Performance Improvement of EMD based Audio Watermarking Technique by Varying Quantization Step Size in QIM Modulation

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Abstract: Watermarking is a technique in which some watermark is embedded into the original record (can be image or audio) and this watermarked original record is distributed in the market. This helps in distinguishing between the original record and pirated record because an algorithm can be applied on distributed record to extract watermark, if it is the same watermark as we have embedded then it means record is original else it is pirated record. In audio watermarking, EMD (Empirical mode decomposition) technique with QIM (Quantization Index Modulation) modulation is very popular technique where EMD breaks the original audio signal into multiple IMFs (Intrinsic Mode Function) and then watermark image is embedded into the original audio signal using QIM modulation. QIM modulation technique makes use of two different step sizes to embed the watermark image. In proposed work, quantization step size pair is varied to find the PSNR & BER and it is found that when pair of quantization step size is varied, it increases the value of PSNR and decreases BER.

Keywords: EMD (Empirical mode decomposition), Audio watermarking, IMF (Intrinsic Mode Function), Quantization step size, QIM (Quantization Index Modulation), Watermark image, BER (Bit Error Rate), MSE(Mean Square Error),Signal to Noise Ratio (SNR).

1. INTRODUCTION

Recording companies are getting lots of losses due to piracy of their records. Now a day, this problem is solving by using audio watermarking where company logo is embedded into the records to detect the piracy or ownership [3]. Audio watermarking can be divided into two category, first is temporal watermarking and another is spectral watermarking technique. Time domain embedding of watermark into the original record is called as temporal watermarking technique. While frequency domain embedding of watermark by doing some frequency transformation in the original record is called as spectral watermarking technique [1].The popular temporal watermarking technique is EMD technique while the popular spectral watermarking technique is DWT (Discrete Wavelet Transform) [5], [7].

EMD technique decomposes the signal recursively into multiple IMFs which are the symmetric envelops of nearly zero mean [1]. When all the IMFs are added again then it recreates the original signal. The best part in EMD technique is it does not have any requirement of predefined basis functions and it totally depends on data-driven method .It is seen that SNR should be greater than 20dB for the good watermarking of audio signal [2].

In proposed work, EMD technique is used to convert original audio into multiple IMFs and it is found that the last IMF has lesser amount of fluctuations and therefore watermark image is embedded in last IMF. QIM technique is used to embed watermark image in last IMF. It is found that QIM technique use a pair of quantization step size to perform watermarking therefore we experiment by varying the quantization step size. This variation in quantization step size helps in increasing PSNR as well decreasing BER.

2. EMD (Empirical mode decomposition)

EMD technique convert main signal into multiple parts in such a way so that all the parts has nearly zero mean symmetric envelops, these envelops or parts are referenced as Intrinsic Mode Functions (IMFs). EMD technique can be equated as shown in the equation 1[4],

$$\text{Xt} = \sum_{n=1}^{\infty} \text{IMFj(t)}_{+}\, rN(t) \qquad (1)$$

Where N is number of IMFs &rN(t) is the residue comes out from EMD technique .The orthogonal nature of IMF is the main feature of IMF [11]. There is finite number of modes in the EMD method and as the process of EMD moves from mode to mode, there is a decrease in number of extremas . In the EMD technique, since the last IMF has fewer disturbances therefore watermark signal is hidden inside it [8], [9].

3. QIM (Quantization Index Modulation)

The frequently used watermarking and data hiding technique is QIM technique. In QIM technique, the watermarking data is embedded inside the host signal in such a way so that host signal will not degrade and it is properly audible [6]. There is a tradeoff has to be done in between the following different properties of audio signal like data rate, signal distortion, and robustness of embedding signals.

3.1. QIM Transmitter

In QIM technique as shown in Fig. 1, a composite signal is created by putting a watermark into the original host signal and this method is utilized in many worldwide applications. This technique comes under a host-interference rejection technique, this shows that the decoder in this technique can work without having the host signal [10]. QIM is very robust technique and it is better than other host-interference rejection techniques like low bit modulation (LBM) [2].

