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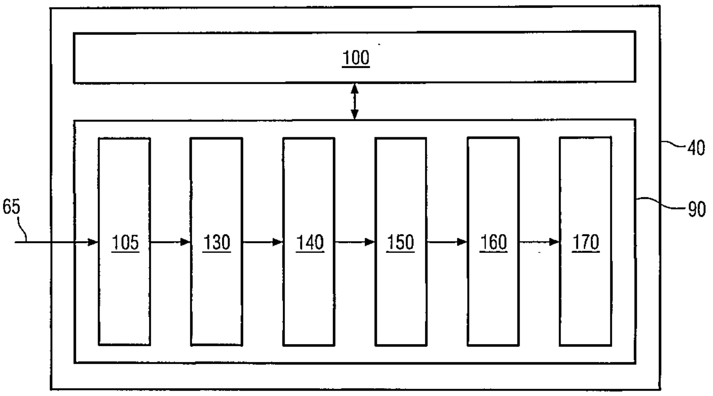
(54) Title: METHOD AND DEVICE FOR COMPRESSING DATA REPRESENTING A TIME DEPENDENT SIGNAL

FIG 2A



(57) Abstract: The present invention relates to a method and a system for compressing data D(nT) representing a time dependent signal A(t) comprising time dependent partial signals Aj(t). A plurality of spectra $S_j(f)$ of the partial signals $A_j(t)$ are received, and a plurality of amplitudes $a_{j,j}$ (121-126) of a plurality of frequencies f_j (111-116) present in the partial signals $A_j(t)$ is computed. Thereafter, a plurality of normalised amplitudes $b_{j,j}$ (141-146) is computed from the plurality of amplitudes $a_{j,j}$ (121-126). Subsequently, for each frequency f_j (111-116), the plurality of normalised amplitudes $b_{j,j}$ (141-146) are modelled based on a distribution with respect to a threshold value, and model parameters MP_j are obtained. Subsequently, a compressed data set CDS comprising MP_j is generated for compressing the data D(nT).

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METHOD AND DEVICE FOR COMPRESSING DATA REPRESENTING A TIME DEPENDENT SIGNAL

The present invention relates to a method and a signal processing device for compressing data representing a time dependent signal.

Data compression plays a pivotal role in managing a colossal amount of data. For instance, many modern day engineering, scientific, and statistical activities mandate the collection of massive amounts of electronic data for processing and maintaining information. For example, the electronic data can be a representation of a time varying signal. The management of the data is an extremely demanding task, wherein the management can also comprise storage and transmission of the data. Efficient data management is achievable by intelligent data compression techniques whereupon the storage space required for storing the information present in the data and/or the transmission bandwidth required for transmitting the data are greatly reduced.

Currently, when colossal amounts of data are collected, for example in case of a continuous stream of data representing a time varying signal collected during a continuous monitoring exercise performed on a machine, i.e. monitoring vibrations of the machine during its operation, the computation and the storage of the Fourier transform, i.e. spectrum data of the time varying signal, especially in its entirety, necessitates a huge amount of storage space.

The normal methods of compressing the spectrum data involve either using universal lossless compression tools (ZIP) or using memory optimised encoding. However, compression ratios (ratio of the storage space/resources required to store the compressed data to the storage space/resources required to store the actual data) for the aforementioned methods are remarkably low and are inefficient methods of data compression. Herewith, the storage space and data transmission bandwidth are not substantially reduced.

The object of the present invention is to provide an efficient method and a signal processing device for compressing data representing a time dependent signal.

The above object is achieved by a method for compressing data according to claim 1 and a signal processing device according to claim 13.

The underlying object of the invention is to compress data D(nT) representing a time dependent signal A(t). The time dependent signal A(t) comprises a plurality of time dependent partial signals $A_i(t)$. The method of compressing commences with a step, wherein a plurality of spectra $S_i(f)$ is received. Each spectrum $S_i(f)$ uniquely corresponds to one of the time dependent partial signals $A_i(t)$ and each spectrum $S_i(f)$ comprises a plurality of frequencies f_j and a plurality of amplitudes $a_{j,i}$ of the plurality of frequencies f_j. The amplitudes $a_{j,i}$ are uniquely assigned to f_j and are measures of contributions of f_j in $A_i(t)$. In a subsequent step, for each spectrum $S_i(f)$ the plurality of amplitudes $a_{j,I}$ are normalised for obtaining a plurality of normalised amplitudes $b_{j,i}$. In a following step, for each frequency f_j, the normalised amplitudes $b_{j,i}$ are processed based on a distribution of the normalised amplitudes $b_{j,i}$ with respect to a threshold value (T_v), and one or more respective model parameters (MP_j) are determined for representing the distribution of the normalised amplitudes $b_{j,i}$. In a subsequent step, a compressed data set (CDS) is generated. CDS comprises at least the one or more model parameters and the frequency f_j. Therefore, the CDS is possible to compress huge amounts of data.

According to an embodiment of the present invention, for each partial signal $A_i(t)$, a time stamp t_i is generated. The time stamp t_i represents a time instant at which the partial signal $A_i(t)$ was acquired. The time stamps t_i are beneficial for identifying the sequence of occurrence of $A_i(t)$, for spectrum wise indexing of the plurality of amplitudes $a_{j,i}$ and the plurality of normalised amplitudes $b_{j,i}$, and for processing the plurality of normalised amplitudes $b_{j,i}$ for obtaining the CDS.

According to another embodiment of the present invention, for each frequency f_j, if every normalised amplitude $b_{j,i}$ is lesser than the threshold value (T_v), then the MP_j determined from the step of processing will comprise an average value (AV) of the normalised amplitudes $b_{j,i}$ for f_j. Additionally, CDS further comprises the first time stamp t_1. Though the contribution of f_j in D(nT) is less than a desired value (i.e. the threshold value), i.e. f_j is not a significant frequency. However, the contribution of f_j can be modelled and maintained by preserving the mean value of f_j in D(nT) for a obtaining a faithful representation of D(nT) by the CDS.

According to yet another embodiment of the present invention, for each frequency f_j, if every normalised amplitude $b_{j,i}$ is greater than the threshold value (T_v), and if a difference $\Delta = b^{\max}_{j,i} - b^{\min}_{j,i}$ between extreme values $(b^{\max}_{j,i}, b^{\min}_{j,i})$ of the normalised amplitudes $b_{j,i}$ is less than the threshold value (T_v), then the MP_j determined from the step of processing will comprise an average value (AV) of the normalised amplitudes $b_{j,i}$ for f_j. Additionally, CDS further comprises the first time stamp t_1. The contribution of f_j in D(nT) is more than a desired value (i.e. the threshold value), thereby making f_j a significant frequency. The contribution of f_j can be modelled and maintained by preserving the mean value of f_j in D(nT) for a obtaining a faithful representation of D(nT) by the CDS.

According to yet another embodiment of the present invention, for each frequency f_j, if at least one of the normalised amplitudes $b_{j,i}$ is not less than the threshold value (T_v) and if the difference between the extreme values $\Delta = b_{j,i}^{max} - b_{j,i}^{min}$ of the normalised amplitudes $b_{j,i}$ is not less than the threshold value (T_v), then in the step of processing an approximation algorithm is performed for modelling the distribution of the normalised amplitudes $b_{j,i}$ of f_j. Thus, the MP_j determined from the step of processing will comprise one or more model parameters of the approximation algorithm. By this, the approximation algorithm simplifies the modelling complicated distributions. According to a variation of the aforementioned embodiment, CDS also comprises the respective time stamps t_k.

According to a variation of the aforementioned embodiment, the approximation algorithm is a polynomial fit, which is a simple method of modelling a distribution.

According to another variation of the aforementioned embodiment, the approximation algorithm is a step function, which increases the speed of modelling a non-linear distribution.

According to a preferred variation of the aforementioned embodiment, the approximation algorithm is an iterative end point fit algorithm, for example a Ramer-Douglas-Peucker algorithm. Thus, a fewer set of points are obtained for defining a distribution containing a large set of points. Thus, very high compression ratios and accuracy of compression are achieved.

According to yet another embodiment of the present invention, CDS comprises for each spectrum $S_i(f)$, a sum SF_i of the plurality of amplitudes $a_{j,i}$. This is advantageous because it helps in the reconstruction of $a_{j,i}$, because the processing is performed on the normalised amplitudes.

According to yet another embodiment of the present invention, the threshold value is proportional to a reciprocal of a cardinal number (NoP) of the plurality of frequencies f_j and also to a tolerance factor (T_f). This renders the threshold variable, and helps in influencing the distribution of the normalised amplitudes $b_{j,i}$.

According to yet another embodiment of the present invention, the method further comprises a step subsequent to the step of processing, wherein a reconstructed data D'(nT) is constructed by processing CDS. In a subsequent step, a correlation coefficient (CC) is determined between the data D(nT) and the reconstructed data D'(nT). The threshold is varied responsive to the CC, and the aforementioned steps are repeated till a satisfactory CC is obtained. By this, the accuracy of CDS is improved.

A signal processing device configured to compress data D(nT) according to anz of the aforementioned embodiments is hereby disclosed. The signal processing device comprises a spectral data receiver module, an amplitude normaliser module, a comparator module, a parameter module and a memory unit. The spectral data receiver module receives the plurality of spectra $S_i(f)$. The amplitude normaliser module normalises the plurality of amplitudes $a_{j,i}$ for each of the plurality of frequencies f_j of each of the plurality of spectra $S_i(f)$. Thus, a plurality of normalised amplitudes $b_{j,i}$ is obtained. The comparator module compares each of the plurality of normalised amplitudes $b_{j,i}$ with the threshold value (T_v). The parameter module processes the normalised amplitudes $b_{j,i}$ of the frequency f_j based on the distribution of the normalised amplitudes $b_{j,i}$ with respect to the threshold value (T_v). Thus, the one or more respective parameters (MP_j) for representing the distribution of the normalised amplitudes $b_{j,i}$ are determined. The memory unit stores the compressed data set (CDS).

