

(51) International Patent Classification:  
*G10L 19/00* (2013.01)(21) International Application Number:  
PCT/EP2012/062194(22) International Filing Date:  
25 June 2012 (25.06.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
11305883.8 8 July 2011 (08.07.2011) EP(71) Applicant (for all designated States except US): **THOMSON LICENSING** [FR/FR]; 1-5 rue Jeanne d'Arc, F-92130 Issy-les-Moulineaux (FR).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **JAX, Peter** [DE/DE]; Am Bokemahle 8, 30171 Hannover (DE).(74) Agent: **HARTNACK, Wolfgang**; Deutsche Thomson OHG, European Patent Operations, Karl-Wiechert-Allee 74, 30625 Hannover (DE).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: METHOD AND APPARATUS FOR QUANTISATION INDEX MODULATION FOR WATERMARKING AN INPUT SIGNAL

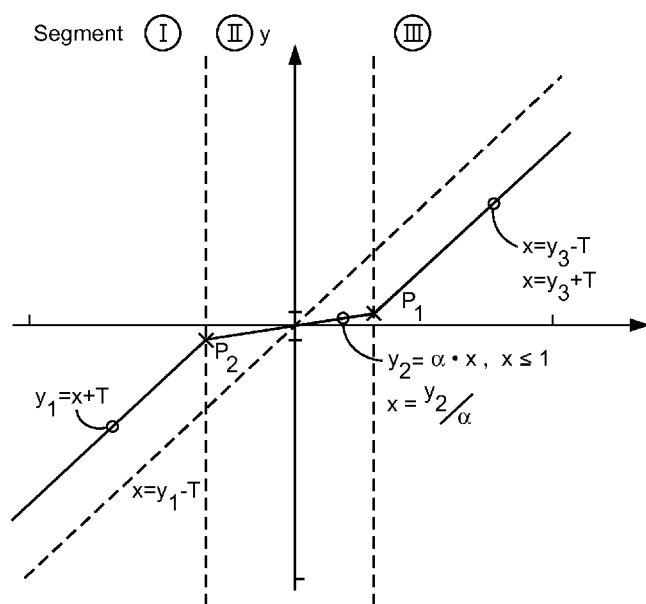


Fig. 1

(57) Abstract: With quantisation index modulation QIM it is possible to achieve a very high data rate, and the capacity of the watermark transmission is mostly independent of the characteristics of the original audio signal, but the audio quality suffers from degradation with each watermark embedding-and-removal step. In order to avoid degradation of the audio quality, the inventive audio signal watermarking uses specific quantiser curves in time domain and in particular in frequency domain for embedding the watermark message into the audio signal, whereby the processing is almost perfectly reversible. Furthermore, it has embedded a power constraint in order to guarantee that the modifications of the audio signal due to the watermark embedding are inaudible.

## Method and Apparatus for quantisation index modulation for watermarking an input signal

The invention relates to a method and to an apparatus for  
5 quantisation index modulation for watermarking an input signal, wherein different quantiser curves are used for quantising said input signal.

### 10 Background

In known digital audio signal watermarking the audio quality suffers from degradation with each watermark embedding-and-removal step.

15 One of the dominant approaches for watermarking of multimedia content is called quantisation index modulation denoted QIM, see e.g. B. Chen, G.W. Wornell, "Quantization Index Modulation: A Class of Provably Good Methods for Digital Watermarking and Information Embedding", IEEE Transaction on  
20 Information Theory, vol.47(4), pp.1423-1443, May 2001, or J.J. Eggers, J.K. Su, B. Girod, "A Blind Watermarking Scheme Based on Structured Codebooks", Proc. of the IEE Colloquium on Secure Images and Image Authentication, pp.1-6, 10 April 2000, London, GB.

25 With QIM it is possible to achieve a very high data rate, and the capacity of the watermark transmission is mostly independent of the characteristics of the original audio signal.

In QIM as described by B. Chen and G.W. Wornell and mentioned above, an input value  $x$  is mapped by quantisation to  
30 a discrete output value  $y = Q_m(x)$ , whereby for each watermark message  $m$  a different quantiser  $Q_m$  is chosen. Therefore the detector can in turn try all possible quantisers and detect the watermark message by finding the quantiser with the  
35 smallest quantisation error.

J.J. Eggers et al. mentioned above have proposed an extension to QIM in order to achieve better capacity in specific watermark channels: in this  $\alpha$ -QIM all input values  $x$  are linearly shifted towards the reference value (i.e. towards the centroid of the quantiser) with a constant factor. The watermarked output value  $y$  can be considered as being computed by  $y = Q_m(x) + \alpha(x - Q_m(x))$ .

## 10 Invention

The Chen/Wornell processing is by definition non-reversible because information is lost in the quantisation step. The Eggers/Su/Girod processing is reversible, but it is not subject to any time-variable distortion constraint.

A problem to be solved by the invention is to avoid degradation of the audio quality with each watermark embedding-and-removal step by improving the known QIM processing. This problem is solved by the quantisation method disclosed in claim 1. An apparatus that utilises this method is disclosed in claim 2. A method for corresponding regaining is disclosed in claim 8.

