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(54) **FLEXIBLE AND SCALABLE COMBINED INNOVATION CODEBOOK FOR USE IN CELP CODER AND DECODER**

FLEXIBLES UND SKALIERBARES CODEBUCH MIT KOMBINIERTEN INNOVATIONEN ZUR VERWENDUNG IN EINEM CELP-KODIERGERÄT UND -DEKODIERGERÄT

LIVRE DE CODES D'INNOVATION COMBINÉ FLEXIBLE ET ÉVOLUTIF À UTILISER DANS UN CODEUR ET DÉCODEUR CELP

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Description

FIELD

[0001] The present disclosure relates to combined innovation codebook devices and corresponding methods for use in a Code-Excited Linear Prediction (CELP) coder and decoder.

BACKGROUND

[0002] The CELP model is widely used to encode sound signals, for example speech, at low bit rates. In CELP, the sound signal is modelled as an excitation processed through a time-varying synthesis filter. Although the time-varying synthesis filter may take many forms, a linear recursive all-pole filter is often used. The inverse of this time-varying synthesis filter, which is thus a linear all-zero non-recursive filter, is called "Short-Term Prediction" (STP) filter since it comprises coefficients calculated in such a manner as to minimize a prediction error between a sample $s[i]$ of the sound signal and a weighted sum of previous samples $s[i\text{-}1]$, $s[i\text{-}2]$, .., $s[i\text{-}m]$ of the sound signal, where m is the order of the filter. Another denomination frequently used for the STP filter is "Linear Prediction" (LP) filter.

[0003] If a residual of the prediction error from the LP filter is applied as the input of the time-varying synthesis filter with proper initial state, the output of the synthesis filter is the original sound signal, such as speech. At low bit rates, it is not possible to transmit an exact prediction error residual. Accordingly, the prediction error residual is encoded to form an approximation referred to as the excitation. In traditional CELP coders, the excitation is encoded as the sum of two contributions; the first contribution is produced from a so-called adaptive codebook and the second contribution is produced from a so-called innovation or fixed codebook. The adaptive codebook is essentially a block of samples from the past excitation with proper gain. The innovation or fixed codebook is populated with codevectors having the task of encoding the prediction error residual from the LP filter and adaptive codebook.

[0004] The innovation or fixed codebook can be designed using many structures and constraints. However, in modern speech coding systems, the Algebraic Code-Excited Linear Prediction (ACELP) model is often used. ACELP is well known to those of ordinary skill in the art of speech coding and, accordingly, will not be described in detail in the present specification. In summary, the codevectors in an ACELP innovation codebook each contain few non-zero pulses which can be seen as belonging to different interleaved tracks of pulse positions. The number of tracks and non-zero pulses per track usually depend on the bit rate of the ACELP innovation codebook. The task of an ACELP coder is to search the pulse positions and signs to minimize an error criterion. In ACELP, this search is performed using an analysis-by-synthesis procedure in which the error criterion is calculated not in the excitation domain but rather in the synthesis domain, i.e. after a given ACELP codevector has been filtered through the time-varying synthesis filter. Efficient ACELP search algorithms have been proposed to allow fast search even with very large ACELP innovation codebooks.

[0005] YANG ET AL.: "Transform-Based CELP Vocoders with Low-Delay Low-Complexity and Variable-Rate Features", INSTITUTE OF ELECTRONICS, INFORMATION AND COMMUNICATION ENGINEERS (IEICE) TRANSACTIONS ON INFORMATION AND SYSTEMS, vol. E85-D, no. 6, June 2002, pages 1003-1014, discloses an encoder that encodes the excitation signal by an adaptive pitch prediction and DCT quantization of the residual signal.

[0006] Figure 1 is a schematic block diagram showing the main components and the principle of operation of an ACELP decoder 100. Referring to Figure 1 the ACELP decoder 100 receives decoded pitch parameters 101 and decoded ACELP parameters 102. The decoded pitch parameters 101 include a pitch delay applied to the adaptive codebook 103 to produce an adaptive codevector. As indicated hereinabove, the adaptive codebook 103 is essentially a block of samples from the past excitation and the adaptive codevector is found by interpolating the past excitation at the pitch delay using an equation including the past excitation. The decoded pitch parameters also include a pitch gain applied to the adaptive codevector from the adaptive codebook 103 using an amplifier 112 to form the first, adaptive codebook contribution 113. The adaptive codebook 103 and the amplifier 112 form an adaptive codebook structure. The decoded ACELP parameters comprise ACELP innovation-codebook parameters including a codebook index applied to the innovation codebook 104 to output a corresponding innovation codevector. The decoded ACELP parameters also comprise an innovation codebook gain applied to the innovation codevector from the codebook 104 by means of an amplifier 105 to form the second, innovation codebook contribution 114. The innovation codebook 104 and the amplifier 105 form an innovation codebook structure 110. The total excitation 115 is then formed through summation in an adder 106 of the first, adaptive codebook contribution 113 and the second, innovation codebook contribution 114. The total excitation 115 is then processed through a LP synthesis filter 107 to produce a synthesis 111 of the original sound signal, for example speech. The memory of the adaptive codebook 103 is updated for a next frame using the excitation of the current frame (arrow 108); the adaptive codebook 103 then shifts to processing the decoded pitch parameters of the next subframe (arrow 109). Several modifications can be made to the basic CELP model previously described. For example the excitation signal at the input of the synthesis filer can be processed to enhance the signal. Also postprocessing can be applied at the output of the synthesis filter. Further, the gains of the adaptive and algebraic codebooks can be jointly quantized.

[0007] Although very efficient to encode speech at low bit rates, ACELP codebooks may not gain in quality as quickly as other approaches such as transform coding and vector quantization when increasing the ACELP codebook size. When measured in dB/bit/sample, the gain at higher bit rates (e.g. bit rates higher than 16 kbit/s) obtained by using more non-zero pulses per track in an ACELP innovation codebook is not as large as the gain (in dB/bit/sample) of transform coding and vector quantization. This can be seen when considering that ACELP essentially encodes the sound signal as a sum of delayed and scaled impulse responses of the synthesis filter. At lower bit rates (e.g. bit rates lower than 12 kbit/s), the ACELP technique captures quickly the essential components of the excitation. But at higher bit rates, higher granularity and, in particular, a better control over how the additional bits are spent across the different frequency components of the signal are useful.

[0008] Therefore, there is a need for an innovation codebook structure better adapted for use at higher bit rates.

SUMMARY

[0009] More specifically, the present disclosure relates to:

a combined innovation codebook coding method as set forth in claim 13;
a combined innovation codebook decoding method as set forth in claim 22;
a combined innovation codebook coding device as set forth in claim 1;
a CELP coder comprising the above-mentioned combined innovation codebook coding device;
a combined innovation codebook as set forth in claim 11, and
a CELP decoder comprising the above described combined innovation codebook.

[0010] The foregoing and other features of the combined innovation codebook devices and corresponding methods will become more apparent upon reading of the following non-restrictive description of illustrative embodiments thereof, given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] In the appended drawings:

Figure 1 is a schematic block diagram of a CELP decoder comprising adaptive and innovation codebook structures and using, in this non-limitative example, ACELP;

Figure 2 is a schematic block diagram of a CELP decoder comprising a combined innovation codebook formed by a first decoding stage operating in the frequency domain and a second decoding stage operating in the time-domain using, for example, an ACELP innovation codebook;

Figure 3 is a schematic block diagram of a portion of a CELP coder using a combined innovation codebook coding device; and

Figure 4 is a graph showing an example of frequency response for a pre-emphasis filter *F(z),* wherein the dynamics of the pre-emphasis filter are shown as the difference (in dB) between the smallest and largest amplitudes of the frequency response.

