

## ROBUST MPEG VIDEO WATERMARKING IN WAVELET DOMAIN

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**Abstract:** A semi-blind image watermarking scheme embeds a pseudo random sequence in all the high pass DWT coefficients above a given threshold  $T_1$ . The attacked DWT coefficients are then correlated with the original watermark. For watermark detection, all the coefficients higher than another threshold  $T_2$  ( $>T_1$ ) are chosen for correlation with the original watermark. This idea was extended to embed the same watermark in two bands (LL and HH). In this paper, we embed a pseudo random sequence in MPEG-1 using two bands (LL and HH). Our experiments show that for one group of attacks (i.e., JPEG compression, Gaussian noise, resizing, low pass filtering, rotation, and frame dropping), the correlation with the real watermark is higher than the threshold in the LL band, and for another group of attacks (i.e., cropping, histogram equalization, contrast adjustment, and gamma correction), the correlation with the real watermark is higher than the threshold in the HH band.

**Keywords:** watermarking, embedding and detection algorithms, PRNS, discrete wavelet transform (DWT), lowpass band, horizontal, vertical, and diagonal highpass bands.

### Wavelet ile Dayanıklı Mpeg Video Damgalama

**Özet:** Yarı kör resim damgalama metodu PRN sayılarını DWT HH bant katsayılarından  $T_1$  basamağından büyük olanlarına damgalama yapılır. Saldırıya uğramış resim katsayıları başlangıç resim ile korelasyon yapılır. Damgayı bulmak için, basamak  $T_2$ 'den ( $T_2 > T_1$ ) büyük olan katsayılar başlangıç resmi ile korelasyon edilir. Bu fikir LL ve HH bantlarına damgalama olarak geliştirilmiştir. Bu makalede ise bu daha önce geliştirdiğimiz bu fikri MPEG videoları için kullandık. Deney sonuçlarımız gösteriyor ki bazı saldırılar için LL bantında damgalama, diğer bir grup saldırıda ise HH bantında damgalama daha iyi sonuç vermektedir.

**Anahtar Kelimeler:** damgalama, gömme ve çıkarma algoritmaları, PRNS, ayırık dalgacık dönüşümü (DWT), düşük geçiş bant, yatay, dikey ve köşe yüksek geçiş bant.

### Introduction

Two-dimensional DWT can be implemented using digital filters and downsamplers. Each level of decomposition produces four bands of data denoted by LL, HL, LH, and HH. The LL subband can further be decomposed to obtain another level of decomposition. A DWT-based semi-blind image watermarking scheme [1] leaves out the low pass band, and embeds a pseudo random number (PRN) sequence (i.e., the watermark) in the other three bands into the coefficients that are higher than a given threshold  $T_1$ . During watermark detection, all the high pass coefficients above another threshold  $T_2$  ( $T_2 \geq T_1$ ) are used in correlation with the original watermark. The algorithms for embedding and detection are as follows:

#### Watermark embedding

1. Compute the DWT of an  $N \times N$  gray scale image  $I$ .
2. Exclude the low pass DWT coefficients.
3. Embed the watermark (i.e., a PRN sequence) into the DWT coefficients higher than a given threshold  $T_1$ :  $T = \{t_i\}$ ,  $t'_i = t_i + \alpha |t_i| x_i$ , where  $i$  runs over all DWT coefficients  $> T_1$ .
4. Replace  $T = \{t_i\}$  with  $T' = \{t'_i\}$  in the DWT domain.
5. Compute the inverse DWT to obtain the watermarked image  $I'$ .

#### Watermark detection

1. Compute the DWT of the watermarked and possibly attacked image  $I^*$ .
2. Exclude the low pass DWT coefficients.
3. Select all the DWT coefficients higher than a given threshold  $T_2$  ( $T_2 \geq T_1$ ).
4. Compute the sum  $Z = \frac{1}{M} \sum_{i=1}^M y_i t_i^*$ , where  $i$  runs over all DWT coefficients  $> T_2$ ,  $M$  is the number of such coefficients,  $y_i$

represents either the real watermark or a fake watermark,  $t_i^*$  represents the watermarked and possibly attacked DWT coefficients.