According to an embodiment of the present invention, the signal processing device further comprises a correlation module. The correlation module determines the correlation coefficient (CC) between the data D(nT) and the reconstructed data D'(nT). By this, the accuracy of CDS for representing the data D(nT) is improved.

According to an embodiment of the present invention, the signal processing device further comprises a spectrum module. The spectrum module receives each of the time dependent partial signals $A_i(t)$ and computes the respective spectrum $S_i(f)$. The spectrum module can be integrated with the aforementioned modules in cascade. By this, the versatility of the signal processing device is improved, as the spectra $S_i(f)$ is readily computed and is available for compressing the data D(nT).

The aforementioned and other embodiments of the invention related to a method and a signal processing device for compressing data representing a time dependent signal will now be addressed with reference to the accompanying drawings of the present invention. The illustrated drawings and the embodiments are intended to illustrate, but not to limit the invention. The accompanying drawings contain the following figures, in which like numbers refer to like parts, throughout the description and drawings.

The figures illustrate in a schematic manner further examples of the embodiments of the invention, in which:

FIG 1 depicts a condition monitoring system comprising a data acquisition module and a signal processing device compressing data representing a time dependent signal,

FIG 2 depicts various modules of the signal processing device referred to in FIG 1, wherein exploded views of a plurality of spectra, an amplitude array, and a normalised amplitude array schematically illustrate operations of a spectrum module, a spectral data receiver module, an amplitude normaliser module respectively,

FIG 3 depicts an exemplary amplitude array, and an exemplary normalised amplitude array referred to in FIG 2, and

FIG 4 depicts an exemplary manner of constructing a compressed data set for reconstructing data for compressing the data representing the time dependent signal referred to in FIG 1, and

FIG 5 depicts a flowchart of the method for compressing data representing compressing data representing the time dependent signal.

A condition monitoring system 10 coupled to a motor 20 for monitoring health of the motor 20 is depicted in FIG 1.

The condition monitoring system 10 comprises a data acquisition module 30 (hereinafter referred to as “the DAQ 30”) and a signal processing device 40 in accordance with an embodiment of the invention. The DAQ 30 acquires a time dependent signal A(t) 45, which is a continuous signal (characterised by an independent time variable “t”) that pertains to vibrations of the motor 20. The DAQ 30 provides data D(nT) 65 to the signal processing device 40. D(nT) 65 is a discrete-time (characterised by an independent variable “nT”) representation of A(t) 45, which is subsequently processed for compressing D(nT) 65 for achieving the object of the present invention.

The DAQ 30 comprises a sensor 31, a signal conditioner 32, and an analog to digital converter ADC 33 (ADC). The sensor 31 acquires A(t) 45 and provides the same to the signal conditioner 32. The signal conditioner 32 conditions A(t) 45 and provides A'(t) to the ADC 33. The ADC 33 digitises A'(t), thereby creating D(nT) 65, which is provided to the signal processing device 40, which effectively represents A(t).

A(t) 45 may be continuously acquired by the DAQ 30 and may be construed as comprising a plurality of time dependent partial signals $A_i(t)$ (with i=1,2,...,NoS) 46-50. $A_i(t)$ 46-50 can be construed as A(t) 45 acquired during a plurality of individual time intervals Δt_i (with i=1,2,...,NoS) 51-55, respectively, or as time domain windowed A(t) 45, wherein window intervals correspond to Δt_i 51-55. Alternatively, the DAQ 30 may acquire A(t) 45 during Δt_i 51-55 by means of time domain windowing, therewith A(t) 45 may be construed as a sequential collection of $A_i(t)$ 46-50.

Durations of Δt_i 51-55 may be definable by a user or can be fixed or variable depending on the type of A(t) 45, signal processing requirements, features of the DAQ 30 and/or the signal processing device 40, et cetera. The durations can be microseconds, milliseconds, or in seconds. Δt_i 51-55 are generally contiguous. However, Δt_i 51-55 may be overlapping or separated by certain spans of time, et cetera.

Herein, the term "partial signals" is defined as a portion of A(t) 45 acquired by the DAQ during respective Δt_i 51-55.

Herein "NoS" is a dimensionless entity and refers to a cardinal number of $A_i(t)$ 46-50 acquired during Δt_i 51-55, which in entirety constitute to form A(t) 45. I.e. NoS represents the number of partial signals $A_i(t)$.

A plurality of time stamps t_i (with i=1,2,...,NoS) 56-60 are determined from A(t), wherein each time stamp t_i 56-60 represents a time of start of the respective partial signal $A_i(t)$ 46-50 acquired during the time interval Δt_i 51-55. For instance, time stamp t_1 56 denotes the time of start of the partial signal $A_1(t)$ 46.

The data D(nT) 65 is a discrete-time representation of A(t) 45. Thus, $A_i(t)$ 46-50 results in a plurality of discrete-time partial signals $D_i(nT)$ (with i=1,2,...,NoS; n=1,2,...,NoP) 66-70 respectively, wherein $D_i(nT)$ 66-70 corresponds to D(nT) 65 present in Δt_i 51-55. $D_i(nT)$ 66-70 may also be obtained by discrete-time domain windowing of A(t) 45. Therefore, D(nT) 65 comprises discrete-time representations of the plurality of partial signals $A_i(t)$ 51-55, i.e. $D_i(nT)$ 66-70. Furthermore, D(nT) 65 may also be a digital representation of the discrete-time equivalent of A(t).

Herein, “NoP” is a dimensionless entity and refers to a cardinal number of samples contained in each discrete-time partial signal $D_i(nT)$ 66-70. “NoP” is also equal to a cardinal number of frequencies determinable from an NoP-point Discrete Fourier Transform (DFT) performed on $D_i(nT)$ 66-70. The significance of the term “NoP” will be elucidated in the subsequent sections.

“NoP” for $D_i(nT)$ 66-70 may be varied by varying a sampling rate of the ADC 33, i.e. by under sampling or over sampling. The “NoP” may also be modified by zero-padding, or in another alternative aspect, the duration of Δt_i 51-55 may be varied to effect a change of “NoP”. A variation of “NoP” accordingly varies the cardinal number of frequencies determinable from an NoP-point DFT.

Herein, the time stamps t_i 56-60 also represent the time of start for $D_i(nT)$ 66-70 respectively. Therefore, the time stamps t_i 56-60 contain information regarding the time of acquisition of the $D_i(nT)$ 66-70, i.e. the start time of Δt_i 51-55, and are beneficial for compression of D(nT) 65 as well as for reconstruction of D(nT) 65. In an alternate aspect, t_i 56-60 can be any instances of time of the respective Δt_i 51-55, from which the information regarding the time of acquisition of the $A_i(nT)$ 66-70 is computable. In other words, the time stamps t_i 56-60 represent a time instant at which the respective partial signal $A_i(t)$ and $D_i(nT)$, respectively, have been acquired.

The signal processing device 40 comprising a processor 90 and a memory unit 100 for compressing D(nT) 65 is depicted in FIG 2. Exemplary NoP = 6 and NoS = 5 is depicted in FIG 2.

The processor 90 comprises a spectrum module 105, a spectral data receiver module 130, an amplitude normaliser module 140, a comparator module 150, a parameter module 160, and a correlation module 170. The aforementioned modules 105, 130, 140, 150, 160, 170 are configured to compress data D(nT).

The spectrum module 105 receives $D_i(nT)$ 66-70 and computes a plurality of spectra $S_i(f)$ (with i=1,2,...,NoS) 106-110.

The module 105 computes $S_i(f)$ 106-110 may be a plurality of NoP-point (Discrete Fourier Transforms) DFTs. $S_i(f)$ 106-110 comprises a plurality of frequencies f_j (with j=1,2,...,NoP) 111-116 and a plurality of amplitudes $a_{j,i}$ (with j=1,2,...,NoP;

with $i=1,2,\ldots,NoS$) 121-126 of the frequencies f_j 111-116. Herein, the computed amplitudes $a_{j,i}$ 121-126 are uniquely assigned to f_j 111-116 and are measures of contributions of f_j 111-116 in $A_i(t)$ 46-50. This assignment of amplitudes $a_{j,i}$ 121-126 and frequencies f_j 111-116 is in compliance with the well-known definition of a spectrum of a time dependent signal, i.e. the amplitudes are a measure of the contribution of the assigned frequency to the underlying time dependent signal.

A schematic operation of the module 105 is depicted as an exploded view "105". Herein, for each of $S_i(f)$ 106-110, the horizontal axis "f" represents "frequency" (f_j 111-116), and the vertical axis "A" represents "amplitude", that is the amplitudes ($a_{j,i}$ 121-126) of f_j 111-116 of the underlying time dependent signal.

An exemplary manner for realizing the operation of the module 105 is elucidated herein. For example, $D_i(nT)$ 66-70 are received by the signal processing device 40 and the same are buffered as blocks of data of a particular length in the memory unit 100. Each block of data corresponds to each of $D_i(nT)$ 66-70 acquired during each of Δt_i 51-55. Each block of data is time stamped with a respective t_i 56-60 for identifying the start time of the $D_i(nT)$ 66-70. The blocks corresponding to $D_i(nT)$ 66-70 are then retrieved and processed for computing $S_i(f)$ 106-110.