DETAILED DESCRIPTION

[0012] Referring to the decoder 200 of Figure 2, a CELP innovation codebook structure, for example the ACELP innovation codebook structure 110 of Figure 1, is modified such that the advantages and coding efficiency of ACELP are retained at lower bit rates while providing better performance and scalability at higher bit rates. Of course, a CELP model other than ACELP could be used.

[0013] More specifically, Figure 2 shows a flexible and scalable "combined innovation codebook" 201 resulting from the modification of the ACELP innovation codebook structure 110 of Figure 1. As illustrated, the combined innovation codebook 201 comprises a combination of two stages: a first decoding stage 202 operating in transform-domain and a second decoding stage 203 using a time-domain ACELP codebook.

[0014] Prior to further describing the decoder 200 of Figure 2, the ACELP coder 300 will be described in part with reference to Figure 3.

Linear Prediction Filtering

[0015] Referring to Figure 3, the ACELP coder 300 comprises a LP filter 301 processing the input sound signal 302 to be coded. The LP filter 301 may present, for example, in the z-transform the following transfer function:

$$A(z)=\sum_{i=0}^{M} a_i z^{-i}$$

where a_i represent the linear prediction coefficients (LP coefficients) with $a_0 = 1$, and M is the number of linear prediction coefficients (order of LP analysis). The LP coefficients a_i are determined in an LP analyzer (not shown) of the ACELP coder 300.

[0016] The LP filter 301 produces at its output a LP residual 303.

Adaptive-Codebook Search

[0017] The LP residual signal 303 from the LP filter 301 is used in an adaptive-codebook search module 304 of the ACELP coder 300 to find an adaptive-codebook contribution 305. The adaptive-codebook search module 304 also produce the pitch parameters 320 transmitted to the decoder 200 (Figure 2), including the pitch delay and the pitch gain. The adaptive codebook search also known as closed-loop pitch search usually includes computation of a so-called target signal and finding the parameters by minimizing the error between the original and synthesis signal in a perceptually weighted domain. Adaptive-codebook search of an ACELP coder is believed to be otherwise well known to those of ordinary skill in the art and, accordingly, will not be further described in the present specification.

[0018] The ACELP coder 300 also comprises a combined innovation codebook coding device including a first coding stage 306 operating in the transform-domain and referred to as pre-quantizer, and a second coding stage 307 operating in the time-domain and using, for example, ACELP. As illustrated in Figure 3 in an illustrative embodiment, the first stage or pre-quantizer 306 comprises a pre-emphasis filter F(z) 308 which emphasizes the low frequencies, a Discrete Cosine Transform (DCT) calculator 309 and an Algebraic Vector Quantizer (AVQ) 310 (which includes an AVQ global gain). The second stage 307 comprises an ACELP innovation-codebook search module 311. It should be noted that the use of DCT and AVQ are examples only; other transforms can be used and other methods to quantize the transform coefficients can also be used.

[0019] As described hereinabove, the pre-quantizer 306 may use, for example, a DCT as frequency representation of the sound signal and an Algebraic Vector Quantizer (AVQ) to quantize and encode the frequency-domain coefficients of the DCT. The pre-quantizer 306 is used more as a pre-conditioning stage rather than a first-stage quantizer, especially at lower bit rates. More specifically, using the pre-quantizer 306, the ACELP innovation-codebook search module 311 (second coding stage 307) is applied to a second excitation residual 312 (Figure 3) with more regular spectral dynamics than a first, adaptive-codebook excitation residual 313. In that sense, the pre-quantizer 306 absorbs the large signal dynamics in time and frequency, due in part to the imperfect work of the adaptive-codebook search, and leaves to the ACELP innovation-codebook search the task to minimize the coding error in the LP weighted domain (in a typical analysis-by-synthesis loop performed at the ACELP coder 300 and well known to those of ordinary skill in the art of speech coding).

Production of the pitch residual signal 313

[0020] The ACELP coder 300 comprises a subtractor 314 for subtracting the adaptive-codebook contribution 305 from the LP residual signal 303 to produce the above-mentioned first, adaptive-codebook excitation residual 313 that is inputted to the pre-quantizer 306. The adaptive codebook excitation residual $r_1[n]$ is given by

$$r_1[n]=r[n]-g_p v[n]$$

where *r[n]* is the LP residual, g_p is the adaptive codebook gain, and $v[n]$ is the adaptive codebook excitation (usually interpolated past excitation).

Pre-quantizing

[0021] Operation of the pre-quantizer 306 will now be described with reference to Figure 3.

Pre-emphasis filtering

[0022] In a given subframe aligned with the subframe of the ACELP innovation-codebook search in the second coding stage 307, the first, adaptive-codebook excitation residual 313 (Figure 3) is pre-emphasized with a pre-emphasis filter *F(z)* 308. Figure 4 shows an example of frequency response of the pre-emphasis filter *F(z)* 308, wherein the dynamics of the pre-emphasis filter are shown as the difference (in dB) between the smallest and largest amplitudes of the frequency response. An example pre-emphasis filter *F(z)* is given by

$$F(z) = 1/(1 - \alpha z^{-1})$$

which corresponds to the difference equation

$$y[n] = x[n] + \alpha\, y[n-1]$$

where *x[n]* is the first, adaptive-codebook excitation residual 313 inputted to the pre-emphasis filter *F(z)* 308, *y*[*n*] is the pre-emphasized, first adaptive-codebook excitation residual, and coefficient α controls a level of pre-emphasis. In this non limitative example, if the value of α is set between 0 and 1, the pre-emphasis filter *F(z)* 308 will have a larger gain in lower frequencies and a lower gain in higher frequencies, which will produce a pre-emphasized, first adaptive-codebook excitation residual *y[n]* with amplified lower frequencies. The pre-emphasis filter *F(z)* 308 applies a spectral tilt to the first, adaptive-codebook excitation residual 313 to enhance lower frequencies of this residual.

DCT Calculation

[0023] A calculator 309 applies, for example, a DCT to the pre-emphasized first, adaptive-codebook excitation residual *y[n]* from the pre-emphasis filter *F(z)* 308 using, for example, a rectangular non-overlapping window. In this non-limitative example, DCT-II is used, which is defined as

$$Y[k] = \sum_{n=0}^{N-1} y[n] \cos\left[\frac{\pi}{N}(n+0.5)k\right]$$

Algebraic Vector Quantizing (AVQ)

[0024] A quantizer, for example the AVQ 310 quantizes and codes the frequency-domain coefficients of the DCT *Y[k]* (DCT-transformed, de-emphasised first adaptive-codebook excitation residual) from the calculator 309. An example of AVQ implementation can be found in US Patent No. 7,106,228. The quantized and coded frequency-domain DCT coefficients 315 from the AVQ 310 are transmitted as pre-quantized parameters to the decoder (Figure 2). For example, the AVQ 310 may produce a global gain and scaled quantized DCT coefficients as pre-quantized parameters.

[0025] Depending on the bit rate, a target signal-to-noise ratio (SNR) for the AVQ 310 (AVQ_SNR (Figure 4)) is set. The higher the bit rate, the higher this SNR is set. The global gain of the AVQ 310 is then set such that only blocks of DCT coefficients with an average amplitude greater than spectral_max - AVQ_SNR will be quantized, where spectrat_max is the maximum amplitude of the frequency response of the pre-emphasis filter F(z) 308. The other non-quantized DCT coefficients are set to 0. In another approach, the number of quantized blocks of DCT coefficients depend on the bit rate budget; for example, the AVQ may encode transform coefficients related to lower frequencies only, depending on the available bit-budget.