The inventive audio signal watermarking uses specific quantiser curves in time domain and in particular in transform domain for embedding the watermark message into the audio signal, whereby it is almost perfectly reversible and the term 'reversible' means that the watermark can be removed in order to recover the original PCM samples with high (i.e. with near-bit-exact) quality - under the preconditions that the watermarked audio signal has not undergone significant signal modification, and that the secret key is known which is required for detection of the watermark.

The inventive reversible quantisation index modulation watermarking processing has embedded a power constraint, which

is important in audio watermarking in order to guarantee that the modifications of the signal due to the watermark embedding are inaudible.

Advantageously, the inventive processing provides robustness and capacity characteristics which are competitive to state-of-the-art, non-reversible watermarking schemes, and the invention allows to reverse the watermark embedding process without significant penalties in terms of data rate, robustness and computational complexity of the watermark scheme, whereby the reversal of the watermark embedding process will deliver almost exactly the original PCM audio signal.

In principle, the inventive quantisation method is suited for quantisation index modulation for watermarking an input signal  $x$ , wherein different quantiser curves  $Q_m$  are used for quantising said input signal  $x$  and a current characteristic of said quantiser curve is controlled by the current content of a watermark message  $m$ , wherein in said quantising the difference between input value and output value at any position is not greater than  $T$ , and said quantising curves  $Q_m$  are reversible in that for any input value  $x$  there is a unique output value  $y$ ,

and wherein  $\pm T$  is a value defining the  $y$  shift towards  $y = 0$  of outer sections of said quantiser curves  $Q_m$  and is determined by the current psycho-acoustic masking level of said input signal  $x$ , and  $y$  is the watermarked output signal, and wherein the different quantiser curves  $Q_m$  are established according to the current value of  $m$  by different shifts of the complete quantiser curve in  $x$  direction.

In particular, said quantising can be carried out according to  $y = Q_m(x) + \max(-T, \min(T, \alpha(x - Q_m(x))))$ , wherein  $\alpha$  is a predetermined steepness of the medium section of said quantiser curves  $Q_m$ ,  $\pm T$  is a value defining the  $y$  shift towards  $y = 0$  of the other sections of said quantiser curves  $Q_m$  and is determined by the current psycho-acoustic masking level of said input signal  $x$ , and  $y$  is the water-

marked output signal.

In principle the inventive quantisation apparatus is suited for quantisation index modulation for watermarking an input  
5 signal  $x$ , wherein different quantiser curves  $Q_m$  are used for quantising said input signal  $x$  and a current characteristic of said quantiser curve is controlled by the current content of a watermark message  $m$ , said apparatus including:

- a psycho-acoustic masking level calculator;
- 10 - an embedder which carries out said quantising in which the difference between input value and output value at any position is not greater than  $T$ , and wherein said quantising curves  $Q_m$  are reversible in that for any input value  $x$  there is a unique output value  $y$ ,

15 wherein  $\pm T$  is a value defining the  $y$  shift towards  $y = 0$  of outer sections (I,III) of said quantiser curves  $Q_m$  and is determined (26) by the current psycho-acoustic masking level of said input signal  $x$ , and  $y$  is the watermarked output signal,

20 and wherein the different quantiser curves  $Q_m$  are established according to the current value of  $m$  by different shifts of the complete quantiser curve in  $x$  direction.

In particular, said quantising can be carried out according to  $y = Q_m(x) + \max(-T, \min(T, \alpha(x - Q_m(x))))$ ,

25 wherein  $\alpha$  is a predetermined steepness of the medium section of said quantiser curves  $Q_m$ ,  $\pm T$  is a value defining the  $y$  shift towards  $y = 0$  of the other sections of said quantiser curves  $Q_m$  and is determined by the current psycho-acoustic masking level of said input signal  $x$ , and  $y$  is the water-  
30 marked output signal.

In principle, the inventive regaining method is suited for regaining an original input signal  $x$  which has been processed according to said inventive quantisation method, said  
35 method including the steps:

- re-quantising according to  $y = Q_m(x) + \max(-T, \min(T,$

- $\alpha(x-Q_m(x)))$  the received watermarked signal using said quantiser curves  $Q_m$  in a corresponding manner, wherein different candidate quantiser curves  $Q_m$  are checked by applying different shifts of the complete quantiser curve in  $x$  direction, and wherein said re-quantisation is carried out with a bit depth that is greater than the bit depth that was applied originally;
- selecting that candidate quantiser curve  $Q_m$  which matches best in the frequency domain;
  - 10 - based on the current  $Q_m$  so determined, removing the corresponding current watermark  $m$  from signal  $y$  so as to provide said regained signal  $x$ .

Advantageous additional embodiments of the invention are  
15 disclosed in the respective dependent claims.

### Drawings

- 20 Exemplary embodiments of the invention are described with reference to the accompanying drawings, which show in:
- Fig. 1 example of a reversible QIM quantiser curve for with embedding power constraint;
  - Fig. 2 signal flow of an embedder according to the invention;
  - 25 Fig. 3 overmarking performance of known phase-based audio WM;
  - Fig. 4 overmarking performance according to the invention (no attack).