Herein, $a_{j,i}$ 121-126 and f_j 111-116 of $S_i(f)$ 106-110 may be displayed as a two dimensional amplitude array 128 arranged in rows and columns, for example with NoP rows (representing the NoP f_j 111-116) and NoS columns (representing the NoS $D_i(nT)$ 66-70).

Each of the $S_i(f)$ 106-110 is computed from a respective $D_i(nT)$ 66-70. Therefore, "NoS" also stands for "Number of Spectra".

The spectral data receiver module 130 receives the spectra $S_i(f)$ 106-110 from the spectrum module 105. The module 130 then arranges a vector of $a_{j,i}$ 121-126 and a vector of f_j 111-116 present in $S_i(f)$ 106-110. Thus, a vector $a_{j,i}$ 121-126 is assigned to a respective time stamp t_i 56-60.

In the amplitude array 128, each column "i" of the NoS columns is designated with a respective time stamp t_i 56-60, which corresponds to the respective $D_i(nT)$ 66-70. Similarly, each row "j" of the NoP rows is designated with a respective frequency f_j 111-116. For example, the first column is designated with time stamp t_1 56 and contains all the amplitudes $a_{j,i}$ 121-126 of the frequencies f_j 111-116 computed from

$S_1(f)$ 106. Similarly, the first row is designated with f_1 111 and contains the amplitudes $a_{j,i}$ 121-126 of f_1 111 computed from NoS number of spectra $S_i(f)$ 106-110.

An exploded view "130" illustrates an example of the amplitude array 128 for five spectra $S_i(f)$ 106-110 (NoS=5) and six frequencies f_j 111-116 (NoP=6). For example, the column values $a_{1,1}$ 121 to $a_{6,1}$ 126 represent the values of the six frequencies f_1 111 to f_6 116 determined from $S_1(f)$ 106 computed for $D_1(nT)$ 66 bearing the time stamp t_1 56. The row values $a_{3,1}$ 123 to $a_{3,5}$ 123 represent the values of the third frequency "f_3 113" determined from $S_1(f)$ 106 to $S_5(f)$ 110 computed respectively for $D_1(nT)$ 66 to $D_5(nT)$ 70 bearing the respective time stamps t_1 56 to t_5 60.

Furthermore, for each of $S_i(f)$ 106-110 the module 130 computes an algebraic sum SF_i (with i=1 to NoS) 135 of the amplitudes $a_{j,i}$ 121-126 of the frequencies f_j 111-116.

For example,

$$\mathrm{SF}_1 = \sum_{j=1}^{NoP} a_{j,1}, \quad \mathrm{SF}_3 = \sum_{j=1}^{NoP} a_{j,3}, \text{ et cetera.}$$

Thus, SF_i 135 is also a vector of length "NoS". Furthermore, each of SF_i 135 can uniquely correspond to each of the NoS time stamps t_i 56-60. For example, SF_1 corresponds to t_1, SF_3 corresponds to t_3, et cetera.

The amplitude normaliser module 140 receives the amplitude array 128 from the spectral data receiver module 130. For each of $S_i(f)$ 106-110, the amplitudes $a_{j,i}$ 121-126 are normalised by the module 140. Thus, a plurality of normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) 141-146 is obtained. Each of $b_{j,i}$ 141-146 is computed in accordance with the following formula:

$$\mathrm{b}_{j,i} = \frac{\mathrm{a}_{j,i}}{\sum_{j=1}^{NoP}(\mathrm{a}_{j,i})},$$

I.e.

$$b_{j,i} = \frac{a_{j,i}}{SF_i}$$

For example,

$$b_{1,3} = \frac{a_{1,3}}{SF_3}, \qquad b_{3,2} = \frac{a_{3,2}}{SF_2}$$, et cetera.

Herein, $b_{j,i}$ 141-146 is also arranged into a normalised amplitude array 148 with respect to $S_i(f)$ 106-110 bearing the time stamps t_i 56-60, respectively. The normalised amplitude array 148 again comprises NoP rows and NoS columns. A schematic operation of the module 140 is depicted as an exploded view "140".

In the aforementioned context, the term "normalisation" is defined as, for each $S_i(f)$ 106-110, a process of dividing the individual amplitudes $a_{j,i}$ 121-126 of f_j 111-116 by the algebraic sum of amplitudes $a_{j,i}$ 121-126. Therefore, by normalisation, relational contributions or percentage contributions of each of f_j 111-116 present in each of $A_i(t)$ 46-50 can be measured. Thus, the contribution of a certain frequency f_j 111-116 is assessable and measurable for determining how that particular frequency f_j 111-116 may be represented for the compression of D(nT) 65, which will be explained subsequently.

The NoP rows and NoS columns of the amplitude array 128 and the normalised amplitude array 148 merely illustrate and represent the manner in which the received $a_{j,i}$ 121-126 of f_j 111-116 of each of $S_i(f)$ 106-110 and the corresponding $b_{j,i}$ 141-146 may be arranged for processing the information in a facile manner. These NoP rows and NoS columns may be transposed and the information therein can be represented and processed accordingly without loss of generality.

The aforementioned example (NoP=6 and NoS=5) is merely illustrative, and is not to be construed to be limiting the invention. The NoP and the NoS can be any two positive integers and the magnitudes of NoP and NoS may be immense. For example, for a 256-point FFT computed for 300 spectra, "NoP" is 256, and "NoS" is 300.

Herein, the cardinal number of f_j 111-116, i.e. NoP, determinable from $S_i(f)$ 106-110 is equal to the cardinal number of samples, i.e. again NoP, present in each of $D_i(nT)$ 66-70. For example, the cardinal number is "16" for a 16-point DFT, "32" for a

32-point DFT, and so on. However, for computing $S_i(f)$ 106-110 from $D_i(nT)$ 66-70 in an efficient manner, i.e. for customizing the number of frequencies f_j 111-116 determinable from each of $S_i(f)$ 106-110, $D_i(nT)$ 66-70 may be up-sampled, down-sampled, zero-padded, et cetera, as aforementioned without loss of generality of $D_i(nT)$ 66-70.

Herein, each $S_i(f)$ 106-110 comprises the same vector of frequencies f_j 111-116, i.e. different $S_i(f)$ 106-110 may only differ in the vector of amplitudes $a_{j,i}$ 121-126 computed for different $D_i(nT)$ 66-70. Herein, each frequency f_j 111-116 comprises the same vector of time stamps t_i 56-60.

The comparator module 150 receives the normalised amplitude array 148. For each spectrum $S_i(f)$ 106-110, the module 150 compares the normalised amplitudes $b_{j,i}$ 141-146 with a threshold value T_V.

T_V is proportional to a reciprocal of "NoP", i.e. the cardinal number of frequencies (NoP) of f_j 111-116. Herein, a relation between T_V and NoP may be indicated as the following:

$$T_V \propto \frac{1}{NoP}$$

By comparing each normalized amplitude $b_{j,i}$ 141-146 of each spectrum $S_i(f)$ 106-110 with the threshold value T_V, the comparator module 150 generates a distribution of normalized amplitudes $b_{j,i}$ 141-146 of frequency f_j with respect to T_V.

Thereafter, by processing the normalised amplitude array 148 containing $b_{j,i}$ 141-146, and the distribution of of $b_{j,i}$ 141-146 with respect to T_V in the parameter module 160, it is possible to model the distribution of $b_{j,i}$ 141-146 over $S_i(f)$ 106-110.

The parameter module 160 receives the normalised amplitude array 148 containing $b_{j,i}$ 141-146, and the distribution of $b_{j,i}$ 141-146 for each frequency f_j 111-116 with respect to T_V.

For each frequency f_j 111-116, the normalised amplitude $b_{j,i}$ 141-146 and the distribution of $b_{j,i}$ 141-146 with respect to T_V, respectively, are processed to obtain one or more model parameters (MP_j) (with j=1 to NoP). The model parameters MP_j are suitable for modelling the distribution of the normalised amplitudes $b_{j,i}$ 141-146. For instance, $b_{1,1}$ to $b_{1,6}$ 141 are processed for obtaining MP_1 for modelling f_1 111 and $b_{4,1}$

to $b_{4,6}$ 144 are processed for obtaining MP_4 for modelling f_4 114, et cetera.

For each of f_j 111-116, the MP_j depends on a trend of distribution of the $b_{j,i}$ 141-146 of f_j 111-116 with respect to T_v. MP_j is computed by modelling the frequencies f_j 111-116 based on the different trends of the distribution of the respective $b_{j,i}$ 141-146.

For this, three different cases are distinguished:

Case 1) In case the trend of the distribution of the respective $b_{j,i}$ 141-146 of a particular frequency f_j 111-116 is such that each of $b_{j,i}$ 141-146 is less than T_v, MP_j for representing the normalised amplitudes $b_{j,i}$ of that particular frequency f_j 111-116 is an average value (AV) of the normalized amplitudes $b_{j,i}$ 141-146 of the particular frequency f_j 111-116 of the spectra $S_i(f)$. The average value (AV) for that particular frequency f_j 111-116 is computed by processing the normalised amplitudes $b_{j,i}$ of that particular frequency f_j 111-116 over $S_i(f)$ 106-110 as indicated below:

$$\mathrm{AV} = \frac{\sum_{i=1}^{NoS} b_{j,i}}{NoS}$$

For example, if for f_1 111, if all of $b_{1,1}$ to $b_{1,5}$ 141 are less than T_v, then AV for f_1 111 is computed as indicated below:

$$\mathrm{AV} = \frac{\sum_{i=1}^{NoS} b_{1,i}}{NoS}$$

Case 2) In case the trend of the distribution of the normalised amplitudes $b_{j,i}$ 141-146 of frequency f_j 111-116 is such that a difference $\Delta = b_{j,i}^{\max} - b_{j,i}^{\min}$ between extreme values (i.e. the difference Δ between the maximum value $b_{j,i}^{\max}$ and the minimum value $b_{j,i}^{\min}$ of $b_{j,i}$) of the normalised amplitudes $b_{j,i}$ of that particular frequency f_j 111-116 is less than T_v, then MP_j for representing the normalised amplitudes $b_{j,i}$ 141-146 of that particular frequency f_j 111-116 is once again the average value (AV) of the normalised amplitudes $b_{j,i}$ 141-146 of the particular frequency f_j 111-116 as computed above.

