

Partially Host-Adaptive Quantization Index Modulation Watermarking in a Baseband-Spread Transformation Domain

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Abstract

In order to reduce the impact of watermark embedding on the perceptual fidelity of the marked signal, watermarking systems process the generated watermark to match it to the local properties of the underlying host signal prior to embedding. However, this adaptation process could distort the watermark, affecting its robustness and information content. In this paper, a new watermark coding technique is proposed, that enables the application of some mark-nondistorting host-adaptation processing, where the intensity of the watermark could be redistributed according to the local properties of the underlying host without changing the way of interpreting the watermark to be embedded. This completely eliminates the need to equalize adaptation distortions prior to decoding, and hence, to pass any side information about the adaptation processing to the decoder, too.

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1. Introduction

As digital multimedia get more widely used and also more easily manipulated, replicated and distributed, and with no loss of quality, their copyright protection issues become more challenging. So far, these challenges have been met by *encrypting* the intelligible multimedia contents to restrict unauthorized accesses. Encryption, however, fails to protect the copyrights of these contents as soon as they are decrypted. So, what is needed here is to permanently adhere some owner identifying

information to these multimedia contents, that can be retrieved later to prove that these contents are properties of their corresponding creators [1], [2]. This implies, on one hand, that the embedded information should be *robust* enough to survive any intentional or unintentional manipulations that the released multimedia works may undergo, or at least any manipulations that may not render the underlying works commercially useless. On the other hand, embedding this information should not degrade the quality of the underlying works beyond the acceptable

limits. Such a piece of information is well-known today as a *digital watermark*.

The idea of watermarking can be traced back into a patent granted at 1954 that has described a method to *imperceptibly* embed an identification code within the music for the purpose of proving ownership [3]. A number of the novice watermarking techniques for the different multimedia formats have been proposed since then. However, digital watermarking did not receive much attention from the academic research community until the beginnings of the 1990's, when it has been recognized as a distinct field of technology. Meanwhile, a better understanding of the subject theory started to develop as the watermarking problem began to be modeled as a communications channel, with the host signal and any distortions applied to the marked signal being treated as additive noise [3]. Later, a better model for the watermarking problem has emerged, that treats the host signal as *the state of the channel* that could be available as *side information* to the encoder and/or the decoder, or neither of them [2]-[6]. This viewpoint is important to understand the watermarking problem, since that the availability of side information, to the encoder and/or the decoder, has many implications on the host-interference rejection properties [4]-[6], and also on the *host-adaptation* capabilities of the different embedding methods.

Host-adaptation processing, defined as that pre-embedding processing, where the watermarking signal is locally adjusted according to the local properties of the underlying host signal [4], can functionally be partitioned into two steps: the *perceptual analysis* step responsible for analyzing the host and the watermarking signals to determine their local features to be used in the following *watermark local-adaptation* step, where the watermark components are accordingly adjusted in order to reduce their perceptibility. Such processing though, can severely *distort* the embedded watermark, making its interpretation, by the

decoder, dependent on how much *resistance* that the employed coding technique can show to these distortions.

To lower the effect of this problem, pre-decoding *equalization* for the adaptation distortions is usually applied. This processing, however, imposes a severe limitation on the watermarking problem, that is the need for the availability of the local features of the host signal, used in the adaptation process, to the decoding side. This should immediately suggest that if sufficient side information about the local features of the host signal is available to the decoder, then adaptation distortions could be well equalized, given that the corresponding host-adaptation algorithm, applied by the encoder, is known to the decoder. A similar *private* marking scenario is proposed by Cox *et. al.* [1]. However, since that such information about the host signal is not, generally, available to the decoder, and also cannot be accurately enough approximated out of the received manipulated signal, *blind* host-adaptation scenarios have to be constrained to exploiting the *coarse* host perceptual details those are capable of preserving an adequate level of accuracy after the distortions applied by both the embedding process and the possible attack channels.

In any case, due to the interferences induced by the host signal and/or the attack channels, pre-decoding equalization processing cannot perfectly compensate the adaptation distortions induced into the embedded watermark, even under the private marking scenario. This motivated such trials to trade-off embedding capacity with the resistance to adaptation distortions, as that made by Solanki *et. al.* [7].

