(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 475 520 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
24.04.1996 Bulletin 1996/17

(51) Int Cl.[6]: **G10L 9/14**

(21) Application number: **91202274.6**

(22) Date of filing: **06.09.1991**

(54) **Method for coding an analog signal having a repetitive nature and a device for coding by said method**

Verfahren und Einrichtung zur Kodierung eines Analogsignals mit Wiederholeigenschaft

Méthode et dispositif de codage d'un signal analogique présentant un caractère répétitif

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IT LI LU NL SE

(30) Priority: **10.09.1990 NL 9001985**

(43) Date of publication of application:
18.03.1992 Bulletin 1992/12

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(56) References cited:
EP-A- 0 280 827 **GB-A- 2 061 071**

- **ICASSP'90 (1990 INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING, Albuquerque, New Mexico, 3rd-6th April 1990), vol. 2, pp. 661-664, IEEE, New York, US; P. KROON et al.: "Pitch predictors with high temporal resolution"**
- **ICASSP'86 (IEEE-IECEJ-ASJ INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING, Tokyo, 7th-11th April 1986), vol. 3, pp. 1717-1720, IEEE, New York, US; T. MIYAMOTO et al.: "Single DSP 8kbps speech codec"**

EP 0 475 520 B1

Printed by Jouve, 75001 PARIS (FR)

Description

The invention relates to a method for coding a sampled analog signal having a repetitive nature, in which, for every signal segment to be coded consisting of a predetermined first number of samples, a search is made in a preceding segment containing a predetermined second number of samples which is greater than the first number of samples for a signal segment which is as similar as possible by comparing the signal segment to be coded, in steps of one sample interval, with a segment containing the first number of samples which forms part of the segment containing the second number of samples, and in which the difference signal is determined between the found, most similar segment and the segment to be coded as well as the difference between a reference time instant in the segment to be coded and a reference time instant in the found, most similar segment, expressed in the number of samples D between the two time instants.

It is known that analog signals having a strongly consistent nature such as, for example, speech signals can be coded after sampling in an efficient manner by consecutively carrying out a number of different transformations on consecutive segments of the signalwhich each have a particular time duration. One of the known transformations for this purpose is linear predictive coding (LPC), for an explanation of which a reference can be made to the book entitled "Digital Processing of Speech Signals" by L.R. Rabiner and R.W. Schafer; Prentice Hall, New Jersey; chapter 8. As stated, LPC is always used for signal segments having a particular time duration, in the case of speech signals, for example, 20 ms, and is considered as short-term coding. It is also known to make use not only of a short-term prediction but also of long-term prediction (LTP), in which a very efficient coding is obtained by a combination of these two techniques. The principle of LTP is described in Frequenz (Frequency), volume 42, no. 2-3, 1988; pages 85-93; P.Vary et al.: "Sprachcodec fur das Europäische Funkfernsprechnetz" ("Speech Coder/Decoder for the European Radio Telephone Network").

In LTP, for a signal segment to be coded, a search is made for a segment with the greatest possible similarity in a signal period, preceding the said segment, having a particular duration and a signal which is representative of the difference between the segment to be coded and the found segment, and also a signal which is representative of the time duration which has elapsed since the found segment, is transmitted in coded form, which can result in an appreciable reduction of the information to be transmitted. Because the basic principle of LTP does not appear to result in all cases in finding a signal segment with optimum similarity, an improvement of the LTP principle has been proposed under the name HLTP (high-resolution LTP). A possible implementation of HLTP is described in Eurospeech 89, European Conference on Speech Communication and Technology, Paris, September 1989, in the article entitled "Pitch Prediction with Fractional Delays in CELP coding" by J. S. Marques et al. In the case of HLTP, the chance that the signal segment with the greatest similarity is found is increased by an increase in the sampling frequency of the preceding signal period by means of interpolation. A draw-back of HLTP is, however, that, as will be explained in greater detail below, the complexity of the coding is much greater than in the case of LTP as a result of an appreciable increase in the number of operations.

The object of the invention is to provide a method in which an improvement in the LTP principle is obtained in that the chance that the segment with the greatest similarity in a preceding period having a particular duration is found increases considerably without the number of operations needed in doing this increasing to the same extent as in the case of HLTP.

For this purpose, the invention provides a method of the above type, characterised in that the number of samples in the segment to be coded is increased by a predetermined factor Ob by placing (Ob - 1) samples having a value equal to 0 between two consecutive samples; in that the number of samples in the preceding segment is also increased by the factor Ob; in that, in the preceding segment, partial segments Cd are determined for which the number of samples Dd, expressed in the numbers of samples after oversampling, between the reference time instant in the segment to be coded and the reference time instant in a partial segment Cd fulfils: $Dd = (D * Ob)/d$,
in which d = 1, 2, 3, 4 ...n, where n is a positive integer, and Ob and n are chosen in a manner such that Dd is always an integer; in that, in the segments Cd, sample values are determined by an interpolation technique at predetermined positions, which predetermined positions are situated at a spacing of Dd samples from the original samples in the segment to be coded before its number of samples was increased; and in that a partial segment Cd is determined which is the most similar to the segment to be coded.

The invention also provides a device for the application of the method according to the invention, comprising means for sampling the signal to be coded; means for splitting off a signal segment to be coded containing a predetermined first number of samples; means for splitting off a preceding signal segment containing a second number of samples, means for comparing, in steps of one sample interval, the sample values of the first segment with corresponding sample values of a partial segment containing the first number of samples which forms part of the preceding segment; means for determining the partial segment which shows the greatest similarity to the signal segment to be coded; means for determining a signal which is representative of the difference between the segment to be coded and the found partial segment and means for determining the number of samples D between a reference time instant in the segment to be

coded and a reference time instant in the found partial segment, characterised by further comprising means for oversampling the signal segment to be coded by a predetermined factor O_b; means for determining the value $Dd = (D * Ob)/d$, where d = 2, 3, 4, ...n;
interpolating means for determining by interpolation for every value of d the samples at all the time instants which differ by Dd samples from the time instants associated with the original sample values; and means for correlating the sample values of the segment to be coded and the sample values determined for a value of d.

The invention will be explained in greater detail below with reference to the drawing, wherein:

Figure 1a-c shows various signal forms to explain the LTP principle and the difficulties associated therewith;
Figure 2 shows a flow chart to explain an aspect of the invention;
Figure 3a, b shows a block diagram of an exemplary embodiment of a device according to the invention.