For example, if for f_5 115, if $b_{5,4}$ is the maximum value $b_{j,i}^{\max}$ and $b_{5,5}$ is the minimum value $b_{j,i}^{\min}$, and if the difference Δ between $b_{5,4}$ and $b_{5,5}$ is less than T_v, then

AV for f_5 115 is computed as indicated below:

$$\mathrm{AV} = \frac{\sum_{i=1}^{NoS} b_{5,i}}{NoS}$$

Case 3) In the remaining cases, if the trend of the distribution of $b_{j,i}$ 141-146 of the particular frequency f_j 111-116 is different from the trends of the aforementioned distributions in cases 1) and 2), the distribution of the normalised amplitudes $b_{j,i}$ 141-146 is modelled and represented by an approximation algorithm. Herein, the MP_j of that particular frequency f_j 111-116 are the resulting model parameters of the approximation algorithm. The approximation algorithm may be one of the following:

a linear fit, wherein the resulting MP_j defining a linear equation for modelling $b_{j,i}$ 141-146 comprises a slope value, and an axis intercept value;

a quadratic fit, wherein the resulting MP_j defining a quadratic equation for modelling $b_{j,i}$ 141-146 are one or more coefficients representing a variable of the quadratic equation;

a cubic fit, wherein the resulting MP_j defining a cubic equation for modelling $b_{j,i}$ 141-146 are one or more coefficients representing a variable of the cubic equation;

an n^{th} order polynomial fit, wherein the resulting MP_j defining an n^{th} order polynomial equation for modelling $b_{j,i}$ 141-146 are one or more coefficients representing a variable of the n^{th} order polynomial equation;

a step function, wherein the resulting MP_j defining the step function for modelling $b_{j,i}$ 141-146 is a cumulative function defined as a sum of elementary step functions; or

an iterative end point fit algorithm, wherein the resulting MP_j defining the iterative end point fit algorithm for modelling $b_{j,i}$ 141-146 may be obtained from a Ramer-Douglas-Peucker algorithm, et cetera.

Thus, depending on the respective distributions of normalized amplitudes $b_{j,i}$ 141-146 for the different frequencies f_j 111-116, model parameters MP_j are computed, finally resulting in data which are suitable to be used as a basis for generating a compressed data set CDS for representing the original data D(nT) 65.

The CDS representing the data D(nT) 65 comprises the following:

the vector of frequencies f_j 111-116, the vector of time stamps t_i 56-60,

the algebraic sum SF_i 135 of the amplitudes $a_{j,i}$ 121-126 of every spectrum $S_i(f)$, which is beneficial for scaling the MP_j for each of f_j 111-116, because MP_j was created using only $b_{j,i}$ 141-146, and

the model parameters MP_j for representing the trends of distribution of the normalised amplitudes $b_{j,i}$ 141-148 of every frequency f_j 111-116.

Moreover, for those frequencies f_j 111-116 for which the respective model parameter MP_j is chosen to be the average value (AV) of the normalised amplitudes $b_{j,i}$ 141-146 (i.e. cases 1) and 2) as described above), additionally the first time stamp t_1 56 is assigned to AV.

In general, for all other cases (i.e. cases than cases 1) and 2)) and for all frequencies, respectively, CDS has to contain information whether MP_j is an average value (cases 1) and 2)) or has been modeled by an approximation algorithm (case 3)). If MP_j for a particular frequency f_j 111-116 is based on an approximation algorithm, then the CDS further comprises the following:

information about the type of approximation algorithm (for example, the step function, the iterative end point fit algorithm, et cetera) used for approximating the normalised amplitudes $b_{j,i}$ 141-148 of the particular frequency f_j 111-116, and

the MP_j of the approximation algorithm for that particular frequency f_j 111-116 will also contain pairs of one or more amplitude values and respective one or more timestamps t_i 56-60 of that particular frequency f_j 111-116. Herein, the amplitude values can be one or more normalised amplitudes $b_{j,i}$ 141-146 itself or average of a certain number of normalised amplitudes $b_{j,i}$ 141-146 of that particular frequency f_j 111-116.

By processing the CDS, it is possible to substantially reconstruct the data D(nT).

In order to assess the quality of compression before finally storing CDS, a data signal D'(nT) is reconstructed from the compressed data set CDS and compared with the original signal D(nT). For the assessment, the correlation module 170 receives the compressed data set CDS and processes the same for constructing data signal D'(nT) for for the corresponding Δt_i 51-55.

The reconstruction of D'(nT) by processing CDS is explained in an exemplary manner with reference to FIG 4.

The correlation module 170 determines a correlation co-efficient CC by correlating D'(nT) and D(nT). CC is a dimensionless entity and is merely a qualitative index for representing a similarity between D'(nT) and D(nT).

Based on the determined CC, it may be decided to repeat the compression with other preconditions. For example, if the correlation co-efficient indicates that the similarity of D'(nT) and D(nT) is not sufficient, the threshold value T_v would have to be varied. This can result in a varied trend of the distribution of the normalized amplitudes $b_{j,i}$ 141-146 of the frequency f_j 111-116 and, thus, in new model parameters MP_j' for that frequency.

The threshold value T_v may be varied to obtain a varied threshold value T_v' by multiplying T_v with a tolerance factor T_f. Herein, a relation between T_v', NoP and T_f may be indicated as the following:

$$T'_v = \frac{T_f}{NoP}$$

T_f may be varied in order to vary T_v. In fact, this results in a change of the distribution of $b_{j,i}$ 141-146 with respect to T_v. Thereby, this results in changing the MP_j for every f_j 111-116. For example, if the CC between D'(nT) and D(nT) is between "0" and "0.8", it may be assumed that the quality of the reconstructed signal D'(nT) is poor, and the quality can be improved by lowering the T_v, i.e. by reducing T_f, thereby selecting different MP_j.

Similarly, if CC is "0.8" or more, it can be assumed that the MP_j for reconstructing D'(nT) are sufficient. Then the current CDS is considered as the final CDS and it is stored in memory.

T_v, T'_v and T_f are dimensionless entities. T_f merely serves to increase or decrease T_v. If T_f is chosen between "0" and "1", then T_v is decreased. Alternatively, if T_f is greater than "1", then T_v is increased. However, preferably T_f should be unequal to "1".

After the variation of the threshold value, the newly defined threshold value T'_v is sent to the comparator module 150. There, the threshold value T_v which is used for comparison with the normalised amplitudes $b_{j,i}$ 141-146 is set to be the new threshold value T'_v, i.e. $T_v = T'_v$.

Thereafter, the same steps as described above for determining the distribution of normalized amplitudes $b_{j,i}$ 141-146 of each spectrum $S_i(f)$ 106-110 with respect to the threshold value T_v are conducted. I.e. the comparator module 150 again generates a distribution of $b_{j,i}$ 141-146 with respect to T_v, wherein T_v corresponds to the varied threshold value T'_v.

After the determination of the distribution, it is again possible to model the distribution of $b_{j,i}$ 141-146 over $S_i(f)$ 106-110.

The parameter module 160 receives information regarding the comparison between each of $b_{j,i}$ 141-146 with T_v, i.e. information about the aforementioned distribution.

Again, for each frequency f_j 111-116, the normalised amplitude $b_{j,i}$ 141-146 and the distribution of $b_{j,i}$ 141-146 with respect to T_v, respectively, are processed to obtain one or more model parameters MP_j, as described above. MP_j is again computed by modelling the frequencies f_j 111-116 based on the different trends of the distribution of the respective $b_{j,i}$ 141-146, again considering the aforementioned three different cases 1), 2) and 3).

After calculation of model parameters MP_j for each frequency f_j 111-116, a new compressed data set CDS is generated, which comprises:

the vector of frequencies f_j 111-116,

the vector of time stamps t_i 56-60,

the algebraic sum SF_i 135 of the amplitudes $a_{j,i}$ 121-126 of every spectrum $S_i(f)$, which is beneficial for scaling the MP_j for each of f_j 111-116, because MP_j was created using only $b_{j,i}$ 141-146, and

the model parameters MP_j for representing the trends of distribution of the normalised amplitudes $b_{j,i}$ 141-148 of every frequency f_j 111-116.

Moreover, for those frequencies f_j 111-116 for which the respective model parameter MP_j is chosen to be the average value (AV) of the normalised amplitudes $b_{j,i}$ 141-146 (i.e. cases 1) and 2) as described above), additionally the first time stamp t_1 56 is assigned to AV.

