



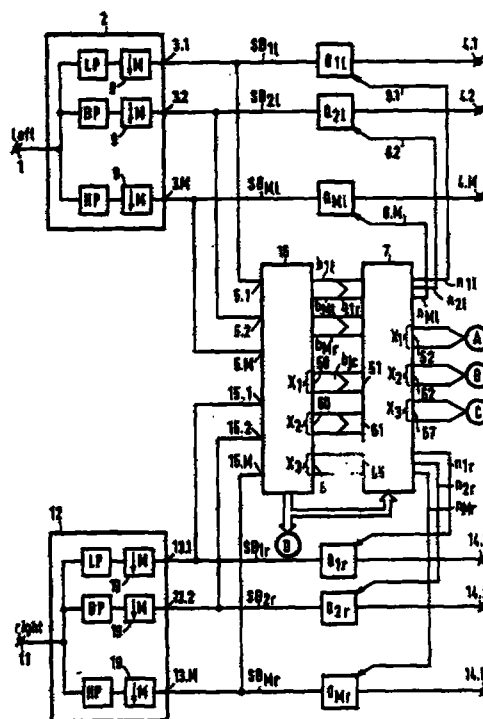
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(54) Title: **ENCODING SYSTEM AND ENCODING METHOD FOR ENCODING A DIGITAL SIGNAL HAVING AT LEAST A FIRST AND A SECOND DIGITAL SIGNAL COMPONENT**

(57) Abstract

An encoding system and an encoding method for encoding a digital signal having at least a first and a second digital signal component. The encoding system comprises splitter means (2, 12) for dividing the bandwidth of the digital signal components into M successive frequency bands, and generating in response to the digital signal components M sub signals (SB_{m1} , SB_{m2}) for each digital signal component, each sub signal of a signal component being associated with one of the frequency bands (m), bit need determining means (16) for determining bit needs for time equivalent signal blocks of the sub signals, signal combination means (25, 26, 27) for combining, in a number of at least one frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component so as to obtain a time equivalent signal block of a composite sub signal in each said at least one frequency bands, quantizing means (Q_{m1} , Q_{m2} , 32.i) for quantizing time equivalent signal blocks of the sub signals in those frequency bands in which no composite sub signal is available and for quantizing the corresponding time equivalent signal blocks of the composite sub signal in said at least one frequency bands in which a composite sub signal is available. Further, bit allocation means (7) are available for deriving the allocation information (n_{m1} , n_{m2}) from bit needs obtained in the bit need determining means and from a value B, where B corresponds to a number of bits in an available bitpool. The bit need determining means (16) is adapted to determine a common bit need b_{mc} for a time equivalent signal block of a composite sub signal SB_{mc} in a frequency band m from the bit needs b_{m1} of the time equivalent signal blocks of the corresponding sub signals of the at least two signal components in that frequency band from which the time equivalent signal block of the composite sub signal has been derived, by taking the common bit need b_{mc} equal to a weighted sum of the bit needs b_{m1} . The encoding system can be a subband encoding system or a transform encoding system.



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Encoding system and encoding method for encoding a digital signal having at least a first and a second digital signal component.

The invention relates to an encoding system for encoding a digital signal having at least a first and a second digital signal component, the signal components having a specific sampling frequency and bandwidth, comprising

- splitter means for dividing the bandwidth of the digital signal components into M successive frequency bands, and generating in response to the digital signal components M sub signals for each digital signal component, each sub signal of a signal component being associated with one of the frequency bands,
- bit need determining means for determining bit needs for time equivalent signal blocks of the sub signals, the signal blocks each containing q samples of a sub signal, a bit need b_{mi} for a signal block of a sub signal SB_{mi} of a signal component i in frequency band m corresponding to the number of bits by which the q samples in that signal block should be represented, where b_{mi} may vary for different signal blocks and different sub signals,
- signal combination means for combining, in a number of at least one frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component so as to obtain a time equivalent signal block of a composite sub signal in each said at least one frequency bands,
- quantizing means for quantizing time equivalent signal blocks of the sub signals in those frequency bands in which no composite sub signal is available and for quantizing the corresponding time equivalent signal blocks of the composite sub signal in said at least one frequency band in which a composite sub signal is available, each sample of the signal block of a sub signal SB_{mi} being quantized by n_{mi} bits, where m denotes a frequency band in which no composite sub signal is available, and each sample of the composite sub signal SB_{mc} being quantized by n_{mc} bits, where m denotes a frequency band in which a composite sub signal is available,
- bit allocation means for deriving the variables n_{mi} and n_{mc} from bit needs obtained in the bit need determining means and from a value B, where B corresponds to a number of bits in an available bitpool, and wherein q is an integer larger than zero, n_{mi} , n_{mc} , b_{mi} , b_{mc} are variables where n_{mi} and n_{mc} are greater than or equal to zero, M is a constant greater than zero, B is an integer, and m is an integer such that $1 \leq m \leq M$, and to an encoding method

for encoding the digital signal. An encoding system as given in the opening paragraph is known from EP 457,390 A1 and EP 457,391 A1, the documents (6a) and (6b) respectively in the list of related documents.

5 The prior art documents disclose an encoding system in which a digital signal, such as a stereo audio signal can be encoded into a data reduced digital audio signal. Both signal components, the left and right hand signal components of the stereo audio signal, are encoded separately.

10 The splitter means in the prior art encoding systems have been disclosed as splitter means for dividing the bandwidth of the digital signal components into a number of sub signals which are called subband signals. The frequency ranges in such an encoding system are called subbands. Such an encoding is called subband encoding.

15 It should however be noted that the invention is not limited to such subband encoding. Also other kinds of encoding systems, such as a transform encoding system, in which a transform encoding is carried out on the digital signal, is possible. Such transform encoding results in a number of transform coefficients, each transform coefficient corresponding to a certain frequency range. As a consequence $q=1$ in that case.

 In the following, however, a discussion will be given on the basis of a subband encoding system.

20 EP 402,973, document (2) in the list of related documents, discloses the possibility that an intensity stereo encoding can be carried out on the at least two subband signal components in a subband, in order to obtain an increased data reduction on the digital signal to be encoded. This can be necessary if the transmission channel via which the data reduced information should be transmitted has a too small bandwidth.

25 Another document relating to a switching over to an intensity stereo mode is document (7) in the list of related documents.

30 The invention aims at providing an encoding system in which an intensity stereo encoding can be realized. The encoding system in accordance with the invention is characterized in that the bit need determining means is adapted to determine a common bit need b_{mc} for a time equivalent signal block of a composite sub signal SB_{mc} in a frequency band m from the bit needs b_{mi} of the time equivalent signal blocks of the corresponding sub signals of the at least two signal components in that frequency band from which the time equivalent signal block of the composite sub signal has been derived, such that common bit

need b_{mc} is equal to the sum of the bit needs b_{mi} , multiplied by a corresponding weighting factor, the bit allocation means being adapted to derive the variables n_{mi} for the time equivalent signal blocks of the sub signals in those frequency bands in which no composite sub signal is available and the at least one variable n_{mc} for the time equivalent signal block of the sub signal in those at least one frequency band for which a composite sub signal is available, from the bit needs b_{mi} available for those frequency bands for which no composite sub signal is available and the at least one common bit need b_{mc} .

More specifically, the weighting factor corresponding to the largest of the bitneeds b_{mi} is larger than the weighting factor corresponding to the other at least one bitneed, or that the weighting factor corresponding to the largest of the bitneeds b_{mi} is equal to one and the other at least one weighting factor is zero.

The invention is based on the following recognition. The prior art available, in which the option of intensity-stereo is disclosed, remains silent about how such an intensity-stereo mode can be realized and how it should be implemented. More specifically, it is unknown how the bitneeds b_{mc} for a composite subband signal in a subband should be determined.

In accordance with the invention, if for a certain subband it is decided that the at least two signal components in the subband should be combined, the bit need b_{mc} for the composite subband signal in the subband SB_m is determined by taking b_{mc} equal to the largest of the at least two b_{mi} values corresponding to the at least two signal components in said subband. By taking b_{mc} equal to the a weighted sum of the at least two b_{mi} values, it has been ascertained that encoding the composite signal assures the correct quantization of the composite signal in the quantization means.

Further, it is unknown from the prior art documents how the decision process is realized to decide between an encoding in a full stereo mode in which a fully separate encoding of the at least two subband signal components in the various M subbands is carried out, and an encoding in an intensity-stereo mode in which an encoding of a composite signal in x_1 subbands is carried out and a separate encoding is carried out in the remaining $M-x_1$ subbands.

To realize this, the encoding system is characterized in that it comprises

- computation means for computing a value B_0 , where B_0 corresponds to the number of bits required when separately encoding the time equivalent signal blocks of the at least first and second sub signals in all M frequency bands,
- comparing means for comparing the value B_0 with the value B , the comparing means being

- adapted to generate a first control signal at an output when B_0 exceeds B ,
- combining control signal generator means for generating a first combining control signal in response to at least the occurrence of the first control signal,
- the signal combination means being adapted to combine in a number of x_1 frequency bands,
- 5 time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in said x_1 frequency bands so as to obtain a time equivalent signal block of a composite sub signal in each said x_1 frequency bands, in response to said first combining control signal,
- the bit allocation means being adapted to derive variables n_{jc} for the time equivalent signal
- 10 blocks of the composite sub signals in said x_1 frequency bands, in response to the first combining control signal, where j denotes one of the x_1 frequency bands,
- the quantizing means being adapted to quantize the time equivalent signal blocks of the composite sub signals in said x_1 frequency bands by n_{jc} bits, in response to the first combining control signal, and where x_1 is an integer larger than zero.
- 15 From the foregoing, it is clear that a calculation is carried out to determine whether the number of bits available in the bitpool for the encoding process suffices for an encoding in the full stereo mode. If it is concluded that it is not, it may be decided to encode the digital signal components in a number of x_1 subbands in an intensity stereo mode. One or more of a number of requirements can be used to decide when an intensity stereo mode encoding
- 20 should be carried out or not in the said x_1 subbands. In one embodiment, the number of bits B_1 is calculated that are required when an encoding in an intensity stereo mode is carried out, such that in x_1 subbands the at least two signal components in a subband are combined. If B_1 does not exceed B , it can be decided to carry out an encoding in the said intensity-stereo mode in the said x_1 subbands.
- 25 In another embodiment, the encoding system is further characterized in that the computation means further being adapted to determine the difference D_1 between B_0 and B_1 , the comparing means being adapted to compare the difference D_1 with a first threshold value T_1 , the comparing means being adapted to generate a third control signal when the difference D_1 exceeds the first threshold value, the combining control signal
- 30 generator means being further adapted to generate said first combining control signal in response to at least the occurrence of the first and third control signal.

This offers the possibility to decide, in the case where B_0 exceeds B and B_1 does not exceed B , not to carry out an intensity stereo encoding in the said x_1 subbands. One could then

decide to carry out an encoding in a full stereo mode, although the bitpool is insufficient for such an encoding in a full stereo mode. The reason for not going over to an intensity stereo encoding mode in the said x_1 subbands is, that the 'profit' when going over to an intensity stereo mode in x_1 subbands is too low. The reason for such choice is that artifacts that can occur because of carrying out an intensity stereo mode in the x_1 subbands can become more audible than the higher quantisation noise because of the fact that too less bits are allocated to the various subband signals in the full stereo mode.

Further, the encoding system is preferably characterized in that the encoding system further comprises antiphase determining means for determining an antiphase situation between the corresponding time equivalent signal blocks in at least one of said x_1 frequency bands and for determining a fourth control signal in the absence of an antiphase situation in at least one of the x_1 subbands, the combining control signal generator means being further adapted to generate said first combining control signal in response to at least the occurrence of the first and fourth control signal.

Antiphase situations occurring during subband encoding have already been described in EP 497,413 A1, document (3) in the list of related documents. Encoding two subband signal components in a subband that are in antiphase with each other, in an intensity stereo mode can result in an incorrect encoding of the signal components, which results in large distortion components occurring in the replicas of the two signal components upon decoding.

Therefore, if such antiphase situation occurs in one or more of the x_1 subbands, it is decided not to carry out an intensity stereo encoding in the said x_1 subbands, resulting in the full stereo encoding to be carried out in the said x_1 subbands.

The decision to go over to an intensity stereo mode encoding in the x_1 subbands can thus be determined by one or more of the above discussed requirements.

