Claims

1. Audio encoder for encoding a non-speech audio signal (AS) so as to produce therefrom a bitstream (BS), the audio encoder (1) comprising:

a combination (2, 3) of a linear predictive coding filter (2) having a plurality of linear predictive coding coefficients (LC) and a time-frequency converter (3), wherein the combination (2, 3) is configured to filter and to convert a frame (FI) of the audio signal (AS) into a frequency domain in order to output a spectrum (SP) based on the frame (FI) and on the linear predictive coding coefficients (LC);

a low frequency emphasizer (4) configured to calculate a processed spectrum (PS) based on the spectrum (SP), wherein spectral lines (SL) of the processed spectrum (PS) representing a lower frequency than a reference spectral line (RSL) are emphasized; ~~and~~

a control device (5) configured to control the calculation of the processed spectrum (PS) by the low frequency emphasizer (4) depending on the linear predictive coding coefficients (LC) of the linear predictive coding filter (2);

a quantization device (6) configured to produce a quantized spectrum (QS) based on the processed spectrum (PS);

and a bitstream producer (7) configured to embed the quantized spectrum (QS) and the linear predictive coding coefficients (LC) into the bitstream (BS).

2. Audio encoder according to the preceding claim, wherein the frame (FI) of the audio signal (AS) is input to the linear predictive coding filter (2), wherein a filtered frame (FF) is output by the linear predictive coding filter

(2) and wherein the time-frequency converter (3) is configured to estimate the spectrum (SP) based on the filtered frame (FF).

3. Audio encoder according to claim 1, wherein the frame (FI) of the audio signal (AS) is input to the time-frequency converter (3), wherein a converted frame (FC) is output by the time-frequency converter (3) and wherein the linear predictive coding filter (2) is configured to estimate the spectrum (SP) based on the converted frame (FC).

~~4. Audio encoder according to one of the preceding claims, wherein the audio encoder (1) comprises a quantization device (6) configured to produce a quantized spectrum (QS) based on the processed spectrum (PS) and a bitstream producer (7) configured to embed the quantized spectrum (QS) and the linear predictive coding coefficients (LC) into the bitstream (BS).~~

~~5.~~4. Audio encoder according to one of the preceding claims, wherein the control device (5) comprises a spectral analyzer (8) configured to estimate a spectral representation (SR) of the linear predictive coding coefficients (LC), a minimum-maximum analyzer (9) configured to estimate a minimum (MI) of the spectral representation (SR) and a maximum (MA) of the spectral representation (SR) below a further reference spectral line and an emphasis factor calculator (10, 11) configured to calculate spectral line emphasis factors (SEF) for calculating the spectral lines (SL) of the processed spectrum (PS) representing a lower frequency than the reference spectral line (RSL) based on the minimum (MI) and on the maximum (MA), wherein the spectral lines (SL) of the processed spectrum (PS) are emphasized by applying the spectral line emphasis factors (SEF) to spectral lines of the spectrum of the filtered frame.

~~6.~~5. Audio encoder according to the preceding claim, wherein the emphasis factor calculator (10, 11) is configured in such way that the spectral line emphasis factors (SEF) increase in a direction from the reference

spectral line (RSL) to the spectral line (SL) representing the lowest frequency of the spectrum (SP).

~~7.~~6. Audio encoder according to claim ~~5~~4 or ~~6~~5, wherein the emphasis factor calculator (10, 11) comprises a first stage (10) configured to calculate a basis emphasis factor (BEF) according to a first formula $\gamma = (\alpha \cdot min / max)^{\beta}$, wherein α is a first preset value, with $\alpha > 1$, β is a second preset value, with $0 < \beta \leq 1$, min is the minimum (MI) of the of the spectral representation (SR), max is the maximum (MA) of the spectral representation (SR) and γ is the basis emphasis factor (BEF), and wherein the emphasis factor calculator (10, 11) comprises a second stage (11) configured to calculate spectral line emphasis factors (SEF) according to a second formula $\varepsilon_i = \gamma^{i'-i}$, wherein i' is a number of the spectral lines (SL) to be emphasized, i is an index of the respective spectral line (SL), the index increases with the frequencies of the spectral lines, with i = 0 to i'-1, γ is the basis emphasis factor (BEF) and ε_i is the spectral line emphasis factor (SEF) with index i.