Figure 1a shows, in the time domain, an example of the sampled version of a signal having a strongly repetitive nature, such as a speech signal. To explain the principles of LTP and HLTP it will be assumed that, before a segment having a duration of 5 ms, a search is always made in a preceding period of 15 ms for the segment of likewise 5 ms having the greatest similarity and that the sampling frequency is 8kHz. The segment to be coded in this connection will be termed segment A, the period of 15 ms segment B and the wanted segment with the greatest similarity segment C. These segments are shown in Figure 1a. Now the principle of LTP is that, before the transmission of segment A, no signals are transmitted which are directly related to the samples in segment A, but firstly signals which are related to the sample values which are produced if the difference signal between segment A and segment C is determined, and in the second place, signals which are related to the time difference between segment A and segment C, expressed, for example, in the number of samples D between the beginning of segment A and the beginning of segment C. In a decoder which receives said transmitted signal, the segment A can now be formed because segment C is in principle already known in the decoder, for example because the samples over the preceding 15 ms are always stored in a memory so that the samples from the segment can be read out of the memory with the received signal which is representative of the difference D in number of samples between the beginning of the segments A and C, after which the segment A can be formed with the signal, also received, which is representative of the difference between the sample values of segment A and segment C.

The complexity of the LTP principle can be defined as follows. In segment A, 40 samples are present,and in segment B 120 samples. The segment B therefore has to be investigated in 81 steps by "shifting" the entire segment A in steps equal to a sample interval over segment B and at every step determining the degree of agreement, expressed in a correlation value, by means of correlation techniques. Said correlation value R(k) can be calculated by means of the formula:

$$R(k) = \sum_{m=o}^{N-1} A(m) * B(m+k) \qquad (1)$$

where:

N = 40, the number of samples in segment A;
k = 0 ... 80, the starting value of a partial segment (a possible segment C) within segment B; and
m = the sample number within segment A.

For a more detailed explanation of this correlation technique, reference can be made to page 147 of the above-mentioned book by L. R. Rabiner. Of course, other correlation techniques can also be used in principle, as well as other techniques for determining the agreement between two groups of sample values, which other techniques are deemed to fall within the definition of correlation.

To calculate the correlation value, 40 multiplications and 39 additions are necessary for each value of k, so that the total number of operations required is equal to: 81 *79 = 6399.

As has already been stated above, a problem in using the LTP principle is that the segment C with the greatest similarity in segment A cannot always be found. This is shown diagrammatically in Figure 1b, from which it is evident that, in terms of signal form (the envelope of the samples), the segment C1 shows the greatest similarity to the segment A, but the sample values of segment C2 shows the greatest similarity to those of segment A so that segment C2 is incorrectly chosen as the most suitable segment for subtraction from segment A to form a difference signal. The HLTP principle effects an improvement in this because the sampling frequency in the segment B has been increased, for example, by a factor of 12. This increases the chance that the correct segment C is found. As has already been stated, this takes place at the expense of an appreciable increase in the complexity, as can be calculated as follows: the sampling frequency of segment B is increased by means of interpolation techniques by a factor of 12, it being assumed that every intermediate sample is calculated from 7 already known samples.

The segment B will now contain 12 ∗ 120 = 1440 samples. To calculate the intermediate samples, (120 ∗ 11) ∗ 7 = 9240 multiplications are necessary and (120 ∗ 11) ∗ 6 = 7920 additions, that is to say 17160 operations.

The sampling frequency of segment A is also increased by a factor of 12 by always inserting 11 samples having a value = 0 between two subsequent known samples. The segment B of 1440 samples now has to be searched in 961 steps by again shifting segment A oversegment B. In calculating the correlation value R(k), the above formula explained for the LTP principle can be used. At the same time, it is not necessary to calculate a correlation value also for the intermediate sample values, so that for every value of k (k = 0 ... 960) 79 operations are necessary, just as in the case of LTP.

The total number of operations needed in HLTP is therefore (961 ∗ 79) + 17160 = 93097.

This means that, with the above mentioned (real) assumptions for the increase in the sampling frequency and the manner of interpolation, the complexity of the HLTP principle is approximately 14.5 times as complex as the LTP principle.

In the example of the HLTP principle described, the spacing D between the beginning of segment A and the beginning of the segment C found can again be expressed in the number of samples between the two time instants (not more than 961) and can thus be reproduced in 10 bits.

According to the invention, the segment C with the greatest similarity is sought in the manner to be described below, which is less complex than the HLTP principle, the chance that the segment found is actually the segment with the greatest similarity being appreciably greater than in the case of the LTP principle.

According to the invention, the segment C having the greatest similarity to the segment A is first sought, according to the LTP principle explained above, in a segment B preceding a segment A to be coded. This segment C is situated at a number D of samples from the segment A. According to the invention, the sampling frequency is then also increased by a factor of Ob, for example also by a factor of Ob = 12. As a result of this, the found segment C ends up at a spacing equal to (D ∗ Ob) from segment A. After that, whether a segment Cd at a spacing of Dd = (D ∗Ob)/d from segment A possibly shows more similarity to segment A than the segment C found with the aid of the LTP technique for the value d = 1, which will therefore hereinafter be termed C1, is determined. Possible values of d are: d = 1, 2, 3, 4 .....

For which values of d an investigation can be made of whether a segment Cd agrees better with segment A than the segment C1 follows from the lengths of the segments A and B. The found value of d at which the best agreement is observed is denoted by $d_{optimum}$.

The complexity of the method according to the invention with respect to that of LTP and HLTP can be calculated as follows:

In the method according to the invention, if the same time duration of the segments A and B (5 and 15 ms, respectively) and the same sampling frequency (8 kHz) is assumed as in the example of the LTP principle described above, 6399 operations are necessary to find the segment C1.

To seek the segment Cd with d = 2, 3 and 4 in the present example, the sampling frequency is increased by a factor of 12, for example by always placing 11 samplevalues equal to 0 between two consecutive known samples and by only calculating the actual sample value for samples at predetermined positions, for example by means of interpolating 7 already known samples. These predetermined positions are the positions of the samples which are situated at a spacing Dd from the original samples in the segment A. The sampling frequency of the segment A is also increased and, just as in the case of HLTP, this is done by always placing 11 samples having a value equal to 0 between two known samples. Segment A therefore consists of 480 samples, of which a maximum of 40 are not equal to 0. As a result of this, in principle, only a maximum of 40 intermediate sample values need to be calculated by interpolation in segment Cd and not, as in the case of HLTP, 440 intermediate values. Only a maximum of 40 ∗ (7 multiplications + 6 additions) = 520 operations are therefore necessary for each segment Cd to calculate the intermediate sample values by means of interpolation. This therefore means 1560 operations for 3 segments Cd. The actual comparison of the segment A with the segments Cd by means of the correlation technique explained above requires for each segment Cd: 40 multiplications + 39 additions = 79 operations. That is to say, for 3 segments Cd: 237 operations.

The total number of operations needed to determine the segment C1 and the subsequent comparison of 3 possibly suitable segments Cd with segment A is, with the method according to the invention, therefore 6399 + 1560 + 237 = 8197. If determined values of Dd aredivisible by 12, this means that the associated segment Cd has already been investigated in the first search procedure according to the LTP principle, so that this does not need to be done again. In such a case, the number of operations needed is therefore less than 8197.