Producing excitation residual signal 312

Inverse DCT calculation

[0026] To obtain the excitation residual signal 312 for the second coding stage 307 (ACELP innovation-codebook search in this example; other CELP structure could also be used), the AVQ-quantized DCT coefficients 315 from the AVQ 310 are inverse DCT transformed in calculator 316.

De-emphasis filtering

[0027] Then the inverse DCT transformed coefficients 315 are processed through a de-emphasis filter $1/F(z)$ 317 to obtain a time-domain contribution 318 from the pre-quantizer 306. The de-emphasis filter $1/F(z)$ 317 has the inverse transfer function of the pre-emphasis filter *F(z)* 308. In the non limitative example for the pre-emphasis filter *F(z)* 308 given herein above, the difference equation of the de-emphasis filter $1/F(z) = 1 - \alpha z^{-1}$ is given by:

$$y[n] = x[n] - \alpha\, x[n-1]$$

where, in the case of the de-emphasis filter, *x[n]* is the pre-emphasized quantized excitation residual (from calculator 316), $y[n]$ is the de-emphasized quantized excitation residual (time-domain contribution 318), and coefficient α has been defined hereinabove.

Subtraction to produce the second excitation residual

[0028] Finally, a subtractor 319 subtracts the de-emphasized excitation residual *y[n]* (time-domain contribution 318) from the adaptive-codebook contribution 305 found by means of the adaptive-codebook search in the current subframe to yield the second excitation residual 312.

ACELP innovation-codebook search

[0029] The second excitation residual 312 is encoded by the ACELP innovation-codebook search module 311 in the second coding stage 307. Innovation-codebook search of an ACELP coder are believed to be otherwise well known to those of ordinary skill in the art and, accordingly, will not be further described in the present specification. The ACELP innovation-codebook parameters 333 at the output of the ACELP innovation-codebook search calculator 311 are transmitted as ACELP parameters to the decoder (Figure 2). The encoding parameters 333 comprise an innovation codebook index and an innovation codebook gain.

Operation of the combined innovation codebook 201

[0030] Referring back to the decoder 200 of Figure 2, the first decoding stage of the combined innovation codebook 201, referred to as de-quantizer 202, comprises an AVQ decoder and an inverse DCT calculator 204, and an inverse filter $1/F(z)$ 205, corresponding to filter 317 of the coder 300 of Figure 3. The contribution from the de-quantizer 202 is obtained as follows.

AVQ decoding

[0031] First of all, the transform-domain decoder (204), AVQ in this example, (204) receives decoded pre-quantized coding parameters for example formed by the AVQ-quantized DCT coefficients 315 (which may include the AVQ global gain) from the AVQ 310 of Figure 3. More specifically, the AVQ decoder de-quantizes the decoded pre-quantized coding parameters received by the decoder 200.

Inverse DCT calculating

[0032] The inverse DCT calculator (204) then applies an inverse transform, for example the inverse DCT, to the de-quantized and scaled parameters from the AVQ decoder $Y'[k]$. Inverse DCT-II is used in this non-limitative example, defined as

$$y'[n] = \frac{2}{N}\left\{0.5Y'[0] + \sum_{k=1}^{N-1} Y'[k]\cos\left[\frac{\pi}{N}(n+0.5)k\right]\right\}$$

De-emphasis filtering (1/F(z))

[0033] The AVQ-decoded and inverse DCT-transformed parameters $y'[n]$ from the decoder/calculator 204 are then processed through the de-emphasis filter $1/F(z)$ 205 to produce a first stage innovation excitation contribution 208 from the de-quantizer 202.

ACELP parameters decoding

[0034] Coding in the ACELP innovation-codebook search calculator 311 of Figure 3 (second coding stage 307) may also incorporate a tilt filter (not shown) which can be, but not necessarily controlled by the information from the DCT calculator 309 and the AVQ 310 of the first coding stage 306. In the decoder 200 of Figure 2, decoded ACELP parameters are received by the second decoding stage 203. The decoded ACELP parameter comprises the ACELP innovation-codebook parameters 313 at the output of the ACELP innovation-codebook search calculator 311, which are transmitted to the decoder (Figure 2) and comprise an innovation codebook index and an innovation codebook gain. The second decoding stage of the combined innovation codebook 201 of Figure 2 comprises an ACELP codebook 206 responsive to the innovation codebook index to produce a codevector amplified by the innovation codebook gain using amplifier 207. A second ACELP innovation-codebook excitation contribution 209 is produced at the output of the amplifier 207. This ACELP innovation-codebook excitation contribution 209 is processed through the inverse of the above mentioned tilt filter in case it is incorporated at the coder (not shown), in the same manner as in the de-quantizer 202 in relation of inverse filter $1/F(z)$ 205. The tilt filter being used can be the same as filter $F(z)$ but in general it will be different from $F(z)$.

Addition of excitation contributions

[0035] Finally, the decoder 200 comprises an adder 210 to sum the adaptive codebook contribution 113, the excitation contribution 208 from the de-quantizer 202 and the ACELP innovation-codebook excitation contribution 209 to form a total excitation signal 211.

Svnthesis filtering

[0036] The excitation signal 211 is processed through an LP synthesis filter 212 to recover the sound signal 213.

[0037] Referring to Figure 3, DCT calculator 309 and AVQ 310 of the pre-quantizer 306 concentrates on coding parts of the excitation residual spectrum that exceed a given threshold in dynamics. It does not aim at whitening the second excitation residual 312 for the second coding stage 307 as would be the case in a typical two-stage quantizer. Therefore, at the coder 300, the second excitation residual 312 that is encoded by the second stage 307 (ACELP innovation-codebook search module 311) is an excitation residual with controlled spectral dynamics, with the "excess" spectral dynamics being in a way absorbed by the pre-quantizer 306 in the first coding stage. As the bit rate increases, both the AVQ_SNR (Figure 4) and number of quantized DCT blocks, starting from the DC component, increase in the first stage. In another example, the number of quantized DCT blocks depends on the available bit rate budget.

[0038] However, the higher the bit rate, the more bits are used, in proportion, by the pre-quantizer 306 in the first coding stage, which results in a total coding noise being shaped more and more to follow the spectral envelope of the weighted LP filter.

[0039] Although the present invention has been described in the foregoing description in relation to illustrative embodiments thereof, these embodiments can be modified at will within the scope of the appended claims without departing from the scope of the present invention.

Claims

1. A combined innovation codebook coding device for a CELP sound coder, comprising:

a pre-quantizer of a first, adaptive-codebook excitation residual, the pre-quantizer operating in transform-domain; and

a CELP innovation-codebook module responsive to a second excitation residual produced from the first, adaptive-codebook excitation residual.

2. A combined innovation codebook coding device as defined in claim 1, wherein the first, adaptive-codebook excitation residual is obtained by subtracting an adaptive codebook contribution from an LP residual.

3. A combined innovation codebook coding device as defined in any one of claims 1 and 2, wherein the pre-quantizer comprises a calculator of a transform of the first, adaptive-codebook excitation residual to frequency-domain.

4. A combined innovation codebook coding device as defined in claim 3, wherein the pre-quantizer comprises a quantizer of the transformed, first adaptive-codebook excitation residual.

5. A combined innovation codebook coding device as defined in any one of claims 3 and 4, further comprising a pre-emphasis filter of the first, adaptive-codebook excitation residual prior to calculating the transform of said first adaptive-codebook excitation residual.

6. A combined innovation codebook coding device as defined in claim 5, wherein the pre-emphasis filter emphasizes low frequencies of the first, adaptive-codebook excitation residual.

