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(54) **Method of synthesizing comfort noise frames (CNF)**

(57)   A method of synthesizing Comfort Noise Frames for generating background noise frames in a receiver terminal during the periods of silence of an emitter terminal is described, and in virtue of receiving a slot whose first half includes a CNF command and whose other half includes the noise parameterization. The invention develops an algorithm for synthesizing the frames, which includes strategies for randomizing the algebraic indices contained in the frames, pitch gain cancellation, and interpolation of the LSP parameters and of the linear energy of the CNF frame of the current and previous periods.
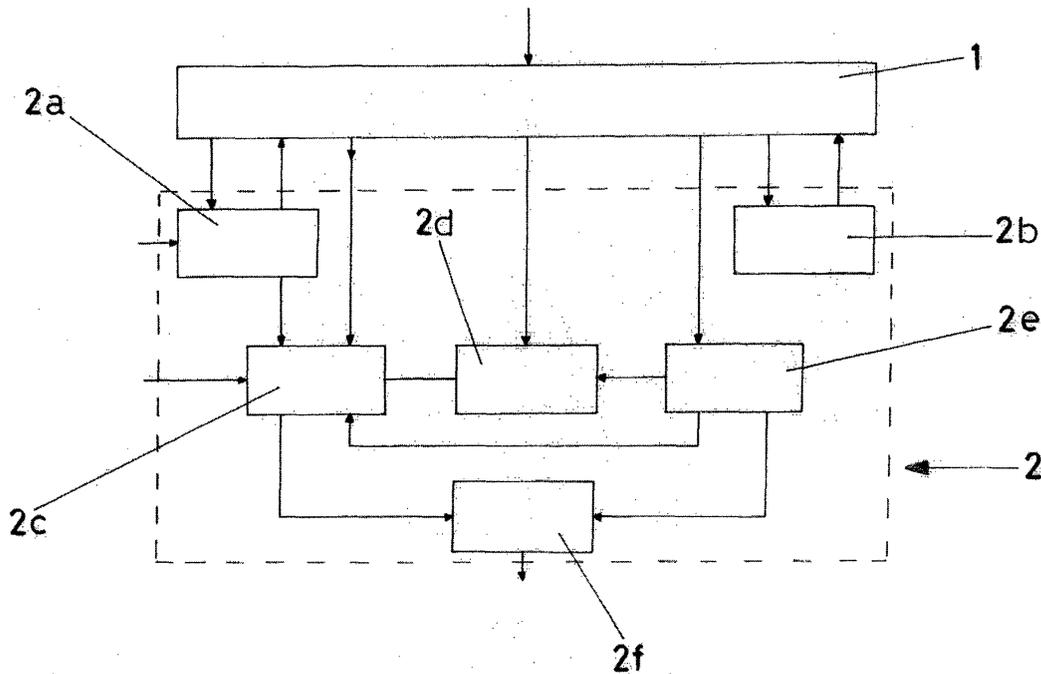
FIG.1

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Description

Object of the Invention

5 **[0001]** The present invention refers to a method of synthesizing Comfort Noise Frames (CNF) that provides essential novel features and significant advantages with respect to the known and used means for the same purposes in the current state of the art.
[0002] More specifically, the invention proposes the development of a method by means of which it is possible to carry out the synthesis of frames capable of being used in a receiver for the purpose of the intermittent transmission
10 from an emitter in TETRA systems, that is to say during the time periods in which said emitter is silent, for the purpose of generating a determined type of noise obtained from said CNF frames.
[0003] The field of application of the invention is comprised within the telecommunications sector in general, and more specifically in the radio transmissions sector.