30

### Exemplary embodiments

- Reversible QIM watermarking with embedding power constraint*
- 35 The invention extends QIM in order:
- to make the mapping performed at the embedder to be re-

versible at the decoder and

- to allow to take a power constraint into account when embedding a watermark.

The related characteristic curve of the quantiser has to

5 fulfil the following two constraints:

- the difference between the input and output value at any position shall not be greater than  $T$  (the embedding power constraint),

- the characteristic curve shall be reversible, that is for  
10 any input value  $x$  there shall be one unique output value  $y$ .

An example of a characteristic curve for one of the quantisers for the inventive reversible QIM processing with embedding power constraint is shown in Fig. 1 with output  $y$  ver-

15 sus input  $x$ . The curve can be divided into three linear segments I, II, III marked at the top of the figure. In segments I and III the output is shifted by the amount of  $T$  towards the reference value, i.e. towards  $y = \text{zero}$ , resulting in  $y_1 = x+T$  and  $y_3 = x-T$ . The shift cannot be higher because  
20 of the power constraint. In segment II a linear curve is used with a gradient of  $\alpha$ , resulting in  $y_2 = \alpha x$  and transition points  $P_1 = (T/(1-\alpha), \alpha T/(1-\alpha))$  and  $P_2 = -P_1$ . I.e., the choice of  $\alpha$  determines the transition points  $P_1$  and  $P_2$  between the three segments: the greater  $\alpha$ , the larger will be  
25 the range which is covered by segment II.

The computation of this example characteristic curve is defined for scalar input values by

$$y = Q_m(x) + \max(-T, \min(T, \alpha(x - Q_m(x)))) ,$$

30 where  $m$  represents the watermark message and  $Q_m$  denotes the different curves of quantisers used for embedding message  $m$ , e.g. one quantiser curve for '0' bits of  $m$  and a different quantiser curve for '1' bits.

The value of  $\alpha$  is fixed in an application, and the choice of  
35  $\alpha$  is a trade-off: if  $\alpha$  is near '1', the robustness of the embedded watermark is likely to be inferior than for lower

values of  $\alpha$ , because the average shift towards the reference value is lower than possible. On the other hand, the higher the value of  $\alpha$  the better is it possible to reverse the characteristic curve of the embedder in noisy conditions.

- 5 The value of  $T$  is adapted to the current psycho-acoustic masking level of the input signal.

The characteristic curve in Fig. 1 has been designed to maximise the average shift of input values towards the reference value. The different quantiser curves  $Q_m$  are established according to the current value of  $m$  by different shifts  $s_{xm}$  of the complete quantiser curve in  $x$  direction. Other characteristic curves are possible as well, as long as they fulfil the aforementioned two constraints.

10

15 *Embedding in MDCT domain*

In order to design a full or near reversible audio watermarking system, it is required to utilise filter banks with perfect reconstruction properties. Furthermore, it is highly advantageous in such application if the filter bank coefficients (e.g. MDCT frequency bins) are mutually independent: that means it is desired that any modification of one coefficient (in the embedding process) does only affect exactly the same coefficient at the decoder side (assuming perfect synchronisation of signal segments used for analysis). Any interference with other (nearby) coefficients shall be avoided. One example filter bank with these properties is the MDCT.

20

25

A corresponding example embodiment of an inventive embedder is illustrated in Fig. 2. The upper signal path is used for determining an additive watermark signal, which can be determined likewise from the watermarked signal, and includes an MDCT step or stage 21, a 2-frames combiner step/stage 22, an embedder 23 that carries out the above-described inventive quantising, in which the (current) value of  $T$  is controlled by a psycho-acoustic analyser 26 receiving its input from the output of step/stage 22, a 2-frames spread step/

30

35

stage 24, an inverse MDCT step/stage 25, and a combiner that adds the output of IMDCT step/stage 25 with the input signal of MDCT step/stage 21.

5 *Definition of a pseudo-complex spectrum*

The inventive quantising processing can be carried out in time domain, but preferably the signal processing takes place in frequency domain, i.e. the input signal is fed into an MDCT analysis block and the output watermark signal is produced via an inverse MDCT. Instead of MDCT/IMDCT, any other suitable time-to-frequency domain/frequency-to-time domain transforms can be used, which must allow perfect (i.e. bit-exact) reconstruction of the time domain signal. According to the invention, two consecutive MDCT frames are interpreted as real and imaginary part of one complex spectrum. Strictly mathematically, this interpretation is wrong. However, it allows to define an angular spectrum for the purpose of embedding a watermark. The actual watermark embedding corresponds to the processings described in WO 2007/031423 A1, WO 2006/128769 A2 or WO 2007/031423 A1. For inserting watermark information, only the angles (i.e. the phases) of the pseudo-complex spectrum are modified according to the constraints provided by a psycho-acoustic analysis of the input signal.

