

$$z1 = r1 * \cos(\theta1)$$
$$z2 = r2 * \sin(\theta1)$$

Where Z2 and Z1 are the samples of the watermark.

If 8 bit key is 'K' then

Z= (z1 xor K)

Z is the final extracted watermark sample

III-RESULTS

The simulation results are been obtain at MATLAB 2013b

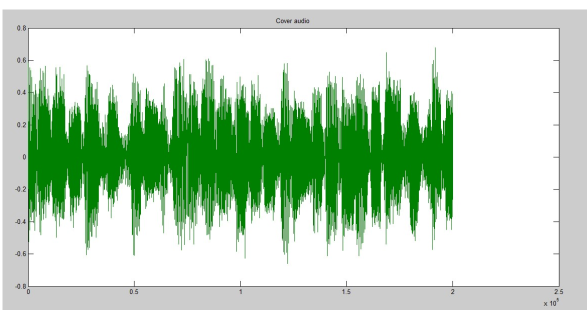

Figure 3 the cover audio

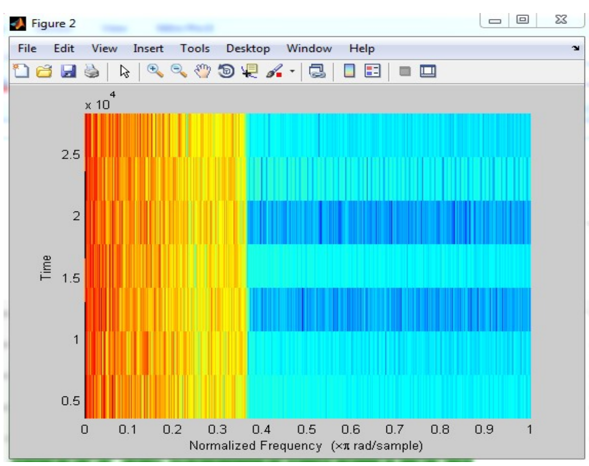

Figure 4 the cover audio spectrogram

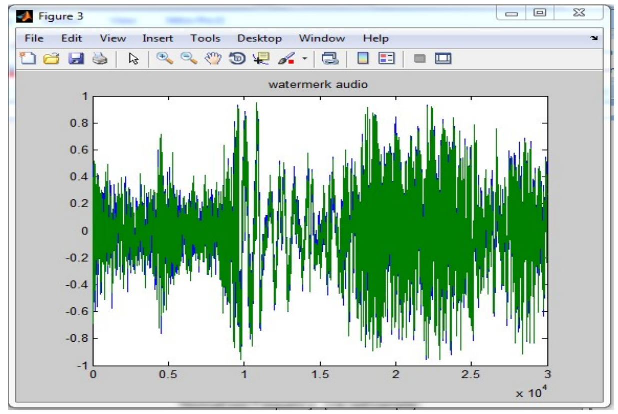

Figure 5 the watermark audio

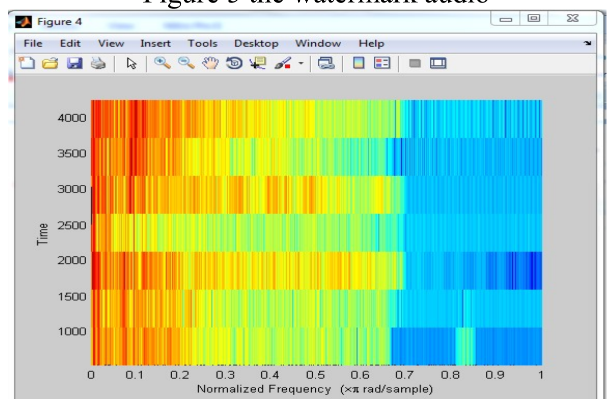

Figure 6 the watermark audio spectrogram

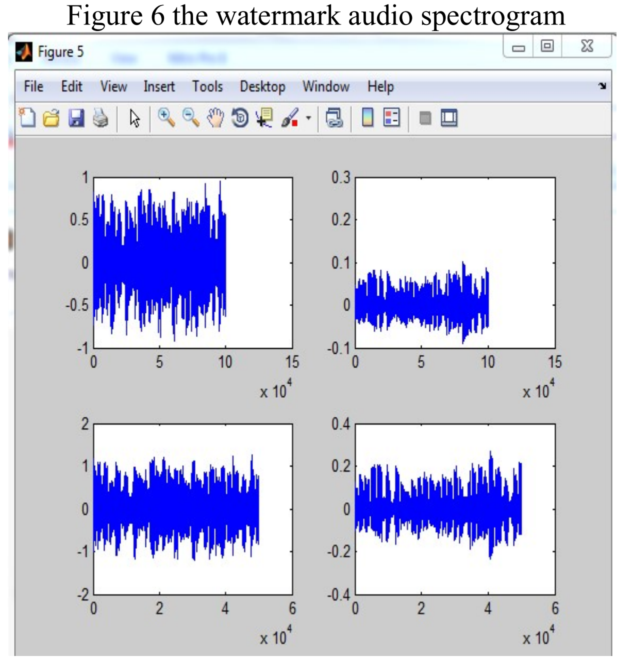

Figure 7 DWT decomposition of cover audio (a) L component (b) H component (c) LL component (d) LH component