It will be clear that, with the method according to the invention, an appreciable simplification is obtained with respect to the HLTP principle, while the chance that the most similar segment C is found is nevertheless appreciably greater than in the case of the LTP principle. Even if segments Cd were to be investigated for greater values of d than 4 in the case of, for example, other lengths of segment A and segment B, the method according to the invention remains simpler than that according to the HLTP principle. Once the segment Cd with the greatest similarity has been found and $d_{optimum}$

is therefore known, the Dd associated therewith can also be calculated. In the example, the value of Dd may be situated between 1 and 120 and that of $d_{optimum}$ between 1 and 4, so that a total of not more than 9 bits are necessary to transmit these two values, which is again more efficient than in the case of HLTP.

According to a further aspect of the invention, to increase the chance further that the most similar segment C is found, segments Cd at spacings of Dd = (D ∗ Ob)/d + eps are also examined, where eps = -(Ob-1), ..., -2, -1, 1, 2, ... (Ob-1) or a portion of these values; in practice, the values eps = -2, -1, 1, 2 are, for example, sufficient. Even if the HLTP principle is used, the situation may arise which is shown in Figure lc. The segment C2 appears to show more resemblance to the segment A than the segment C1 situated nearer the segment A. More detailed analysis shows, however, that this latter segment is in fact the wanted segment because the fundamental regularity P which is present in the signal and which, for example in the case of speech, is determined by the fundamental frequency of the vocal cords, is determined by the spacing D1 between segment A and segment C1 and not by the spacing D2 between segment A and segment C2. This phenomenon may be due, for example, to the presence of noise.

It is important that the fundamental regularity P in the signal is found as often as possible every time a segment C is sought because at the end where the transmitted coded signal is decoded, this regularity, expressed in the spacing D, is again provided in the decoded signal by the decoder. If this regularity is disturbed too often between consecutive coded segments, this results in undesirable interferences in the decoded signal. Said interference is a known problem in HLTP and in LTP.

In order to offer a solution for this as well, according to a further aspect of the invention, after the segment Cd with the greatest similarity has been found with the aid of the method described above, which is established in that the highest value is found for that segment in calculating the correlation value Rd with the aid of formula (1), hereinafter to be termed R_{max}, it is investigated whether there are segments Cd which are situated at a smaller spacing D from the segment A and have a correlation value Rd which is greater to $q * R_{max}$, where $q < 1$, for example $q = 0.8$. Of all the segments Cd, the correlation value Rd of which fulfils this condition, the segment Cd which is situated nearest segment A, that is to say the segment having the smallest value for D, is then chosen as the most suitable segment, despite the fact that there are one or more segments with greater similarity. This choice is based on the insight that such a segment C situated nearer segment A is most probably the correct one because of the smaller value of D in view of the specific properties of the (speech) signal to be coded. If none of the segments Cd investigated fulfils said condition, the segment C1 is chosen. The method described above for seeking the most suitable segment C, taking account of the regularity P in the signal, is shown in a flow chart in Figure 2. It is pointed out that this principle for determining the fundamental regularity as well as possible can also be used in the conventional LTP and HLTP techniques. In that case it is then necessary to investigate which correlation values Ri are greater than $q * R_{max}$, where $q < 1$, for example $q = 0.8$. Of the spacings Di, or Di ∗ Ob respectively, associated therewith, the smallest spacing is selected, which is denoted by $D_{optimum}$. $D_{optimum}$ will never be greater than D because, after all, it is the case that $R_{max} > R_{max} * q$. The invention therefore also relates to a method for coding a sampled analog signal having a repetitive nature, in which, for a signal segment to be coded consisting of a predetermined first number of samples, a search is always made in a preceding segment containing a predetermined second number of samples which is greater than the first number of samples for a signal segment which agrees as well as possible by always comparing the signal segment to be coded, in steps of one sample interval, with a segment containing the first number of samples which forms part of the segment containing the second number of samples, and in which the difference signal is determined between the found, most similar segment and the segment to be coded as well as the difference between a reference time instant in the segment to be coded and a reference time instant in the found, most similar segment, expressed in the number of samples D between the two time instants, characterised in that of the partial segments compared with the segment to be coded that segment is chosen as the partial segment with the greatest agreement which has a correlation value R with the samples of the segment to be coded for which $R \geq q. R_{max}$, where $q < 1$ and R_{max} is the maximum correlation value which has been found in correlating the partial segment from the preceding segments and the segment to be coded, and is that segment which yields the smallest associated value for D.

Figure 3a shows a block diagram of a coding/decoding system for carrying out the method according to the invention in the case of a speech signal comprising a coding unit 10 and a decoding unit 30. An analog signal delivered by a microphone 11 is limited in bandwidth by a low pass filter 12 and converted in an analog/digital convertor into a series of sampled values which are representative of the analog signal. The output signal of the convertor 13 is fed to the inputs of a short-term prediction filter 14 and of a short-term analysis unit 15. These two units provide the above-mentioned short-term prediction and the analysis unit 15 provides an output signal in the form of short-term prediction filter coefficients, which output signal is transmitted to the decoder 30. The structure and the operation of the filter 14 and the unit 15 are well known to those skilled in the field of speech coding and are not of further importance for the essence of the present invention, so that a further explanation can be omitted.

The output signal of the filter 14, which consists of a series of equidistant samples of the analog input signal, is fed to a circuit 16 in which a pre-determined number (40 samples in the example given above) is always split off from the incoming series of samples, and to a long-term prediction analysis unit 17 in which a part of the method according to the invention is carried out. Said unit 17 is shown in greater detail in Figure 3b and comprises a unit 18 for splitting off the segment A, possibly the output signal of unit 16 can also be used for this purpose, and also a unit 19 for splitting off the segment B. The output signals of the units 18 and 19 are fed to a circuit 20 in which the correlation value R_{c1} is calculated for the segment C1 in the manner outlined above and also the value of D is determined. The calculated value of D is transmitted to the decoder 30 and is also fed to a unit 21 which is designed to calculate the different values of Dd on the basis of the pre-chosen values for d and Ob. The value of Dd and the segment B are fed to a unit 22 for the purpose of calculating the segments Cd. The calculated Cd's are fed to a circuit 23 which calculates with the aid of formula (1) the correlation values R_{cd} for the different segments Cd on the basis of the segment A also fed to it. In a circuit 24, the correlation values R_{c1} and R_{cd} are compared with one another (see also Figure 2), and $d_{optimum}$ is determined in the manner described above and transmitted to the decoder.

The optimum segment Cd determined in the unit 25 is subtracted sample by sample from corresponding samples of the segment A in a subtraction unit 26 and the resultant difference signal is quantified in a manner known per se in a unit 27 and coded in a unit 28 in order to be transmitted to the decoding unit 30.