In general, for all other cases (i.e. cases than cases 1) and 2)) and for all frequencies, respectively, CDS has to contain information whether MP_j is an average value (cases 1) and 2)) or has been modeled by an approximation algorithm (case 3)). If MP_j for a particular frequency f_j 111-116 is based on an approximation algorithm, then the CDS further comprises the following:

information about the type of approximation algorithm (for example, the step function, the iterative end point fit algorithm, et cetera) used for approximating the normalised amplitudes $b_{j,i}$ 141-148 of the particular frequency f_j 111-116, and

the MP_j of the approximation algorithm for that particular frequency f_j 111-116 will also contain pairs of one or more amplitude values and respective one or more timestamps t_i 56-60 of that particular frequency f_j 111-116. Herein, the amplitude values can be one or more normalised amplitudes $b_{j,i}$ 141-146 itself or average of a certain number of normalised amplitudes $b_{j,i}$ 141-146 of that particular frequency f_j 111-116.

The frequencies for which the model parameters have been computed using the approximation algorithms are f_k and the corresponding time stamps stored in the model parameters of f_k are t_k.

To assure a sufficient compression quality, as described above, a data signal D'(nT) is again reconstructed from the compressed data set CDS and compared with the original signal D(nT). The correlation module 170 determines the new correlation co-efficient CC by correlating D'(nT) and D(nT).

Based on the determined CC, it may be decided to repeat the compression again with other preconditions. In this case, the aforementioned procedure starting with the variation of the threshold value T_v with another tolerance factor T_f would be repeated, resulting in a new distribution and new model parameters MP_j etc.

Finally, when the CC indicates a sufficient similarity between D'(nT) and D(nT), the respective compressed data set CDS is stored. Since instead of all amplitudes $a_{j,i}$ only average values and/or model parameters MP_j are stored, an effective compression rate can be achieved.

The spectrum module 105 and the spectral data receiver module 130 may be consolidated to form a single module capable of executing the functions of both the modules 105, 130.

The comparator module 150, the parameter module 160 and the correlation module 180 may be consolidated to form a single module capable of executing the functions of the modules 150, 160, 170.

The memory unit 100 is capable of storing the $D_i(nT)$ 66-70 received from the

DAQ 30, interim data obtained during different stages of processing $D_i(nT)$ 66-70, by the aforementioned modules 105, 130, 140, 150, 160, 170, $a_{j,i}$ 121-126 and f_j 111-116 computed from $S_i(f)$ 106-110, et cetera.

The one or more of the aforementioned modules 105, 130, 140, 150, 160, 170 are operably coupled to the processor 90 and are realizable as independent modules or as partly consolidated modules or a wholly consolidated module, wherein the processor 90 is configured accordingly for performing respective functions of the one or more aforementioned modules 105, 130, 140, 150, 160, 170. Additionally, the one or more modules 105, 130, 140, 150, 160, 170, may be interconnected and may be locatable inside or outside the processor 90.

The processor 90 may be a general purpose processor, a microcontroller, a Digital Signal Processor, a Field Programmable Gate Array (FPGA), a Partial Dynamic Reconfigurable FPGA, an Application Specific Integrated Circuit, and a combination thereof.

The sufficient modules for achieving the object of the invention are the module 130, the module 140, the module 150 and the module 160. However, signal processing device of FIG 2 is provided with supplementary modules, i.e. the memory unit 100, the module 105, and the module 170.

An example of the amplitude array 128 and the normalised amplitude array 148, wherein NoP=4 and NoS=10, comprising exemplary values of $a_{j,i}$ 121-126 and $b_{j,i}$ 141-146 respectively are illustrated in FIG 3. Since NoP is equal to "4", the corresponding T_v is "0.25". The columns of the amplitude array 128 and the normalised amplitude array 148 bear the respective time stamps t_i 56-60.

Herein, for f_1, the amplitude array 128 comprises exemplary amplitude values of [5, 6, 6, 7, 5, 6, 1, 2, 5, 3], for f_2, the amplitude array 128 comprises exemplary amplitude values of [54, 56, 52, 54, 52, 58, 59, 55, 53, 51], for f_3, the amplitude array 128 comprises exemplary amplitude values of [10, 20, 30, 10, 20, 30, 0, 20, 30, 30], and for f_4, the amplitude array 128 comprises exemplary amplitude values of [20, 5, 25, 30, 23, 5, 24, 6, 23, 5] obtained from exemplary ten spectra $S_1(f)$ to $S_{10}(f)$. Correspondingly, SF_1 is 89, SF_2 is 87, SF_3 is 113, SF_4 is 101, SF_5 is 100, SF_6 is 99, SF_7 is 84, SF_8 is 83, SF_9 is 111, and SF_{10} is 89. The each column of the amplitude array 128 is assigned to a respective time stamp t_1 to t_{10}, generated from the respective $D_1(nT)$ to

$D_{10}(nT)$.

Herein, for f_1, the normalised amplitude array 148 comprises exemplary normalised amplitude values of [0.06, 0.07, 0.05, 0.07, 0.05, 0.06, 0.01, 0.02, 0.05, 0.03], for f_2, the normalised amplitude array 148 comprises exemplary normalised amplitude values of [0.61, 0.64, 0.46, 0.53, 0.52, 0.59, 0.70, 0.66, 0.48, 0.57], for f_3, the normalised amplitude array 148 comprises exemplary normalised amplitude values of [0.11, 0.23, 0.27, 0.10, 0.20, 0.30, 0.00, 0.24, 0.27, 0.34], and for f_4, the normalised amplitude array 148 comprises exemplary normalised amplitude values of [0.22, 0.06, 0.22, 0.30, 0.23, 0.05, 0.29, 0.07, 0.21, 0.06].

For f_1, it may be observed from here that each of the normalised amplitude values of [0.06, 0.07, 0.05, 0.07, 0.05, 0.06, 0.01, 0.02, 0.05, 0.03] is below T_v. Therefore, MP_1 corresponding to f_1 is the average value (AV) of [0.06, 0.07, 0.05, 0.07, 0.05, 0.06, 0.01, 0.02, 0.05, 0.03], which is “0.047” and the first time stamp t_1.

For f_2, it may be observed from here that each of the normalised amplitude values of [0.61, 0.64, 0.46, 0.53, 0.52, 0.59, 0.70, 0.66, 0.48, 0.57] is above T_v, as well as the difference between the extreme values (“0.70” and “0.46”) is “0.24”, which is below T_v. Therefore, MP_2 corresponding to f_2 is the average value (AV) of [0.61, 0.64, 0.46, 0.53, 0.52, 0.59, 0.70, 0.66, 0.48, 0.57], which is “0.576” and first time stamp t_1.

For f_3, it may be observed from here that some of the normalised amplitude values of [0.11, 0.23, 0.27, 0.10, 0.20, 0.30, 0.00, 0.24, 0.27, 0.34] are above T_v, whereas others are below T_v. Also, the difference between the extreme values (“0.30” and “0.00”) is “0.30”, which is above T_v. Therefore, MP_3 corresponding to f_3 are obtained from Ramer-Douglas-Peucker algorithm, wherein the MP_3 constitutes [(0.11, t_1), (0.3, t_6), (0, t_7), (0.24, t_8), (0.34, t_{10})].

For f_4, it may be observed from here that some of the normalised amplitude values of [0.22, 0.06, 0.22, 0.30, 0.23, 0.05, 0.29, 0.07, 0.21, 0.06] are above T_v, whereas others are below T_v. Also, the difference between the extreme values (“0.30” and “0.05”) is “0.25”, which is equal to T_v. Therefore, MP_3 corresponding to f_4 are obtained from Ramer-Douglas-Peucker algorithm, wherein the MP_3 constitutes [(0.22, t_1), (0.06, t_2), (0.3, t_4), (0.05, t_6), (0.29, t_7), (0.07, t_8), (0.21, t_9), (0.06, t_{10})].

Therefore the CDS comprises the following:

the vector of frequencies f_1 to f_{10}, the vector of time stamps t_1 to t_{10},

the algebraic sum SF_1 to SF_{10} of the amplitudes of every spectrum $S_1(f)$ to $S_{10}(f)$, i.e., [89, 87, 113, 101, 100,99, 84, 83, 111, 89], and

the model parameters (MP) as indicated below:

MP_1: [(0.047, t_1)]

MP_2: [(0.576, t_1)]

MP_3: [(0.11, t_1), (0.3, t_6), (0, t_7), (0.24, t_8), (0.34, t_{10})], and

MP_4: [(0.22, t_1), (0.06, t_2), (0.3, t_4), (0.05, t_6), (0.29, t_7), (0.07, t_8), (0.21, t_9), (0.06, t_{10})].

Herein, f_3 and f_4 constitute f_k, and the time stamps t_1, t_6, t_7, t_8 and t_{10} constitute the t_k for MP_3 and the time stamps t_1, t_2, t_4, t_7, t_8, t_9 and t_{10} constitute the t_k for MP_4.

FIG 4 depicts an exemplary reconstructed amplitude array for reconstructing D'(nT) based on the aforementioned CDS. For each frequency f_j the reconstructed amplitude of f_j depends on the type of model parameter MP_j.

In the aforementioned case 1) and case 2), if a frequency f_j is represented by a corresponding MP_j that comprises only the average value of the normalised amplitudes of f_j and the first time stamp t_1, then each reconstructed amplitude $a'_{j,i}$ of f'_j for a time stamp t_i in the reconstructed amplitude array will be generated by multiplying the average value of the normalised amplitudes of f_j with the corresponding SF_i. That is, the reconstructed amplitudes $a'_{j,i}$ of f'_j will be as follows: [$AV*SF_1$, $AV*SF_1$, ----, $AV*SF_{NoS-1}$, $AV*SF_{NoS}$].