15 **Background and Summary of the Invention**

[0004] Skilled persons in the art know the features which define the TETRA standard based on the intermittent performance of an emission from a suitable emitting device, whose emission must be received and completed in the corresponding receiver device. Actually, said TETRA system permits, as a functioning option, that while a person
20 speaking from an emitter device remains silent (absence of voice or tones), the emitter device periodically sends a frame, denominated a Comfort Noise Frame (CNF), in which the spectral features of the room noise are parameterized as if it were a normal speech signal, such that by ceasing to emit during alternating time periods, a considerable saving of the terminal feed batteries is achieved, as well as a reduction in the co-channel interferences with the rest of the system users. The sending of this frame is indicated to the receiver by means of the insertion of a CNF command in
25 the first half of a slot, reserving the second half of the slot in order to include the parameterization of the noise.
[0005] The emitter device does not transmit this background noise information during several subsequent frames, whose number is a compromise between the desired update frequency, the danger of disconnecting from the base due to an absence of signal in the uplink, and the desired level of energetic saving and of co-channel interference reduction. In the moment in which the Vocal Activity Detector (VAD) of said emitter device detects the presence of an
30 information signal, it immediately switches to the normal transmission : mode.
[0006] Concerning the receiver device, it must be able to reconstruct the room noise signal as from said periodic frame while the silence lasts in the emitter device. The reconstruction of this signal is carried out as from the reception of a CNF command, applying an algorithm to the received CNF parameters for generating the frame with the information of the received noise, and a synthesis will be carried out in the subsequent frames, being based on a determined
35 algorithm. When a new noise frame is received, it proceeds in the same manner as with the first CNF command, and determined parameters used in the synthesis are updated.
[0007] Different methods and devices are already known by means of which determined techniques of speech analysis-synthesis, their coding and decoding are carried out. In this sense, those currently constituting the most relevant prior art are cited below.
40 **[0008]** International patent number PCT WO 98/48524 discloses methods and apparatuses for generating noise signals as from speech signals, which mentions several comfort noise generation processes as from an LPC (Lineal Predictive Coding) coded speech signal. The disclosed processes make use of statistical processes such as the calculation of the average, or of the exponential average, of the values of the LPC coefficients or of the frame energy, calculated on the current frame and on a series of previous frames.
45 **[0009]** International patent number PCT WO 00/11648 refers to a voice decoder using a Vocal Activity Detector in the noise coding. Said document proposes various methods for generating the speech signal in case of an absence of vocal activity, among which there is a method based on the generation of a random excitation sequence which can be generated in the voice decoder. Other proposed methods are based on the use of information relative to the energy level or to the spectral profile.
50 **[0010]** US patent number 5,809,460 discloses an LPC speech signal decoder, in which background noise is simulated during the periods of silence of the transmission terminal on the basis of a background noise frame containing information about such background noise. The decoder incorporates an interpolation circuit for updating the background noise, the interpolation of the parameters being carried out by means of a buffer memory which stores the parameters of a previous frame.
55 **[0011]** International patent number PCT WO 00/75919 refers to methods and apparatuses for generating comfort noise with the use of noise model parametric statistics, which describes a process for generating comfort noise by means of randomizing determined statistical noise values.
[0012] British patent number GB-2 350 532 refers to the generation of comfort noise during the periods of silence in

a packet switching system, which includes and describes a random selection process of silence samples, mainly applied to telephone communications, and in which when the receiver detects the silence, it generates a random sequence of silence packets which are sent to the receiver as comfort noise.

[0013] International patent number PCT WO 99/63521 refers to a signal breakdown method for voice coding, which codes a signal including the speech and background noise by first breaking down the signal into the components of speech and of noise, and then using a first algorithm of word coding in order to generate code indices for the speech component, and then a second algorithm in order to generate code indices for the noise component. The code indices produced by the algorithms have a similar form as that disclosed in recommendation G. 729.

[0014] The present invention refers to a synthesis method of Comfort Noise Frames (CNF), which includes the development of algorithms capable performing in the receiver block of a TETRA system, and basically consisting of three algorithms, namely:

- Indices randomization
- Pitch gain cancellation, and
- CNF parameters interpolation

[0015] Basically, the first of such algorithms is based on randomizing the algebraic indices contained in the frames by means of a pseudorandom sequence with a specific generator polynomial; the second algorithm takes into consideration the total energy, that is to say the sum of the linear energies of the algebraic code and of the adaptive code or of pitch, as if it were only a question of algebraic code energy, and it thus calculates the resulting gain; lastly, the third algorithm adds to the last mentioned one the interpolation of LSP parameters and of the linear energy of the CNF frame of the current and previous periods, such that in the case that the energy value generated by the CNF frames generator of the emitter is not the same in the four sub-frames forming the frame, an averaging must be performed beforehand in order to carry out the interpolation.

Brief Description of the Drawings

[0016] These and other features and advantages of the invention will become more clearly evident based on the following detailed description of a preferred embodiment, given only as an illustrative and non-limiting example, with reference to the accompanying drawings in which:

Figures 1 and 2 show illustrative graphic representations of blocks of coding and decoding devices, respectively, according to that encompassed by the TETRA standard, and

Figure 3 shows an illustrative diagram of the function performed by the missing frame generation sub-block in the voice decoder control block of the receiver, according to the invention.