~~8.~~7. Audio encoder according to the preceding claim, wherein the first preset value is smaller than 42 and larger than 22, in particular smaller than 38 and larger than 26, more particular smaller 34 and larger than 30.

~~9.~~8. Audio encoder according to claim ~~7~~6 or ~~8~~7, wherein the second preset value is determined according to the formula $\beta = 1 / (\theta \cdot i')$, wherein i' is the number of the spectral lines being emphasized, θ is a factor between 3 and 5, in particular between 3,4 and 4,6, more particular between 3,8 and 4,2.

~~10.~~9. Audio encoder according to one of the preceding claims, wherein the reference spectral line (RSL) represents a frequency between 600 Hz and 1000Hz, in particular between 700 Hz and 900 Hz, more particular between 750 Hz and 850 Hz.

~~11.~~10. Audio encoder according to one of the claims ~~54~~ to ~~109~~, wherein the further reference spectral line represents the same or a higher frequency than the reference spectral line (RSL).

~~12.~~11. Audio encoder according to one of the preceding claims, wherein the control device (5) is configured in such way that the spectral lines (SL) of the processed spectrum (PS) representing a lower frequency than the reference spectral line (RSL) are emphasized only if the maximum (MA) is less than the minimum (MI) multiplied with the first preset value.

~~13.~~12. Audio decoder for decoding a bitstream (BS) based on a non-speech audio signal (AS) so as to produce from the bitstream (BS) a non-speech audio output signal (OS), in particular for decoding a bitstream (BS) produced by an audio encoder (1) according to claims 1 to 12, the bitstream (BS) containing quantized spectrums (QS) and a plurality of linear predictive coding coefficients (LC), the audio decoder (12) comprising:

a bitstream receiver (13) configured to extract the quantized spectrum (QS) and the linear predictive coding coefficients (LC) from the bitstream (BS);

a de-quantization device (14) configured to produce a de-quantized spectrum (DQ) based on the quantized spectrum (QS);

a low frequency de-emphasizer (15) configured to calculate a reverse processed spectrum (RS) based on the de-quantized spectrum (DQ), wherein spectral lines (SLD) of the reverse processed spectrum (RS) representing a lower frequency than a reference spectral line (RSLD) are deemphasized; and

a control device (16) configured to control the calculation of the reverse

processed spectrum (RS) by the low frequency de-emphasizer (15) depending on the linear predictive coding coefficients (LC) contained in the bitstream (BS).

~~14.~~13. Audio decoder according to the preceding claim, wherein the audio decoder (12) comprises combination (17, 18) of a frequency-time converter (17) and an inverse linear predictive coding filter (18) receiving the plurality of linear predictive coding coefficients (LC) contained in the bitstream (BS), wherein the combination (17, 18) is configured to inverse-filter and to convert the reverse processed spectrum (RS) into a time domain in order to output the output signal (OS) based on the reverse processed spectrum (RS) and on the linear predictive coding coefficients (LC).

~~15.~~14. Audio decoder according to the preceding claim, wherein the frequency-time converter (17) is configured to estimate a time signal (TS) based on the reverse processed spectrum (RS) and wherein the inverse linear predictive coding filter (18) is configured to output the output signal (OS) based on the time signal (TS).

~~16.~~15. Audio decoder according to claim ~~14~~13, wherein the inverse linear predictive coding filter (18) is configured to estimate an inverse filtered signal (IFS) based on the reverse processed spectrum (RS) and wherein the frequency-time converter (17) is configured to output the output signal (OS) based on the inverse filtered signal (IFS).