25 The above definition of a pseudo-complex spectrum in MDCT domain has some advantages, compared to a real angular spectrum in DFT domain as used in WO 2007/031423 A1, WO 2006/128769 A2 or WO 2007/031423 A1:

- 30 - Because of the orthogonal properties of the MDCT filter bank, all MDCT coefficients are fully independent from each other, and in turn all complex coefficients of the angular spectrum interpretation are independent as well. As motivated above, this is a precondition for reversible watermarking.
- 35 - Because only the angles of the pseudo-complex spectrum are modified for embedding the watermark, and because

only the amplitudes are required for the psycho-acoustic analysis, the results of the psycho-acoustic analysis both for the original input signal and for the water-marked signal are perfectly identical. Again, this is re-  
5 quired for reversibility of the embedding process.

#### *Embedding process*

The embedding of the watermark message  $m$  is performed according to the inventive reversible QIM with embedding power  
10 constraint as described in connection with Fig. 1. The psycho-acoustic analysis of the original signal is used in order to derive maximum modifications of the angles or phases of individual coefficients of the pseudo-complex spectrum. These maximum values constitute the constraint  $T$  used in the  
15 characteristic curve from section *Reversible QIM watermarking with embedding power constraint*.

The input values  $x$  to the embedding curve from that section are the angles of the pseudo-complex spectrum, and the output values  $y$  are used to derive the angles of the additive  
20 watermark-only signal (in MDCT domain)  $y-x$ . The reference angles are derived from a pseudo-noise sequence according to the principles described in WO 2007/031423 A1, WO 2006/128769 A2 or WO 2007/031423 A1. The amplitudes of the complex values defined by two consecutive MDCT spectra are not  
25 modified by the watermark embedder.

The new angles (according to  $y-x$  as explained in the previous paragraph), together with the amplitudes of the complex interpretation, are again split into two real-valued, consecutive MDCT spectra. The resulting stream of MDCT spectra  
30 is fed into the inverse MDCT filter bank 25 in order to produce the additive watermark signal.

#### *Reversibility*

The watermark process is reversible because all analysis  
35 steps that are applied in order to derive the additive watermark signal are invariant to the embedding of the water-

mark. That means, the same additive watermark signal can be derived from the original signal as well as from the watermarked signal. There are, however, two preconditions to this property:

- 5    - The watermarked signal shall not be altered significantly. Any major attack or signal modification will impact the reproducibility of the computation of the watermark signal.
- The detection of the watermark message to be removed has  
10   to be without error. Any detection error will result in the reversion of the wrong watermark modifications. Together with the above condition this means that the watermark processing shall have 100% error free detection results for no or minor attacks.
- 15   In practice, the watermark embedding process typically will not be 100% reversible if the watermarked output signal of the embedder is quantised to integer values. If, for example, the watermarked signal is quantised to 16 bit integer values, the output signal of a watermark remover will suffer  
20   from the quantisation noise of this 16 bit quantiser as compared to the original PCM samples.

#### *Overmarking performance of a practical system*

The above example system has been built and used to determine overmarking performance figures. The term 'overmarking'  
25   means that a sequence of embedding and removal of watermarks has been applied to one original audio signal.

Typically, the quality of the signal degrades according to the number of consecutive overmarkings. Fig. 3 shows an example of the performance of the phase-based watermarking according to WO 2007/031423 A1, WO 2006/128769 A2 or WO 2007/031423 A1. The performance metric is the objective difference grade ODG (a lower ODG value indicates worse signal quality; ODG is described in the ITV Recommendation BS.1387  
30   (PEAQ)), which estimates the subjective difference between  
35   the original audio signal and the watermarked signal after

several overmarking steps. It ranges from 0 = non-noticeable distortion to 3 = annoying and 4 = very annoying. It is clearly visible that the quality of the watermarked signal decreases considerably after a major number of overmarkings.

5

For comparison, Fig. 4 shows the corresponding overmarking performance for the inventive processing for the same input signal using the embodiment described in Fig. 2 (no attack, which means that the watermarked signal has not been modified). The subjective quality of the watermarked signal stays essentially constant even after 100 overmarking steps. The noise-like fluctuation of the ODG for each overmarking step is produced by the fact that for each overmarking a different embedding key (i.e. reference sequence) has been applied, which leads to different subjective qualities of the watermarked signals.

*Fully reversible (bit-exact) audio watermarking*

In a special embodiment, the above principles can also be applied in order to provide a full removal of the watermark, leading with high probability to the bit-exact original input PCM samples of the embedder. For this purpose, in a system as depicted in Fig. 2 at the output of adder 27, the output signal of the embedder is quantised with different candidate quantiser curves like at embedding side but with a bit depth (e.g. 24 bit per sample) that is consistently higher than the bit depth of the original embedder-side input PCM samples (e.g. 16 bit per sample). The actual QM curve is determined in MDCT domain as described above.