5. Choose a predefined threshold  $T_z = \frac{\alpha}{2M} \sum_{i=1}^M |r'_i|$ .

6. If  $z$  exceeds  $T_z$ , the conclusion is that the watermark is present.

In a recent paper [2], the above idea is extended to embed the same PRN sequence in two bands (LL and HH) using the first level decomposition.

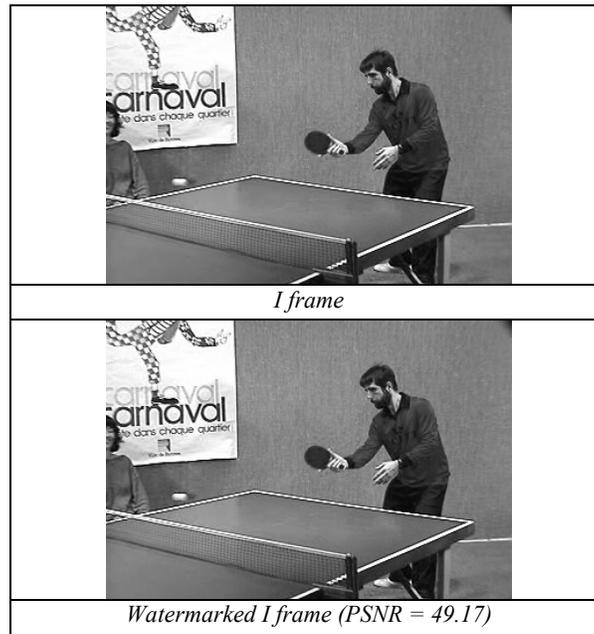
Some of the problems associated with video watermarking are discussed in [3]. Content owners are interested in digital rights management (DRM) systems which can protect their rights and preserve the economic value of digital video. A DRM system protects and enforces the rights associated with the use of digital content. An overview of the concepts and approaches for video DRM and a description of the methods for providing security, including the roles of encryption and video watermarking are given in [4]. Video watermarking techniques can be broadly classified in two categories. In the first category, the watermark is embedded into compressed video, and in the second category, the watermark is embedded into uncompressed video. Swanson et al [5] presents image, audio, and video data embedding approaches, and the issues associated with copy and copyright protections. Hsu and Wu [6] embed a pseudo random number sequence into both intra and inter frames using DCT with different residual masks in MPEG-1. Simitopoulos et al [7] describe a new technique for MPEG-1/2 compressed video streams. Perceptual models are used in the embedding process to preserve the quality of the video. Qui et al [8] propose a novel H.264/AVC watermarking method. The robust watermark is embedded in the DCT domain and the fragile watermark is embedded into the motion vectors. It is argued that the proposed method can jointly achieve both copyright protection and authentication. Wang et al [9] uses the spatial domain for watermark embedding with much lower computation complexity in MPEG-2. Swanson et al [10] proposes scene-based and video dependent MPEG watermarking. Deguillaume et al [11] proposes a Discrete Fourier Transform (DFT) method for embedding into  $I$  frames only.

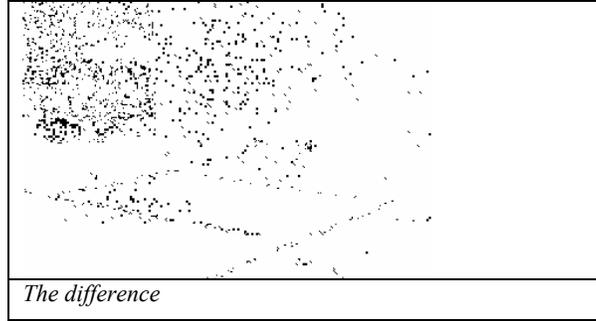
In this paper, we also embed a PRN sequence into  $I$  frames for two bands (LL and HH). The scaling factor and the threshold values are given in **Table 1**.

**Table 1.** Scaling factor  $\alpha$  and threshold  $T$

Parameters/Bands	LL	HH
$\alpha$	0.2	0.8
$T_1$	10	30
$T_2$	20	40

A 352x240 sample from the original test sequence, the watermarked image, and their difference are shown in **Figure 1**.