~~17.~~16. Audio decoder according to one of the claims ~~13~~12 to ~~16~~15, wherein the control device (16) comprises a spectral analyzer (19) configured to estimate a spectral representation (SR) of the linear predictive coding coefficients (LC), a minimum-maximum analyzer (20) configured to estimate a minimum (MI) of the spectral representation (SR) and a maximum (MA) of the spectral representation (SR) below a further reference spectral line

and a de-emphasis factor calculator (21, 22) configured to calculate spectral line de-emphasis factors (SDF) for calculating the spectral lines (SLD) of the reverse processed spectrum (RS) representing a lower frequency than the reference spectral line (RSLD) based on the minimum (MI) and on the maximum (MA), wherein the spectral lines (SLD) of the reverse processed spectrum (RS) are de-emphasized by applying the spectral line de-emphasis factors (SDF) to spectral lines of the spectrum of the de-quantized spectrum (DQ).

~~18.~~17. Audio decoder according to the preceding claim, wherein the de-emphasis factor calculator (21, 22) is configured in such way that the spectral line de-emphasis factors (SDF) decrease in a direction from the reference spectral line (RSLD) to the spectral line (SL) representing the lowest frequency of the reverse process spectrum (RS).

~~19.~~18. Audio decoder according to claim ~~17~~16 or ~~18~~17, wherein the de-emphasis factor calculator (21, 22) comprises a first stage (21) configured to calculate a basis de-emphasis factor (BDF) according to a first formula $\delta = (\alpha \cdot min / max)^{-\beta}$, wherein α is a first preset value, with $\alpha > 1$, β is a second preset value, with $0 < \beta \leq 1$, min is the minimum (MI) of the of the spectral representation (SR), max is the maximum (MA) of the spectral representation (SR) and δ is the basis de-emphasis factor (BDF), and wherein the de-emphasis factor calculator (21, 22) comprises a second stage (22) configured to calculate spectral line de-emphasis factors (SDF) according to a second formula $\zeta_i = \delta^{i'-i}$, wherein i' is a number of the spectral lines (SLD) to be de-emphasized, i is an index of the respective spectral line (SLD), the index increases with the frequencies of the spectral lines, with i = 0 to i'-1, δ is the basis de-emphasis factor (BDF) and ζ_i is the spectral line de-emphasis factor (SDF) with index i.

~~20.~~19. Audio decoder according to the preceding claim, wherein the first preset value is smaller than 42 and larger than 22, in particular smaller than 38 and larger than 26, more particular smaller 34 and larger than 30.

~~21.~~20. Audio decoder according to claim ~~19~~ 18 or ~~20~~19, wherein the second preset value is determined according to the formula $\beta = 1 / (\theta \cdot i')$, wherein i' is the number of the spectral lines (SLD) being de-emphasized, θ is a factor between 3 and 5, in particular between 3,4 and 4,6, more particular between 3,8 and 4,2.

~~22.~~21. Audio decoder according to one of the claims ~~13~~ 12 to ~~21~~20, wherein the reference spectral line (RSLD) represents a frequency between 600 Hz and 1000Hz, in particular between 700 Hz and 900 Hz, more particular between 750 Hz and 850 Hz.

~~23.~~22. Audio decoder according to one of the claims ~~17~~ 16 to ~~22~~21, wherein the further reference spectral line represents the same or a higher frequency than the reference spectral line (RSLD).

~~24.~~23. Audio decoder according to one of the claims ~~13~~ 12 to ~~23~~22, wherein the control device (16) is configured in such way that the spectral lines (SLD) of the reverse processed spectrum (RS) representing a lower frequency than the reference spectral line (RSLD) are de-emphasized only if the maximum (MA) is less than the minimum (MI) multiplied with the first preset value.

~~25.~~24. A system comprising a decoder (1) and an encoder (12), wherein the encoder (1) is designed according to one of the claims 1 to ~~12~~ 11 and/or the decoder is designed according to one of the claims ~~13~~ 12 to ~~24~~23.