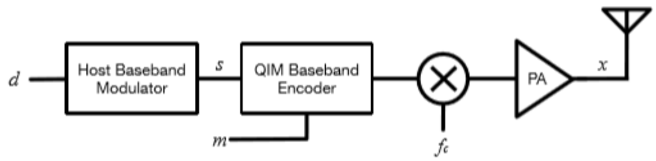


Fig. 1: Transmitter section of QIM Technique

In QIM technique, if h is considered as host signal, n is considered as message signal which is used for watermarking. Then, y (h,n), the output signal is defined in the form of functions of h and it is indexed by n. In this way, QIM technique can be equated after the distortion inserted due to the embedded information and shown in equation 2,

$$Y(h,n) \cong h \quad (2)$$

In general, the range of functions in the design is taken far away means quite a distance is kept in between the range of different functions. One can say that, functions must be nonintersecting in nature which is helpful in decoding the hidden message, m, perfectly. This nonintersecting property of functions can be achieved by keeping the functions discontinuous [12]. Therefore quantizers are created by using discontinuous functions and they are required to approximately define the original audio content, and this thing makes it useful in data hiding operations. Therefore QIM is performing a modulation of an index by using the information in embedded data and then this is used to quantize the original signal with the corresponding quantizer .

For example, if we assume b is the one bit data which will be embedded in the original signal represented byh, then the resultant signal can be formulated in equation 3 as follows [2]:

$$y(h,b) = \begin{cases} quan0(h), if\ b = 0 \\ quan1(h), if\ b = 1 \end{cases} \quad (3)$$

Here quan0 & quan1 are quantizers with nonintersecting range spaces.

3.2. QIM Receiver

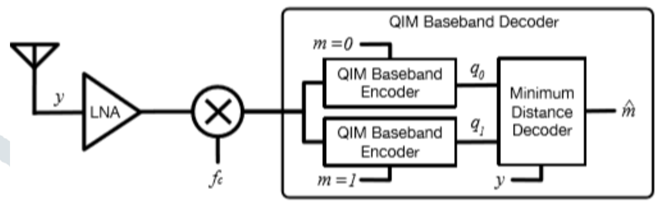


Fig. 2: Receiver section of QIM Technique

Fig. 2above represents the process of a QIM receiver. There are many receiver based on RF architecture, one of them is QIM receiver but it is very close to commodity receiver as both has same complexity & power consumption. In QIM receiver, decoder block is created in digital domain and QIM function is applied on the host audio signal for both of the digital value that is 0 and 1 bit, this will result in the two quantized signals q0 & q1. These quantized value are input into a minimum distance decoder so that it can be compared with the original signal y which helps in obtaining the estimated message as shown in equation 4 [2],