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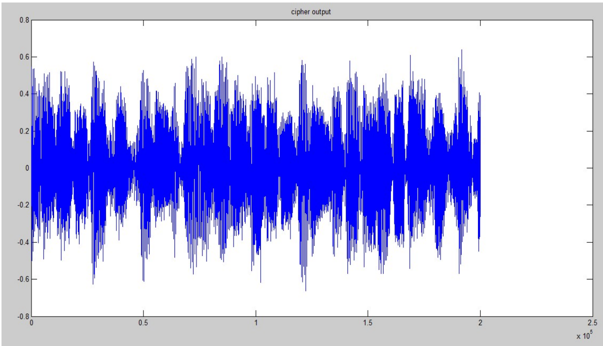

Figure 8 the cipher audio

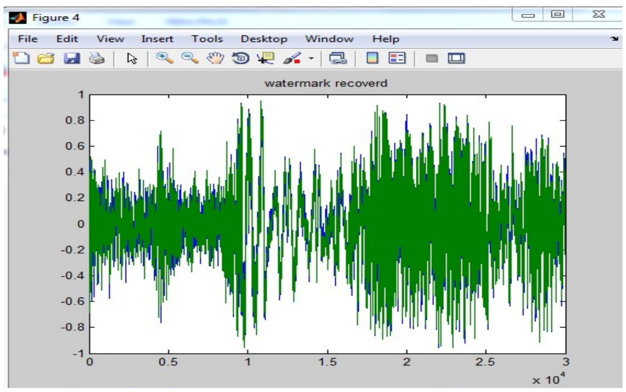

Figure 9 the extracted watermark audio

Figure 3 to figure 9 above shows the simulation graphs obtain while execution of the proposed work, it can be observe that the cover audio and the cipher audio waveforms plots are almost equals and the original watermark and extracted watermark audio are also equals.

Table 1 below is the results observe for the proposed work, the MSE, BER and SNR is been obtain for the different test conditions here the results developed for the MATLAB standard audio signals 'jazz', 'pop' and 'classic' and the length of watermark is of one second and the length of cover is 4 second. Above test scenario is the standard test scenario which is been use for the MATLAB based audio signal processing study.

The simulation results obtain at the MATLAB and the parameters for the proposed work are:

MSE= (D – C)^2/ Len

SNR= 10 log 10 (256^2/MSE)

BER = sum of (Data *xor* Cipher) / (Len x 8)

Cover size	**Watermark Audio**	**SNR**	**MSE**	**BER**
4-second 784 kb Jazz-2	1-second 120 kb	43.341 1	0.0185	0.0077
4-second 784 kb Pop-2	1-second 120 kb	43.854 8	0.0181	0.0075
4-second 784 kb Classic-2	1-second 120 kb	42.215 8	0.0167	0.0082
22-second 3.81 Mb Jazz-1	2-second 392 kb	49.243	0.0094	0.0061
22-second 1.91 Mb Pop-1	2-second 392 kb	44.184 6	0.0172	0.0069
22-second 7.63 Mb Classic-1	2-second 392 kb	50.573 9	0.0135	0.0058

Table 1 SNR, MSE and BER observation for different test cases

Table 2 below show the SNR observation for the proposed work for MATLAB standard jazz, pop and classic audio cover and 1sec watermark audio

AUTHOR	**Audio type**	**RESULTS**
Neethu V et al [2]	Pop	34.11
	Jazz	37.79
	classic	35.8
Masato Ogura et al [1]	Pop	30.0
	Jazz	30.4
	classic	30.7
Proposed work	Pop	43.8548
	Jazz	43.3411
	classic	42.2158

Table 4.2 the Comparative results: SNR

It can be clearly observe from the figure above that the proposed work SNR value is higher than available work ant all test conditions. The average BER observe by Masato Ogura et al is 0.6 and proposed work average BER is for the 0.0079 which again less in comparison.

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IV-CONCLUSION

The original objective of the thesis work was to develop an optimised technique for hiding audio inside cover audio also to reduce the amount of audio signal while data transmission, the objective are completed as was expected. The problem with watermarking is that it requires lots of data means another bigger audio for sending some small watermark audio, proposed work achieved that same size of watermark can be transmitted with small size of cover audio as achieved SNR is better than available work 43.524.

This thesis considers desired properties and possible applications of audio watermarking algorithms. This thesis describes the different methods involves in process of audio watermarking also it describe the available methods developed by researchers for audio watermarking. This thesis also describes the problems associate with audio watermarking and problems in available work , observe from SNR value is higher than available work ant all test conditions. The average BER observe by Masato Ogura et al is 0.6 and proposed work average BER is for the 0.0079 which again less in comparison.

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