In the aforementioned case 3), if a frequency f_j is represented by MP_j obtained from an approximation algorithm, for example, a Ramer-Douglas-Peucker algorithm, then each reconstructed amplitude $a'_{j,i}$ of f_j may be generated by passing the MP_j to an inverse approximation algorithm module, in this case an inverse Ramer-Douglas-Peucker algorithm module for obtaining each of reconstructed amplitude $a'_{j,i}$ of f'_j for each of the time stamp t_i.

As aforementioned, the CDS is processed for reconstructing a reconstructed normalised amplitude array 180 and subsequently the reconstructed amplitude array 190 of f_j. By computing the inverse DFT of each of the columns of the reconstructed amplitude array 190 it is possible to construct $D'_i(nT)$, i.e., the reconstructed partial signals. By contiguous and sequential placement of $D'_i(nT)$ with respect to the time stamps, D'(nT) is constructed.

FIG 5 depicts a summarizing flowchart of the method for compressing D(nT) 65 representing A(t) 45.

In a step 200, signals $D_i(nT)$ 66-70 with t_i 56-60 are received and the respective $S_i(f)$ 106-110 are computed.

In a subsequent step 210, for each of the NoS number of $S_i(f)$ 106-110, the NoP number of amplitudes $a_{j,i}$ 121-126, each of which correspond to each of f_j 111-116, are received and arranged as aforementioned. Each of $S_i(f)$ 106-110 is time stamped with the respective t_i 56-60. Thus, the amplitude array 128 with NoP rows and NoS columns, wherein each column is assigned to a time-stamp t_i 56-60, is created. The amplitude array 128 may be created providing outputs of the module 105 to the module 130. Furthermore, for each of $S_i(f)$ 106-110, the corresponding SF_i 135 is computed as aforementioned.

In a following step 220, each column of the amplitude array 128 is normalised to obtain the normalised amplitude array 148 as disclosed in the preceding sections. The amplitude array 128 may be provided to the module 140 for obtaining $b_{j,i}$ 141-146. For each of $S_i(f)$ 106-110, the respective $a_{j,i}$ 121-126 are normalised to obtain $b_{j,i}$ 141-146.

In a subsequent step 230, each of $b_{j,i}$ 141-146 of each of $S_i(f)$ 106-110 is compared with T_v, which is proportional to the reciprocal of "NoP", i.e. the cardinal number of frequencies f_j 111-116 of each of $S_i(f)$ 106-110. The normalised amplitude array 148 may be provided to the module 150 for comparing each of $b_{j,i}$ 141-146 of each of $S_i(f)$ 106-110 with T_v. Herewith, a distribution of $b_{j,i}$ 141-146 with respect to T_v may be obtained and exemplified.

In a following step 240, for each of f_j 111-116, the distribution of $b_{j,i}$ 141-146 of f_j 111-116 over $S_i(f)$ 106-110 is received for computing the respective MP_j for the respective frequency f_j 111-116 as described above.

In a step 250, the compressed data set (CDS) as defined above is generated.

In a step 260, D'(nT) is reconstructed from CDS. In a following step 270, D'(nT) is correlated with D(nT) 65 for obtaining the correlation co-efficient CC. Based on the determined CC as elucidated in the preceding sections, T_f may be varied in order to vary the threshold value T_v. In case CC indicates that the similarity between D'(nT) and D(nT) is not sufficient, a new threshold value T'_v is generated by varying the last threshold value T_v. Then, the procedure returns to step 230, wherein each of the normalised amplitudes $b_{j,i}$ 141-146 of each of spectrum $S_i(f)$ 106-110 is compared with the threshold value $T_v=T'_v$. In case CC indicates that the similarity between D'(nT) and D(nT) is sufficient, the procedure continues with step 280.

The correlation co-efficient CC is inversely proportional to the tolerance factor T_f.

In step 280, the current compressed data set CDS is stored or, depending on the application, further processed.

Finally, D(nT) 65 is compressed, i.e. storage space for storing the information (amplitude, frequency and time) contained in D(nT) 65 is greatly reduced by merely storing CDS in the memory unit 100. Subsequently, it is possible to use the same either for reference or for transmission also.

In the aforementioned method for compressing D(nT) 65, the step 200 and the steps 260, 270 are optional steps for achieving the object of the invention.

Though the invention has been described with reference to specific embodiments, this description is not meant to be construed in a limiting sense. Various examples of the disclosed embodiments, as well as alternate embodiments of the invention, will become apparent to persons skilled in the art upon reference to the description of the invention. It is therefore contemplated that such modifications can be made without departing from the embodiments of the present invention as defined.

List of reference signs

10	Condition monitoring system
20	Motor
30	Data acquisition module
31	Sensor
32	Signal conditioner
33	Analog to Digital converter
40	Signal processing device
45	Time dependent signal A(t)
46-50	Plurality of time dependent partial signals $A_i(t)$
51-55	Plurality of time intervals Δt_i
56-60	Plurality of time instances t_i (time stamps)

65	Date $D(nT)$
66-70	Plurality of discrete time partial signals $D_i(nT)$
90	Processor
100	Memory unit
105	Spectrum module
106-110	Plurality of spectra $S_i(f)$
111-116	Plurality of frequencies f_j
121-126	Plurality of amplitudes $a_{j,i}$
128	Amplitude array
130	Spectral data receiver module
131-135	Sum of frequencies SF_i
140	Amplitude normaliser module
141-146	Plurality of normalised amplitudes $b_{j,i}$
148	Normalised amplitude array
150	Comparator module
160	Parameter module
170	Correlation module
180	Reconstructed normalised amplitude array
190	Reconstructed amplitude array
200	Step of receiving $D_i(nT)$ and computing $S_i(f)$
210	Step of creating the amplitude array
220	Step of creating the normalised amplitude array
230	Step of comparing the normalised amplitude array with the threshold
240	Step of processing normalised amplitudes $b_{j,i}$ for computing model parameters MP_j
250	Step of generating a compressed data set
260	Step of constructing $D'(nT)$
270	Step of correlating $D'(nT)$ and $D(nT)$
280	Step of storing the compressed data set

CLAIMS

1. A method for compressing data D(nT) (65) representing a time dependent signal A(t) (45), wherein the time dependent signal A(t) (45) comprises a plurality of time dependent partial signals $A_i(t)$ (with i=1,2,...,NoS) (46-50), the method comprising:

- a step (210) of receiving a plurality of spectra $S_i(f)$ (with i=1,2,...,NoS) (106-110), wherein each spectrum $S_i(f)$ (with i=1,2,...,NoS) (106-110) uniquely corresponds to one of the time dependent partial signals $A_i(t)$ (with i=1,2,...,NoS) (46-50), wherein each spectrum $S_i(f)$ (with i=1,2,...,NoS) (106-110) comprises a plurality of frequencies f_j (with j=1,2,...,NoP) (111-116) and a plurality of amplitudes $a_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (121-126) of the plurality of frequencies f_j (with j=1,2,...,NoP) (111-116),

- for each spectrum $S_i(f)$ (with i=1,2,...,NoS) (106-110), a step (220) of normalising the plurality of amplitudes $a_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (121-126) for obtaining a plurality of normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146),

- for each frequency f_j (with j=1,2,...,NoP) (111-116), a step (250) of processing the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146) of the frequency f_j (with j=1,2,...,NoP) (111-116) based on a distribution of the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146) of the frequency f_j (with j=1,2,...,NoP) (141-146) with respect to the threshold value (T_v) for determining one or more respective model parameters (MP_j) (with j=1,2,...,NoP) for representing the distribution of the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146), and

- a step (250) of generating a compressed data set (CDS) comprising at least the one or more model parameters (MP_j) (with j=1,2,...,NoP) and the frequency f_j (with j=1,2,...,NoP) (111-116).

2. The method according to claim 1, wherein for each partial signal $A_i(t)$ (with i=1,2,...,NoS) (46-50), a time stamp t_i (with i=1,2,...,NoS) (56-60) is generated, wherein the time stamp t_i (with i=1,2,...,NoS) (56-60) represents a time instant at which the partial signal $A_i(t)$ (with i=1,2,...,NoS) (46-50) was acquired.

3. The method according to claim 2, wherein, for each frequency f_j (with

j=1,2,...,NoP) (111-116), in case every normalised amplitude $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146) of the frequency f_j (with j=1,2,...,NoP) (111-116) is less than the threshold value (T_v),

- the respective model parameter (MP_j) (with j=1,2,...,NoP) determined by the step (250) of processing comprises an average value (AV) of the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146) of the frequency f_j (with j=1,2,...,NoP) (111-116), and

- the compressed data set (CDS) further comprises the time stamp t_1.

4. The method according to claim 2 or 3, wherein, for each frequency f_j (with j=1,2,...,NoP) (111-116), in case a difference $\Delta = b_{j,i}^{max} - b_{j,i}^{min}$ between extreme values ($b_{j,i}^{max}$, $b_{j,i}^{min}$) of the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) 141-146 of the frequency f_j (with j=1,2,...,NoP) (111-116) is less than the threshold value (T_v),

- the respective parameter (MP_j) (with j=1,2,...,NoP) determined by the step (250) of processing comprises an average value (AV) of the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146) of the frequency f_j (with j=1,2,...,NoP) (111-116), and

- the compressed data set (CDS) further comprises the time stamp t_1.

5. The method according to any of the claims 1 to 4, wherein, for each frequency f_j (with j=1,2,...,NoP) (111-116), in case

- at least one of the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146) of the frequency f_j (with j=1,2,...,NoP) (111-116) is not less than the threshold value (T_v) and

- a difference $\Delta = b_{j,i}^{max} - b_{j,i}^{min}$ between extreme values ($b_{j,i}^{max}$, $b_{j,i}^{min}$) of the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146) of the frequency f_j (with j=1,2,...,NoP) (111-116) is not less than the threshold value (T_v),

the step (250) of processing performs an approximation algorithm for modelling the distribution of the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146), wherein the one or more model parameters (MP_j) (with j=1,2,...,NoP) are resulting model parameters of the approximation algorithm.