The difference

Figure 1. Embedding two watermarks into an I frame

**Experiments**

Matlab was used for all attacks. The chosen attacks were JPEG compression, resizing, adding Gaussian noise, low pass filtering, rotation, histogram equalization, contrast adjustment, gamma correction, and cropping. The attacked images and the Matlab attack parameters are shown in Figure 3.

Embedding:

1. Split the video into frames *I*, *B*, and *P*.
2. Compute the DWT of the luminance layer (*Y*).
3. In each DWT band (LL and HH), embed a PRN sequence to the luminance layer only.
4. Replace the watermarked *I* frames with original *I* frames in the original video.

Detection:

1. Split the watermarked (and possibly attacked) video into *I*, *B*, and *P* frames.
2. Compute the DWT of the luminance layer (*Y*).
3. Calculate the threshold ( $T_z$ ) and the correlation (*Z*) for each luminance layer of *I* frames in each DWT band (LL and HH).
4. In each band, if  $Z > T_z$ , the watermark is present.

The attacks on a watermarked frame are shown in Figure 2.

		
JPEG compression ( $Q=25$ ) PSNR = 25.65	Resizing PSNR = 21.66	Gaussian noise (mean=0, variance=0.001) PSNR = 30.14
		
Low pass filtering (window size=3x3) PSNR = 20.91	Rotation ( $5^\circ$ ) PSNR = 12.87	Histogram equal (automatic) PSNR = 15.69

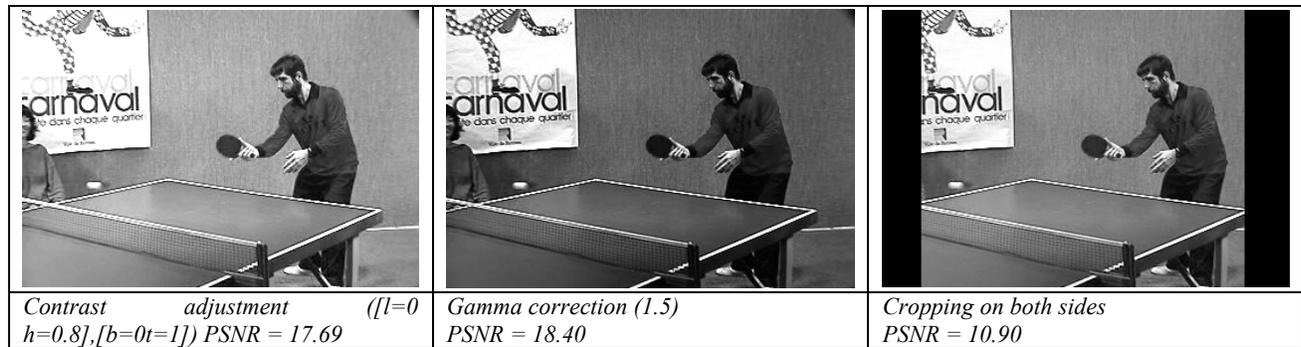


Figure 2. Attacks on a watermarked frame

In Figures 3-14, we display the detector responses for the real watermark, and 99 randomly generated watermarks. In each figure, the correlation with the real watermark is located at 80 on the x-axis, and the dotted line shows the value of the threshold.