Based on the current  $Q_m$  so determined, the corresponding current watermark message  $m$  is removed from signal  $y$  so as to provide the regained signal  $x$ . As explained above, the removal of the watermark will lead to PCM samples that suffer from the quantisation noise from the quantisation of the watermarked signal. With the processing described, this quantisation noise will only affect some LSBs of the higher

35

bit depth output signal of the watermark remover. Therefore this output signal can in turn be quantised to the original precision of the input PCM samples (16 bit per sample in the example above). This will remove the impairment by the quantisation noise and recover the original PCM samples.

The invention can be used for applications like:

- content tracking and forensics in professional workflows including audience measurement;
- 10 - intelligent DRM (digital rights management) where marks and associated rights can be modified by exchanging the watermark;
- reversible degradation of the content;
- for video watermarking.

15

The inventive processing can also be used in connection with spread spectrum based watermarking techniques.

Claims

1. Method for quantisation index modulation for watermarking an input signal  $x$ , wherein different quantiser curves  $Q_m$  are used for quantising said input signal  $x$  and a current characteristic of said quantiser curve is controlled by the current content of a watermark message  $m$ , **characterised** in that in said quantising the difference between input value and output value at any position is not greater than  $T$ , and that said quantising curves  $Q_m$  are reversible in that for any input value  $x$  there is a unique output value  $y$ , wherein  $\pm T$  is a value defining the  $y$  shift towards  $y = 0$  of outer sections (I,III) of said quantiser curves  $Q_m$  and is determined (26) by the current psycho-acoustic masking level of said input signal  $x$ , and  $y$  is the watermarked output signal, and wherein the different quantiser curves  $Q_m$  are established according to the current value of  $m$  by different shifts of the complete quantiser curve in  $x$  direction.
2. Apparatus for quantisation index modulation for watermarking an input signal  $x$ , wherein different quantiser curves  $Q_m$  are used for quantising said input signal  $x$  and a current characteristic of said quantiser curve is controlled by the current content of a watermark message  $m$ , said apparatus including:
- a psycho-acoustic masking level calculator (26);
  - an embedder (23) which carries out said quantising in which the difference between input value and output value at any position is not greater than  $T$ , and wherein said quantising curves  $Q_m$  are reversible in that for any input value  $x$  there is a unique output value  $y$ , wherein  $\pm T$  is a value defining the  $y$  shift towards  $y = 0$  of outer sections (I,III) of said quantiser curves  $Q_m$  and is determined (26) by the current psycho-acoustic masking

level of said input signal  $x$ , and  $y$  is the watermarked output signal,

and wherein the different quantiser curves  $Q_m$  are established according to the current value of  $m$  by different shifts of the complete quantiser curve in  $x$  direction.

3. Method according to claim 1, or apparatus according to claim 2, wherein said quantising is carried out (23) according to  $y = Q_m(x) + \max(-T, \min(T, \alpha(x - Q_m(x))))$ ,  
10 wherein  $\alpha$  is a predetermined steepness of the medium section (II) of said quantiser curves  $Q_m$ ,  $\pm T$  is a value defining the  $y$  shift towards  $y = 0$  of the other sections (I, III) of said quantiser curves  $Q_m$  and is determined (26) by the current psycho-acoustic masking level of said  
15 input signal  $x$ , and  $y$  is the watermarked output signal.

4. Method according to claim 1 or 3, or apparatus according to claim 2 or 3, wherein said quantising (23) is carried out in frequency domain.

20

5. Method according to the method of claim 4, wherein prior to said quantisation (23) said input signal  $x$  passes through a time-to-frequency transform (21) and a combining (22) of every successive frame pair, of which one  
25 frame is treated as representing a real part of one current frame and the other frame is treated as representing an imaginary part of that current frame, and wherein the quantised (23) input signal passes through a spreading (24) of every successive frame pair, of which one frame  
30 is treated as representing a real part of one current frame and the other frame is treated as representing an imaginary part of that current frame, and a frequency-to-time transform (25), so as to form said watermarked output signal  $y$ ,  
35 or apparatus according to the apparatus of claim 4, comprising:

- means (21,22) being arranged prior to said embedder (23) and being adapted for time-to-frequency transform and frame pair combining, wherein of every successive frame pair one frame is treated as representing a real part of one current frame and the other frame is treated as representing an imaginary part of that current frame,
  - means (24,25) being arranged following said embedder (23) and being adapted for spreading every successive frame pair of which one frame is treated as representing a real part of one current frame and the other frame is treated as representing an imaginary part of that current frame, and for frequency-to-time transform, so as to form said watermarked output signal  $y$ .
6. Method according to the method of claim 5, or apparatus according to the apparatus of claim 5, wherein said time-to-frequency transform is an MDCT and said frequency-to-time transform is an IMDCT.
7. Method according to the method of one of claims 1 and 3 to 6, or apparatus according to the apparatus of one of claims 2 to 6, wherein said output signal  $y$  controls phase modifications of said input signal  $x$ .
8. Method according to the method of one of claims 1 and 3 to 7, or apparatus according to the apparatus of one of claims 2 to 7, wherein said input signal  $x$  is an audio signal.
9. Method for regaining an original input signal  $x$  which has been processed according to the method of one of claims 3 to 8, said method including the steps:
- re-quantising according to  $y = Q_m(x) + \max(-T, \min(T, \alpha(x - Q_m(x))))$  the received watermarked signal using said quantiser curves  $Q_m$  in a corresponding manner, wherein different candidate quantiser curves  $Q_m$  are checked by

applying different shifts of the complete quantiser curve in x direction, and wherein said re-quantisation is carried out with a bit depth that is greater than the bit depth that was applied originally;

- 5    - selecting that candidate quantiser curve  $Q_m$  which matches best in the frequency domain;
- based on the current  $Q_m$  so determined, removing the corresponding current watermark  $m$  from signal  $y$  so as to provide said regained signal  $x$ .