$$n = \arg\min dist(y, ym) \quad (4)$$

4. PROPOSED WORK

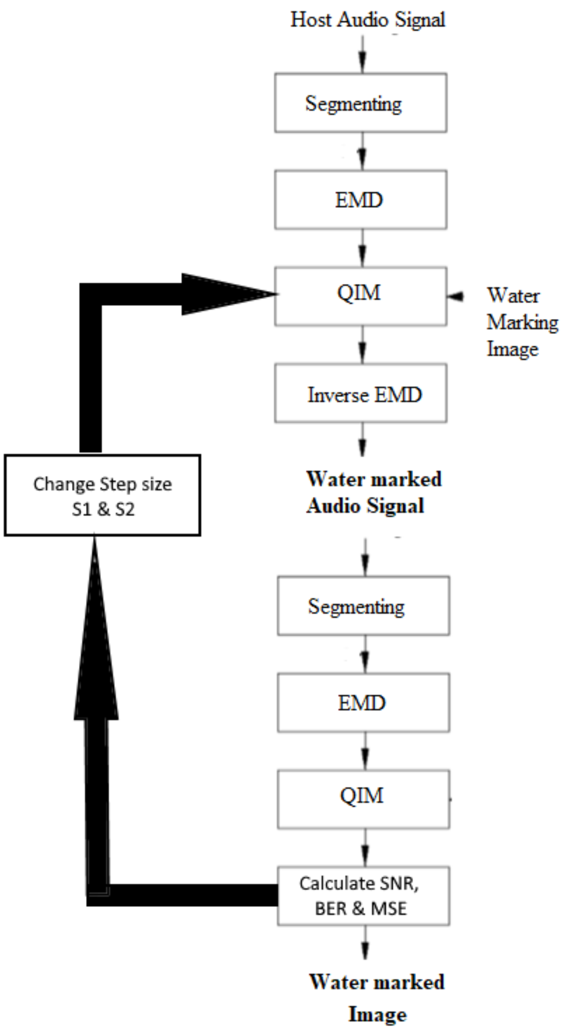


Fig. 3: Flow chart of proposed work

As shown in fig. 3, the host or original audio signal is first transformed from audio signal to multi-dimensional array in MATLAB. This multi-dimensional array is then segmented the multi tone to single tone audio as shown in fig. 4. Then EMD technique is used to decompose this segmented audio into multiple IMFs out of which last IMF is important for watermarking because of its less fluctuating nature.

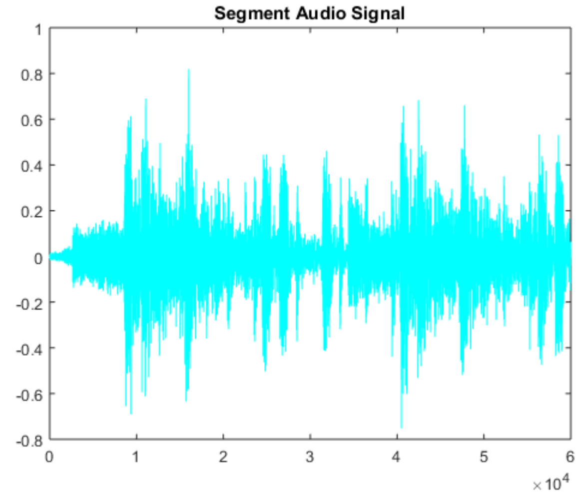


Fig. 4: Audio used for watermarking

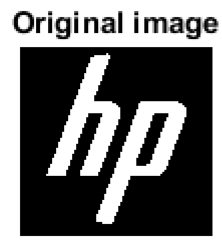
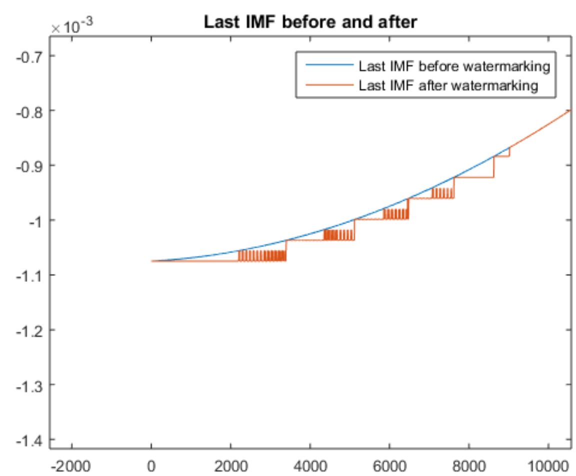
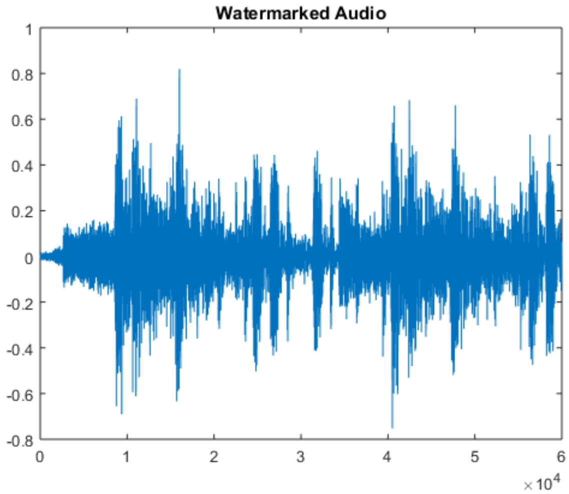


Fig. 5: Image used for watermarking

Fig. 5 above shows the watermarking image which is selected to embedded into the last IMF of original audio signal.