Description of a Preferred Embodiment Example

[0017] As has previously been stated, the detailed description of the preferred embodiment of the invention will be carried out with the use of the attached drawings, for the purposes of making a provision for, in the first place and with illustrative purposes, the representations of the conventional technique appearing in figures 1 and 2.

[0018] As can be seen, the block diagram in figure 1 corresponds to a coder structured in the emitter terminal according to the TETRA standard, and includes a vocoder block 1, and a vocoder control block 2, the latter including several sub-blocks among which a sub-block 2a is distinguished for functions in test mode, a sub-block 2b for the reset function of the coder 1, a sub-block 2c for the frame uptake function, a sub-block 2d responsible for the comfort noise function, a sub-block 2e for the speech importance function, and lastly, an enciphering interface sub-block 2f. The blocks affected by the insertion of the comfort noise are, in particular, those identified as control noise function sub-block 2d and speech importance function sub-block 2e. The voice activity detection is carried out in this last sub-block, while the comfort noise function sub-block 2d is responsible for carrying out the calculations of the parameters of the comfort noise to be sent in the CNF slot, on the basis of the parameters given by the vocoder 1.

[0019] Concerning the decoder device according to the TETRA standard, incorporated in the receiver terminal and schematically shown in the drawing in figure 2, it includes a voice decoder control block 3 and a voice decoder block 4. In the control block 3, several sub-blocks are distinguished, such as the enciphering interface sub-block 3a, reset function sub-block 3b of the decoder 4, the missing frame generation sub-block 3c, the missing frame substitution sub-block 3d, and the sub-block 3e for functions in test mode. In this case, the blocks affected by the comfort noise are, particularly, the sub-block 3c corresponding to the missing frame generation, which detects the presence of a CNF slot and carries out the noise frames synthesis, and the missing frame substitution sub-block 3d, with which the frame

provided by the missing frame generation sub-block 3c is simply inserted in the frame fed to said voice decoder 4.

[0020] According to the invention, the proposed method precisely consists of the generation of an algorithm for synthesizing the Comfort Noise Frames (CNF) in the receiver terminal, and for this purpose the previously defined algorithms are developed, specifically an indices randomization algorithm, a pitch gain cancellation algorithm and a CNF parameters interpolation algorithm, which are performed in the receiver terminal in relation to the missing frame generation sub-block 3c, included in block 3 of the voice decoder control as previously stated. This sub-block 3c is responsible for generating the parameters corresponding to the Comfort Noise Frames as from the information received in the CNF frames, and according to that shown in figure 3, which graphically shows the actuation mode of the frames synthesizer, it is precisely in the shaded slots where said synthesizer must act, while in the non-shaded slots, the information received will directly pass to the voice decoder 4. Thus, when a voice slot is received, the parameters of both frames 5 will directly pass to the decoder 4 as the arrows F1 indicate, without any process being carried out on them. However, when it is a CNF slot 6, the information contained in the second speech frame will be seized and will be used to update the parameters of the CNF synthesizer as graphically indicated by means of the intermediate boxes "S" indicative of the synthesis operation.

[0021] It is possible to apply several strategies in the calculation of the frames to be passed to the decoder, according to that commented below.

[0022] In the first place, it is necessary to refer to the indices randomization. Basically, N (reception rate of CNF frames) frames are generated, with the same parameters, in turn equal to those received, except with respect to the random code indices corresponding to each sub-frame, which is randomized.

[0023] This randomization is obtained by means of generating a pseudorandom (PN) sequence of a maximum length (ML) of 16 bits. The generator polynomial is:

$$g(x) = 1 + x^5 + x^{14} + x^{16}$$

[0024] These 16 bits corresponded to the necessary ones in order to represent the algebraic code indices. Since not all the possible binary words are used, a control is included, such that when an invalid word is generated, a predetermined index is taken.

[0025] The following table shows the bits structure of a frame of the TETRA vocoder, with the inclusion of the parameters to be randomized.