The encoding system may be further characterized in that in response to a second combining control signal the signal combination means is further adapted to combine, in a number of x_2 frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in said x_2 frequency bands so as to obtain a time equivalent signal block of a composite sub signal in each said x_2 frequency bands, the bit allocation means being adapted to derive variables n_{jc} for the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands, in response to the second combining control signal, where j denotes one of the x_2 frequency bands, the quantizing means being adapted to quantize the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands by n_{jc} bits, in response to the second

combining control signal,

that the combining control signal generator means being further adapted to generate said second combining control signal in response to at least the detection of the absence of the second control signal, where x_2 is an integer larger than zero.

- 5 From the foregoing, it is clear that a calculation is carried out to determine whether the number of bits available in the bitpool for the encoding process suffices for an encoding in an intensity stereo mode in x_1 of the M subbands. If it is concluded that it is not, it is calculated how many bits are required when an encoding in an intensity stereo mode is carried out, such that in x_2 subbands the at least two signal components in a subband are
10 combined. The x_2 subbands can include the x_1 subbands, or can be different subbands. If B_2 does not exceed B , it can be decided to carry out an encoding in the said intensity-stereo mode in the x_2 subbands.

One or more of the requirements discussed above can also be used for the decision to go over into an intensity stereo mode encoding in the x_2 subbands.

- 15 Preferably, the x_1 subbands are the x_1 highest subbands. This for the reason that the phase sensitivity of the ear is smaller for higher frequencies.

The claims 24 to 43 are the subject of the encoding method for encoding the digital signal into an intensity stereo encoding mode in one or more of the subbands.

- 20 These and other aspects of the invention will be further explained with reference to some embodiments of an encoding system in the following figure description, in which

figure 1 shows part of the encoding system for encoding a stereo audio digital signal,

- 25 figure 1a shows subsequent time equivalent signal blocks of the $2M$ subband signals present in the M subbands, when encoding the digital signal in a full stereo mode,

figure 2 the remaining part of the encoding system of figure 1 for carrying out the encoding in an intensity stereo mode,

- 30 figure 3 shows subsequent time equivalent signal blocks when encoding the digital signal in an intensity stereo mode,

figure 4 shows a flow diagram of the functioning of the encoding system, and

figure 5 shows another flow diagram of the functioning of the encoding

system.

Fig. 1 shows an embodiment of the encoding system for coding a stereo audio signal. For example, samples of 16 bit or more of the left signal component of the audio signal are applied to input 1 with a sampling frequency of 44.1 kHz. The audio signal is applied to a subband splitter 2. The subband splitter 2 splits up the left audio signal component into M subband signals by means of a number of M filters, that is to say, a low-pass filter LP, M-2 band-pass filters BP and a high-pass filter HP. For example, M is equal to 32. The sampling frequency of the M left subband signal components is reduced in the blocks referenced 9. In these blocks the sampling frequency is reduced by a factor of M. The signals thus obtained are presented at the outputs 3.1, 3.2, ... 3.M. At the output 3.1 the subband signal SB_{1l} is presented, which is the subband signal present in the lowest subband, which is the subband with the index $m=1$. At the output 3.2 the subband signal SB_{2l} is presented in the lowest but one subband, which is the subband with the index $m=2$. At the output 3.M the subband signal SB_{Ml} is available, which is the subband signal present in the highest subband, which has the index $m=M$. The signals at the outputs 3.1 to 3.M have the form of successive samples expressed in 16 or over, for example 24-bit numbers. The samples of the left subband signal component thus appear at the outputs 3.1 to 3.M in Fig. 1. These samples are referenced $l[k]$.

16-bit samples of the right signal component of the audio signal are presented with a 44 KHz sampling frequency at input 11. The signal is applied to a subband splitter 12 which distributes the right audio signal component over M subbands by means of M filters which are identical with the filters in the splitter 2 as regards their filtering function. Subsequently, the sampling frequency of the M right subband signal components is reduced in the blocks referenced 19. The signals thus obtained are presented at the outputs 13.1 to 13.M. At the output 13.1 there is again available the subband signal SB_{1r} from the lowest subband with index $m=1$, and at the output 13.M the subband signal SB_{Mr} from the highest subband is available. The signals are also in the form of samples having identical numbers of bits with the signals presented at the outputs 3.1 to 3.M of the splitter 2. The samples are referenced $r[k]$.

Fig. 1a shows the two signal components in each subband plotted against time. The signal stream of the successive samples in the two signal components in each subband are combined to q-sample signal blocks of as is apparent from Fig. 1a. For example, q is equal to 12.

In the present embodiment the subbands having the indices $m=1$ to $m=M$ have all identical widths. This is not necessary, however. The prior-art publication (4), Krasner, discusses, for example, a subdivision into a number of subbands whose bandwidths approximately correspond to the bandwidths of the critical bands of the human auditory system in the respective frequency ranges.

The operation of the subband splitters 2 and 12 will not be further discussed, because their operation has already been extensively discussed. To this end reference be made to prior-art documents (1), (4) and (5) which are considered included in this application where deemed necessary.

The corresponding signal blocks of q successive samples of the left subband signal components are applied to the associated quantizers Q_{1l} to Q_{Ml} . In a quantizer Q_{ml} the samples in a signal block are quantized to quantized samples comprising a number of bits n_{ml} , where n_{ml} is generally smaller than 16.

Similarly, the corresponding signal blocks of the right subband signal components are applied to the associated quantizers Q_{1r} to Q_{Mr} . In a quantizer Q_{mr} the samples in a signal block are quantized to quantized samples comprising a number of bits n_{mr} , where n_{mr} is generally smaller than 16.

Prior to quantization, the q samples in a signal block are first normalized. This normalization is effected by dividing the amplitudes of the q samples by the amplitude of the sample having the largest absolute value in the signal block. The amplitude of the sample having the largest amplitude in the signal block provides the scale factor SF, cf. document (2). Subsequently, the amplitudes of the normalized samples, which are now situated in an amplitude range from -1 to +1, are quantized.

In prior-art document (2) this quantization is extensively discussed, cf. Figs. 24, 25 and 26 and the associated descriptions in that document.

The quantized samples of the left signal components in the M subbands are thereafter presented at the respective outputs 4.1 to 4.M. The quantized samples of the right signal components in the M subbands are presented at the respective outputs 14.1 to 14.M.

The outputs 3.1 to 3.M are further coupled to the respective inputs 5.1 to 5.M of the unit 16 which function as the bit need determining means. Furthermore, the outputs 13.1 to 13.M are coupled to the respective inputs 15.1 to 15.M of the unit 16. The unit 16 determines the bit needs b_{ml} and b_{mr} for q -sample signal blocks corresponding with time of the left and right subband signal components in the M subbands. The bit needs b_{ml}

and b_{mr} are numbers related to the number of bits with which the q samples in a q -sample signal block of the left and right signal components in a subband with index m ought to be quantized.

The bit needs b_{1l} to b_{Ml} , and b_{1r} to b_{Mr} derived by the bit need determining means 16 are applied to the bit allocation means 7. The bit allocation means 7 determine, on the basis of the bit needs, the real numbers of bits n_{1l} to n_{Ml} and n_{1r} to n_{Mr} with which the q samples of the corresponding signal blocks of the left and right subband signal components in the subbands $m=1$ to $m=M$ are quantized. Control signals corresponding to the numbers n_{1l} to n_{Ml} are applied to the respective quantizers Q_{1l} to Q_{Ml} over the lines 8.1 to 8.M, so that the quantizers are capable of quantizing the samples of the left signal components with the correct numbers of bits. Control signals corresponding to the numbers of n_{1r} to n_{Mr} are applied to associated quantizers Q_{1r} to Q_{Mr} over the lines 18.1 to 18.M, so that also these quantizers are capable of quantizing the samples of the right signal components with the correct numbers of bits.

The documents (6a) and (6b) of the list of references extensively discuss how the bit need determining means 16 and the bit allocation means 7 may function.

The documents (6a) and (6b) explain how the powers v_{ml} and the magnitudes w_{ml} may be derived from the samples in the corresponding signal blocks of the left subband signal components, and how the bit needs b_{ml} may be derived from the magnitudes w_{ml} and the scale factors SF_{ml} . The magnitude w_{ml} then represents the power of the masked quantization noise in a signal block of the left subband signal component in the subband SB_m . Similarly, the unit 16 derives the powers v_{mr} and the magnitudes w_{mr} from the samples in the corresponding signal blocks of the right subband signal components, and the bit needs b_{mr} from the magnitudes w_{mr} and the scale factors SF_{mr} . The magnitude w_{mr} then represents the power of the masked quantization noise in a signal block of the right subband signal component in the subband m .

The documents then describe the bit allocation as performed in the bit allocation means 7. The bit allocation is mainly described for a mono signal. In the described bit allocation algorithm for the left signal component of the audio signal, the available number of bits B , starting from the calculated bit needs b_{1l} to b_{Ml} , are distributed over the samples in the time equivalent signal blocks in the M subbands so as to obtain the magnitudes n_{1l} to n_{Ml} . In the described method always the largest bit need b_{jl} is determined in a number of cyclic steps, after which a number of bits p per sample are allocated to the time equivalent signal block in the subband j , which subband was the subband of the time

equivalent signal block having the largest bitneed. In the event of bits being allocated to the signal block in the subband j for the first time, p is equal to, for example, 2. If bits are again allocated to the signal block in the subband j at a later stage, p will have a smaller value. For example, p will then be equal to 1.

5 Above documents also describe that stereo signals may be processed by the bit allocation means 7. In that case there are two options. The first option is as follows.

In this option the bit allocation is separately performed for the left and right subband signal components. In the method discussed previously, the value of B was used for the bit allocation. B was then equal to the number of available bits. It may be
10 evident that in the present case just half the number of available bits are taken for B for the calculation of n_{1l} to n_{Ml} . The other half of the number of available bits will be used for the bit allocation to the right subband signals for obtaining the values n_{1r} to n_{Mr} .

In contradiction of the first option, in which there were separate bit allocations for the left and right subband signals, in the second option the $2M$ bit needs b_{1l} to b_{Ml} and b_{1r} to b_{Mr} are applied to a bit allocation unit similar to unit 7. In this unit the $2M$
15 numbers of n_{1l} to n_{Ml} and n_{1r} to n_{Mr} are derived from the real number of available bits B in a manner similar to that described in the two documents with respect to mono signals.

Figure 2 shows the remaining circuit part of the encoding system of figure 1, which is the circuit part that realizes the encoding in an intensity stereo mode. Figure 2
20 again shows the subband splitters 2 and 12, with their outputs 3.1 to 3.M and 13.1 and 13.M respectively for supplying the $2M$ subband signals.

Signal combination means are present, denoted by the reference numerals 25, 26 and 27. x_1 outputs of the subband splitter 2 are coupled to corresponding x_1 inputs of a signal combiner 25. The x_1 outputs of the splitter 2 are the outputs 3.M- x_1 +1 to 3.M, on
25 which the subband signals in the x_1 highest subbands of the left hand signal component are available. x_1 outputs of the subband splitter 12 are coupled to corresponding x_1 other inputs of the signal combiner 25. The x_1 outputs of the splitter 12 are the outputs 13.M- x_1 +1 to 13.M, on which the subband signals in the x_1 highest subbands of the right hand signal component are available. The signal combiner 25 is adapted to combine time equivalent
30 signal blocks of corresponding subband signals of the left and right hand signal component in a subband so as to obtain a time equivalent signal block of a composite subband signal in each said x_1 subbands.

For example, the subband signals at the outputs 3.M and 13.M of the splitters 2 and 12 respectively, are added and divided by 2, so as to obtain a composite

subband signal SB_{Mc} for the subband with index $m=M$. The subband signals at the outputs 3.M-1 and 13.M-1 are added and divided by 2, so as to obtain a composite subband signal $SB_{(M-1)c}$ for the subband with index $M-1$. In this way x_1 composite subband signals are obtained, which will be available at x_1 outputs of the signal combiner 25. Those outputs are
 5 denoted by 29.1 to 29. x_1 , where the composite subband signal in the subband M is available at the output 29.1 and the composite subband signal in the subband $m=M-x_1+1$ is available at the output 29. x_1 .

x_2 outputs of the subband splitter 2 are coupled to corresponding x_2 inputs of a signal combiner 26. The x_2 outputs of the splitter 2 are the outputs 3.M- x_1-x_2+1 to
 10 3.M- x_1 , on which the subband signals in the x_2 next lower subbands of the left hand signal component are available. x_2 outputs of the subband splitter 12 are coupled to corresponding x_2 other inputs of the signal combiner 26. The x_2 outputs of the splitter 12 are the outputs 13.M- x_1-x_2+1 to 13.M- x_1 , on which the subband signals in the x_2 next lower subbands of the right hand signal component are available. The signal combiner 26 is adapted to combine
 15 time equivalent signal blocks of corresponding subband signals of the left and right hand signal component in a subband so as to obtain a time equivalent signal block of a composite subband signal in each said x_2 subbands, having indexes $m=M-x_1-x_2+1$ to $m=M-x_1$.