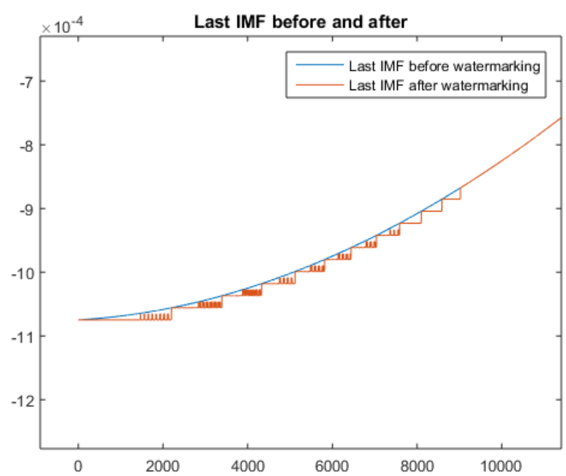
(a)



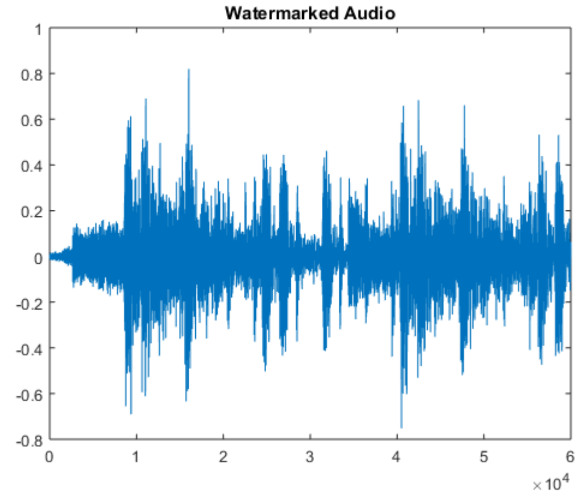
(b)

Fig.6: (a) Comparison of last IMF before and after watermarking (b) watermarked audio output for quantization step size of S1=64, S2=128.

QIM modulation makes use of two different quantisers to embed watermark image into last IMF. Now by using QIM modulation, this watermark image is embedded into the Last IMF. The last IMF with or without watermark is represented in Fig. 6(a) while Fig. 6(b) show the output watermarked audio signal for the quantization step size of S1=64, S2=128.



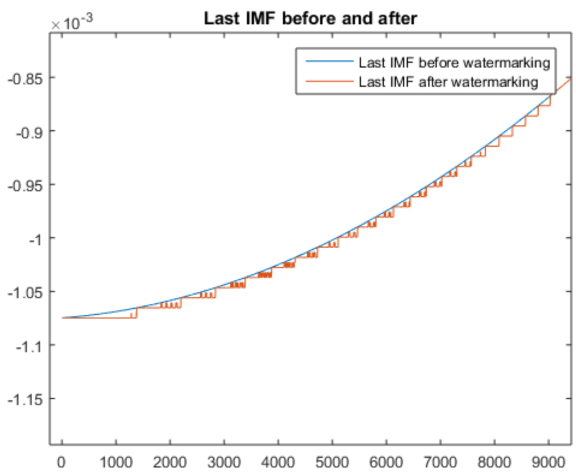
(a)



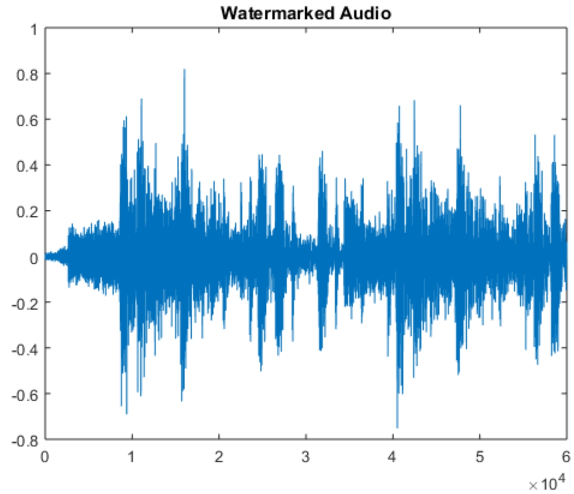
(b)

Fig.7: (a) Comparison of last IMF before and after watermarking (b) watermarked audio output for quantization step size of S1=128, S2=256.

Similarly after setting the Quantization step size into S1=128 & S2=256, the last IMF with or without watermark is represented in Fig. 7(a) while Fig. 7(b) show the output watermarked audio signal.