7. A combined innovation codebook coding device as defined in any one of claims 4 to 6, comprising a calculator of an inverse transform of the quantized and transformed, first adaptive-codebook excitation residual, a de-emphasis filter of the inverse-transformed adaptive-codebook excitation residual to produce a time-domain contribution, and a subtractor of the time-domain contribution from an adaptive-codebook contribution to produce the second excitation residual.

8. A combined innovation codebook coding device as defined in any one of claims 1 to 7, wherein the pre-quantizer quantizes only frequency-domain transform coefficients having an energy exceeding a specified threshold, so that spectral dynamics of the second excitation residual are reduced or maintained within a desired range.

9. A combined innovation codebook coding device as defined in any one of claims 4 to 8, wherein the quantizer encodes transform coefficients related to lower frequencies only, depending on an available bit-budget.

10. A CELP coder comprising the combined innovation codebook coding device as defined in any one of claims 1 to 9.

11. A combined innovation codebook for a CELP sound decoder, comprising:

a de-quantizer of pre-quantized coding parameters into a first innovation excitation contribution, wherein a) the de-quantizer comprises an inverse transform calculator responsive to the coding parameters, b) the de-quantizer comprises a decoder for de-quantizing the pre-quantized coding parameters, c) the inverse transform calculator is responsive to the de-quantized coding parameters, and d) the de-quantizer comprises a de-emphasis filter supplied with the inverse-transformed, de-quantized coding parameters to produce the first innovation excitation contribution; and
a CELP innovation-codebook structure responsive to CELP innovation-codebook parameters to produce a second innovation excitation contribution.

12. A CELP decoder comprising the combined innovation codebook as defined in claim 11.

13. A combined innovation codebook coding method for a CELP sound coder, comprising:

pre-quantizing a first, adaptive-codebook excitation residual, the pre-quantizing being performed in transform-domain; and
searching a CELP innovation-codebook in response to a second excitation residual produced from the first, adaptive-codebook excitation residual.

14. A combined innovation codebook coding method as defined in claim 13, comprising obtaining the first, adaptive-codebook excitation residual by subtracting an adaptive codebook contribution from an LP residual.

15. A combined innovation codebook coding method as defined in any one of claims 13 and 14, wherein pre-quantizing the first, adaptive-codebook excitation residual comprises calculating a transform of the first, adaptive-codebook

excitation residual to frequency-domain.

16. A combined innovation codebook coding method as defined in claim 15, wherein pre-quantizing the first, adaptive-codebook excitation residual comprises quantizing the transformed, first adaptive-codebook excitation residual.

17. A combined innovation codebook coding method as defined in any one of claims 15 and 16, further comprising pre-emphasis filtering the first, adaptive-codebook excitation residual prior to calculating the transform of the first adaptive-codebook excitation residual.

18. A combined innovation codebook coding method as defined in claim 17, wherein pre-emphasis filtering comprises emphasizing low frequencies of the first, adaptive-codebook excitation residual.

19. A combined innovation codebook coding method as defined in any one of claims 16 to 18, comprising calculating an inverse transform of the quantized and transformed, first adaptive-codebook excitation residual, de-emphasis filtering the inverse-transformed adaptive-codebook excitation residual to produce a time-domain contribution, and subtracting the time-domain contribution from an adaptive-codebook contribution to produce the second excitation residual.

20. A combined innovation codebook coding method as defined in any one of claims 13 to 19, wherein pre-quantizing the first, adaptive-codebook excitation residual comprises pre-quantizing only frequency-domain transform coefficients having an energy exceeding a specified threshold, so that spectral dynamics of the second excitation residual are reduced or maintained within a desired range.

21. A combined innovation codebook coding method as defined in any one of claims 16 to 20, wherein quantizing the transformed, first adaptive-codebook excitation residual comprises encoding transform coefficients related to lower frequencies only, depending on an available bit-budget.

22. A combined innovation codebook decoding method for a CELP sound decoder, comprising:

de-quantizing pre-quantized coding parameters into a first innovation excitation contribution, wherein a) de-quantizing the pre-quantized coding parameters comprises calculating an inverse transform of the coding parameters, b) de-quantizing the pre-quantized coding parameters comprises decoding the pre-quantized coding parameters to produce de-quantized coding parameters, c) calculating an inverse transform of the coding parameters comprises calculating the inverse transform of the de-quantized coding parameters, and d) the method comprises de-emphasis filtering the inverse-transformed, de-quantized coding parameters to produce the first innovation excitation contribution; and
applying CELP innovation-codebook parameters to a CELP innovation-codebook structure to produce a second innovation excitation contribution.

23. A combined innovation codebook decoding method as defined in claim 22, wherein decoding the pre-quantized coding parameters comprises AVQ decoding said pre-quantized coding parameters.

Patentansprüche

1. Kombinierte Innovationscodebuch-Codierungsvorrichtung für einen CELP-Audiocodierer, die Folgendes umfasst:

einen Vorquantisierer eines ersten, adaptiven Codebuch-Anregungsrests, wobei der Vorquantisierer in einer Transformationsdomain betrieben wird; und
ein CELP-Innovationscodebuchmodul, das auf einen zweiten Anregungsrest, der von dem ersten, adaptiven Codebuch-Anregungsrest erzeugt wird, reagiert.

2. Kombinierte Innovationscodebuch-Codierungsvorrichtung nach Anspruch 1, wobei der erste, adaptive Codebuch-Anregungsrest durch Subtrahieren eines adaptiven Codebuchbeitrags von einem LP-Rest erhalten wird.

3. Kombinierte Innovationscodebuch-Codierungsvorrichtung nach einem der Ansprüche 1 und 2, wobei der Vorquantisierer einen Rechner einer Transformation des ersten, adaptiven Codebuch-Anregungsrests in eine Frequenzdomain umfasst.

4. Kombinierte Innovationscodebuch-Codierungsvorrichtung nach Anspruch 3, wobei der Vorquantisierer einen Quantisierer des transformierten, ersten adaptiven Codebuch-Anregungsrests umfasst.

5. Kombinierte Innovationscodebuch-Codierungsvorrichtung nach einem der Ansprüche 3 und 4, die ferner einen Voremphasefilter des ersten, adaptiven Codebuch-Anregungsrests vor dem Berechnen der Transformation des ersten, adaptiven Codebuch-Anregungsrests umfasst.

6. Kombinierte Innovationscodebuch-Codierungsvorrichtung nach Anspruch 5, wobei der Voremphasefilter niedrige Frequenzen des ersten, adaptiven Codebuch Anregungsrests hervorhebt.

7. Kombinierte Innovationscodebuch-Codierungsvorrichtung nach einem der Ansprüche 4 bis 6, die einen Rechner einer inversen Transformation des quantisierten und transformierten, ersten adaptiven Codebuch-Anregungsrests, einen Deemphasefilter des invers transformierten adaptiven Codebuch-Anregungsrests, um einen Zeitdomain-Beitrag zu erzeugen, und einen Subtrahierer um den Zeitdomain-Beitrag von einem adaptiven Codebuchbeitrag zu subtrahieren, um den zweiten Anregungsrest zu erzeugen, umfasst.

8. Kombinierte Innovationscodebuch-Codierungsvorrichtung nach einem der Ansprüche 1 bis 7, wobei der Vorquantisierer nur Frequenzdomain-Transformationskoeffizienten quantisiert, deren Energie einen festgelegten Schwellenwert übersteigt, so dass die Spektraldynamik des zweiten Anregungsrests innerhalb eines gewünschten Bereichs verringert oder beibehalten wird.