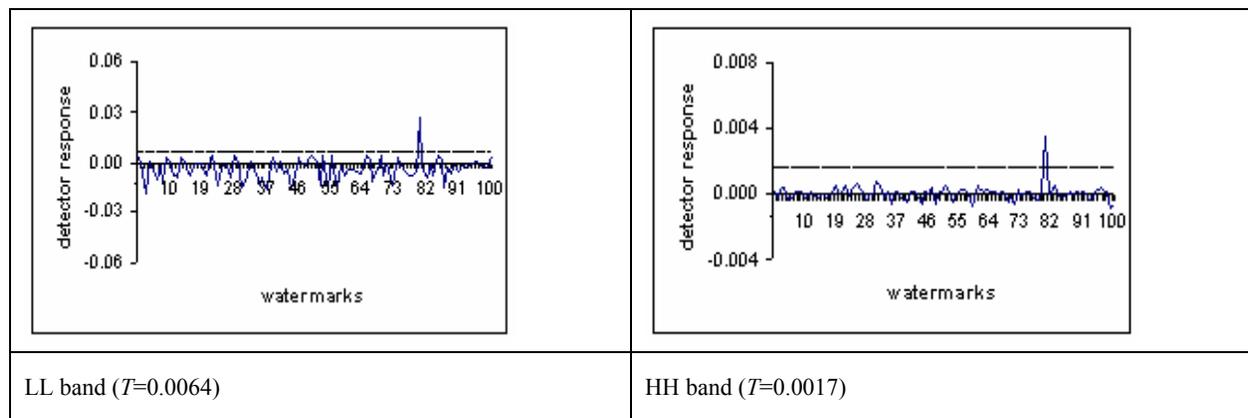


Figure 3. Detector response for unattacked watermarked I Frame

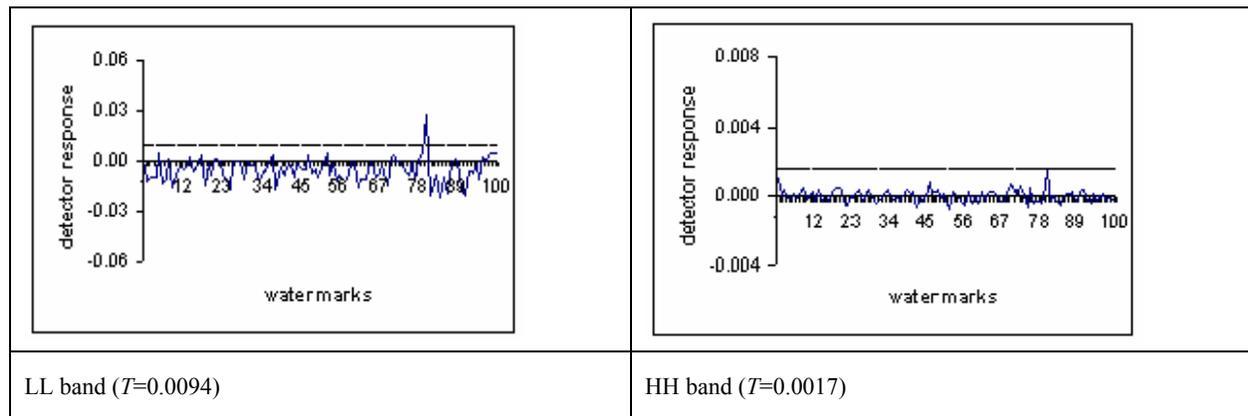


Figure 4. Detector response for JPEG compression:  $Q=25$