10

10. Digital audio or video signal that is encoded according to the method of one of claims 1 and 3 to 8.

11. Storage medium, for example an optical disc, that contains or stores, or has recorded on it, a digital audio  
15       or video signal according to claim 10.

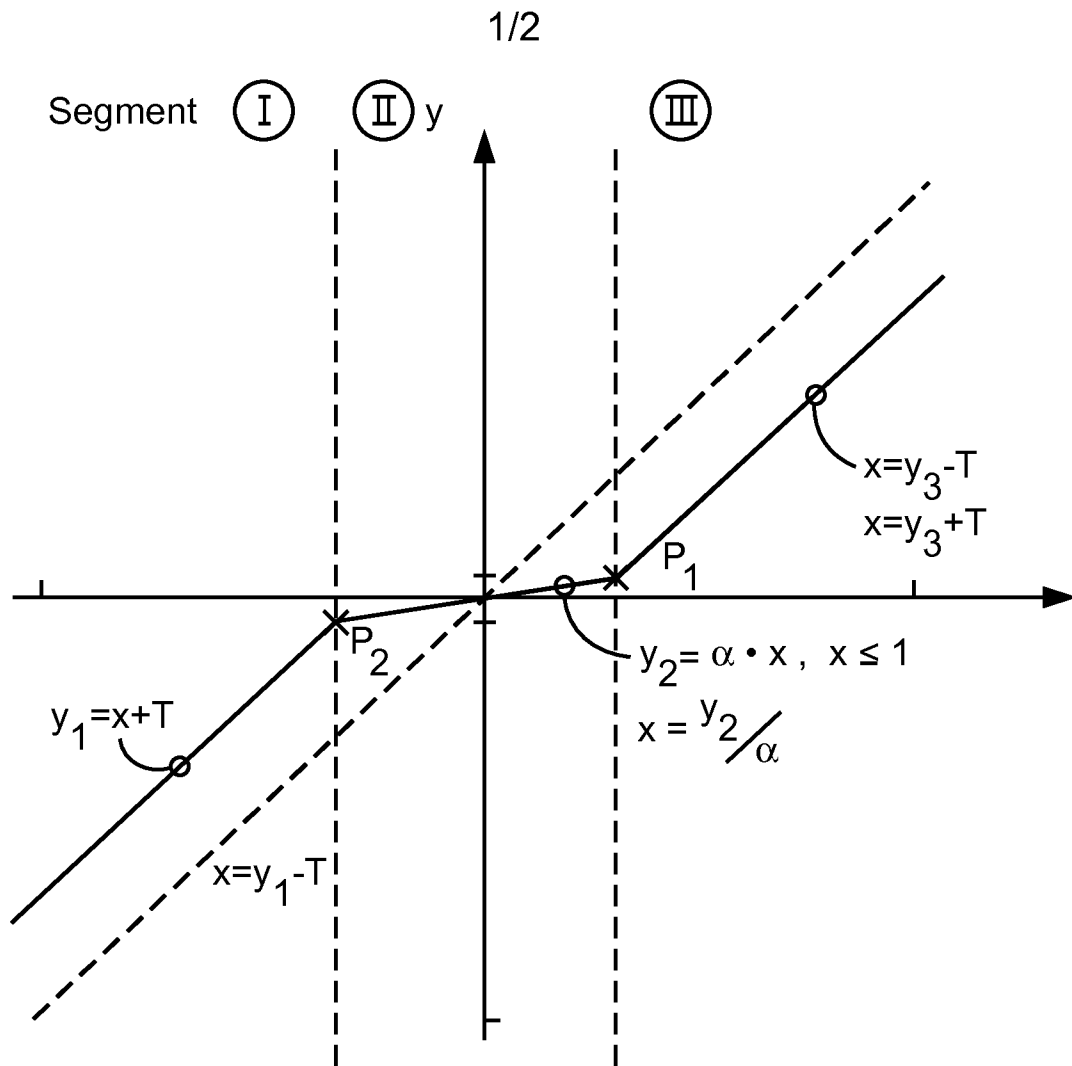


Fig. 1

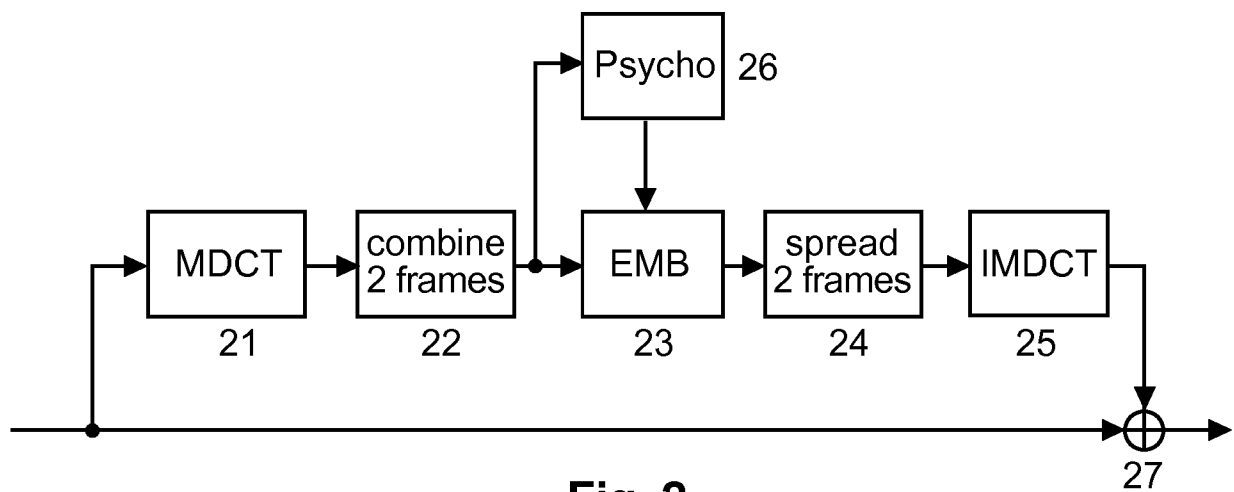
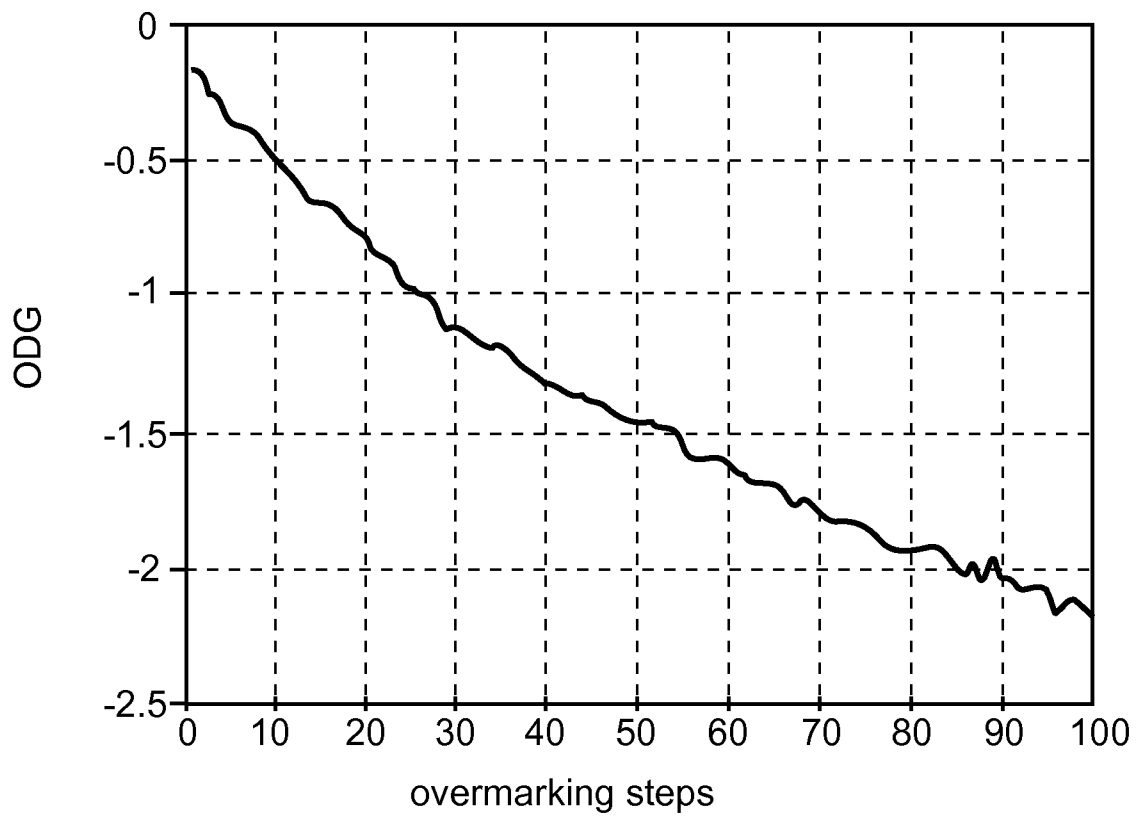
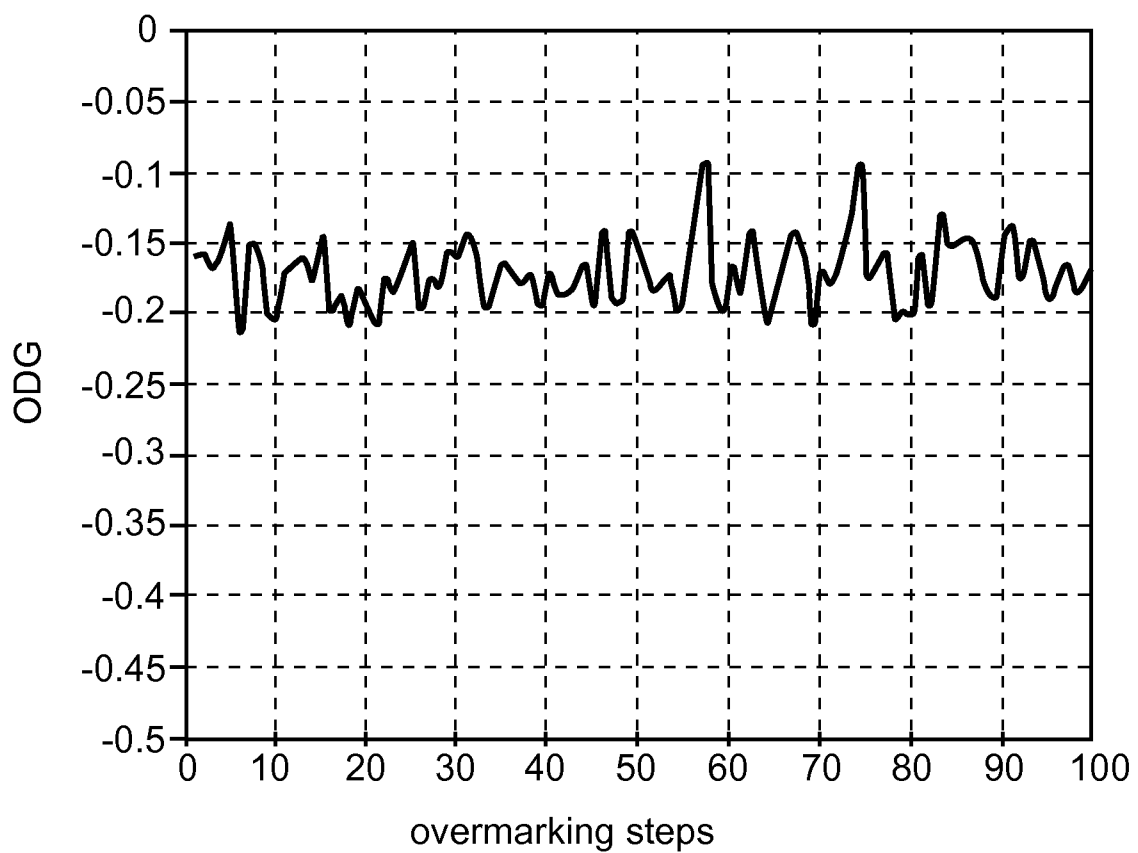