For example, the subband signals at corresponding outputs 3.m and 13.m of the splitters 2 and 12 respectively, are added and divided by 2, so as to obtain a composite
 20 subband signal SB_{mc} for the subband with index m , where m runs from $m=M-x_1-x_2+1$ to $m=M-x_1$. In this way x_2 composite subband signals are obtained, which will be available at x_2 outputs of the signal combiner 26. Those outputs are denoted by 30.1 to 30. x_2 , where the composite subband signal in the subband $m=M-x_1$ is available at the output 30.1 and the composite subband signal in the subband $m=M-x_1-x_2+1$ is available at the output 30. x_2 .

x_3 outputs of the subband splitter 2 are coupled to corresponding x_3 inputs of a signal combiner 27. The x_3 outputs of the splitter 2 are the outputs 3.M- $x_1-x_2-x_3+1$ to
 3.M- x_1-x_2 , on which the subband signals in the x_3 again next lower subbands of the left hand signal component are available. x_3 outputs of the subband splitter 12 are coupled to
 corresponding x_3 other inputs of the signal combiner 27. The x_3 outputs of the splitter 12 are
 30 the outputs 13.M- $x_1-x_2-x_3+1$ to 13.M- x_1-x_2 , on which the subband signals in the x_3 again next lower subbands of the right hand signal component are available. The signal combiner 27 is adapted to combine time equivalent signal blocks of corresponding subband signals of the left and right hand signal component in a subband so as to obtain a time equivalent signal block of a composite subband signal in each said x_3 subbands, having indexes $m=M-x_1-x_2-$

$x_3 + 1$ to $m = M - x_1 - x_2$.

For example, the subband signals at corresponding outputs 3.m and 13.m of the splitters 2 and 12 respectively, are added and divided by 2, so as to obtain a composite subband signal SB_{mc} for the subband with index m , where m runs from $m = M - x_1 - x_2 - x_3 + 1$ to $m = M - x_1 - x_2$. In this way x_3 composite subband signals are obtained, which will be available at x_3 outputs of the signal combiner 27. Those outputs are denoted by 31.1 to 31. x_3 , where the composite subband signal in the subband $m = M - x_1 - x_2$ is available at the output 31.1 and the composite subband signal in the subband $m = M - x_1 - x_2 - x_3 + 1$ is available at the output 31. x_3 .

The signal combiner 25 is controlled to combine corresponding time equivalent signal blocks in the x_1 highest subbands under the influence of a first control signal supplied to its control signal input 33. The signal combiner 26 is controlled to combine corresponding time equivalent signal blocks in the x_2 next lower subbands under the influence of a second control signal supplied to its control signal input 34. The signal combiner 27 is controlled to combine corresponding time equivalent signal blocks in the x_3 next lower subbands under the influence of a third control signal supplied to its control signal input 35. The control signals supplied to the signal combiners arrive via control lines denoted by the encircled D. The way in which the control signals are generated will be explained later.

The x_1 outputs of the signal combiner 25 are each coupled to an input of a corresponding quantizer, denoted by 32.1 to 32. x_1 respectively. In the same way, the x_2 outputs of the signal combiner 26 are each coupled to an input of a corresponding quantizer, denoted by 32. $x_1 + 1$ to 32. $x_1 + x_2$ respectively. In the same way, the x_3 outputs of the signal combiner 27 are each coupled to an input of a corresponding quantizer, denoted by 32. $x_1 + x_2 + 1$ to 32. $x_1 + x_2 + x_3$ respectively. At the outputs of the quantizers 32.1 to 32. $x_1 + x_2 + x_3$ are available the quantized versions of the composite subband signals in the subbands of index m , where m runs from M downwards to $M - x_1 - x_2 - x_3 + 1$.

In order to carry out quantization on time equivalent signal blocks of a composite subband signal in a subband m , bit allocation information in the form of an n_{mc} value should be available. This bit allocation information is presented to the quantizers via the control signal lines denoted by the encircled A, for the quantizers 32.1 to 32. x_1 , via the control lines denoted by the encircled B, for the quantizers 32. $x_1 + 1$ to 32. $x_1 + x_2$, and via the control lines denoted by the encircled C, for the quantizers 32. $x_1 + x_2 + 1$ to 32. $x_1 + x_2 + x_3$. The control signals arriving via the control lines A, B, C and D in figure 2

are generated in the parts of the encoding system shown in figure 1. The way how the bit allocation information for the composite subband signals is generated will be explained later.

It should be noted that the quantizers 32.m in figure 2 need not be additional quantizers, in the sense that they are present in addition to the 2M quantizers Q_{ml} and Q_{mr} of figure 1. As will be understood from the foregoing, the quantizers 32.m are used in an intensity stereo mode. In this intensity stereo mode in a subband m, the composite subband signal, and not the original left and right hand subband signal component in that subband, is encoded. That means that the quantizers Q_{ml} and Q_{mr} need not quantize the original left and right hand subband signal components in that subband, so that one of them can be used as the quantizer 32.m. This can be realized by the appropriate switching of one of the two quantizers to the corresponding output of one of the signal combiners 25, 26 or 27.

Going back to figure 1, it will now be described how the bit allocation information n_{mc} for a stereo intensity mode is derived. As has been said earlier, bit needs b_{ll} to b_{Ml} and b_{lr} to b_{Mr} have been derived in the bit need determining means 16, in a way known in the prior art. Sometimes the bitpool, that is the total number of bits available for a fully separate encoding of the 2M subband signals, is insufficient. That means that carrying out a full stereo encoding will lead to a too rough quantization of one or more of the subband signals, which can lead to audible quantization noise upon decoding. In that situation, the subband signals in one or more of the subbands are combined so as to obtain a composite subband signal for each of said subbands.

An example of a calculation that can be carried out to identify whether the bitpool is insufficient to carry out a full stereo encoding, is as follows.

The bitneeds b_{ml} and b_{mr} , as determined in the prior art publications (6a) and (6b) are relative figures on a dB scale and have a relation to the signal-to-mask ratio for the left and right hand signal component respectively. Dividing the bitneeds by 6 results in the number of bits needed to cover the signal range over the masking curve. Division by 6 is carried out, for the fact that each bit covers 6 dB. By adding all the 2M bit needs divided by 6 results in a value B_1 for the required number of bits for a full stereo encoding. This value can be compared to the bitpool B, which is the number of bits available for encoding. If B_1 exceeds B, there are insufficient bits to code the signal in a full stereo mode.

Going over to an intensity stereo mode in which the left and right hand subband signals in each of one or more subbands are combined as given above so as to obtain a composite subband signal in each said subbands can lead to a situation where the

bitpool available is sufficient.

Now, the bitneed b_{jc} must be derived for the composite subband signal for a subband with index j . As the bitneeds b_{jl} and b_{jr} for the original subband signals of that subband are available, it is decided to take b_{jc} equal to a weighted sum of the values for b_{jl} and b_{jr} . Otherwise said:

$$b_{jc} = c_1 \cdot b_{jl} + c_2 \cdot b_{jr},$$

where c_1 and c_2 are weighting factors. The weighting factor for the largest of the two values b_{jl} and b_{jr} can be taken larger than the weighting factor for the smaller of the two values. More specifically, the weighting factor for the largest of the two values b_{jl} and b_{jr} is equal to one, and the other weighting factor is zero. In that situation, b_{jc} has been taken equal to the largest of the two bitneed values b_{jl} and b_{jr} .

If intensity stereo encoding is to take place in one subband, we have $2M-2$ bitneeds b_{ml} and b_{mr} and one bitneed b_{jc} . Dividing the $2M-1$ bitneed values by 6, as previously explained and adding them, results in a lower value.

In the example of the embodiment of figure 2, it is decided that an intensity stereo mode can be carried out in which in the x_1 highest subbands the subband signals are combined so as to obtain x_1 composite signals. This results in x_1 values b_{jc} , where j runs from $M-x_1+1$ to M , one for each of the subbands with index $M-x_1+1$ to M . Dividing the $2M - x_1$ bitneeds by 6 and adding the results, offers a value B_1 , which indicates the number of bits required for an encoding in which the separate subband signals in each of the $2M-x_1$ lower subbands and the composite subband signals in the x_1 highest subbands are encoded. If B_1 does not exceed B , such encoding is possible if other requirements are preferably also fulfilled.

Suppose that a decision is taken to carry out an intensity stereo encoding in the x_1 highest subbands. A first control signal is now generated by the means 16, which control signal is applied to the output 55. This control signal is applied to the input 56 of the means 7, as well as to the control signal input 33 of the signal combiner 25. The x_1 values b_{jc} are supplied to x_1 outputs of the bit need determining means 16, denoted by the reference numeral 50, and are supplied to x_1 inputs of the bit allocation means 7, denoted by the reference numeral 51, so as to enable a bit allocation leading to $M-x_1$ values for n_{ml} , $M-x_1$ values for n_{mr} and x_1 values for n_{jc} , under the influence of the first control signal applied to the control signal input 56. Those x_1 values for n_{jc} being applied to x_1 outputs of the bit

allocation means 7, denoted by the reference numeral 52. Those x_1 n_{jc} values are supplied via the x_1 signal lines indicated by the encircled A, to the quantizers 32.1 to 32. x_1 in figure 2. Further, the signal combiner 25 combines the subband signals in each of the x_1 highest subbands in response to the first control signal applied to its input 33, so as to obtain the x_1 composite subband signals, which are applied to the quantizers 32.1 to 32. x_1 . As a results quantized composite subband signals are available at the outputs of those quantizers.

The further explanation will be done with reference to the flow diagram of figure 4. Figure 4 shows a flow diagram, which starts in 100. The sequence that follows, is a sequence of steps that is carried out on a 'megablock' comprising one time equivalent block of each of the 2M subband signals. First, the 2M bit need values b_{ml} and b_{mr} are calculated. It is assumed here that M equals 32. That is: 32 values b_{ml} and 32 values b_{mr} are calculated in block 102. Next, in block 104, the value B_1 is calculated in the way explained above, namely, by dividing the 64 bitneed values by 6 and adding the results. The value B_0 is compared to B in block 106, and if B_0 appears to be smaller than or equal to B, a full stereo encoding can be carried out. This results in the derivation of 32 values for n_{ml} and 32 values for n_{mr} in the bit allocation means, see block 108. The process ends in block 110. This is followed by a full stereo encoding of the 2M subband signals in the 2M quantizers shown in figure 1.

If it is determined in block 106 that B_0 exceeds B, the process continues in block 112, in which the b_{jc} values are calculated for the x_1 , in this case the 16, highest subbands, in the way explained above. Next B_1 is calculated, being the number of bits required when separately encoding the subband signals in the 16 lowest subbands, and encoding the composite subband signals in the highest 16 subbands, see block 114. Next, a comparison is made between B_1 and B, block 116. If B_1 is smaller than or equal to B, the process continues in block 118, where the difference D_1 between B_1 and B_0 is determined, and in block 120 where it is determined whether the difference exceeds a certain threshold T_1 . If not, it is decided that the 'profit' in number of bits is too low to justify an intensity stereo encoding, instead of a full stereo encoding. This for the reason that intensity stereo encoding can lead to artifacts that can become more annoying than an increased quantization noise in the case of full stereo encoding with a too low number of bits in the bitpool.

If it is decided that the gain in number of bits is too low, the process continues via the line 128 to block 108. If the gain exceeds the threshold T_1 , the process continues to block 122, where it is determined whether an antiphase situation occurs in one of the subbands 17 to 32. An antiphase situation occurs if the left signal component in a

subband has a polarity opposite to the polarity of the right signal component in that subband. If so, the process continues via the line 130 and 128 to block 108. This for the reason that intensity stereo encoding two subband signals in a subband that have opposite phase lead to larger artifacts in the reproduced signal than when the increased quantization noise in the case of a full stereo encoding with a too low number of bits in the bitpool.