9. Kombinierte Innovationscodebuch-Codierungsvorrichtung nach einem der Ansprüche 4 bis 8, wobei der Quantisierer Transformationskoeffizienten ausschließlich bezüglich niedriger Frequenzen in Abhängigkeit von einem vorhandenen Bit-Budget codiert.

10. CELP-Codierer, der die kombinierte Innovationscodebuch-Codierungsvorrichtung nach einem der Ansprüche 1 bis 9 umfasst.

11. Kombiniertes Innovationscodebuch für einen CELP-Audiodecodierer, das Folgendes umfasst:

einen Dequantisierer von vorquantisierten Codierparametern in einen ersten Innovationsanregungsbeitrag, wobei a) der Dequantisierer einen Rechner für inverse Transformation, der auf die Codierparameter reagiert, umfasst, b) der Dequantisierer einen Decodierer zum Dequantisieren der vorquantisierten Codierparameter umfasst, c) der Rechner für inverse Transformation auf die dequantisierten Codierparameter reagiert, und d) der Dequantisierer ein Deemphasefilter umfasst, das mit den invers transformierten, dequantisierten Codierparametern versorgt wird, um den ersten Innovationsanregungsbeitrag zu erzeugen; und
eine CELP-Innovationscodebuchstruktur, die auf CELP-Innovationscodebuchparameter reagiert, um einen zweiten Innovationsanregungsbeitrag zu erzeugen.

12. CELP-Decodierer, der das kombinierte Innovationscodebuch nach Anspruch 11 umfasst.

13. Verfahren zum Codieren eines kombinierten Innovationscodebuchs für einen CELP-Audiocodierer, das Folgendes umfasst:

Vorquantisieren eines ersten, adaptiven Codebuch-Anregungsrests, wobei das Vorquantisieren in einer Transformationsdomain durchgeführt wird; und
Suchen eines CELP-Innovationscodebuchs in Reaktion auf einen zweiten Anregungsrest, der von dem ersten, adaptiven Codebuch-Anregungsrest erzeugt wird.

14. Verfahren zum Codieren eines kombinierten Innovationscodebuchs nach Anspruch 13, das das Erhalten des ersten, adaptiven Codebuch-Anregungsrests durch Subtrahieren eines adaptiven Codebuchbeitrags von einem LP-Rest umfasst.

15. Verfahren zum Codieren eines kombinierten Innovationscodebuchs nach einem der Ansprüche 13 und 14, wobei das Vorquantisieren des ersten, adaptiven Codebuch-Anregungsrests das Berechnen einer Transformation des ersten, adaptiven Codebuch-Anregungsrests in eine Frequenzdomain umfasst.

16. Verfahren zum Codieren eines kombinierten Innovationscodebuchs nach Anspruch 15, wobei das Vorquantisieren

des ersten, adaptiven Codebuch-Anregungsrests das Quantisieren des transformierten, ersten adaptiven Codebuch-Anregungsrests umfasst.

17. Verfahren zum Codieren eines kombinierten Innovationscodebuchs nach einem der Ansprüche 15 und 16, das ferner das Voremphasefiltern des ersten, adaptiven Codebuch-Anregungsrests vor dem Berechnen der Transformation des ersten adaptiven Codebuch-Anregungsrests umfasst.

18. Verfahren zum Codieren eines kombinierten Innovationscodebuchs nach Anspruch 17, wobei das Voremphasefiltern das Hervorheben niedriger Frequenzen des ersten, adaptiven Codebuch-Anregungsrests umfasst.

19. Verfahren zum Codieren eines kombinierten Innovationscodebuchs nach einem der Ansprüche 16 bis 18, das das Berechnen einer inversen Transformation des quantisierten und transformierten, ersten adaptiven Codebuch-Anregungsrests, Deemphasefiltern des invers transformierten, adaptiven Codebuch-Anregungsrests, um einen Zeitdomain-Beitrag zu erzeugen, und das Subtrahieren des Zeitdomain-Beitrags von einem adaptiven Codebuchbeitrag, um den zweiten Anregungsrest zu erzeugen, umfasst.

20. Verfahren zum Codieren eines kombinierten Innovationscodebuchs nach einem der Ansprüche 13 bis 19, wobei das Vorquantisieren des ersten, adaptiven Codebuch-Anregungsrests das Vorquantisieren ausschließlich von Frequenzdomain-Transformationskoeffizienten umfasst, deren Energie einen festgelegten Schwellenwert übersteigt, so dass die Spektraldynamik des zweiten Anregungsrests innerhalb eines gewünschten Bereichs verringert oder beibehalten wird.

21. Verfahren zum Codieren eines kombinierten Innovationscodebuchs nach einem der Ansprüche 16 bis 20, wobei das Quantisieren des transformierten, ersten adaptiven Codebuch-Anregungsrests ausschließlich das Codieren der Transformationskoeffizienten bezüglich niedriger Frequenzen in Abhängigkeit von einem vorhandenen Bit-Budget umfasst.

22. Verfahren zum Decodieren eines kombinierten Innovationscodebuchs für einen CELP-Audiodecodierer, das Folgendes umfasst:

Dequantisieren von vorquantisierten Codierparametern in einen ersten Innovationsanregungsbeitrag, wobei a) das Dequantisieren der vorquantisierten Codierparameter das Berechnen einer inversen Transformation der Codierparameter umfasst, b) das Dequantisieren der vorquantisierten Codierparameter das Decodieren der vorquantisierten Codierparameter umfasst, um dequantisierte Codierparameter zu erzeugen, c) das Berechnen einer inversen Transformation der Codierparameter das Berechnen der inversen Transformation der dequantisierten Codierparameter umfasst, und d) das Verfahren das Deemphasefiltern der invers transformierten, dequantisierten Codierparameter umfasst, um den ersten Innovationsanregungsbeitrag zu erzeugen; und
Anwenden eines CELP-Innovationscodebuchparameters auf eine CELP-Innovationscodebuchstruktur, um einen zweiten Innovationsanregungsbeitrag zu erzeugen.

23. Verfahren zum Decodieren eines kombinierten Innovationscodebuchs nach Anspruch 22, wobei das Decodieren der vorquantisierten Codierparameter das AVQ-Decodieren der vorquantisierten Codierparameter umfasst.

Revendications

1. Dispositif de codage de livre de codes d’innovation combiné pour codeur audio CELP, comprenant :

un pré-quantificateur d’un premier résidu d’excitation de livre de codes adaptatif, le pré-quantificateur fonctionnant dans le domaine de transformée ; et
un module de livre de codes d’innovation CELP sensible à un second résidu d’excitation produit à partir du premier résidu d’excitation de livre de codes adaptatif.

2. Dispositif de codage de livre de codes d’innovation combiné selon la revendication 1, dans lequel le premier résidu d’excitation de livre de codes adaptatif est obtenu en soustrayant une contribution de livre de codes adaptatif à un résidu LP.

3. Dispositif de codage de livre de codes d’innovation combiné selon l’une quelconque des revendications 1 et 2, dans lequel le pré-quantificateur comprend un calculateur de transformée du premier résidu d'excitation de livre de codes adaptatif dans le domaine fréquentiel.

4. Dispositif de codage de livre de codes d'innovation combiné selon la revendication 3, dans lequel le pré-quantificateur comprend un quantificateur d'une transformée du premier résidu d'excitation de livre de codes adaptatif.

5. Dispositif de codage de livre de codes d'innovation combiné selon l'une quelconque des revendications 3 et 4, comprenant en outre un filtre de pré-accentuation du premier résidu d'excitation de livre de codes adaptatif avant de calculer la transformée dudit premier résidu d'excitation de livre de codes adaptatif.