~~26.~~25. Method for encoding a non-speech audio signal (AS) so as to produce therefrom a bitstream (BS), the method comprising the steps:

filtering with a linear predictive coding filter (2) having a plurality of linear predictive coding coefficients (LC) and converting a frame (FI) of the audio signal (AS) into a frequency domain in order to output a spectrum (SP) based on the frame (FI) and on the linear predictive coding coefficients (LC);

calculating a processed spectrum (PS) based on the spectrum (SP), wherein spectral lines (SL) of the processed spectrum (PS) representing a lower frequency than a reference spectral line (RSL) are emphasized; and

controlling the calculation of the processed spectrum (PS) depending on the linear predictive coding coefficients (LC) of the linear predictive coding filter (2);

producing a quantized spectrum (QS) based on the processed spectrum (PS); and

embedding the quantized spectrum (QS) and the linear predictive coding coefficients (LC) into the bitstream (BS).

~~27.~~26. Method for decoding a bitstream (BS) based on a non-speech audio signal (AS) so as to produce from the bitstream (BS) a non-speech audio output signal (OS), in particular for decoding a bitstream (BS) produced by the method according to the preceding claim, the bitstream (BS) containing quantized spectrums (QS) and a plurality of linear predictive coding coefficients (LC), the method comprising the steps:

extracting the quantized spectrum (QS) and the linear predictive coding coefficients (LC) from the bitstream (BS);

producing a de-quantized spectrum (DQ) based on the quantized spectrum (QS);

calculating a reverse processed spectrum (RS) based on the de-quantized spectrum (DQ), wherein spectral lines (SLD) of the reverse processed spectrum (RS) representing a lower frequency than a reference spectral line (RSLD) are deemphasized; and

controlling the calculation of the reverse processed spectrum (RS) depending on the linear predictive coding coefficients (LC) contained in the bitstream (BS).

~~28.~~27. Computer program for performing, when running on a computer or a processor, the method of claim ~~26~~ 25 or ~~27~~26.

Claims

1. Audio encoder for encoding a non-speech audio signal so as to produce therefrom a bitstream, the audio encoder comprising:

a combination of a linear predictive coding filter having a plurality of linear predictive coding coefficients and a time-frequency converter, wherein the combination is configured to filter and to convert a frame of the audio signal into a frequency domain in order to output a spectrum based on the frame and on the linear predictive coding coefficients ;

a low frequency emphasizer configured to calculate a processed spectrum based on the spectrum, wherein spectral lines of the processed spectrum representing a lower frequency than a reference spectral line are emphasized;

a control device configured to control the calculation of the processed spectrum by the low frequency emphasizer depending on the linear predictive coding coefficients of the linear predictive coding filter;

a quantization device configured to produce a quantized spectrum based on the processed spectrum;

and a bitstream producer configured to embed the quantized spectrum and the linear predictive coding coefficients into the bitstream.

2. Audio encoder according to the preceding claim, wherein the frame of the audio signal is input to the linear predictive coding filter, wherein a filtered frame is output by the linear predictive coding filter

and wherein the time-frequency converter is configured to estimate the spectrum based on the filtered frame.

3. Audio encoder according to claim 1, wherein the frame of the audio signal is input to the time-frequency converter, wherein a converted frame is output by the time-frequency converter and wherein the linear predictive coding filter is configured to estimate the spectrum based on the converted frame.

4. Audio encoder according to one of the preceding claims, wherein the control device comprises a spectral analyzer configured to estimate a spectral representation of the linear predictive coding coefficients, a minimum-maximum analyzer configured to estimate a minimum of the spectral representation and a maximum of the spectral representation below a further reference spectral line and an emphasis factor calculator configured to calculate spectral line emphasis factors for calculating the spectral lines of the processed spectrum representing a lower frequency than the reference spectral line based on the minimum and on the maximum, wherein the spectral lines of the processed spectrum are emphasized by applying the spectral line emphasis factors to spectral lines of the spectrum of the filtered frame.

5. Audio encoder according to the preceding claim, wherein the emphasis factor calculator is configured in such way that the spectral line emphasis factors increase in a direction from the reference

spectral line to the spectral line representing the lowest frequency of the spectrum.