A further feature of the block 122 (and all the other blocks to be discussed later, such as the blocks 142, 162 in figure 4 and the blocks 202, 222 and 242 in figure 5) can be that, if an antiphase situation exists in a subband but one of the at least two signal components in said subband lie below the masking threshold of the wideband digital signal, and thus is inaudible, one still can decide to carry out an intensity stereo encoding.

If no antiphase situation exists, the process continues to block 124, in which in the bit allocation step the 16 values for n_{ml} and n_{mr} for the 16 lowest subbands and the 16 values n_{jc} for the 16 highest subbands are derived. The process ends in block 126. This is followed by an intensity stereo encoding on the subband signals, two in each of the 16 lowest subbands, and on the composite subband signals, one in each of the 16 highest subbands.

If it is determined in block 116 that B_1 exceeds B , the process continues in block 132, in which the b_{jc} values are calculated for the x_2 , in this case the 4, next lower subbands, in the way explained above. Next B_2 is calculated, being the number of bits required when separately encoding the subband signals in the 12 lowest subbands, and encoding the composite subband signals in the highest 20 subbands, see block 134. Next, a comparison is made between B_2 and B , block 136. If B_2 is smaller than or equal to B , the process continues in block 138, where the difference D_2 between B_2 and B_0 is determined, and in block 140 where it is determined whether the difference exceeds a certain threshold T_2 . If not, it is decided that the 'profit' in number of bits is too low to justify an intensity stereo encoding in the 20 highest subbands. This, again, for the reason that intensity stereo encoding in the 20 highest subbands can lead to artifacts that can become more annoying than an increased quantization noise in the case of an intensity stereo encoding in the 16 highest subbands or in the case of a full stereo encoding, both with a too low number of bits in the bitpool.

If it is decided that the gain in number of bits is too low, the process continues via the line 148 to block 118. If the gain exceeds the threshold T_2 , the process continues to block 142, where it is determined whether an antiphase situation occurs in one of the subbands 13 to 32. If so, the process continues via the line 148 to block 118. This for

the reason that intensity stereo encoding two subband signals in a subband that have opposite phase lead to larger artifacts in the reproduced signal than when the increased quantization noise in the case of an encoding with a too low number of bits in the bitpool.

If not, the process continues to block 144, in which in the bit allocation
 5 step the 12 values for n_{ml} and n_{mr} for the 12 lowest subbands and the 20 values n_{jc} for the 20 highest subbands are derived. A second control signal is now generated, which is supplied to the output 55 of the bitneed determining means 16.

As regards the encoding system of figure 1 and 2, this means that the bit
 10 determining means 16 supply the $x_1(=16)$ bitneeds b_{jc} at the output 50 and the $x_2(=4)$ bitneeds b_{jc} at an output 60. The x_2 bitneeds b_{jc} are supplied to an input 61 of the bit allocation means 7. Further, $M-x_1-x_2(=12)$ values b_{ml} and 12 values b_{mr} , for the 12 lowest subbands, are supplied to the bit allocation means 7. The allocation means 7 derive the 12 values n_{ml} , the 12 values n_{mr} and the 20 values for n_{jc} from the bitneed values received, and in response to the second control signal applied to its input 56. Further, the second control
 15 signal is applied via the lines denoted by the encircled D to the combining units 25 and 26, so that $x_1(=16)$ composite signals are generated by the combining unit 25 and the $x_2(=4)$ composite signals are generated by the combining unit 26, in response to the second control signal.

The $x_1(=16)$ values n_{jc} derived for the highest subbands are supplied to
 20 the output 52 of the means 7, and the $x_2(=4)$ values n_{jc} for the x_2 next lower subbands are supplied to an output 62 of the means 7. Those values are supplied via the lines denoted by the encircled A and B to the quantizers 32.1 to 32. x_1+x_2 , so that the quantization of the composite subband signals can be carried out.

If it is determined in block 136 that B_2 exceeds B, the process continues
 25 in block 152, in which the b_{jc} values are calculated for the x_3 , in this case the 4, next lower subbands, in the way explained above. Next B_3 is calculated, being the number of bits required when separately encoding the subband signals in the 8 lowest subbands, and encoding the composite subband signals in the highest 24 subbands, see block 154. Next, a comparison is made between B_3 and B, block 156. If B_3 is smaller than or equal to B, the
 30 process continues in block 158, where the difference D_3 between B_3 and B_0 is determined, and in block 160 where it is determined whether the difference exceeds a certain threshold T_3 . If not, it is decided that the 'profit' in number of bits is too low to justify an intensity stereo encoding in the 24 highest subbands. This, again, for the reason that intensity stereo encoding in the 24 highest subbands can lead to artifacts that can become more annoying

than an increased quantization noise in the case of an intensity stereo encoding in the 20 highest subbands, the 16 highest subbands or when encoding in a full stereo mode, all with a too low number of bits in the bitpool.

If it is decided that the gain in number of bits is too low, the process
5 continues via the line 168 to block 138. If the gain exceeds the threshold T_3 , the process continues to block 162, where it is determined whether an antiphase situation occurs in one of the subbands 9 to 32. If so, the process continues via the line 168 to block 138.

If not, the process continues to block 164, in which in the bit allocation
10 step the 8 values for n_{ml} and n_{mr} for the 8 lowest subbands and the 24 values n_{jc} for the 24 highest subbands are derived. A third control signal is now generated, which is supplied to the output 55 of the bitneed determining means 16.

As regards the encoding system of figure 1 and 2, this means that the bit
determining means 16 supply the $x_1(=16)$ bitneeds b_{jc} at the output 50 and the $x_2(=4)$
bitneeds b_{jc} at the output 60 and the $x_3(=4)$ bitneeds b_{jc} at an output 64. The x_3 bitneeds b_{jc}
15 are supplied to an input 65 of the bit allocation means 7. Further, $M-x_1-x_2-x_3(=8)$ values b_{ml} and 8 values b_{mr} , for the 8 lowest subbands, are supplied to the bit allocation means 7. The allocation means 7 derive the 8 values n_{ml} , the 8 values n_{mr} and the 24 values for n_{jc} from the bitneed values received, and in response to the third control signal applied to its
input 56. Further, the third control signal is applied via the lines denoted by the encircled D
20 to the combining units 25, 26 and 27, so that $x_1(=16)$ composite signals are generated by the combining unit 25, the $x_2(=4)$ composite signals are generated by the combining unit 26, and the $x_3(=4)$ composite signal are generated by the combining unit 27, in response to the third control signal.

The $x_1(=16)$ values n_{jc} derived for the highest subbands are supplied to
25 the output 52 of the means 7, the $x_2(=4)$ values n_{jc} for the x_2 next lower subbands are supplied to an output 62 of the means 7, and the $x_3(=4)$ values for n_{jc} for the again next lower subbands are supplied to an output 67 of the means 7. Those values are supplied via the lines denoted by the encircled A, B and C to the quantizers 32.1 to 32. $x_1+x_2+x_3$, so that the quantization of the composite subband signals can be carried out.

30 The process now ends in block 166. The process can be continued from block 156 via line 170, if B_3 exceeds B. If there is no further signal path for a further increase of the number of subbands in which an intensity stereo encoding can be carried out, the block 156 can be left out.

The method described in figure 4 can have some of the blocks at other

locations in the flow diagram, without leading to a different overall functioning. As an example, the block 122 for determining the antiphase situation, can be located in the branch 107 coupling the 'no' output of the block 106 with the block 112. In this situation, when having decided that B_0 is larger than B , it is decided whether an antiphase situation exists in one or more of the 16 highest subbands. If so, the method proceeds to block 108. Otherwise, the method proceeds to block 112. In the same way, the block 142 can be located in the branch 117 coupling the 'no' output of the block 116 with the block 132, and the block 162 can be located in the branch 137 coupling the 'no' output of the block 136 with the block 152.

Further, it should be noted that, in more simple methods, not all the requirements shown in figure 4 are needed. As an example, if the requirement that the 'profit' in number of bits should exceed a certain threshold value, such as the values T_1 , T_2 and T_3 , is not relevant, this leads to a method, such as the method of figure 4, in which the blocks 118, 120, 138, 140, 158 and 160 have been left out.

Figure 3 shows the encoding of subsequent 'macroblocks' of time equivalent signal blocks of the subband signals. Figure 3 shows, indicated by MB1, a macroblock in which a full stereo encoding is carried out. That is: all $2M(=64)$ subband signals are present for encoding. MB2 is a macroblock for which has been decided that an encoding in an intensity stereo mode on the highest $x_1(=16)$ subbands will be carried out. That means that for the lowest $M-x_1(=16)$ subbands the separate subband signals are present, whereas in the highest subbands, for $m=16$ to $m=32$, a composite subband signal, having samples $c[1], c[2], \dots, c[q]$, is available. The next macroblock MB3 shows a composite signal in the 20 highest subbands, whereas the macroblock MB4 (only a part of the macroblock is shown) shows a composite signal in the 24 highest subbands.

Figure 5 shows another embodiment of a method for encoding a digital signal in an intensity stereo encoding mode.

The method starts in block 100 and continues via the blocks 102, 104 and 106, in the same way as shown in figure 4. The branch including the decision process that leads to a full stereo encoding via the blocks 108 and 110, is fully equivalent to the branch including the same blocks in figure 4.

If B_0 is larger than B , the program continues via block 200, in which a value BT is made equal to B_0 , to block 202. In this block 202 it is determined whether an antiphase situation exists in one or more of the (in this case) eight highest subbands. If not, the program proceeds to block 204 in which the values b_{jc} for the eight highest subbands are

calculated. Next, the required number of bits B_1 , when encoding the 24 lowest subbands in a full stereo mode and the 8 highest subbands in an intensity stereo mode, is calculated in block 206, using b_{mi} for $1 \leq m \leq 24$ and b_{jc} for $25 \leq j \leq 32$. In block 208, the difference D_1 between B_0 and B_1 is calculated.

5 In block 210 it is determined whether D_1 is larger than a first threshold value T_1 . If so, it is decided that an intensity stereo mode coding will be carried out in the eight highest subbands, block 214. Moreover, in block 212 the value BT is replaced by the original value for BT from which the difference value D_1 has been subtracted, and it is determined in block 216 whether BT is smaller than or equal to B. If so, the program
10 continues via the path 217 to block 256, in which the values n_{mi} are determined for $1 \leq m \leq 24$ and the values n_{jc} are determined for $25 \leq j \leq 32$. As a result, an intensity stereo mode encoding is carried out in the eight highest subbands.

In the case that it is decided in block 202 that an antiphase situation is present, the program continues via the path 218 to block 222. In the same way if D_1 is not
15 larger than T_1 , see block 210, the program continues via the path 218 to block 222. In both cases, no intensity stereo mode encoding will take place in the eight highest subbands. Further, if BT appears to be larger than B in block 216, the program also continues via the path 218 to block 222. In this situation, however, it has been decided, in block 214, to carry out an intensity stereo mode encoding in at least the eight highest subbands.

20 In block 222 it is determined whether an antiphase situation exists in one or more of the (in this case) eight next lower subbands, for which it holds that $17 \leq j \leq 24$. If not, the program proceeds to block 224 in which the values b_{jc} for the eight next lower subbands are calculated. Next, the required number of bits B_2 , when encoding the subbands m, with $1 \leq m \leq 16$ and $25 \leq m \leq 32$, in a full stereo mode and the subbands j, with
25 $17 \leq j \leq 24$, in an intensity stereo mode, is calculated in block 226, using b_{mi} for $1 \leq m \leq 16$ and $25 \leq m \leq 32$ and b_{jc} for $17 \leq j \leq 24$.

In block 228, the difference D_2 between B_0 and B_2 is calculated.

In block 230 it is determined whether D_2 is larger than a first threshold value T_2 . If so, it is decided that an intensity stereo mode coding will be carried out in the
30 eight next lower subbands, block 234. Moreover, in block 232 the value BT is replaced by the present value for BT from which the difference value D_2 has been subtracted, and it is determined in block 236 whether BT is smaller than or equal to B. If so, the program continues via the path 217 to block 256, in which the values n_{mi} are determined for $1 \leq m \leq 16$, the values n_{jc} are determined for $17 \leq j \leq 24$. Further, if the program has avoided

the block 214, a full stereo encoding will be carried out in the eight highest subbands, so that also the values n_{mi} are calculated for $25 \leq m \leq 32$. If the program has passed the block 214, an intensity stereo mode encoding will be carried out in the 16 highest subbands, so that in the block 256 also the values n_{jc} for $25 \leq j \leq 32$ are calculated. As a result, an intensity stereo mode encoding is carried out in either the eight next higher subbands or in the 16 highest subbands.