6. Dispositif de codage de livre de codes d'innovation combiné selon la revendication 5, dans lequel le filtre de pré-accentuation accentue les basses fréquences du premier résidu d'excitation de livre de codes adaptatif.

7. Dispositif de codage de livre de codes d'innovation combiné selon l'une quelconque des revendications 4 à 6, comprenant un calculateur d'une transformée inverse du premier résidu d'excitation de livre de codes adaptatif quantifié et transformé, un filtre de désaccentuation du résidu d'excitation de livre de codes adaptatif soumis à une transformation inverse afin de produire une contribution dans le domaine temporel, et un soustracteur de la contribution dans le domaine temporel à une contribution de livre de codes adaptatif afin de produire le second résidu d'excitation.

8. Dispositif de codage de livre de codes d'innovation combiné selon l'une quelconque des revendications 1 à 7, dans lequel le pré-quantificateur ne quantifie que les coefficients de la transformée dans le domaine de fréquence qui ont une énergie dépassant un seuil spécifié de manière à ce que la dynamique spectrale du second résidu d'excitation soit réduite ou maintenue dans une gamme souhaitée.

9. Dispositif de codage de livre de codes d'innovation combiné selon l'une quelconque des revendications 4 à 8, dans lequel le quantificateur code des coefficients de transformée qui ne dépendent que des basses fréquences en fonction d'un bilan de bits disponible.

10. Codeur CELP comprenant le dispositif de codage de livre de codes d'innovation combiné selon l'une quelconque des revendications 1 à 9.

11. Livre de codes d'innovation combiné pour décodeur audio CELP, comprenant :

un dé-quantificateur de paramètres de codage pré-quantifiés en une première contribution d'excitation d'innovation, dans lequel a) le dé-quantificateur comprend un calculateur de transformée inverse sensible aux paramètres de codage, b) le dé-quantificateur comprend un décodeur destiné à dé-quantifier les paramètres de codage pré-quantifiés, c) le calculateur de transformée inverse est sensible aux paramètres de codage dé-quantifiés, et d) le dé-quantificateur comprend un filtre de désaccentuation auquel sont fournis les paramètres de codage dé-quantifiés soumis à une transformation inverse afin de produire la première contribution d'excitation d'innovation ; et

une structure de livre de codes d'innovation CELP sensible à des paramètres de livre de codes d'innovation CELP afin de produire une seconde contribution d'excitation d'innovation.

12. Décodeur CELP comprenant le livre de codes d'innovation combiné selon la revendication 11.

13. Procédé de codage de livre de codes d'innovation combiné pour codeur audio CELP, comprenant :

la pré-quantification d'un premier résidu d'excitation de livre de codes adaptatif, la pré-quantification étant effectuée dans le domaine de transformée ; et

la recherche d'un livre de codes d'innovation CELP en réponse à un second résidu d'excitation produit à partir du premier résidu d'excitation de livre de codes adaptatif.

14. Procédé de codage de livre de codes d'innovation combiné selon la revendication 13, comprenant l'obtention du premier résidu d'excitation de livre de codes adaptatif en soustrayant une contribution de livre de codes adaptatif à un résidu LP.

15. Procédé de codage de livre de codes à innovation combiné selon l'une quelconque des revendications 13 et 14,

dans lequel la pré-quantification du premier résidu d'excitation de livre de codes adaptatif comprend le calcul d'une transformée du premier résidu d'excitation de livre de codes adaptatif dans le domaine fréquentiel.

16. Procédé de codage de livre de codes d'innovation combiné selon la revendication 15, dans lequel la pré-quantification du premier résidu d'excitation de livre de codes adaptatif comprend la quantification d'une transformée du premier résidu d'excitation de livre de codes adaptatif.

17. Procédé de codage de livre de codes d'innovation combiné selon l'une quelconque des revendications 15 et 16, comprenant en outre un filtrage de pré-accentuation du premier résidu d'excitation de livre de codes adaptatif avant de calculer la transformée du premier résidu d'excitation de livre de codes adaptatif.

18. Procédé de codage de livre de codes d'innovation combiné selon la revendication 17, dans lequel le filtrage de pré-accentuation comprend l'accentuation des basses fréquences du premier résidu d'excitation de livre de codes adaptatif.

19. Procédé de codage de livre de codes d'innovation combiné selon l'une quelconque des revendications 16 à 18, comprenant le calcul d'une transformée inverse du premier résidu d'excitation de livre de codes adaptatif quantifié et transformé, le filtrage de désaccentuation du résidu d'excitation de livre de codes adaptatif soumis à une transformation inverse afin de produire une contribution dans le domaine temporel, et la soustraction de la contribution dans le domaine temporel à une contribution de livre de codes adaptatif afin de produire le second résidu d'excitation.

20. Procédé de codage de livre de codes d'innovation combiné selon l'une quelconque des revendications 13 à 19, dans lequel la pré-quantification du premier résidu d'excitation de livre de codes adaptatif consiste à ne pré-quantifier que les coefficients de la transformée dans le domaine fréquentiel qui ont une énergie dépassant un seuil spécifié, de manière à ce que la dynamique spectrale du second résidu d'excitation soit réduite ou maintenue dans une gamme souhaitée.

21. Procédé de codage de livre de codes d'innovation combiné selon l'une quelconque des revendications 16 à 20, dans lequel la quantification du premier résidu d'excitation de livre de codes adaptatif transformé consiste à coder des coefficients de transformée qui ne sont associés qu'aux basses fréquences en fonction d'un bilan de bits disponible.

22. Procédé de décodage de livre de codes d'innovation combiné pour codeur audio CELP, comprenant :

la dé-quantification de paramètres de codage pré-quantifiés en une première contribution d'excitation d'innovation, dans lequel a) la dé-quantification des paramètres de codage pré-quantifiés consiste à calculer une transformée inverse des paramètres de codage, b) la dé-quantification des paramètres de codage pré-quantifiés consiste à décoder les paramètres de codage pré-quantifiés afin de produire des paramètres de codage dé-quantifiés, c) le calcul d'une transformée inverse des paramètres de codage comprend le calcul de la transformée inverse des paramètres de codage déquantifiés, et d) le procédé comprend le filtrage de désaccentuation des paramètres de codage dé-quantifiés soumis à une transformation inverse afin de produire la première contribution d'excitation d'innovation ; et
l'application de paramètres de livre de codes d'innovation CELP à une structure de livre de codes d'innovation CELP afin de produire une seconde contribution d'excitation d'innovation.

23. Procédé de décodage de livre de codes d'innovation combiné selon la revendication 22, dans lequel le décodage des paramètres de codage pré-quantifiés comprend le décodage AVQ desdits paramètres de codage pré-quantifiés.