Error! Bookmark not defined.Class of parameter	Buffer memory shift	Name of the parameter
Filter	+0 +1 +2	Code index: LSP1 to LSP3 Code index: LSP4 to LSP6 Code index: LSP7 to LSP10
Sub-frame #1	+3 +4 +5 +6 +7	Pitch delay Code index: pulse 4 Code index: pulse 3 Code index: pulse 2 Code index: pulse 1 Global pulse sign Pulse shift Code index: gains
Sub-trame #2	+8 +9 +10 +11 +12	Pitch delay Code index: pulse 4 Code index: pulse 3 Code index: pulse 2 Code index: pulse 1 Global pulse sign Pulse shift Code index: gains
Error! Bookmark not defined. Sub-frama #3	+13 +14 +15 +16 +17	Pitch delay Code index: pulse 4 Code index: pulse 3 Code index: pulse 2 Code index: pulse 1 Global pulse sign Pulse shift Code index: gains
Sub-frame #4	+18 +19 +20 +21 +22	Pitch delay Code index: pulso 4 Code index: pulso 3 Code index: pulso 2 Code index: pulso 1 Global pulse sign Pulse shift Code index: gains

[0026] With respect to the algorithmic strategy related to the pitch gain cancellation, this equation consists of canceling the pitch gain directly in the receiver terminal decoder 4. In this case, the calculation of the logarithmic energies of the algebraic random code Ec and of the adaptive or pitch code Ep is carried out as from the received quantified Rp and Rc values, with the use of the following expressions:

$$Ec = (8/3)Rc + (4/3)Rp - 12$$

$$Ep = (8/3)\ Rp + (4/3)\ Rc - 12$$

which are the inverse of those used to calculate Rp and Rc in function of Ep and Ec.

[0027] Next, the corresponding liner energies are obtained and added together in order to obtain the total energy (doing so directly on the logarithmic magnitude introduces a high error in the estimation of this total frame energy). The pitch energy is cancelled and the total energy is assigned to that of the random code. The logarithmic energy Ec is again calculated, and the code gain gc is obtained by means of the expression (39) in previously mentioned document {1} (p. 23). The gp value is set to zero.

[0028] This obtains totally eliminating the pitch structure and maintaining the frame energy. By directly working with the already decoded gains, the inherent problems of the poor quantification thereof are avoided, obtaining a more exact reconstruction of the energy levels of the Comfort Noise Frame.

[0029] In reference to the interpolation of CNF parameters, it should be observed that despite canceling the pitch gain, there are still problems of sudden energy hops between contiguous CNF periods. In addition to the pitch gain cancellation, carrying out an interpolation between the CNF parameters of the previous and current period may also be considered, through the N frames composing the updating rate of the CNF frame, which gives way to the alternative explained below.

[0030] It consists of carrying out a simple linear interpolation of the LSP parameters and of the frame energy throughout the current CNF period. It is preferable to carry out the interpolation of the linear frame energy rather than that related to the gain gc, since the latter depends on the LSP parameters, through Ef [see the expressions (34) and (39), pp. 22-23 of document {1}: TETRA: Speech codec for full-rate traffic channel; Part 2; TETRA codec. Document ETS 300 395-2. February, 1998], which vary from frame to frame.

[0031] The transmitted LSPs are those denominated as coefficients qi in the cosine domain [see p. 17 of the same previously mentioned document {1}], and the interpolation is carried out on them according to the following expressions:

$$q_i\ (m) = q_{i\ former} + m\Delta q; \qquad for\ m = 1, ..., N$$

$$\Delta q = (q_{i\ new} - q_{i\ former})/N$$

with:

m, the frame number
N, the number of frames in the updating/transmission period of the CNF parameters,
$q_i\ (m)$, the i-th new LSP received, corresponding to the current CNF period,
$q_{i\ former}$/ the i-th former LSP, corresponding to the previous CNF period, and
Δ, the linear interpolation slope.

[0032] The previous interpolation expression can be simplified to:

$$q_i\ (m) = q_i\ (m-1) + \Delta q; \qquad for\ m = 1, ..., N$$

with: $q_i\ (0) = q_{i\ former}$
[0033] Note that $q_i\ (N) = q_{i\ new}$.
[0034] The interpolation of the linear frame energy Et is carried out in a similar manner:

$$Et(m) = Et\ (m-1) + \Delta e; \qquad for\ m=1, ..., N$$

$$\Delta e = (Et_{new} - Et_{former})/N$$

[0035] In order to calculate the gains gc(m) of each frame, the logarithmic energy Ec(m) must be obtained as from Et(m), and apply the expression (39) from the previously mentioned document {1}.