In the case that it is decided in block 222 that an antiphase situation is present, the program continues via the path 238 to a branch (not shown), such as the branch including the blocks 222 to 236. In the same way if D_2 is not larger than T_2 , see block 230, the program continues via the path 238 to the said branch. In both cases, no intensity stereo mode encoding will take place in the eight next lower subbands. Further, if BT appears to be larger than B in block 236, the program also continues via the path 238 to the said branch. In this situation, however, it has been decided, in block 234, to carry out an intensity stereo mode encoding in at least the eight next lower subbands.

In the said branch, for a number of next lower subbands it is decided whether an intensity stereo mode encoding should take place. The processing is fully equivalent to the two branches already discussed above.

Figure 5 shows the last, or i -th, branch which starts with the block 242, which is equivalent to the block 222. Blocks equivalent to the blocks 224, 226 and 228 are also present in the last branch. In block 242 it is decided whether an antiphase situation exists in one or more of the subbands 5 to 8. If so, the program proceeds to block 256 and no intensity stereo mode encoding is carried out in the subbands 5 to 8. In block 250 it is determined whether D_i , relating to the difference between B_0 and B_i is larger than T_i . If not, again no intensity stereo mode encoding is carried out in the subbands 5 to 8. If so, the program proceeds to block 254 and 256, resulting in an intensity stereo mode encoding in at least the subbands 5 to 8.

In the embodiments discussed hereinbefore it has been assumed that in all cases it was a matter of coding a wideband digital signal constituted by first and second signal components, for example a stereo signal constituted by a left and a right signal component. The wideband digital signal, however, may also be constituted by three or more signal components. With three signal components one may think of a left, a centre and a right component. With four signal components one may think of, for example, a left, centre, right and surround signal. With five signal components, one may think of a left, centre, right, left surround and right surround signal.

References

- (1) European Patent Application No. 289 080 (PHN 12.108)
- (2) European Patent Application No. 402 973 (PHN 13.241)
- 5 (3) European Patent Application No. 497,413 (PHN 13.581)
- (4) IEEE ICASSP 80, Vol. 1, 327-331, April 9-11, 1980
M.A. Krasner "The Critical Band Coder ... Digital
Encoding of Speech Signals Based on the Perceptual
Requirements of the Auditory System".
- 10 (5) European Patent Application No. 400,755 (PHQ 89.018A)
- (6a) European Patent Application No. 457,390 (PHN 13.328)
- (6b) European Patent Application No. 457,391 (PHN 13.329)
- (7) Proc. of the ICASSP, 1991, Toronto, pp. 3601-4, R.G. van der Waal et al,
'Subband coding of stereophonic digital audio signals'.

CLAIMS

1. An encoding system for encoding a digital signal having at least a first and a second digital signal component, the signal components having a specific sampling frequency and bandwidth, comprising
 - splitter means for dividing the bandwidth of the digital signal components into M successive
 - 5 frequency bands, and generating in response to the digital signal components M sub signals for each digital signal component, each sub signal of a signal component being associated with one of the frequency bands,
 - bit need determining means for determining bit needs for time equivalent signal blocks of the sub signals, the signal blocks each containing q samples of a sub signal, a bit need b_{mi}
 - 10 for a signal block of a sub signal SB_{mi} of a signal component i in frequency band m corresponding to the number of bits by which the q samples in that signal block should be represented, where b_{mi} may vary for different signal blocks and different sub signals,
 - signal combination means for combining, in a number of at least one frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal
 - 15 component so as to obtain a time equivalent signal block of a composite sub signal in each said at least one frequency bands,
 - quantizing means for quantizing time equivalent signal blocks of the sub signals in those frequency bands in which no composite sub signal is available and for quantizing the corresponding time equivalent signal blocks of the composite sub signal in said at least one
 - 20 frequency band in which a composite sub signal is available, each sample of the signal block of a sub signal SB_{mi} being quantized by n_{mi} bits, where m denotes a frequency band in which no composite sub signal is available, and each sample of the composite sub signal SB_{mc} being quantized by n_{mc} bits, where m denotes a frequency band in which a composite sub signal is available,
 - 25 - bit allocation means for deriving the variables n_{mi} and n_{mc} from bit needs obtained in the bit need determining means and from a value B, where B corresponds to a number of bits in an available bitpool, and wherein q is an integer larger than zero, n_{mi} , n_{mc} , b_{mi} , b_{mc} are variables where n_{mi} and n_{mc} are greater than or equal to zero, M is a constant greater than zero, B is an integer, and m is an integer such that $1 \leq m \leq M$,

characterized in that the bit need determining means is adapted to determine a common bit need b_{mc} for a time equivalent signal block of a composite sub signal SB_{mc} in a frequency band m from the bit needs b_{mi} of the time equivalent signal blocks of the corresponding sub signals of the at least two signal components in that frequency band from which the time equivalent signal block of the composite sub signal has been derived, such that common bit need b_{mc} is equal to the sum of the bit needs b_{mi} , multiplied by a corresponding weighting factor, the bit allocation means being adapted to derive the variables n_{mi} for the time equivalent signal blocks of the sub signals in those frequency bands in which no composite sub signal is available and the at least one variable n_{mc} for the time equivalent signal block of the sub signal in those at least one frequency band for which a composite sub signal is available, from the bit needs b_{mi} available for those frequency bands for which no composite sub signal is available and the at least one common bit need b_{mc} .

2. Encoding system as claimed in claim 1, characterized in that the weighting factor corresponding to the largest of the bitneeds b_{mi} is larger than the weighting factor corresponding to the other at least one bitneed.

3. Encoding system as claimed in claim 2, characterized in that the weighting factor corresponding to the largest of the bitneeds b_{mi} is equal to one and the other at least one weighting factor is zero.

4. The encoding system of claim 1, 2 or 3, characterized in that it comprises
 - computation means for computing a value B_0 , where B_0 corresponds to the number of bits required when separately encoding the time equivalent signal blocks of the at least first and second sub signals in all M frequency bands,

- comparing means for comparing the value B_0 with the value B , the comparing means being adapted to generate a first control signal at an output when B_0 exceeds B ,

- combining control signal generator means for generating a first combining control signal in response to at least the occurrence of the first control signal,

the signal combination means being adapted to combine in a number of x_1 frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in said x_1 frequency bands so as to obtain a time equivalent signal block of a composite sub signal in each said x_1 frequency bands, in response to said first combining control signal,

the bit allocation means being adapted to derive variables n_{jc} for the time equivalent signal blocks of the composite sub signals in said x_1 frequency bands, in response to the first combining control signal, where j denotes one of the x_1 frequency bands,



the quantizing means being adapted to quantize the time equivalent signal blocks of the composite sub signals in said x_1 frequency bands by n_{jc} bits, in response to the first combining control signal, and where x_1 is an integer larger than zero.

5 The encoding system as claimed in claim 4, characterized in that, in response to the occurrence of the first control signal, the computation means are further adapted to compute a value B_1 , where B_1 corresponds to the number of bits required when encoding corresponding time equivalent signal blocks of composite sub signals in said x_1 frequency bands and separately encoding the corresponding time equivalent signal blocks of the at least first and second sub signals in the remaining $M - x_1$ frequency bands, the
10 comparing means being further adapted to compare the value B_1 with the value B , the comparing means being adapted to generate a second control signal when B_1 does not exceed B .

6. The encoding system as claimed in claim 5, characterized in that the combining control signal generator means being further adapted to generate said first
15 combining control signal in response to at least the occurrence of the first and second control signal.

7. The encoding system as claimed in claim 4, characterized in that the computation means further being adapted to determine the difference D_1 between B_0 and B_1 , the comparing means being adapted to compare the difference D_1 with a first threshold value
20 T_1 , the comparing means being adapted to generate a third control signal when the difference D_1 exceeds the first threshold value, the combining control signal generator means being further adapted to generate said first combining control signal in response to at least the occurrence of the first and third control signal.

8. The encoding system as claimed in claim 4, characterized in that the
25 encoding system further comprises antiphase determining means for determining an antiphase situation between the corresponding time equivalent signal blocks in at least one of said x_1 frequency bands and for determining a fourth control signal in the absence of an antiphase situation in at least one of the x_1 subbands, the combining control signal generator means being further adapted to generate said first combining control signal in response to at least
30 the occurrence of the first and fourth control signal.

9. The encoding system as claimed in claim 6 and 7, characterized in that the combining control signal generator means being further adapted to generate said first combining control signal in response to at least the occurrence of the first, second and third control signal.



10. The encoding system as claimed in claim 6 and 8, characterized in that the combining control signal generator means being further adapted to generate said first combining control signal in response to at least the occurrence of the first, second and fourth control signal.

5 11. The encoding system as claimed in claim 7 and 8, characterized in that the combining control signal generator means being further adapted to generate said first combining control signal in response to at least the occurrence of the first, third and fourth control signal.

12. The encoding system as claimed in claim 6 and 7 and 8, characterized in
10 that the first combining control signal generator means being further adapted to generate said first combining control signal in response to the occurrence of the first, second, third and fourth control signal.

13. The encoding system as claimed in claim 4, characterized in that the x_1 frequency bands are the x_1 highest frequency bands of the M frequency bands.

15 14. The encoding system as claimed in claim 5, characterized in that in response to a second combining control signal the signal combination means is further adapted to combine, in a number of x_2 frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in said x_2 frequency bands so as to obtain a time equivalent signal block of a composite sub signal in
20 each said x_2 frequency bands, the bit allocation means being adapted to derive variables n_{jc} for the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands, in response to the second combining control signal, where j denotes one of the x_2 frequency bands,

the quantizing means being adapted to quantize the time equivalent signal blocks of the
25 composite sub signals in said x_2 frequency bands by n_{jc} bits, in response to the second combining control signal,

that the combining control signal generator means being further adapted to generate said second combining control signal in response to at least the detection of the absence of the second control signal, where x_2 is an integer larger than zero.

30 15. The encoding system as claimed in claim 7, characterized in that in response to a second combining control signal the signal combination means is further adapted to combine, in a number of x_2 frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in said x_2 frequency bands so as to obtain a time equivalent signal block of a composite sub signal in

each said x_2 frequency bands, the bit allocation means being adapted to derive variables n_{jc} for the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands, in response to the second combining control signal, where j denotes one of the x_2 frequency bands,

- 5 the quantizing means being adapted to quantize the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands by n_{jc} bits, in response to the second combining control signal, that the combining control signal generator means being further adapted to generate said second combining control signal in response to at least the detection of the absence of the third control signal, where x_2 is an integer larger than zero.

- 10 16. The encoding system as claimed in claim 8, characterized in that in response to a second combining control signal the signal combination means is further adapted to combine, in a number of x_2 frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in said x_2 frequency bands so as to obtain a time equivalent signal block of a composite sub signal in
- 15 each said x_2 frequency bands, the bit allocation means being adapted to derive variables n_{jc} for the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands, in response to the second combining control signal, where j denotes one of the x_2 frequency bands,

- the quantizing means being adapted to quantize the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands by n_{jc} bits, in response to the second combining control signal, that the combining control signal generator means being further adapted to generate said second combining control signal in response to at least the detection of the absence of the fourth control signal, where x_2 is an integer larger than zero.

17. The encoding system as claimed in claim 14, 15 or 16, characterized in
- 25 that the computation means are further adapted to compute a value B_2 , where B_2 corresponds to the number of bits required when encoding corresponding time equivalent signal blocks of composite sub signals in said number of x_2 frequency bands and separately encoding the corresponding time equivalent signal blocks of the at least first and second sub signals in the remaining $M - x_2$ frequency bands.

- 30 18. The encoding system as claimed in claim 17, characterized in that the comparing means being further adapted to compare the value B_2 with the value B , the comparing means being adapted to generate a fifth control signal when B_2 does not exceed B .

19. The encoding system as claimed in claim 18, characterized in that the combining control signal generating means is further adapted to generate the second



combining control signal only if also the presence of the fifth control signal has been detected.