Figure 1

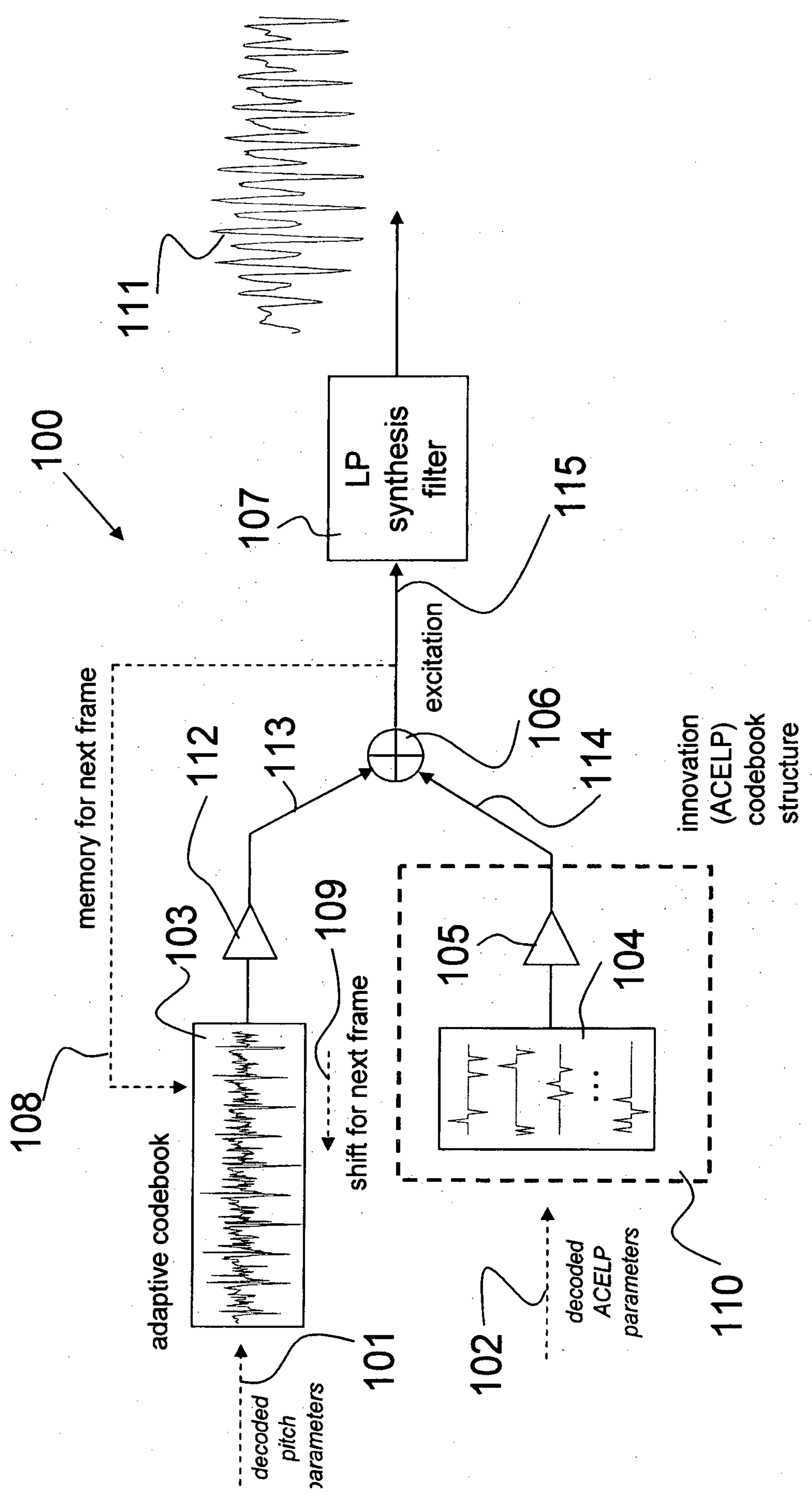

100
111
107
LP synthesis filter
115
excitation
memory for next frame
106
112
113
114
innovation (ACELP) codebook structure
103
109
105
104
108
adaptive codebook
shift for next frame
110
102
decoded ACELP parameters
101
decoded pitch parameters

Figure 2

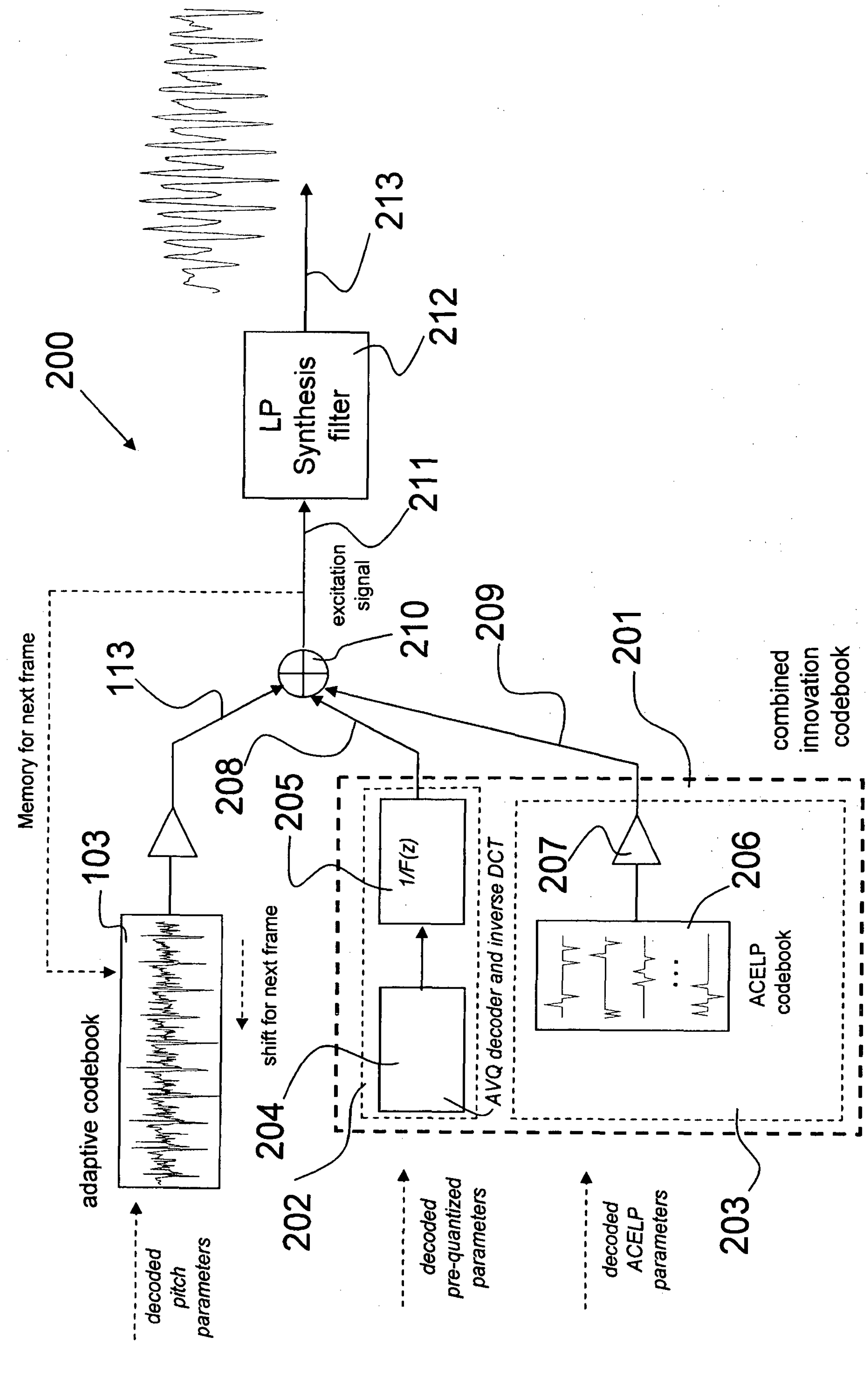
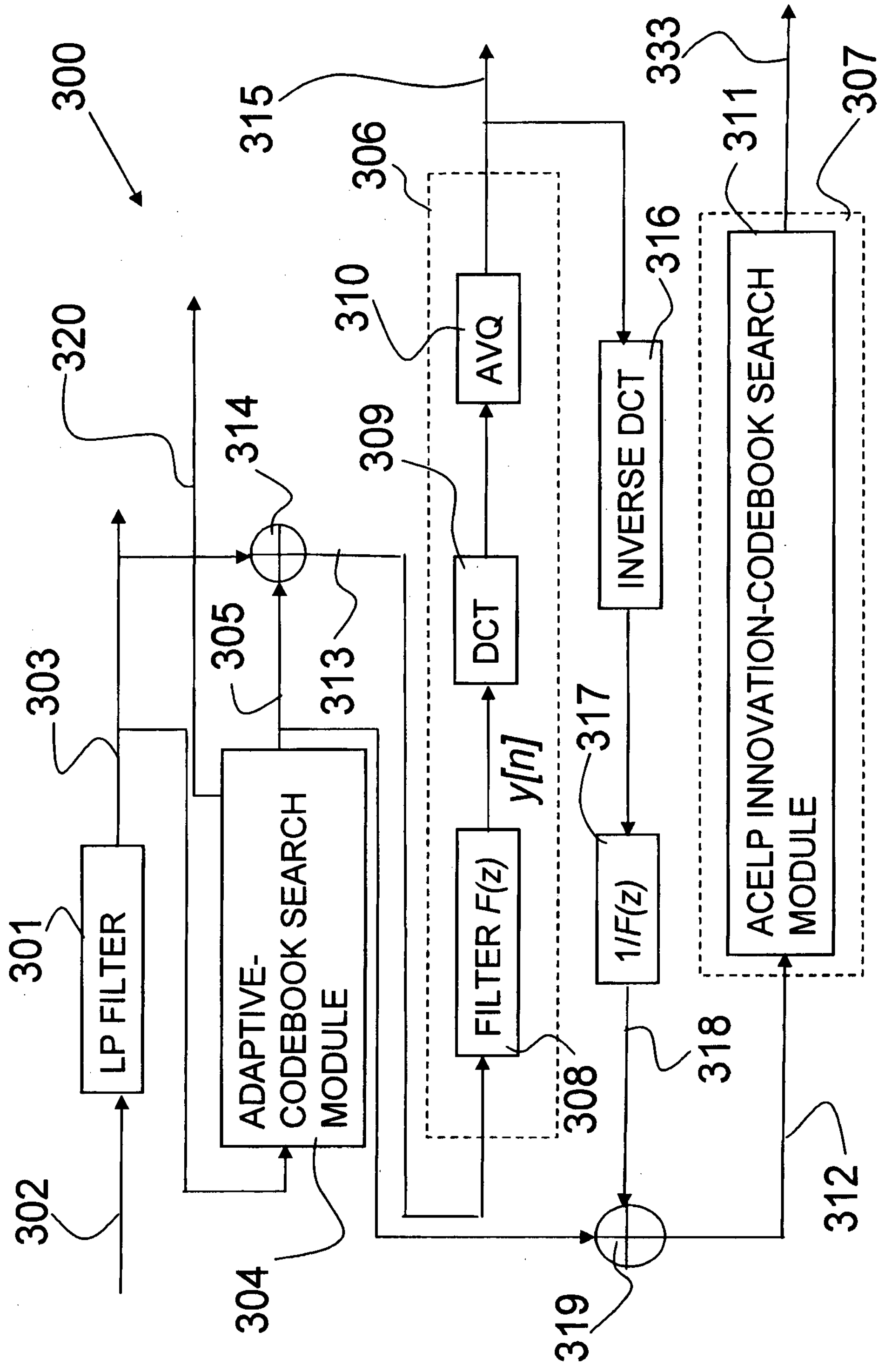