6. The method according to claim 5, wherein, for those frequencies f_k, for which in the step (250) of processing the approximation algorithm for modelling the distribution of the normalised amplitudes has been performed, the compressed data set (CDS) further comprises the respective time stamps t_k (with i=1,2,...,NoS).

7. The method according to claim 5 or 6, wherein the approximation algorithm is a polynomial fit.

8. The method according to claim 5 or 6, wherein the approximation algorithm is a step function.

9. The method according to claim 5 or 6, wherein the approximation algorithm is an iterative end point fit algorithm.

10. The method according to any of the claims 1 to 9, wherein the compressed data set (CDS) further comprises for each spectrum $S_i(f)$ (with i=1,2,...,NoS) (106-110), a sum SF_i (with i=1,2,...,NoS) (131-135) of the plurality of amplitudes $a_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (121-126).

11. The method according to any of the claims 1 to 10, wherein in the step (250) of processing, the threshold value (T_v) is proportional to:

- a reciprocal of a cardinal number (NoP) of the plurality of frequencies f_j (with j=1,2,...,NoP) (111-116) and

- to a tolerance factor (T_f).

12. The method according to any of the claims 1 to 11, further comprising:

- after the step (250) of processing, a step (270) of constructing a reconstructed data D'(nT) by processing the compressed data set (CDS),

- a step (260) of determining a correlation coefficient (CC) by correlating the data D(nT) (65) and the reconstructed data D'(nT),

and, responsive to the correlation coefficient (CC), a step of repeating the step (240) of processing and the step (250) of generating a compressed data set (CDS), wherein in the step () of processing, the threshold value (T_v) is proportional to

- a reciprocal of a cardinal number (NoP) of the plurality of frequencies f_j (with j=1,2,...,NoP) (111-116) and

- a tolerance factor (T_f).

13. A signal processing device (40), configured to compress data D(nT) (65) according to any of the methods 1 to 11, the signal processing device (40) comprising:

- a spectral data receiver module (130) for receiving the plurality of spectra $S_i(f)$ (with i=1,2,...,NoS) (106-110),

- an amplitude normaliser module (140) for normalising the plurality of amplitudes $a_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (121-126) for each of the plurality of frequencies f_j (with j=1,2,...,NoP) (111-116) of each of the plurality of spectra $S_i(f)$ (with i=1,2,...,NoS) (106-110) for obtaining the plurality of normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146),

- a comparator module (150) for comparing each of the plurality of normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146) with the threshold value (T_v),

- a parameter module (160) for processing the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146) of the frequency f_j (with j=1,2,...,NoP) (111-116) based on the distribution of the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146) of each frequency f_j (with j=1,2,...,NoP) (141-146) with respect to the threshold value (T_v) for determining the one or more respective parameters (MP_j) (with j=1,2,...,NoP) for representing the distribution of the normalised amplitudes $b_{j,i}$ (with j=1,2,...,NoP; with i=1,2,...,NoS) (141-146), and

- a memory unit (100) for storing the compressed data set (CDS).

14. The signal processing device (40) according to claim 13, further comprising:

- a correlation module (170) for determining the correlation coefficient (CC) between the data D(nT) (65) and the reconstructed data D'(nT).

15. The signal processing device (40) according to claim 13, or claim 14 further comprising:

- a spectrum module (105) for receiving each of the time dependent partial signals $A_i(t)$ (with i=1,2,...,NoS) (46-50) for computing the respective spectrum $S_i(f)$ (with i=1,2,...,NoS) (106-110).

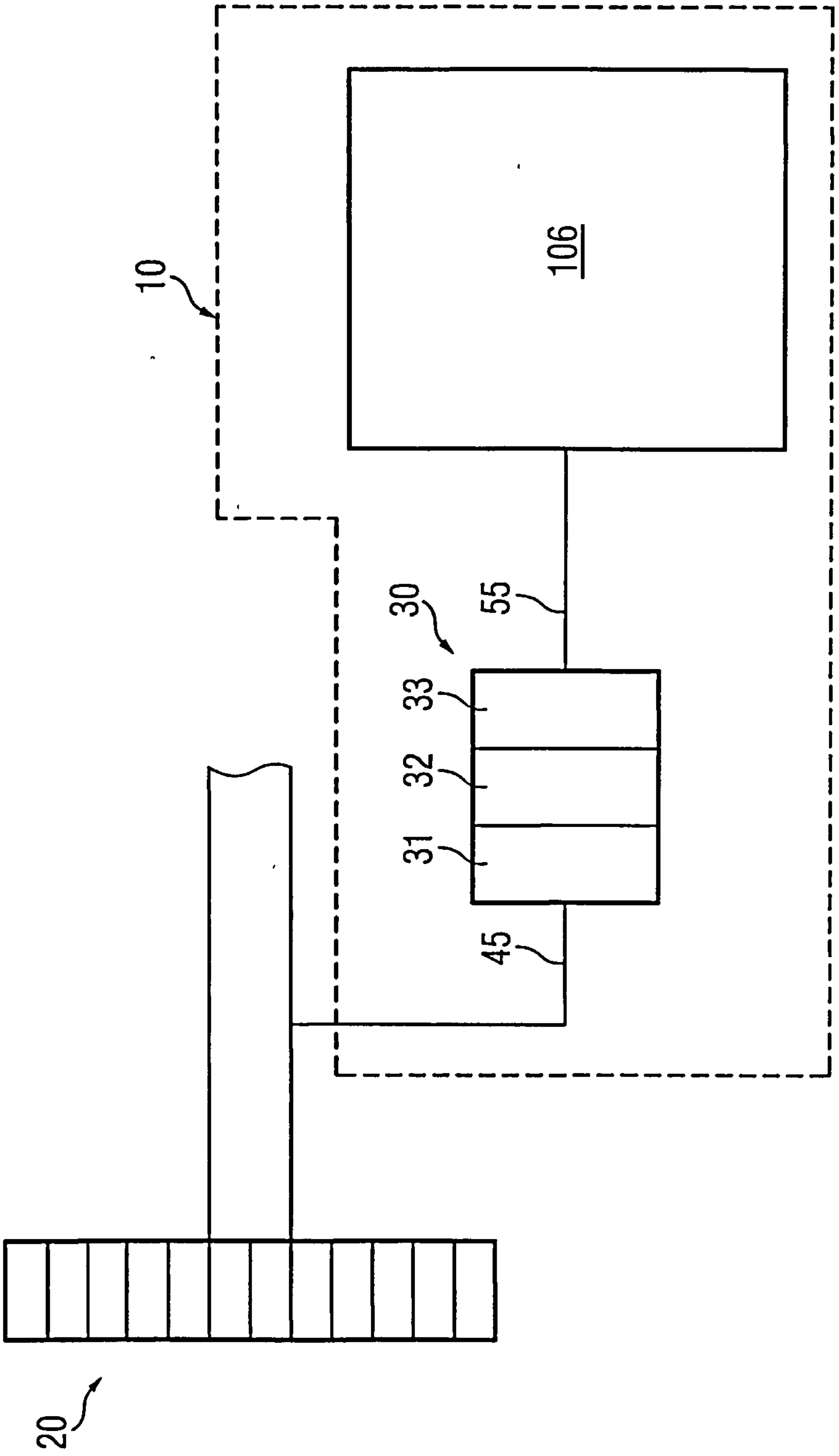
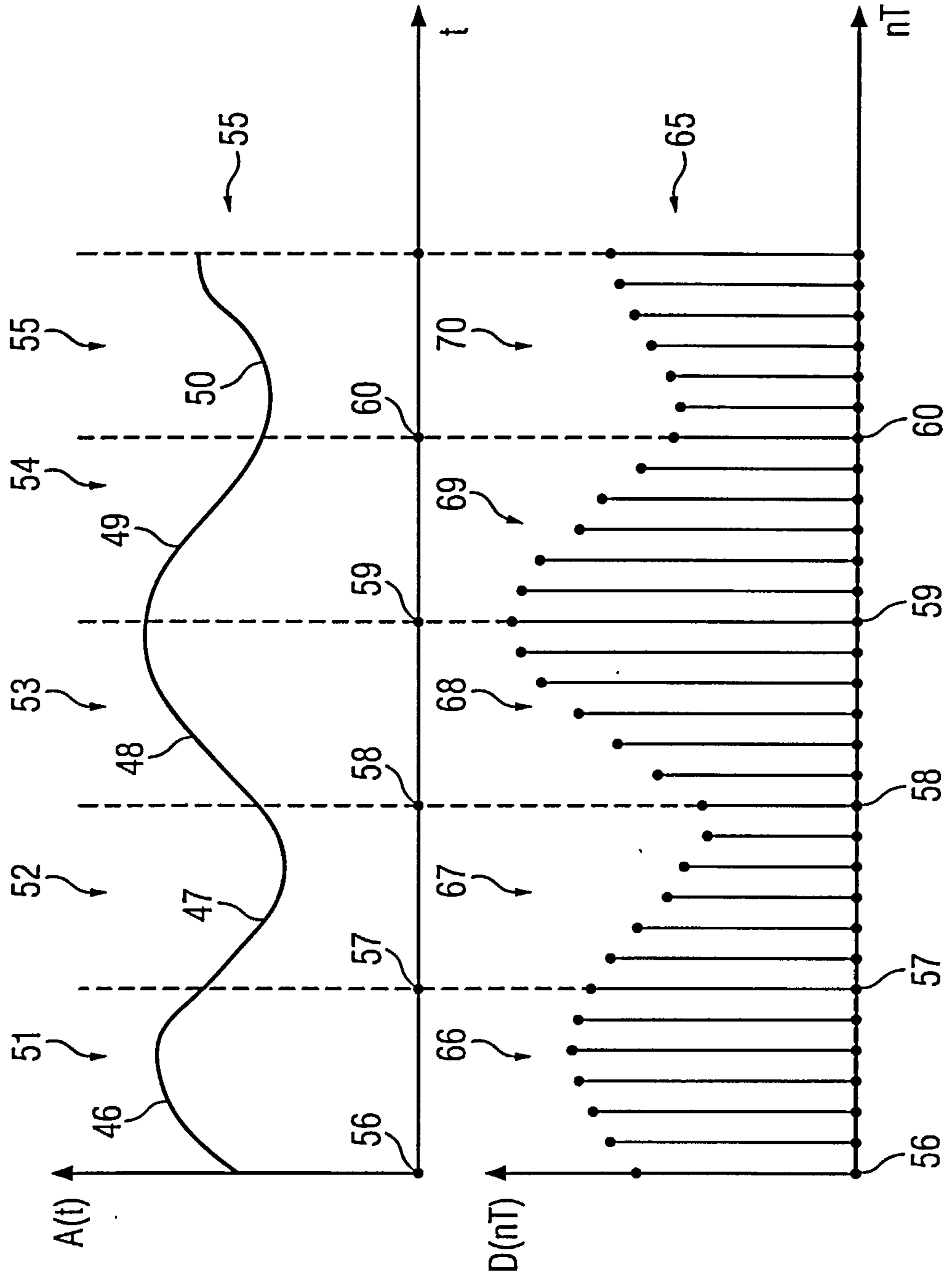