20. The encoding system as claimed in claim 17, characterized in that the computation means further being adapted to determine the difference D_2 between B_0 and B_2 ,
5 the comparing means being adapted to compare the difference D_2 with a second threshold value T_2 , the comparing means being adapted to generate a sixth control signal when the difference D_2 exceeds the second threshold value, the combining control signal generator means being further adapted to generate said second combining control signal only if also the presence of the sixth control signal has been detected.

10 21. The encoding system as claimed in claim 14, 15 or 16, characterized in that the antiphase determining means are further adapted to determining an antiphase situation between the corresponding time equivalent signal blocks in at least one of said x_2
frequency bands and for determining a seventh control signal in the absence of an antiphase situation in at least one of the x_2 subbands, the combining control signal generator means
15 being further adapted to generate said second combining control signal if also the presence of the seventh control signal has been detected.

22. The encoding system as claimed in claim 20, characterized in that the second threshold value T_2 which is larger than the first threshold value T_1 .

23. The encoding system as claimed in claim 14, characterized in that the x_2
20 subbands are the next lower x_2 subbands.

24. An encoding method for encoding a digital signal having at least a first and a second digital signal component, the signal components having a specific sampling frequency and bandwidth, in which the bandwidth of the digital signal components are splitted into M successive frequency bands, and M sub signals are generated for each digital
25 signal component in response to the digital signal components, each sub signal of a signal component being associated with one of the frequency bands, bit needs for time equivalent signal blocks of the sub signals are determined, the signal blocks each containing q samples of a sub signal, a bit need b_{mi} for a signal block of a sub signal SB_{mi} of a signal component i in frequency band m corresponding to the number of bits by which the q samples in that
30 signal block should be represented, where b_{mi} may vary for different signal blocks and different sub signals, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in a number of at least one frequency band may be combined so as to obtain a time equivalent signal block of a composite sub signal in each said at least one frequency bands, time equivalent signal blocks of the sub signals in those



- frequency bands in which no composite sub signal is available are quantized and the corresponding time equivalent signal blocks of the composite sub signal in said at least one frequency band in which a composite sub signal is available are quantized, each sample of the signal block of a sub signal SB_{mi} being quantized by n_{mi} bits, where m denotes a
- 5 frequency band in which no composite sub signal is available, and each sample of the composite sub signal SB_{mc} being quantized by n_{mc} bits, where m denotes a frequency band in which a composite sub signal is available, the variables n_{mi} and n_{mc} are derived from bit needs obtained and from a value B , where B corresponds to a number of bits in an available bitpool, and wherein q is an integer larger than zero, n_{mi} , n_{mc} , b_{mi} , b_{mc} are variables where
- 10 n_{mi} and n_{mc} are greater than or equal to zero, M is a constant greater than zero, B is an integer, and m is an integer such that $1 \leq m \leq M$,
- characterized in that a common bit need b_{mc} for a time equivalent signal block of a composite sub signal SB_{mc} in a frequency band m is determined from the bit needs b_{mi} of the time equivalent signal blocks of the corresponding sub signals of the at least two signal
- 15 components in that frequency band from which the time equivalent signal block of the composite sub signal has been derived, by taking the common bit need b_{mc} equal to the sum of the bit needs b_{mi} , multiplied by a corresponding weighting factor, and that the variables n_{mi} for the time equivalent signal blocks of the sub signals in those frequency bands in which no composite sub signal is available and the at least one variable n_{mc} for the time equivalent
- 20 signal block of the sub signal in those at least one frequency band for which a composite sub signal is available, are derived from the bit needs b_{mi} available for those frequency bands for which no composite sub signal is available and the at least one common bit need b_{mc} .
25. Encoding method as claimed in claim 24, characterized in that the weighting factor corresponding to the largest of the bitneeds b_{mi} is taken larger than the
- 25 weighting factor corresponding to the other at least one bitneed.
26. Encoding method as claimed in claim 25, characterized in that the weighting factor corresponding to the largest of the bitneeds b_{mi} is taken equal to one and the other at least one weighting factor is taken equal to zero.
27. The encoding method of claim 24, 25 or 26, characterized in that a value
- 30 B_0 is computed, where B_0 corresponds to the number of bits required when separately encoding the time equivalent signal blocks of the at least first and second sub signals in all M frequency bands, the value B_0 is compared with the value B and a first control signal is generated when B_0 exceeds B , a first combining control signal is generated in response to at least the occurrence of the first control signal, that, in response to the occurrence of the first



combining control signal,

- in a number of x_1 frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in said x_1 frequency bands are combined so as to obtain a time equivalent signal block of a composite sub signal in each
5 said x_1 frequency bands,

- variables n_{jc} for the time equivalent signal blocks of the composite sub signals in said x_1 frequency bands are generated, where j denotes one of the x_1 frequency bands,

- the time equivalent signal blocks of the composite sub signals in said x_1 frequency bands are quantized by n_{jc} bits, and where x_1 is an integer larger than zero.

10 28. The encoding method as claimed in claim 27, characterized in that, in response to the occurrence of the first control signal,

- a value B_1 is computed, where B_1 corresponds to the number of bits required when encoding corresponding time equivalent signal blocks of composite sub signals in said x_1 frequency bands and separately encoding the corresponding time equivalent signal blocks of
15 the at least first and second sub signals in the remaining $M - x_1$ frequency bands,
- the value B_1 is compared with the value B and a second control signal is generated when B_1 does not exceed B .

20 29. The encoding method as claimed in claim 28, characterized in that said first combining control signal is generated in response to at least the occurrence of the first and second control signal.

30. The encoding method as claimed in claim 27, characterized in that the difference D_1 between B_0 and B_1 is determined, the difference D_1 is compared with a first threshold value T_1 and a third control signal is generated when the difference D_1 exceeds the first threshold value, and that said first combining control signal is generated in response to
25 at least the occurrence of the first and third control signal.

31. The encoding method as claimed in claim 27, characterized in that an antiphase situation is determined between the corresponding time equivalent signal blocks in at least one of said x_1 frequency bands and a fourth control signal is generated in the absence of an antiphase situation in at least one of the x_1 subbands, and that said first combining
30 control signal is generated in response to at least the occurrence of the first and fourth control signal.

32. The encoding method as claimed in claim 29 and 30, characterized in that said first combining control signal is generated in response to at least the occurrence of the first, second and third control signal.



33. The encoding method as claimed in claim 29 and 31, characterized in that said first combining control signal is generated in response to at least the occurrence of the first, second and fourth control signal.

34. The encoding method as claimed in claim 30 and 31, characterized in that said first combining control signal is generated in response to at least the occurrence of the first, third and fourth control signal.

35. The encoding method as claimed in claim 29 and 30 and 31, characterized in that said first combining control signal is generated in response to the occurrence of the first, second, third and fourth control signal.

36. The encoding method as claimed in claim 28, characterized in that in response to a second combining control signal,
- in a number of x_2 frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in said x_2 frequency bands are combined so as to obtain a time equivalent signal block of a composite sub signal in each said x_2 frequency bands,
- variables n_{jc} for the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands are derived, where j denotes one of the x_2 frequency bands,
- the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands are quantized by n_{jc} bits,
and that said second combining control signal is generated in response to at least the detection of the absence of the second control signal, where x_2 is an integer larger than zero.

37. The encoding method as claimed in claim 30, characterized in that in response to a second combining control signal,

- in a number of x_2 frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in said x_2 frequency bands are combined so as to obtain a time equivalent signal block of a composite sub signal in each said x_2 frequency bands,
- variables n_{jc} for the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands are derived, where j denotes one of the x_2 frequency bands,
- the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands are quantized by n_{jc} bits,

and that said second combining control signal is generated in response to at least the detection of the absence of the third control signal, where x_2 is an integer larger than zero.

38. The encoding method as claimed in claim 31, characterized in that in



response to a second combining control signal,

- in a number of x_2 frequency bands, time equivalent signal blocks of corresponding sub signals of the at least first and second signal component in said x_2 frequency bands are combined so as to obtain a time equivalent signal block of a composite sub signal in each
5 said x_2 frequency bands,

- variables n_{jc} for the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands are derived, where j denotes one of the x_2 frequency bands,

- the time equivalent signal blocks of the composite sub signals in said x_2 frequency bands are quantized by n_{jc} bits,

10 and that said second combining control signal is generated in response to at least the detection of the absence of the fourth control signal, where x_2 is an integer larger than zero.

39. The encoding method as claimed in claim 36, 37 or 38, characterized in that a value B_2 is computed, where B_2 corresponds to the number of bits required when encoding corresponding time equivalent signal blocks of composite sub signals in said
15 number of x_2 frequency bands and separately encoding the corresponding time equivalent signal blocks of the at least first and second sub signals in the remaining $M - x_2$ frequency bands.

40. The encoding method as claimed in claim 39, characterized in that the value B_2 is compared with the value B , and that a fifth control signal is generated when B_2
20 does not exceed B .

41. The encoding method as claimed in claim 40, characterized in that the second combining control signal is generated only if also the presence of the fifth control signal has been detected.

42. The encoding method as claimed in claim 39, characterized in that the
25 difference D_2 between B_0 and B_2 is determined, the difference D_2 is compared with a second threshold value T_2 , a sixth control signal is generated when the difference D_2 exceeds the second threshold value, and that said second combining control signal is generated only if also the presence of the sixth control signal has been detected.

43. The encoding method as claimed in claim 36, 37 or 38, characterized in
30 that an antiphase situation is determined between the corresponding time equivalent signal blocks in at least one of said x_2 frequency bands and that a seventh control signal is generated in the absence of an antiphase situation in at least one of the x_2 subbands, and that said second combining control signal is generated if also the presence of the seventh control signal has been detected.



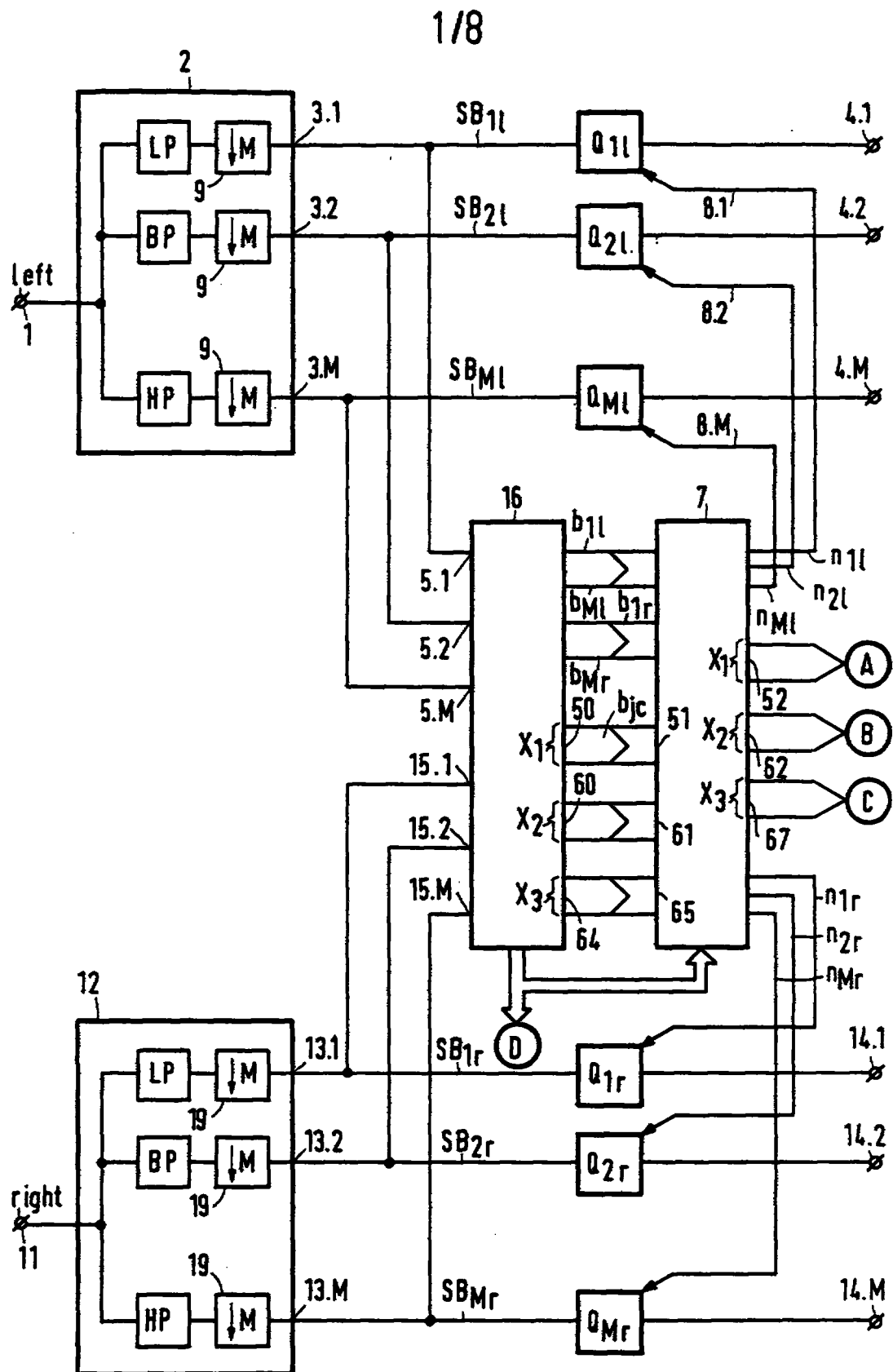


FIG. 1

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m=1	{	...l[q]	l[1],...,l[q]	l[1],...,l[q]	l[1],...,l[q]	l[1],...
		...r[q]	r[1],...,r[q]	r[1],...,r[q]	r[1],...,r[q]	r[1],...
m=2	{	...l[q]	l[1],...,l[q]	l[1],...,l[q]	l[1],...,l[q]	l[1],...
		...r[q]	r[1],...,r[q]	r[1],...,r[q]	r[1],...,r[q]	r[1],...
m=M	{	...l[q]	l[1],...,l[q]	l[1],...,l[q]	l[1],...,l[q]	l[1],...
		...r[q]	r[1],...,r[q]	r[1],...,r[q]	r[1],...,r[q]	r[1],...