[0036] As will be understood, the calculations can be simplified by directly carrying out the interpolation on the logarithmic energies, which saves the need of calculating the linear logarithm Et(m) in each frame. This would not change

the audible perception of the comfort noise.

[0037] The following table shows the structure of the bits provided by the TETRA decoder, with the inclusion of the parameters upon which an interpolation is carried out.

Error! Bookmark not defined.Class of parameter	Buffer memoria Shift	Name of the parameter
Filter	+0 +1 +2	Code index: LSP1 to LSP3 Code index: LSP4 to LSP6 Code index: LSP7 to LSP10
Sub-frame #1	+3 +4 +5 +6 +7	Pitch delay Code index: pulse 4 Code index: pulse 3 Code index: pulse 2 Code index: pulse 1 Global pulse sign Pulse shift Code index: gains
Sub-trama #2	+8 +9 +10 +11 +12	Pitch delay Code index: pulse 4 Code index: pulse 3 Code index: pulse 2 Code index: pulse 1 Global pulse sign Pulse shift Code index: gains
Sub-frame #3	+13 +14 +15 +16 +17	Pitch delay Code index: pulse 4 Code index: pulse 3 Code index: pulse 2 Code index: pulse 1 Global pulse sign Pulse shift Code index: gains
Sub-frame #4	+18 +19 +20 +21 +22	Pitch delay Code index: pulse 4 Code index: pulse 3 Code index: pulse 2 Code index: pulse 1 Global pulse sign Pulse shift Code index: gains

[0038] Lastly, the averaging of the sub-frames energies should also be mentioned in the sense that the interpolation can be carried out as long as the CNF frames generator has generated the same energy value within each one of the 4 sub-frames forming a frame.

[0039] There is also a possibility that the CNF frames generator assigns a different value to each one of the sub-

frames. In this case, so that the interpolation is effective, a prior averaging of the sub-frames energies must be carried out, that averaged value becoming the representative energy value of the frame.

[0040] As can be understood, the preceding explanation corresponds only to one preferred embodiment of the invention, therefore different variants and modifications are possible without changing the scope of the invention, limited only by the content of the following claims.

Claims

1. A method of synthesizing Comfort Noise Frames (CNF), particularly applicable in combination with a receiver terminal according to the TETRA standard, by means of which an emission sent from an emitter device is received and completed in the corresponding receiver terminal, in virtue of the generation of frames in this last terminal as from a CNF command included in the first half of a slot whose other half includes the noise parameterization, and whose receiver terminal includes a voice decoder control block (3) comprising, among others, a missing frame generation sub-block (3c) and a missing frame substitution sub-block (3d), and a voice decoder block (4),
   characterized in that the method includes synthesizing Comfort Noise Frames with the use of said sub-block (3c) which generates the parameters corresponding to the Comfort Noise Frames as from the information received in the CNF frames, such that when a voice slot (5) is received, both frames pass directly to the decoder (4), while in the case of receiving a CNF slot (6), the information contained in the second speech frame is gathered so as to update the parameters of the CNF synthesizer,
   and **in that** the calculation of the frames to be passed to the decoder (4) is preferably carried out on the basis of strategies such as randomization of the algebraic indices contained in the frames, the pitch gain cancellation for maintaining the frame energy, and interpolation of the CNF parameters.

2. A method according to claim 1, **characterized in that** the algebraic indices randomization algorithm, contained in the frames, is obtained by means of generating a pseudorandom sequence whose generator polynomial is determined by:

$$g(x) = 1 + x^5 + x^{14} + x^{16}$$

3. A method according to claim 1, **characterized in that** said pitch gain cancellation strategy is carried out in the decoder (4), and to do so, in successive phases, the calculation of the logarithmic energies of the algebraic random code (Ec) and of the adaptive or pitch code (Ep) is carried out, and after adding the corresponding linear energies, it carries out the pitch energy (Ep) cancellation and the assignment of the total energy value to that of random code, and it recalculates the logarithmic energy (Ec) in order to obtain the code gain (gc), setting the pitch gain (gp) to zero, with the obtainment of a more exact reconstruction of the energy levels of the Comfort Noise Frame.