In the decoding unit 30, the difference signal received is decoded in a decoder 31 while the segment Cd_{opt} is reconstructed in a unit 32 from the received values of D and d_{opt} and from the previously received and reconstructed signal segment B. In an adder 33, the decoded difference signal and the segment Cd_{opt} are added sample by sample in order thus to reconstruct the segment A. The reconstructed segment Aand the received short-term prediction filter coefficients are fed to an inverse short-term prediction filter which reconstructs the transmitted signal samples as well as possible in a manner known per se. The output signal of the filter 34 is converted in a digital/analog convertor into an analog signal which is fed to a loudspeaker 37 via a pass filter 36.

Claims

1. Method for coding a sampled analog signal having a repetitive nature, in which, for every signal segment to be coded consisting of a predetermined first number of samples, a search is made in a preceding segment containing a predetermined second number of samples which is greater than the first number of samples for a signal segment which is as similar as possible by comparing the signal segment to be coded, in steps of one sample interval, with a segment containing the first number of samples which forms part of the segment containing the second number of samples, and in which the difference signal is determined between the found, most similar segment and the segment to be coded as well as the difference between a reference time instant in the segment to be coded and a reference time instant in the found, most similar segment, expressed in the number of samples D between the two time instants, characterised in that the number of samples in the segment to be coded is increased by a predetermined factor Ob by placing (Ob - 1) samples having a value equal to 0 between two consecutive samples; in that the number of samples in the preceding segment is also increased by the factor Ob by oversampling ;in that, in the preceding segment, partial segments Cd are determined for which the number of samples Dd, expressed in the numbers of samples after oversampling, between the reference time instant in the segment to be coded and the reference time instant in a partial segment Cd fulfils:
$$Dd = (D * Ob)/d,$$
in which d = 1, 2, 3, 4 ...n, where n is a positive integer, and Ob and n are chosen in a manner such that Dd is always an integer; in that, in the segments Cd, sample values are determined by an interpolation technique at predetermined positions, which predetermined positions are situated at a spacing of Dd samples from the original samples in the segment to be coded before its number of samples was increased; and in that a partial segment Cd is determined which is most similar to the segment to be coded.

2. Method according to Claim 1, characterised in that the comparison between the segment to be coded and segments Cd is also carried out for segments for which $Dd = (D * Ob)/d + eps$, where eps is equal to at least a portion of the values in the range eps = -(Ob-1), ...-2, -1, +1, +2, .. (Ob-1).

3. Method according to Claim 1 or 2, characterised in that, of the segments Cd, that segment Cd is chosen as the most similar segment which has a correlation value Rd with the samples of the segment to be coded for which $Rd \geq q * R_{max}$, where $q < 1$ and R_{max} is the maximum correlation value which has been found in correlating the segments Cd and the segment to be coded, and is that segment which yields the smallest associated value of Dd.

4. Method for coding a sampled analog signal having a repetitive nature, in which, for every signal segment to be coded consisting of a predetermined first number of samples, a search is made in a preceding segment containing a predetermined second number of samples which is greater than the first number of samples for a signal segment

which is as similar as possible by comparing the signal segment to be coded, in steps of one sample interval, with a segment containing the first number of samples which forms part of the segment containing the second number of samples, and in which the difference signal is determined between the found, most similar segment and the segment to be coded as well as the difference between a reference time instant in the partial segment to be coded and a reference time instant in the found, most similar partial segment, expressed in the number of samples D between the two time instants, characterised in that, of the partial segments compared with the segment to be coded, a segment is chosen as the partial segment with the greatest agreement which has a correlation value R with the samples of the segment to be coded for which $R \geq q * R_{max}$, where $q < 1$ and R_{max} is the maximum correlation value which has been found in correlating the partial segments from the preceding segment and the segment to be coded, and is the partial segment which yields the smallest associated value for D.

5. Device for coding an analog signal having a repetitive nature, comprising means for sampling the signal to be coded; means for splitting off a signal segment to be coded containing a predetermined first number of samples; means for splitting off a preceding signal segment containing a second number of samples,means for comparing, in steps of one sample interval, the sample values of the first segment with corresponding sample values of a partial segment containing the first number of samples which forms part of the preceding segment; means for determining the partial segment which shows the greatest similarity to the signal segment to be coded; means for determining a signal which is representative of the difference between the segment to be coded and the found partial segment and means for determining the number of samples D between a reference time instant in the segment to be coded and a reference time instant in the found partial segment, characterised by further comprising means for oversampling the signal segment to be coded and the preceding segment by a predetermined factor O_b; means for determining the value $Dd = (D * Ob)/d$, where $d = 2, 3, 4, ...n$; interpolating means for determining by interpolation for every value of d the samples at all the time instants which differ by Dd samples from the time instants associated with the original sample values; and means for correlating the sample values of the segment to be coded and the sample values determined for a value of d.

Patentansprüche

1. Verfahren zum Codieren eines abgetasteten analogen Signals mit repetitivem Charakter, bei dem für jedes zu codierende Signalsegment, das aus einer vorbestimmten ersten Anzahl Proben besteht, in einem vorhergehenden Segment, das eine vorbestimmte zweite Anzahl Proben enthält, die grösser ist als die erste Anzahl Proben, eine Suche nach einem Signalsegment durchgeführt wird, das so ähnlich wie möglich ist, indem das zu codierende Signalsegment in Schritten von einem Abtastintervall mit einem Segment verglichen wird, das die erste Anzahl Proben enthält, welche einen Teil des Segments bilden, das die zweite Anzahl Proben enthält, und bei dem das Differenzsignal zwischen dem gefundenen, ähnlichsten Segment und dem zu codierenden Segment bestimmt wird, sowie die Differenz zwischen einem Referenzzeitmoment im zu codierenden Segment und einem Referenzzeitmoment im gefundenen, ähnlichsten Segment, ausgedrückt in der Anzahl Proben D zwischen den zwei Zeitmomenten, **dadurch gekennzeichnet**, dass die Anzahl Proben im zu codierenden Segment um einen vorbestimmten Faktor Ob erhöht wird, indem (Ob - 1) Proben mit einem Wert gleich 0 zwischen zwei aufeinanderfolgende Proben plaziert werden; dass die Anzahl Proben im vorhergehenden Segment durch Überabtastung ebenfalls um den Faktor Ob erhöht wird; dass im vorhergehenden Segment Teilsegmente Cd bestimmt werden, für welche die Anzahl Proben Dd, ausgedrückt in der Anzahl Proben nach dem Überabtasten, zwischen dem Referenzzeitmoment im zu codierenden Segment und dem Referenzzeitmoment in einem Teilsegment Cd, folgende Bedingung erfüllt:

$$Dd = (D * Ob)/d,$$

worin $d = 1, 2, 3, 4 ...n$, wobei n eine positive ganze Zahl ist, und Ob und n derart ausgewählt sind, dass Dd immer eine ganze Zahl ist; dass in den Segmenten Cd durch eine Interpolationstechnik in vorbestimmten Positionen Abtastwerte bestimmt werden, wobei sich diese vorbestimmten Positionen in Abständen von Dd Proben von den ursprünglichen Proben im zu codierenden Segment befinden, bevor dessen Anzahl Proben erhöht wurde; und dass ein Teilsegment Cd bestimmt wird, das dem zu codierenden Segment am ähnlichsten ist.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet**, dass der Vergleich zwischen dem zu codierenden Segment und den Segmenten Cd ebenfalls für Segmente ausgeführt wird, für die $Dd = (D * Ob)/d + eps$ gilt, worin eps mindestens gleich einem Teil der Werte im Bereich von $eps = -(Ob-1), ...-2, -1, +1, +2, .. (Ob-1)$ ist.

3. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet**, dass von den Segmenten Cd dasjenige Segment

Cd als das ähnlichste Segment ausgewählt wird, welches einen Korrelationswert Rd mit den Proben des zu codierenden Segments aufweist, für den $Rd \geq q * R_{max}$ gilt, worin $q < 1$ und R_{max} der maximale Korrelationswert ist, der beim Korrelieren der Segmente Cd und dem zu codierenden Segment gefunden wurde, und welches dasjenige Segment ist, das den kleinsten assoziierten Wert von Dd ergibt.

4. Verfahren zum Codieren eines abgetasteten analogen Signals mit repetitivem Charakter, bei dem für jedes zu codierende Signalsegment, das aus einer vorbestimmten ersten Anzahl Proben besteht, in einem vorhergehenden Segment, das eine vorbestimmte zweite Anzahl Proben enhält, die grösser ist als die erste Anzahl Proben, eine Suche nach einem Signalsegment durchgeführt wird, das so ähnlich wie möglich ist, indem das zu codierende Signalsegment in Schritten von einem Abtastintervall mit einem Segment verglichen wird, das die erste Anzahl Proben enthält, welche einen Teil des Segments bilden, das die zweite Anzahl Proben enthält, und bei dem das Differenzsignal zwischen dem gefundenen, ähnlichsten Segment und dem zu codierenden Segment bestimmt wird, sowie die Differenz zwischen einem Referenzzeitmoment im zu codierenden Teilsegment und einem Referenzzeitmoment im gefundenen, ähnlichsten Teilsegment, ausgedrückt in der Anzahl Proben D zwischen den zwei Zeitmomenten, **dadurch gekennzeichnet**, dass von den Teilsegmenten, die mit dem zu codierenden Segment verglichen werden, ein Segment als dasjenige Teilsegment mit der grössten Übereinstimmung ausgewählt wird, das einen Korrelationswert R mit den Proben des zu codierenden Segments aufweist, für den $R \geq q * R_{max}$, worin $q < 1$ und R_{max} der maximale Korrelationswert ist, der beim Korrelieren der Teilsegmente des vorhergenden Segments und dem zu codierenden Segment gefunden wurde, und welches das Teilsegment ist, das den kleinsten assozierten Wert für D ergibt.

5. Vorrichtung zum Codieren eines analogen Signals mit repetitivem Charakter, umfassend Mittel zum Abtasten des zu codierenden Signals; Mittel zum Abspalten eines zu codierenden Signalsegments, das eine vorbestimmte erste Anzahl Proben enthält; Mittel zum Abspalten eines vorhergehenden Signalsegments, das eine zweite Anzahl Proben enthält; Mittel zum Vergleichen, in Schritten von einem Abtastintervall, der Abtastwerte des ersten Segments mit entsprechenden Abtastwerten eines Teilsegments, das die erste Anzahl Proben enthält, die einen Teil des vorhergehenden Segments bilden; Mittel zum Bestimmen des Teilsegments, das die grösste Ähnlichkeit mit dem zu codierenden Signalsegment aufweist; Mittel zum Bestimmen eines Signals, das repräsentativ ist für die Differenz zwischen dem zu codierenden Segment und dem gefundenen Teilsegment, und Mittel zum Bestimmen der Anzahl Proben D zwischen einem Referenzzeitmoment im zu codierenden Segment und einem Referenzzeitmoment im gefundenen Teilsegment, **gekennzeichnet, dass** sie weiter Mittel zum Überabtasten des zu codierenden Signalsegments und des vorhergehenden Segments um einen vorbestimmten Faktor O_b umfasst; Mittel zum Bestimmen des Wertes $Dd = (D * Ob)/d$, worin $d = 2, 3, 4, \ldots n$ ist; Interpolationsmittel zum Bestimmen, mittels Interpolation, jedes Wertes d der Proben in all den Zeitmomenten, die sich um Dd Proben von den Zeitmomenten unterscheiden, die mit den ursprünglichen Abtastwerten assoziiert sind; und Mittel zum Korrelieren der Abtastwerte des zu codierenden Segments und der für einen Wert d bestimmten Abtastwerte.

Revendications

1. Procédé de codage d'un signal analogique échantillonné présentant un caractère répétitif, dans lequel, pour chaque segment de signal à coder, constitué d'un premier nombre prédéterminé d'échantillons, on recherche, dans un segment antérieur contenant un second nombre prédéterminé d'échantillons qui est plus grand que le premier nombre d'échantillons, un segment de signal qui soit aussi ressemblant que possible, en comparant, par pas d'un intervalle d'échantillon, le segment de signal à coder à un segment contenant le premier nombre d'échantillons qui fait partie du segment contenant le second nombre d'échantillons ; et dans lequel on détermine le signal différence entre le segment le plus ressemblant trouvé et le segment à coder, ainsi que la différence entre un instant de référence du segment à coder et un instant de référence du segment le plus ressemblant trouvé exprimée par le nombre d'échantillons D entre les deux instants ; caractérisé en ce que l'on augmente, d'un facteur prédéterminé Ob, le nombre des échantillons dans le segment à coder, en plaçant (Ob-1) échantillons ayant une valeur égale à O entre deux échantillons consécutifs ; en ce que l'on augmente également du facteur Ob, par suréchantillonnage, le nombre des échantillons dans le segment antérieur ; en ce que, l'on détermine, dans le segment antérieur, des segments partiels Cd pour lesquels le nombre d'échantillons Dd, exprimé par les nombres d'échantillons après suréchantillonnage, entre l'instant de référence dans le segment à coder et l'instant de référence dans un segment partiel Cd, satisfait :

$$Dd = (D * Ob)/d$$

dans laquelle $d = 1, 2, 3, 4, \ldots n$, où n est un nombre entier positif, et Ob et n sont choisis de manière telle que Dd soit toujours un nombre entier ; en ce que, dans les segments Cd, on détermine les valeurs d'échantillon par une technique d'interpolation au droit de positions prédéterminées, lesquelles positions prédéterminées sont situées à un écartement de Dd échantillons par rapport aux échantillons d'origine dans le segment à coder, avant que l'on ait augmenté son nombre d'échantillons ; et en ce que l'on détermine un segment partiel Cd qui est le plus ressemblant au segment à coder.