Fig. 2

2/2

**Fig. 3****Fig. 4**

# INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2012/062194

## A. CLASSIFICATION OF SUBJECT MATTER

INV. G10L19/00

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                           | Relevant to claim No. |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | DELPHA C ET AL: "An Efficient Low Bit-Rate Information Embedding Costa Based Scheme using a Perceptual Model", 2007 IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING 15-20 APRIL 2007 HONOLULU, HI, USA, IEEE, PISCATAWAY, NJ, USA, 15 April 2007 (2007-04-15), pages II-189, XP031463148, ISBN: 978-1-4244-0727-9 paragraph [0003] | 10,11                 |
| A         | -----<br>-/--                                                                                                                                                                                                                                                                                                                                                | 1,2,9                 |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

23 July 2012

Date of mailing of the international search report

31/07/2012

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040,  
Fax: (+31-70) 340-3016

Authorized officer

Krembel, Luc

## INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2012/062194

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                               | Relevant to claim No. |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | QIAO LI ET AL: "Using Perceptual Models to Improve Fidelity and Provide Resistance to Valumetric Scaling for Quantization Index Modulation Watermarking", IEEE TRANSACTIONS ON INFORMATION FORENSICS AND SECURITY, IEEE, PISCATAWAY, NJ, US, vol. 2, no. 2, 1 June 2007 (2007-06-01), pages 127-139, XP011181486, ISSN: 1556-6013, DOI: 10.1109/TIFS.2007.897266 | 10,11                 |
| A         | paragraphs [0III], [00IV]<br>figure 7                                                                                                                                                                                                                                                                                                                            | 1,2,9                 |
| X         | -----<br>B. CHEN, G.W. WORNELL: "Quantization Index Modulation: A Class of Provably Good Methods for Digital Watermarking and Information Embedding", IEEE TRANSACTION ON INFORMATION THEORY, vol. 47, no. 4, May 2001 (2001-05), pages 1423-1443, XP011027937, cited in the application                                                                         | 10,11                 |
| A         | paragraph [IV.A]<br>-----                                                                                                                                                                                                                                                                                                                                        | 1,2,9                 |