In the next section, we will discuss the proposed watermark coding technique that will be shown, in section 3, to enable the application of the partial host-adaptation processing. The structure of the proposed watermarking system is to be developed in section 4, followed by simulation results on image data in section 5. Concluding remarks will be provided in section 6.

2. Quantization index modulation in a baseband-spread transformation domain

In order that a *coded-quantization index modulated* (QIM) piece of information could be locally adapted to another signal, the way it is coded must show flexibility to the adjustments to be applied to the components of the code by the adaptation process. To achieve this, the rigid *direct sequence-based spread transformation coding* is proposed to be *segmented* into an equivalent number of the *repetitions* of some *smaller* spread transformation code. This would provide the required flexibility to *redistribution* adjustments through the *baseband channels* proposed by the *repetition coding* along the distinct dimensions of the code segments. The *integrate-and-dump* processing can then be applied along these baseband channels, in order to *compensate* the reduction in the *processing gain* resulting from lowering the spreading dimensionality.

To be more specific, let the proposed coding technique use an integer number, N/D , of repetitions of some low dimensional, a D -dimensional with $D \ll N$, spreading sequence segment T^D to code a message m . The aggregate N -dimensional baseband-spread transformation array \mathbf{T}^N is constructed by tiling these N/D identical spreading sequence segments in a similar way to that shown in Fig. 1, where the D baseband channels resulting from repetition coding lay along the columns of the array. The transformation array \mathbf{T}^N is used to *scalar-multiply* the host signal coefficients array \mathbf{S}^N (whose structure is to be discussed in section 4.2) to calculate its *projection* (*inner product*) onto the transformation array's direction, as in Eq. (2.1). The resulting transformed host coefficient x , a *scalar*, is then quantized with the *scalar quantizer* $q(\cdot, m)$ to mark it with message m . However, to mark the host coefficients array \mathbf{S}^N , it has to be adjusted by the difference array \mathbf{W}^N (also will be called the *watermarking array*), which represents the *error* induced into the host array \mathbf{S}^N by

quantizing its projection onto the direction of \mathbf{T}^N , see Eqs. (2.2) and (2.3).

$$x = \mathbf{T}^N \cdot \mathbf{S}^N \quad (2.1)$$

$$\mathbf{W}^N = [q(x, m) - x] \mathbf{T}^N \quad (2.2)$$

$$\mathbf{S}_m^N = \mathbf{S}^N + \mathbf{W}^N, \quad (2.3)$$

where \mathbf{S}_m^N is the marked coefficients array.

To decode the received coefficients array $\hat{\mathbf{S}}_m^N$, it is scalar-multiplied again by the transformation array \mathbf{T}^N to make an estimate \hat{x} of its projection onto the latter array. A *minimum-distance* decoding scheme can be applied to determine an estimate \hat{m} of the embedded message

$$\hat{m} = \underset{i}{\operatorname{argmin}} \| q(\hat{x}, m_i) - \hat{x} \|.$$

Note here that the complexity of the proposed encoding/decoding schemes can be further reduced if the N/D rows of the host coefficients array \mathbf{S}^N are first accumulated into one D -dimensional row vector that is then scalar-multiplied by the D -dimensional spreading sequence segment T^D to calculate the projection scalar x , see Eq. (2.4). The *accumulate-project* processing of Eq. (2.4) is equivalent to the projection processing of Eq. (2.1), given that all the elements on any *distinct* column of array \mathbf{T}^D are identical (repetition coding).

$$\begin{aligned} x &= \mathbf{T}^N \cdot \mathbf{S}^N = \sum_{j=1}^D \sum_{i=1}^{N/D} \mathbf{T}(i, j) \mathbf{S}(i, j) \\ x &= \sum_{j=1}^D \sum_{i=1}^{N/D} T(j) \mathbf{S}(i, j) \\ x &= \sum_{j=1}^D T(j) \sum_{i=1}^{N/D} \mathbf{S}(i, j), \quad (2.4) \end{aligned}$$

where $T(j)$ in Eq. (2.4) is the j th element of the spreading sequence segment T^D . This accumulate-project processing reduces the