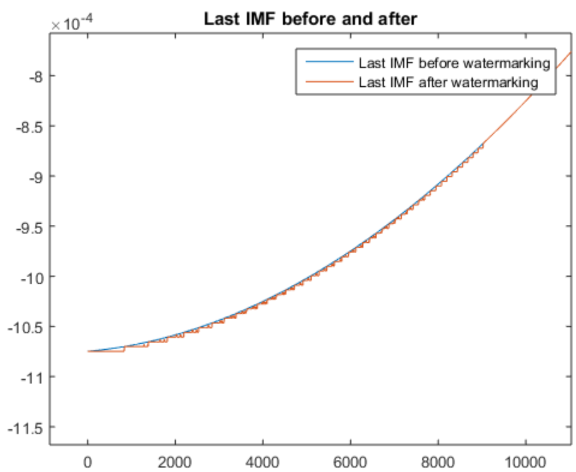
(a)



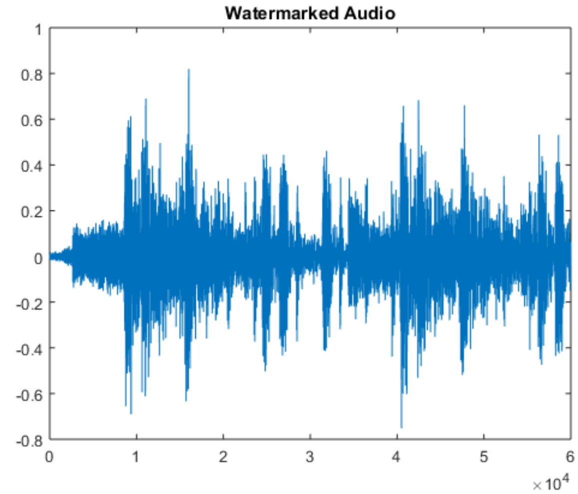
(b)

Fig.8: (a) Comparison of last IMF before and after watermarking (b) watermarked audio output for quantization step size of S1=256, S2=512.

Similarly after setting the Quantization step size into S1=256 & S2=512, the last IMF with or without watermark is represented in Fig. 8(a) while Fig. 8(b) show the output watermarked audio signal.



(a)



(b)

Fig.9: (a) Comparison of last IMF before and after watermarking (b) watermarked audio output for quantization step size of S1=512, S2=1024.

Similarly after setting the Quantization step size into S1=512 & S2=1024, the last IMF with or without watermark is represented in Fig. 9(a) while Fig. 9(b) show the output watermarked audio signal. Further variation in step size is not taken into consideration because results were achieving the saturation.

Table 1: PSNR, BER & MSE values for different pair of quantization step size with extracted watermark image

S. No.	Quantization Pair (step size)	PSNR	BER	MSE	Extracted image
1	S1=64, S2=128	101.3232	0.015	4.95e-11	
2	S1=128, S2=256	106.99	5.54e-04	1.34e-11	
3	S1=256, S2=512	112.78	0	3.53e-12	
4	S1=512, S2=1024	118.69	0	9.07e-13	

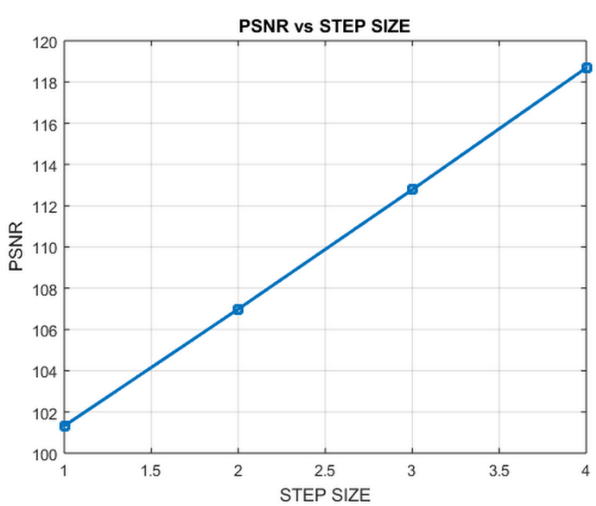


Fig. 10: PSNR plot for different quantization step size, here 1 represents pair 1: S1=64 & S2=128, 2 represents pair 2: S1=128 & S2=256, 3 represents pair 3: S1=256 & S2=512, 4 represents pair 4: S1=512 & S2=1024

The result of PSNR for different quantization pairs is represented in Fig. 10. It is concluded from the above figure that as the value in the quantization pair increases then it increases the PSNR value. And since PSNR should be low for good results therefore higher set of quantization step size is better for watermarking as compare to lower set of quantization step sizes.