FIG. 1a

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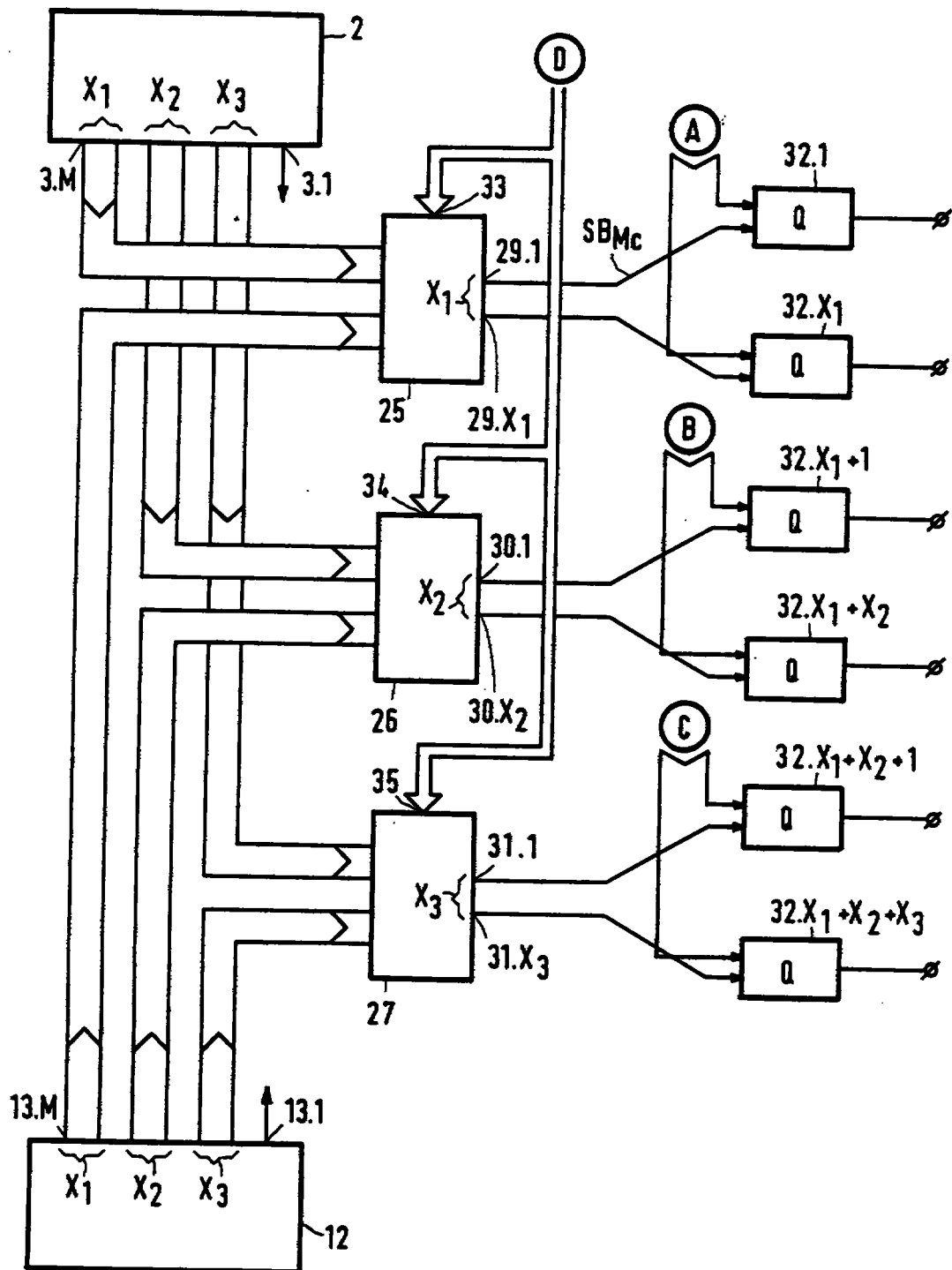
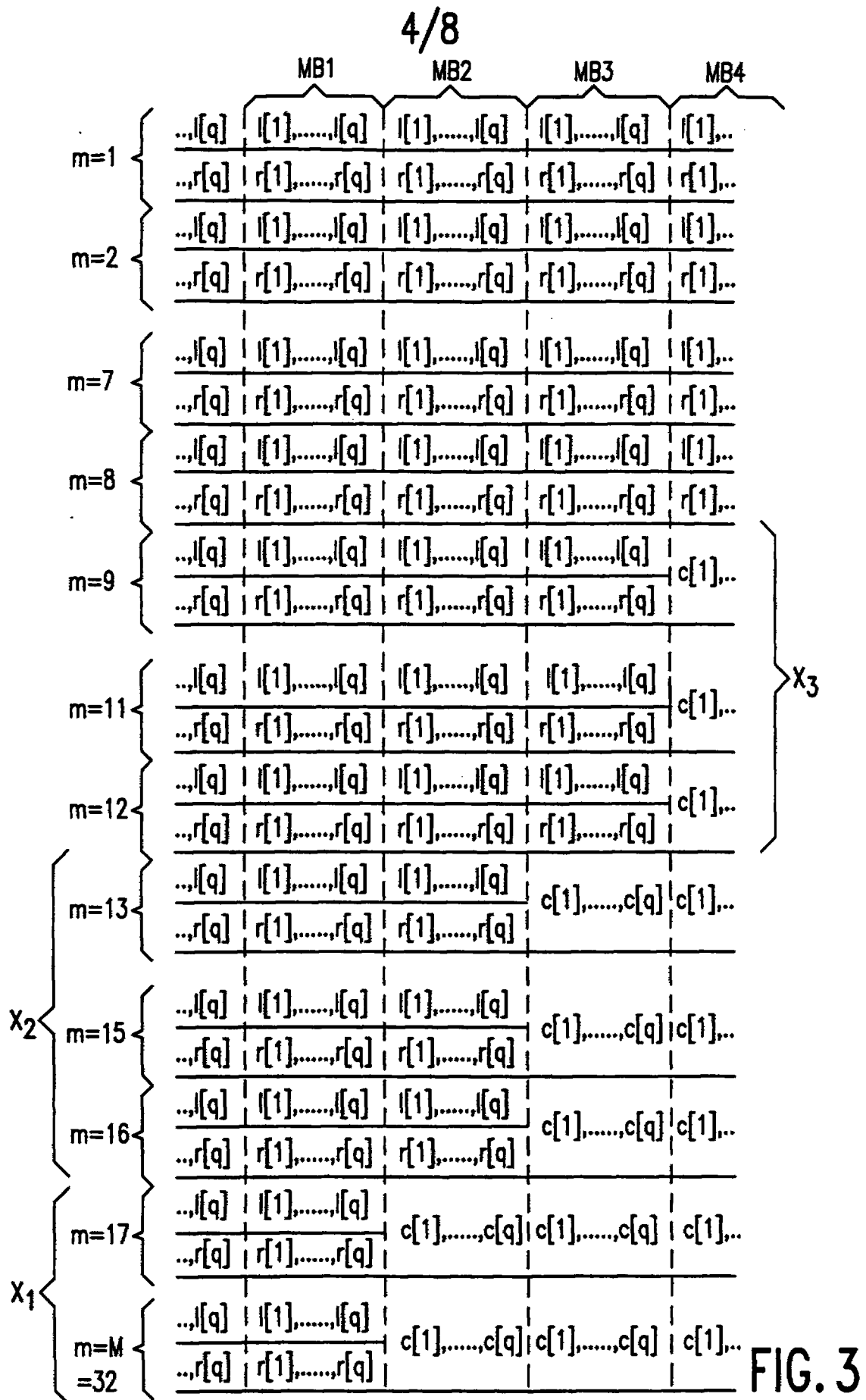
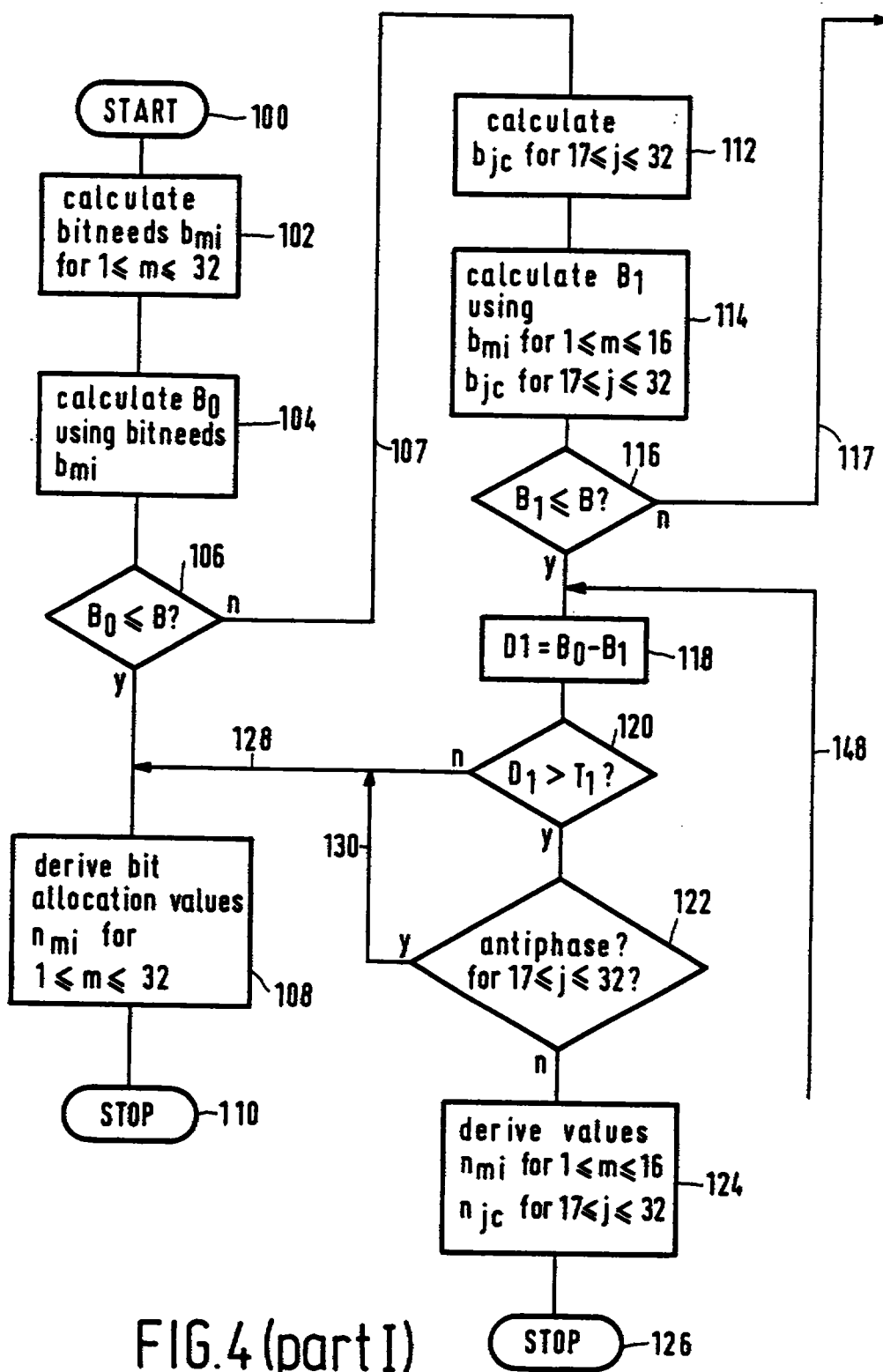