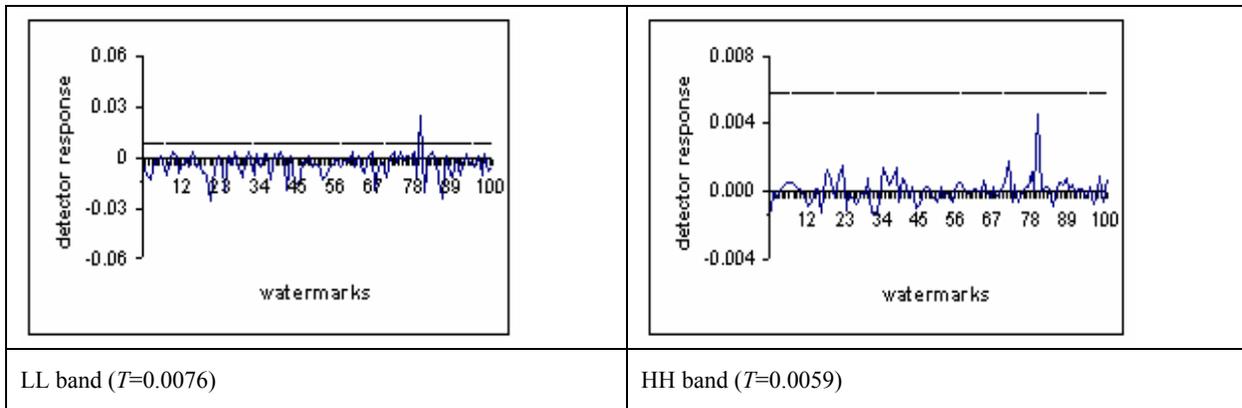


Figure 5. Detector response for Gaussian noise

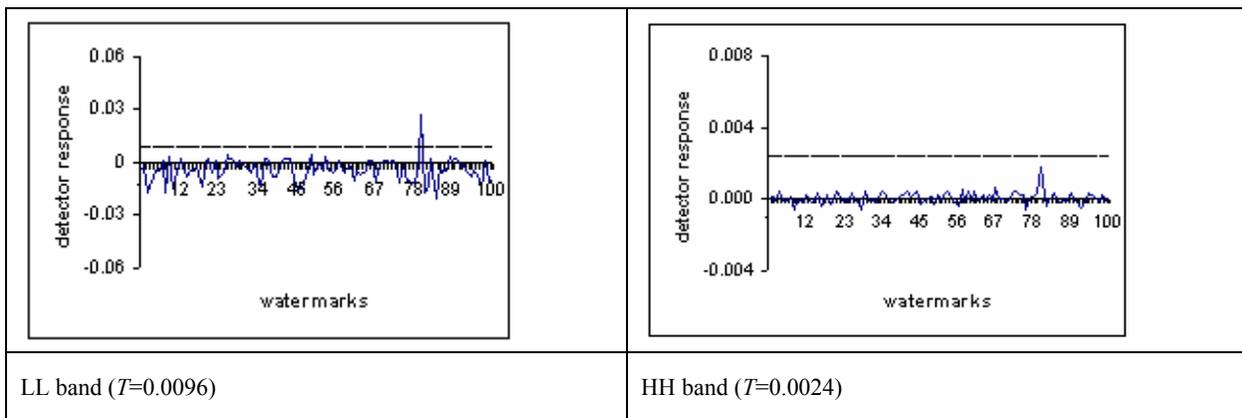


Figure 6. Detector response for resizing