200
LP Synthesis filter
212
213
211
excitation signal
210
209
201
combined innovation codebook
113
103
Memory for next frame
adaptive codebook
shift for next frame
208
205
1/F(z)
204
AVQ decoder and inverse DCT
207
206
ACELP codebook
202
203
decoded pitch parameters
decoded pre-quantized parameters
decoded ACELP parameters

Figure 3


300
301
302
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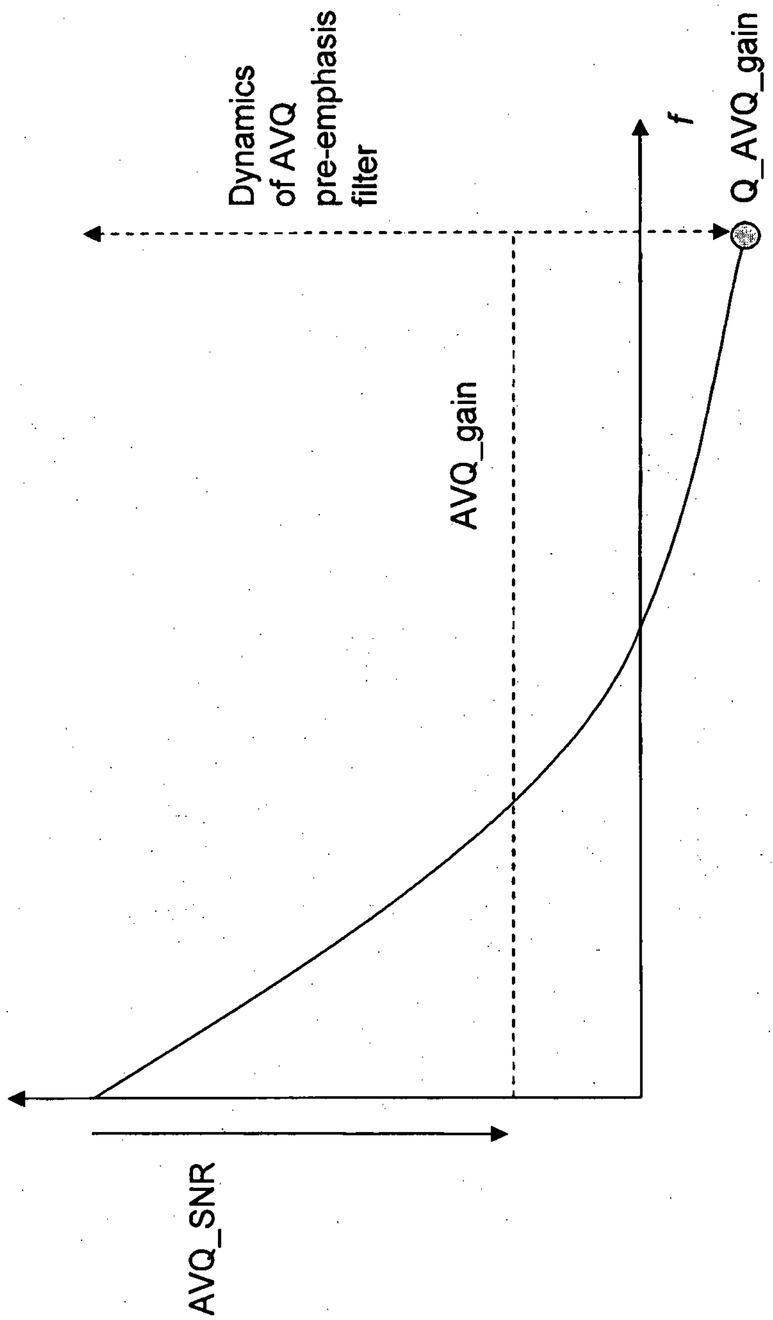
317
318
319
320
333
LP FILTER
ADAPTIVE-CODEBOOK SEARCH MODULE
FILTER F(z)
y[n]
DCT
AVQ
INVERSE DCT
1/F(z)
ACELP INNOVATION-CODEBOOK SEARCH MODULE

Figure 4


Dynamics
of AVQ
pre-emphasis
filter
f
Q_AVQ_gain
AVQ_gain
AVQ_SNR

REFERENCES CITED IN THE DESCRIPTION

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