4. A method according to claim 1, **characterized in that** the parameters interpolation algorithm is carried out by means of a simple linear interpolation of the LSP parameters and of the frame energy throughout the current CNF period, and it is generally determined by the expressions:

$$q_i(m) = q_{i\ former} + m\Delta q; \qquad \text{for } m = 1, ..., N$$

$$\Delta q = (q_{i\ new} - q_{i\ former})/N$$

with:

   m: the frame number
   N: the number of frames in the updating/transmission period of the CNF parameters,
   $q_i(m)$: the i-th new LSP received, corresponding to the current CNF period,
   $q_{i\ new}$: the i-th new LSP received corresponding to the current CNF period,
   $q_{i\ former}$: the i-th former LSP, corresponding to the previous CNF period, and
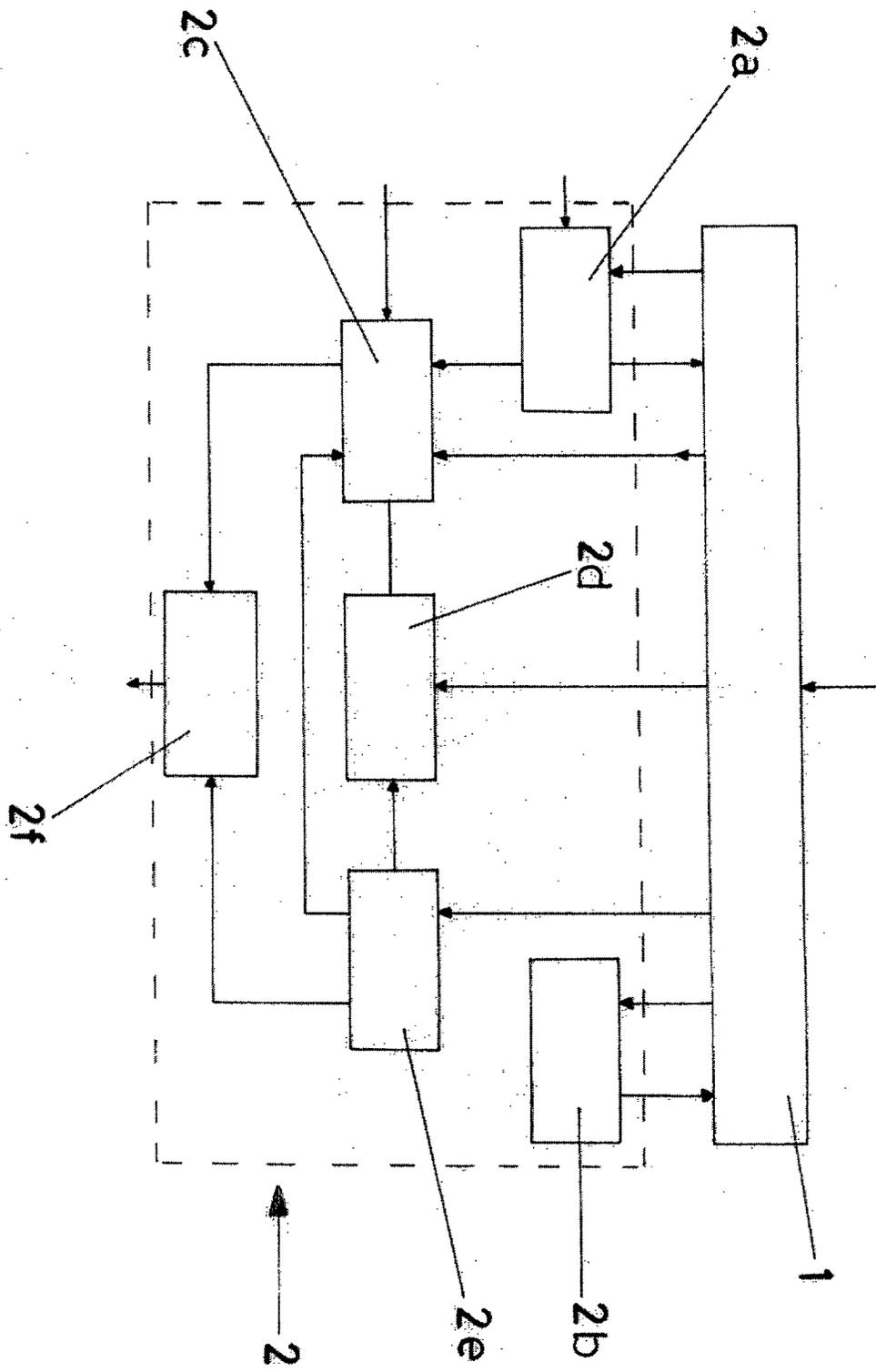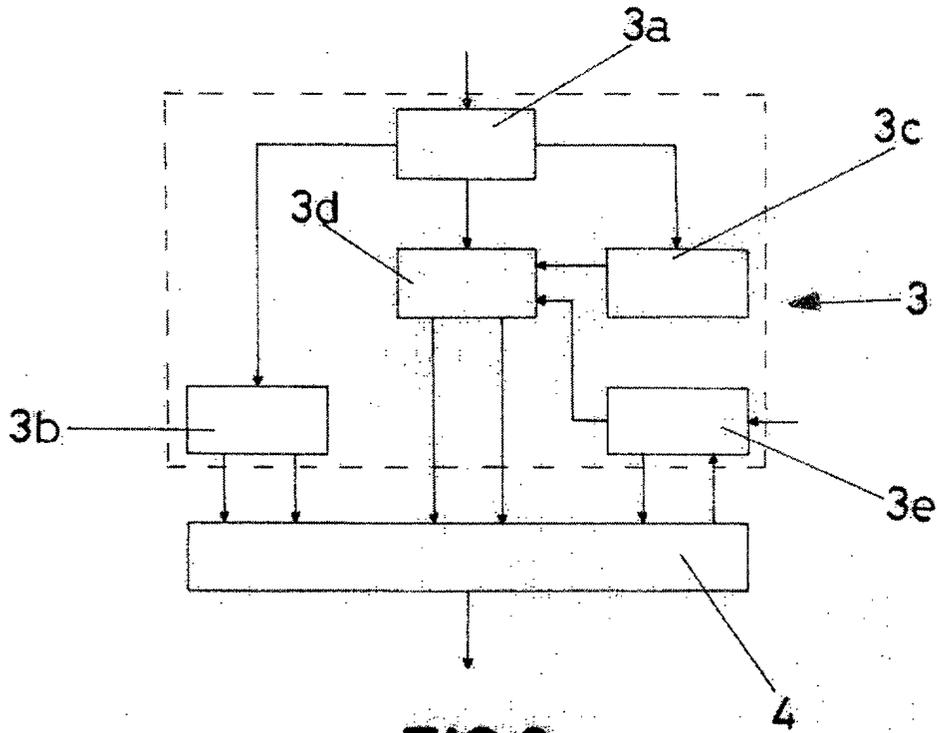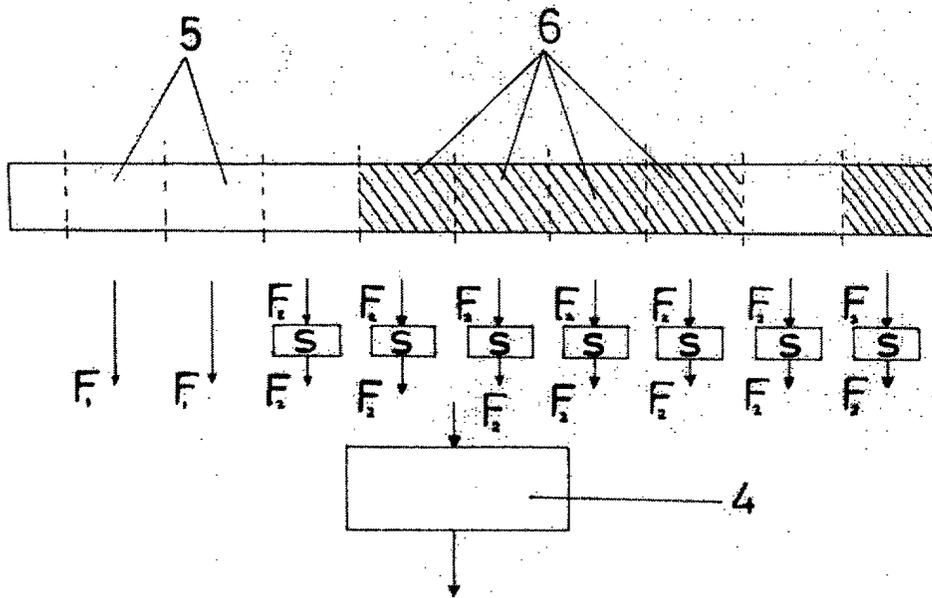 Δ: the linear interpolation slope.

FIG.1

FIG.2

FIG.3

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EUROPEAN SEARCH REPORT

Application Number

EP 02 38 0145

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	19 December 2002	De Vos, L

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Place of search	Date of completion of the search	Examiner
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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