2. Procédé selon la revendication 1, caractérisé en ce que la comparaison entre le segment à coder et les segments Cd s'effectue également pour des segments pour lesquels : $Dd = (D * Ob)/d + eps$, où eps est égal à au moins une partie des valeurs dans la plage de eps =-(Ob-1), ..., -2, -1, +1, +2, ... (Ob-1).

3. Procédé selon la revendication 1 ou 2, caractérisé en ce que parmi les segments Cd, on choisit, comme segment le plus ressemblant, le segment Cd qui a une valeur de corrélation Rd avec les échantillons du segment à coder pour lequel : $R \geq q.\ R_{max}$, où $q < 1$, et R_{max} est la valeur de corrélation maximale que l'on a trouvée en corrélant les segments Cd et le segment à coder et qui est le segment qui donne pour Dd la valeur associée la plus petite.

4. Procédé de codage d'un signal analogique échantillonné présentant un caractère répétitif, dans lequel, pour chaque segment de signal à coder, constitué d'un premier nombre prédéterminé d'échantillons, on recherche, dans un segment antérieur contenant un second nombre prédéterminé d'échantillons qui est plus grand que le premier nombre d'échantillons, un segment de signal qui est aussi ressemblant que possible, en comparant, par pas d'un intervalle d'échantillon, le segment de signal à coder à un segment contenant le premier nombre d'échantillons qui fait partie du segment contenant le second nombre d'échantillons ; et dans lequel on détermine le signal différence entre le segment le plus ressemblant trouvé et le segment à coder, ainsi que la différence entre un instant de référence du segment partiel à coder et un instant de référence du segment le plus ressemblant trouvé exprimée par le nombre d'échantillons D entre les deux instants, caractérisé en ce que parmi les segments partiels comparés au segment à coder, on choisit, comme segment partiel qui a la plus grande correspondance, le segment qui a une valeur de corrélation R avec les échantillons du segment à coder pour lequel : $R \geq q.\ R_{max}$, où $q < 1$, et R_{max} est la valeur de corrélation maximale que l'on a trouvée en corrélant les segments partiels provenant des segments antérieurs et le segment à coder et qui est le segment qui donne pour D la valeur associée la plus petite.

5. Dispositif de codage d'un signal analogique ayant un caractère répétitif, comprenant : un moyen pour échantillonner le signal à coder ; un moyen pour séparer un segment de signal à coder contenant un premier nombre prédéterminé d'échantillons ; un moyen pour séparer un segment de signal antérieur contenant un second nombre d'échantillons ; un moyen pour comparer, par pas d'un intervalle d'échantillon, les valeurs d'échantillon du premier segment avec les valeurs d'échantillon correspondantes d'un segment partiel contenant le premier nombre d'échantillons qui fait partie du segment antérieur ; un moyen pour déterminer le segment partiel qui présente la plus grande ressemblance avec le segment de signal à coder ; un moyen pour déterminer un signal qui est représentatif de la différence entre le segment à coder et le segment partiel trouvé ; et un moyen pour déterminer le nombre d'échantillons D entre un instant de référence dans le segment à coder et un instant de référence dans le segment partiel trouvé ; caractérisé en ce qu'il comprend en outre un moyen pour suréchantillonner le segment de signal à coder à l'aide d'un facteur prédéterminé Ob ; un moyen pour déterminer la valeur $Dd = (D * Ob)/d$, où $d = 2, 3, 4, ..., n$; un moyen d'interpolation pour déterminer, par interpolation, pour chaque valeur de d, les échantillons à tous les instants qui différent de Dd échantillons des instants associés aux valeurs d'échantillon d'origine ; et un moyen pour corréler les valeurs d'échantillon du segment à coder et les valeurs d'échantillon déterminées pour une valeur de d.