6. Audio encoder according to claim 4 or 5, wherein the emphasis factor calculator comprises a first stage configured to calculate a basis emphasis factor according to a first formula $\gamma = (\alpha \cdot \min / \max)^{\beta}$, wherein α is a first preset value, with $\alpha > 1$, β is a second preset value, with $0 < \beta \leq 1$, min is the minimum of the of the spectral representation, max is the maximum of the spectral representation and γ is the basis emphasis factor, and wherein the emphasis factor calculator comprises a second stage configured to calculate spectral line emphasis factors according to a second formula $\varepsilon_i = \gamma^{i'-i}$, wherein i' is a number of the spectral lines to be emphasized, i is an index of the respective spectral line, the index increases with the frequencies of the spectral lines, with i = 0 to i'-1, γ is the basis emphasis factor and ε_i is the spectral line emphasis factor with index i.

7. Audio encoder according to the preceding claim, wherein the first preset value is smaller than 42 and larger than 22, in particular smaller than 38 and larger than 26, more particular smaller 34 and larger than 30.

8. Audio encoder according to claim 6 or 7, wherein the second preset value is determined according to the formula $\beta = 1 / (\theta \cdot i')$, wherein i' is the number of the spectral lines being emphasized, θ is a factor between 3 and 5, in particular between 3,4 and 4,6, more particular between 3,8 and 4,2.

9. Audio encoder according to one of the preceding claims, wherein the reference spectral line represents a frequency between 600 Hz and 1000Hz, in particular between 700 Hz and 900 Hz, more particular between 750 Hz and 850 Hz.

10. Audio encoder according to one of the claims 4 to 9, wherein the further reference spectral line represents the same or a higher frequency than the reference spectral line.

11. Audio encoder according to one of the preceding claims, wherein the control device is configured in such way that the spectral lines of the processed spectrum representing a lower frequency than the reference spectral line are emphasized only if the maximum is less than the minimum multiplied with the first preset value.

12. Audio decoder for decoding a bitstream based on a non-speech audio signal so as to produce from the bitstream a non-speech audio output signal, in particular for decoding a bitstream produced by an audio encoder according to claims 1 to 12, the bitstream containing quantized spectrums and a plurality of linear predictive coding coefficients, the audio decoder comprising:

a bitstream receiver configured to extract the quantized spectrum and the linear predictive coding coefficients from the bitstream;

a de-quantization device configured to produce a de-quantized spectrum based on the quantized spectrum;

a low frequency de-emphasizer configured to calculate a reverse processed spectrum based on the de-quantized spectrum, wherein spectral lines of the reverse processed spectrum representing a lower frequency than a reference spectral line are deemphasized; and

a control device configured to control the calculation of the reverse

processed spectrum by the low frequency de-emphasizer depending on the linear predictive coding coefficients contained in the bitstream.

13. Audio decoder according to the preceding claim, wherein the audio decoder comprises combination of a frequency-time converter and an inverse linear predictive coding filter receiving the plurality of linear predictive coding coefficients contained in the bitstream, wherein the combination is configured to inverse-filter and to convert the reverse processed spectrum into a time domain in order to output the output signal based on the reverse processed spectrum and on the linear predictive coding coefficients.

14. Audio decoder according to the preceding claim, wherein the frequency-time converter is configured to estimate a time signal based on the reverse processed spectrum and wherein the inverse linear predictive coding filter is configured to output the output signal based on the time signal.

15. Audio decoder according to claim 13, wherein the inverse linear predictive coding filter is configured to estimate an inverse filtered signal based on the reverse processed spectrum and wherein the frequency-time converter is configured to output the output signal based on the inverse filtered signal.

16. Audio decoder according to one of the claims 12 to 15, wherein the control device comprises a spectral analyzer configured to estimate a spectral representation of the linear predictive coding coefficients, a minimum-maximum analyzer configured to estimate a minimum of the spectral representation and a maximum of the spectral representation below a further reference spectral line

and a de-emphasis factor calculator configured to calculate spectral line de-emphasis factors for calculating the spectral lines of the reverse processed spectrum representing a lower frequency than the reference spectral line based on the minimum and on the maximum, wherein the spectral lines of the reverse processed spectrum are de-emphasized by applying the spectral line de-emphasis factors to spectral lines of the spectrum of the de-quantized spectrum.