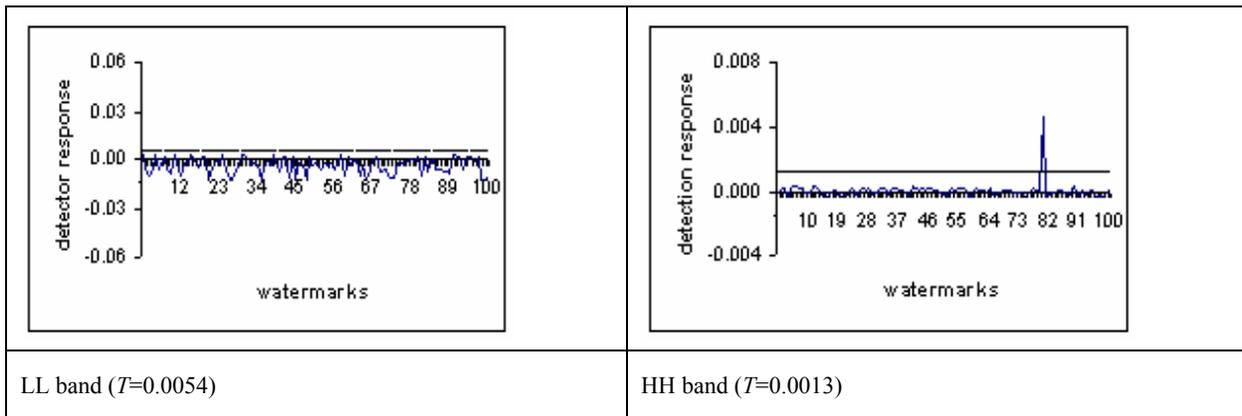
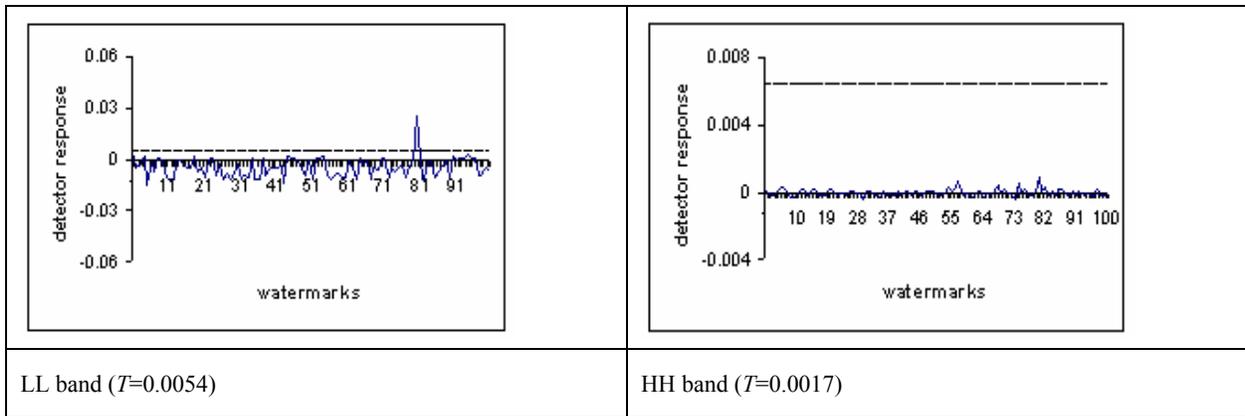
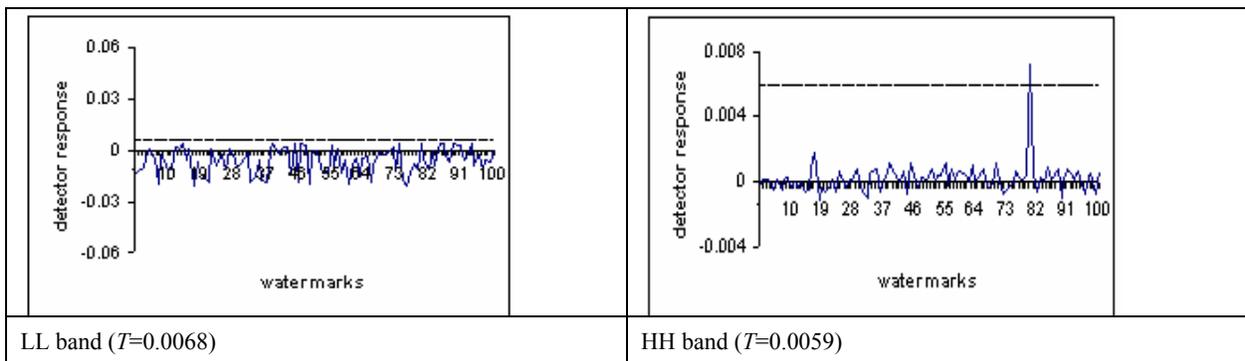


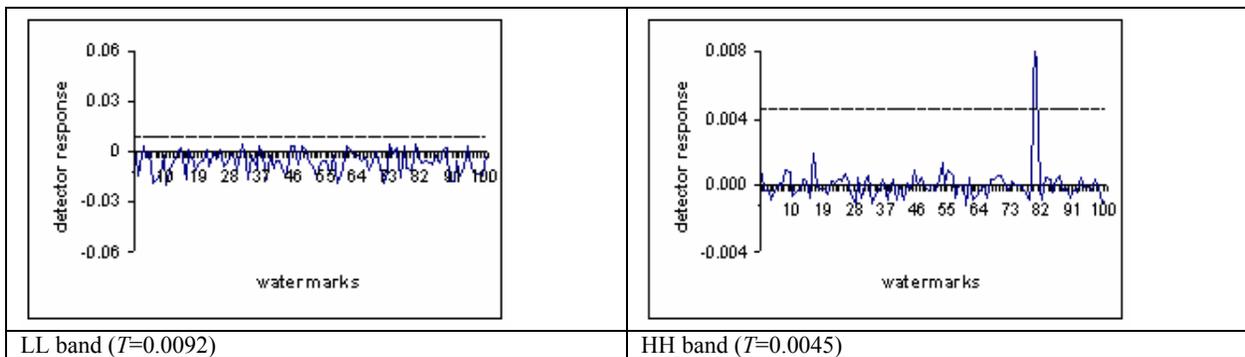
Figure 7. Detector response for cropping