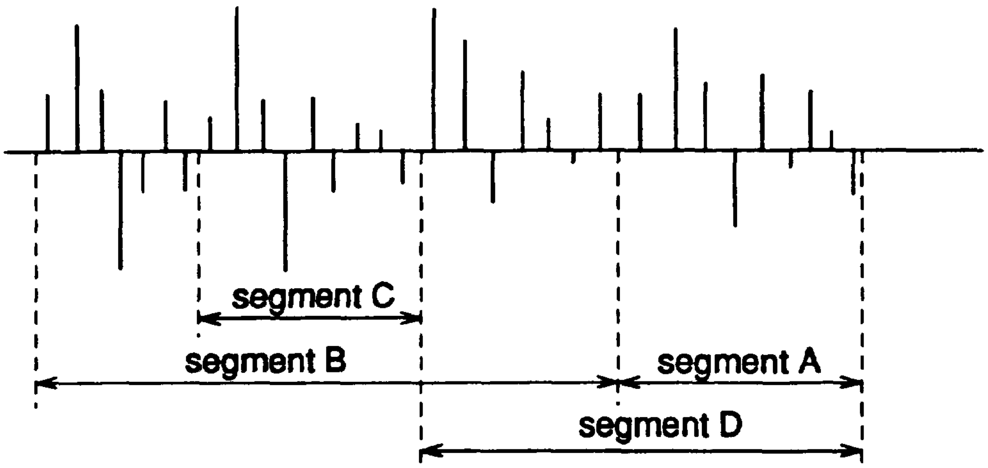


FIG. 1a

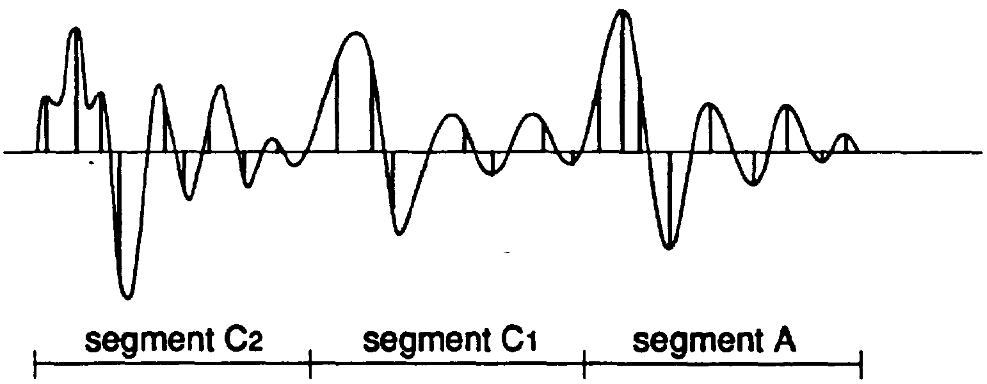


FIG. 1b

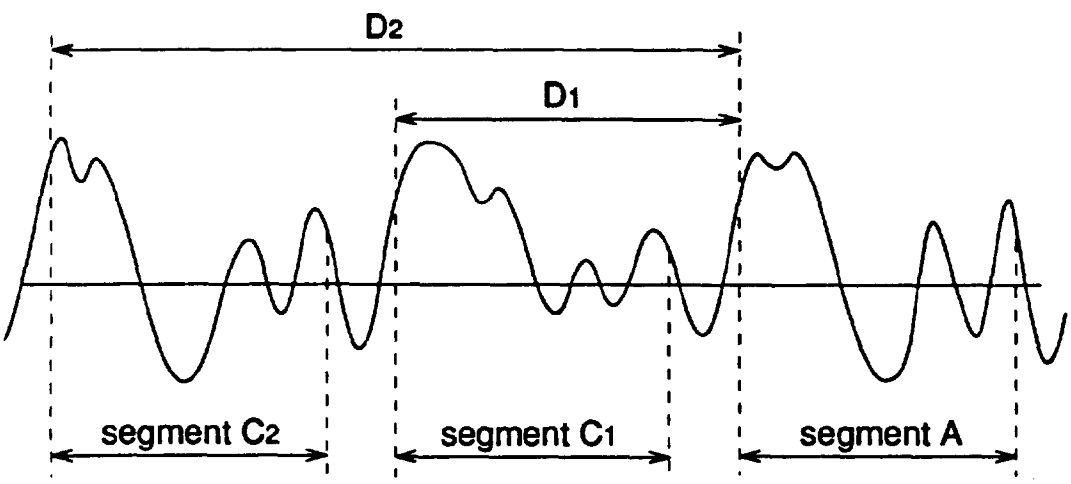


FIG. 1c

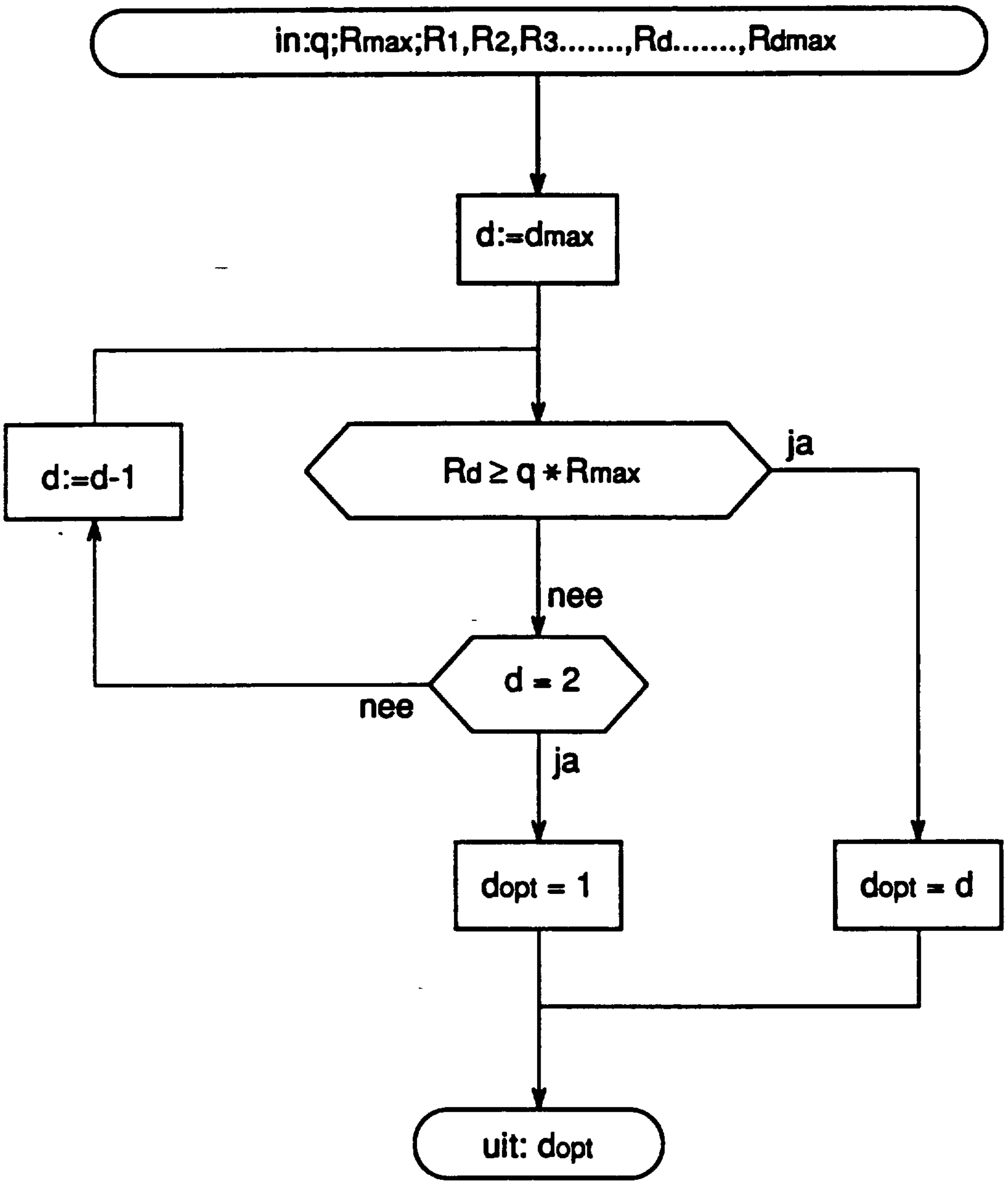
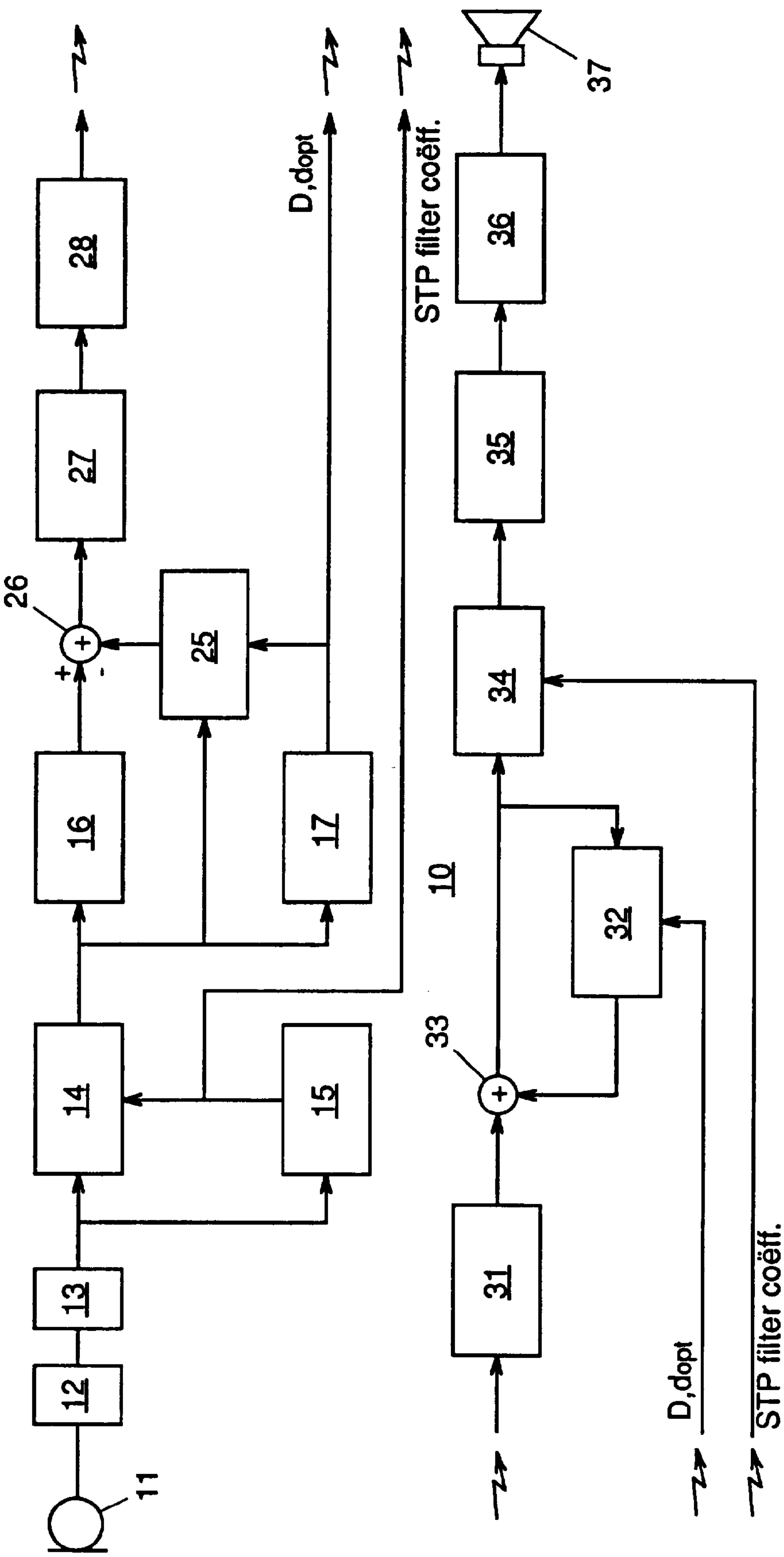