FIG. 2



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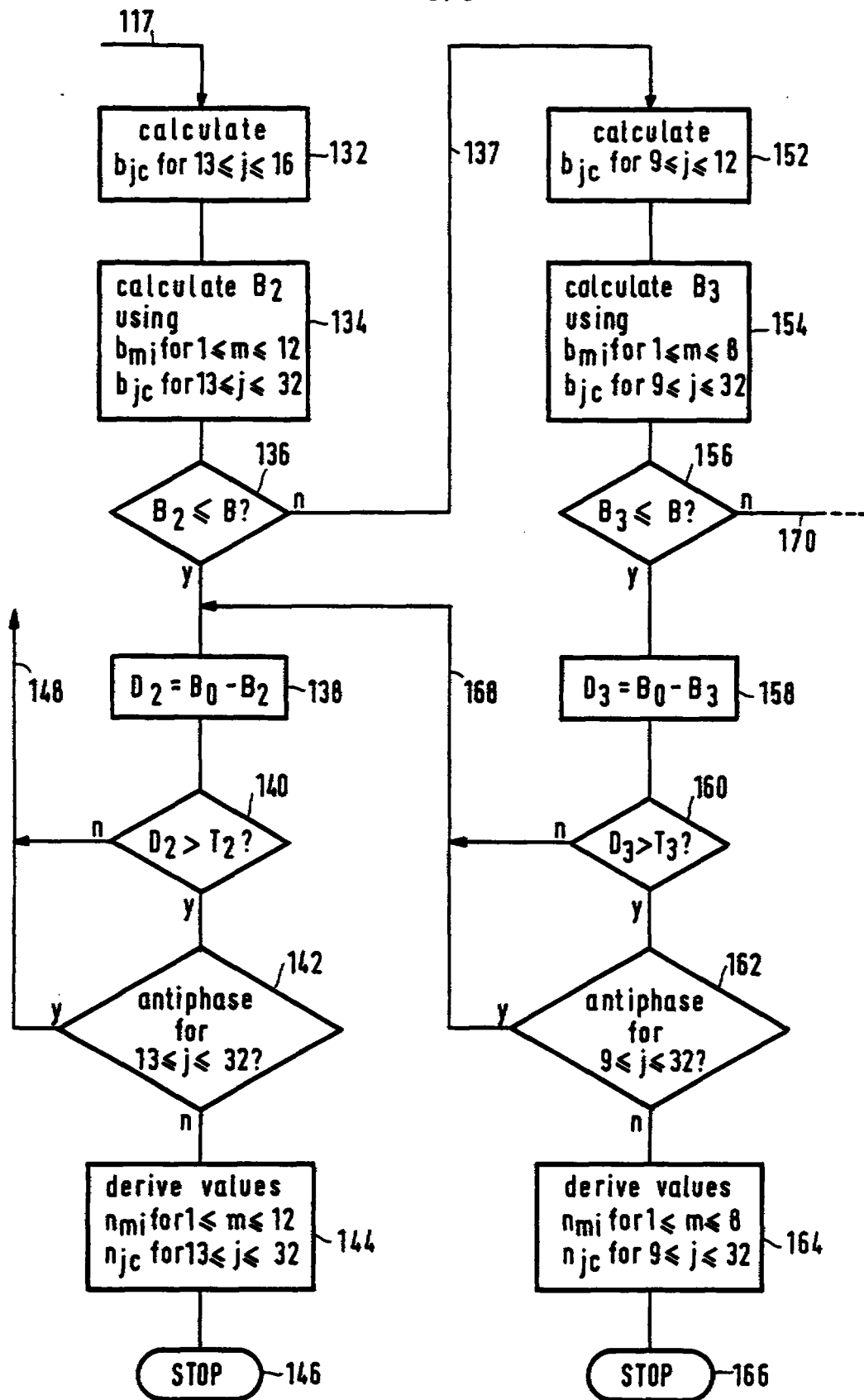


FIG. 4 (part II)

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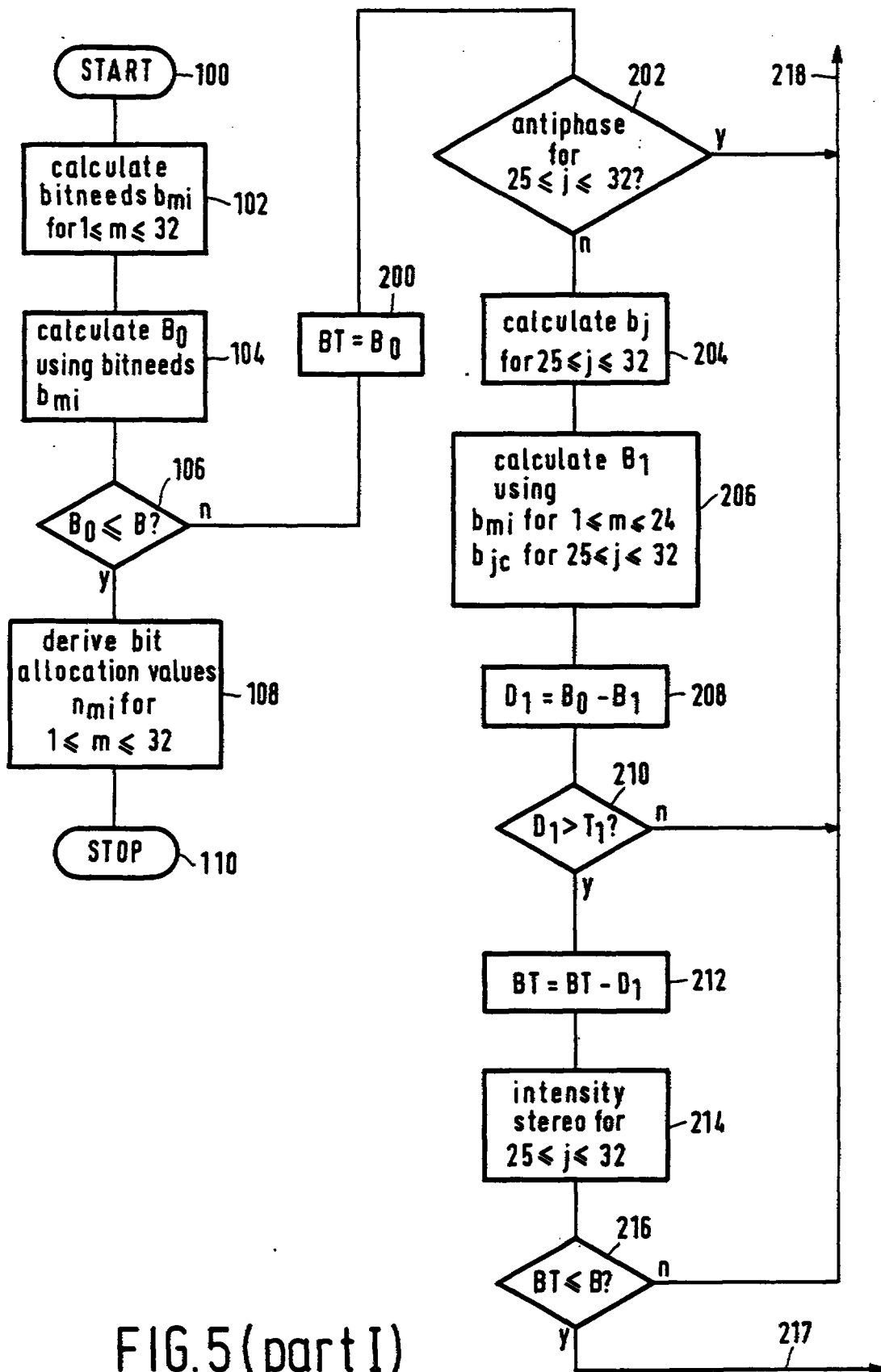


FIG. 5 (part I)

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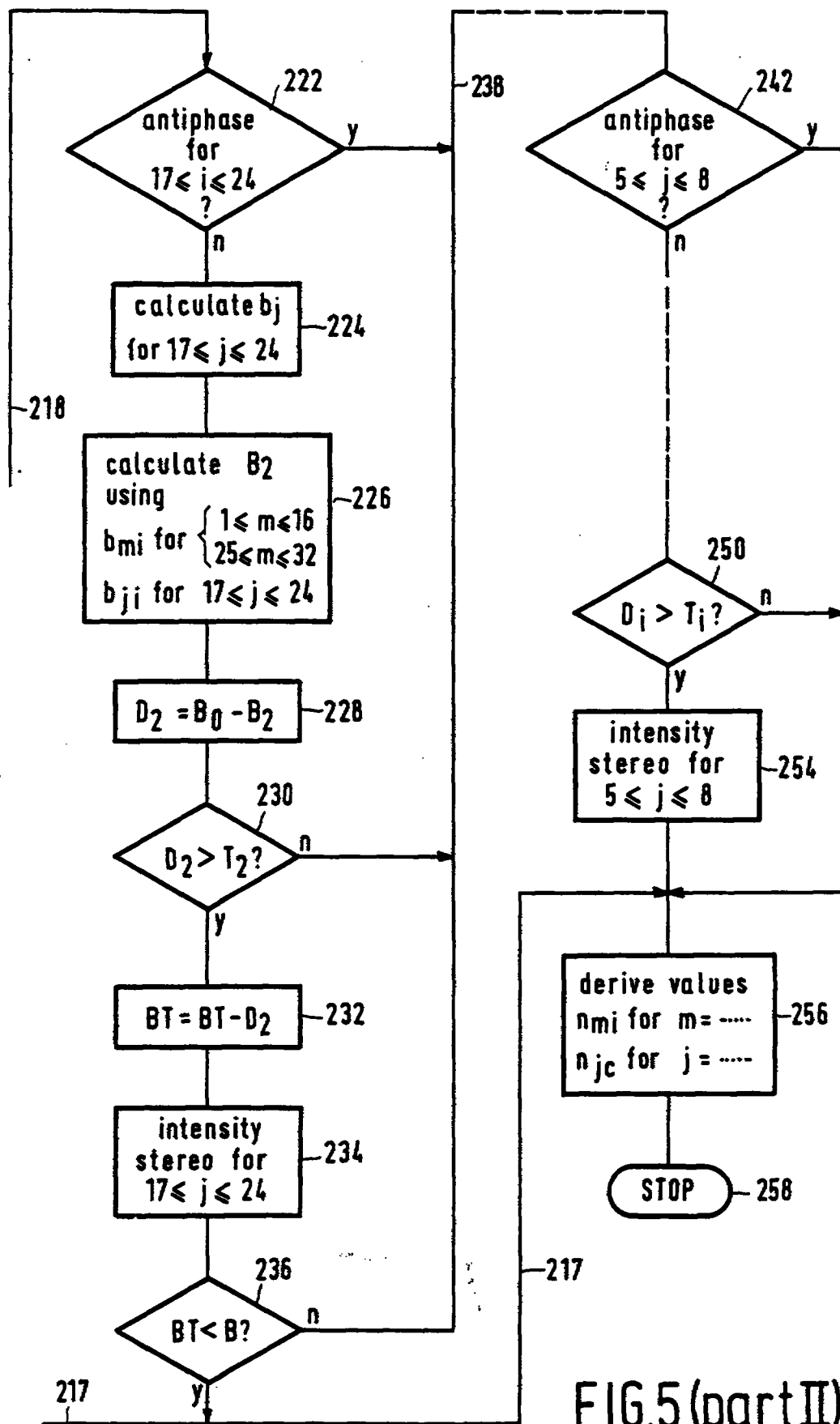


FIG. 5 (part II)