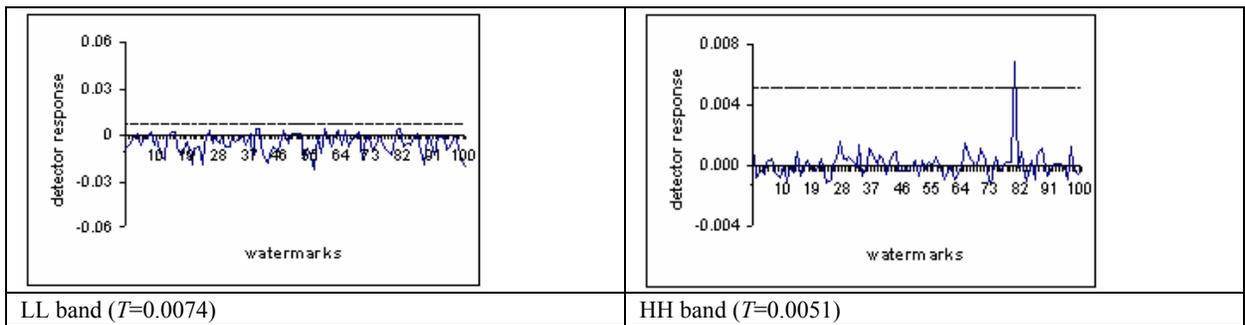
*Figure 8. Low pass filtering*



*Figure 9. Detector response for histogram equalization*



*Figure 10. Detector response for contract adjustment*



*Figure 11. Detector response for gamma correction*

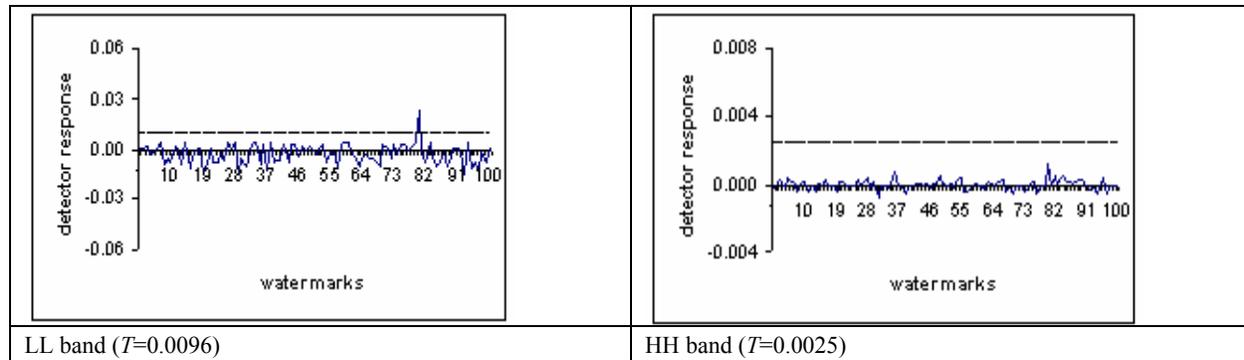


Figure 12. Rotation ( $5^\circ$ )

### Conclusions

In this paper, we presented a semi-blind image watermarking scheme for an MPEG 1 video clip. A pseudo random sequence is embedded in two bands (LL and HH). The chosen attacks were JPEG compression, resizing, adding Gaussian noise, low pass filtering, rotation, histogram equalization, contrast adjustment, gamma correction, cropping, frame dropping, and frame swapping.

Our experiments show that for one group of attacks (i.e., JPEG compression, Gaussian noise, resizing, low pass filtering, rotation, and frame dropping), the correlation with the real watermark is higher than the threshold in the LL band, and for another group of attacks (i.e., cropping, histogram equalization, contrast adjustment, and gamma correction), the correlation with the real watermark is higher than the threshold in the HH band. Only for frame swapping, the correlation with the real watermark is higher than the threshold in both of the bands.

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