in:q;Rmax;R1,R2,R3.......,Rd.......,Rdmax
d:=dmax
d:=d-1
Rd ≥ q * Rmax
ja
nee
d = 2
nee
ja
dopt = 1
dopt = d
uit: dopt

FIG. 2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D,dopt
STP filter coëff.
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37
D,dopt
STP filter coëff.
30

FIG. 3a

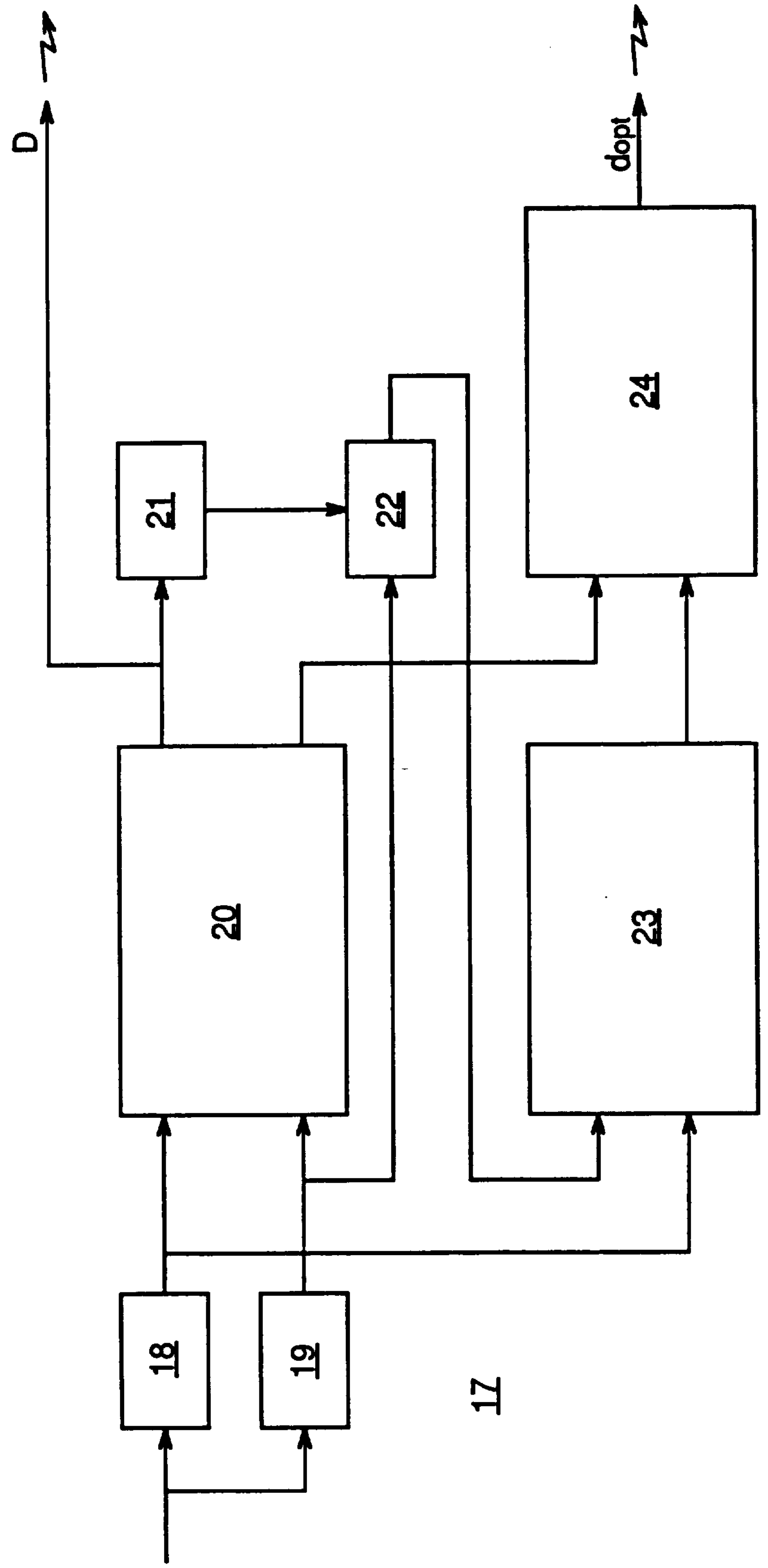

FIG. 3b