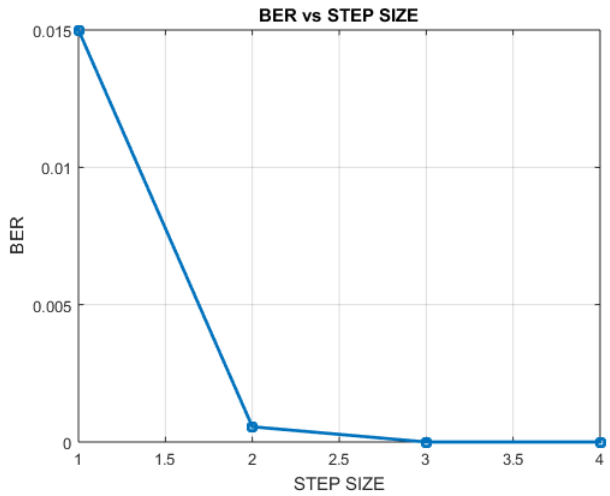


Fig. 11: BER plot for different quantization step size, here 1 represents pair 1: S1=64 & S2=128, 2 represents pair 2: S1=128 & S2=256, 3 represents pair 3: S1=256 & S2=512, 4 represents pair 4: S1=512 & S2=1024

The result of BER for different quantization pairs is represented in Fig. 11. It is concluded from the above figure that as the value in the quantization pair increases then it decreases the BER value. And since BER should be low for good results therefore higher set of quantization step size is better for watermarking as compare to lower set of quantization step sizes.

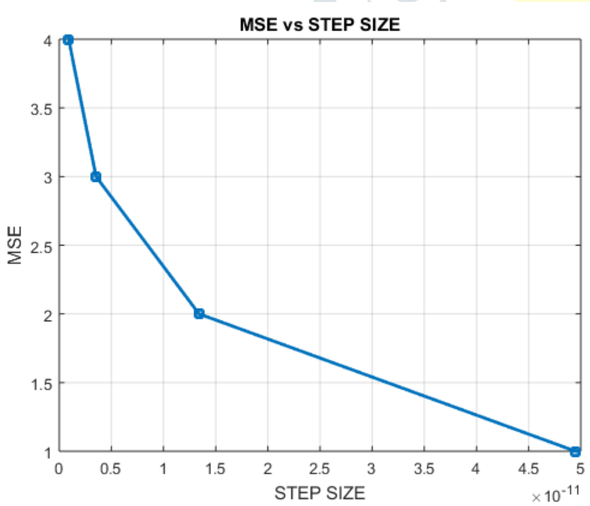


Fig. 12: MSE plot for different quantization step size, here 1 represents pair 1: S1=64 & S2=128, 2 represents pair 2: S1=128 & S2=256, 3 represents pair 3: S1=256 & S2=512, 4 represents pair 4: S1=512 & S2=1024

The result of MSE for different quantization pairs is represented in Fig. 12. It is concluded from the figure above that as the value in the quantization pair increases then it decreases theMSEvalue. And since MSE should be low for good results therefore higher set of quantization step size is better for watermarking as compare to lower set of quantization step sizes.

5. CONCLUSION

EMD technique is used to convert the audio signal into multiple IMFs and it is very easy to create an audio signal again just by adding all the IMFs. This recreation makes the watermarking process lesser complex. while QIM modulation makes use of two quantisers with predefined set of quantization step size. These quantisers are used to embed water mark image into the last IMF of original audio signal. Then some quality parameters like PSNR, BER, MSE can be calculated to find the quality of watermarking. In proposed work, variation is performed in the value of quantization pair and it is seen that by increasing the value of set of quantization pair, value of PSNR is increases, BER decreases and MSE also decreases. And it is giving the better results at S1=512 & S2=1024 quantization step size set. Overall it can be concluded that watermarking results are improved by increasing value of quantization step size.

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