17. Audio decoder according to the preceding claim, wherein the de-emphasis factor calculator is configured in such way that the spectral line de-emphasis factors decrease in a direction from the reference spectral line to the spectral line representing the lowest frequency of the reverse process spectrum.

18. Audio decoder according to claim 16 or 17, wherein the de-emphasis factor calculator comprises a first stage configured to calculate a basis de-emphasis factor according to a first formula $\delta = (\alpha \cdot min / max)^{-\beta}$, wherein α is a first preset value, with $\alpha > 1$, β is a second preset value, with $0 < \beta \leq 1$, min is the minimum of the of the spectral representation, max is the maximum of the spectral representation and δ is the basis de-emphasis factor , and wherein the de-emphasis factor calculator comprises a second stage configured to calculate spectral line de-emphasis factors according to a second formula $\zeta_i = \delta^{i'-i}$, wherein i' is a number of the spectral lines to be de-emphasized, i is an index of the respective spectral line, the index increases with the frequencies of the spectral lines, with i = 0 to i'-1, δ is the basis de-emphasis factor and ζ_i is the spectral line de-emphasis factor with index i.

19. Audio decoder according to the preceding claim, wherein the first preset value is smaller than 42 and larger than 22, in particular smaller than 38 and larger than 26, more particular smaller 34 and larger than 30.

20. Audio decoder according to claim 18 or 19, wherein the second preset value is determined according to the formula $\beta = 1 / (\theta \cdot i')$, wherein i' is the number of the spectral lines being de-emphasized, θ is a factor between 3 and 5, in particular between 3,4 and 4,6, more particular between 3,8 and 4,2.

21. Audio decoder according to one of the claims 12 to 20, wherein the reference spectral line represents a frequency between 600 Hz and 1000Hz, in particular between 700 Hz and 900 Hz, more particular between 750 Hz and 850 Hz.

22. Audio decoder according to one of the claims 16 to 21, wherein the further reference spectral line represents the same or a higher frequency than the reference spectral line.

23. Audio decoder according to one of the claims 12 to 22, wherein the control device is configured in such way that the spectral lines of the reverse processed spectrum representing a lower frequency than the reference spectral line are de-emphasized only if the maximum is less than the minimum multiplied with the first preset value.

24. A system comprising a decoder and an encoder, wherein the encoder is designed according to one of the claims 1 to 11 and/or the decoder is designed according to one of the claims 12 to 23.

25. Method for encoding a non-speech audio signal so as to produce therefrom a bitstream, the method comprising the steps:

filtering with a linear predictive coding filter having a plurality of linear predictive coding coefficients and converting a frame of the audio signal into a frequency domain in order to output a spectrum based on the frame and on the linear predictive coding coefficients;

calculating a processed spectrum based on the spectrum, wherein spectral lines of the processed spectrum representing a lower frequency than a reference spectral line are emphasized; and

controlling the calculation of the processed spectrum depending on the linear predictive coding coefficients of the linear predictive coding filter;

producing a quantized spectrum based on the processed spectrum; and

embedding the quantized spectrum and the linear predictive coding coefficients into the bitstream.

26. Method for decoding a bitstream based on a non-speech audio signal so as to produce from the bitstream a non-speech audio output signal, in particular for decoding a bitstream produced by the method according to the preceding claim, the bitstream containing quantized spectrums and a plurality of linear predictive coding coefficients, the method comprising the steps:

extracting the quantized spectrum and the linear predictive coding coefficients from the bitstream;

producing a de-quantized spectrum based on the quantized spectrum;

calculating a reverse processed spectrum based on the de-quantized spectrum, wherein spectral lines of the reverse processed spectrum representing a lower frequency than a reference spectral line are deemphasized; and

controlling the calculation of the reverse processed spectrum depending on the linear predictive coding coefficients contained in the bitstream.

27. Computer program for performing, when running on a computer or a processor, the method of claim 25 or 26.