FIG 1A

FIG 1B


A(t)
t
46
47
48
49
50
51
52
53
54
55
55
56
57
58
59
60
D(nT)
nT
65
66
67
68
69
70
56
57
58
59
60

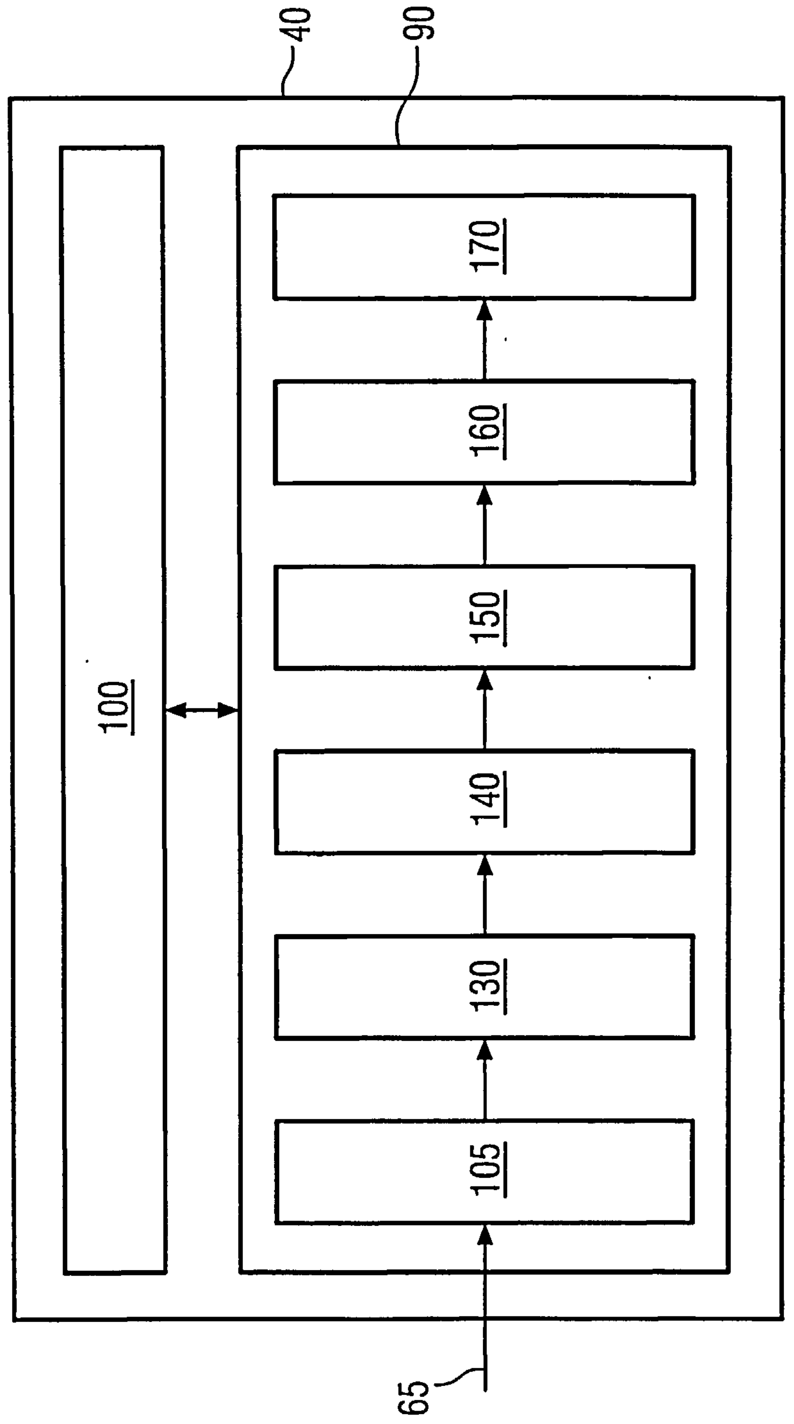


FIG 2A

FIG 2B

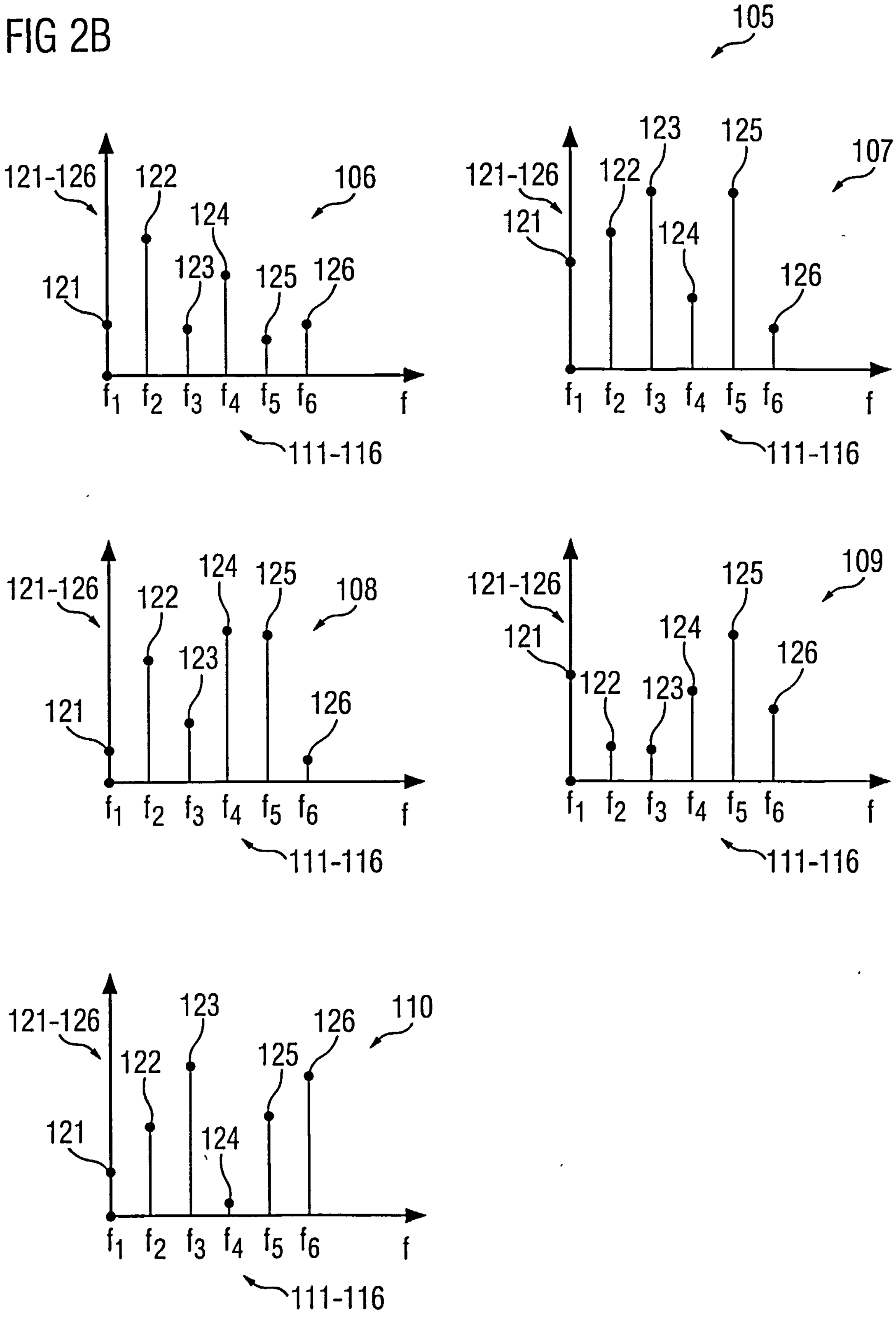
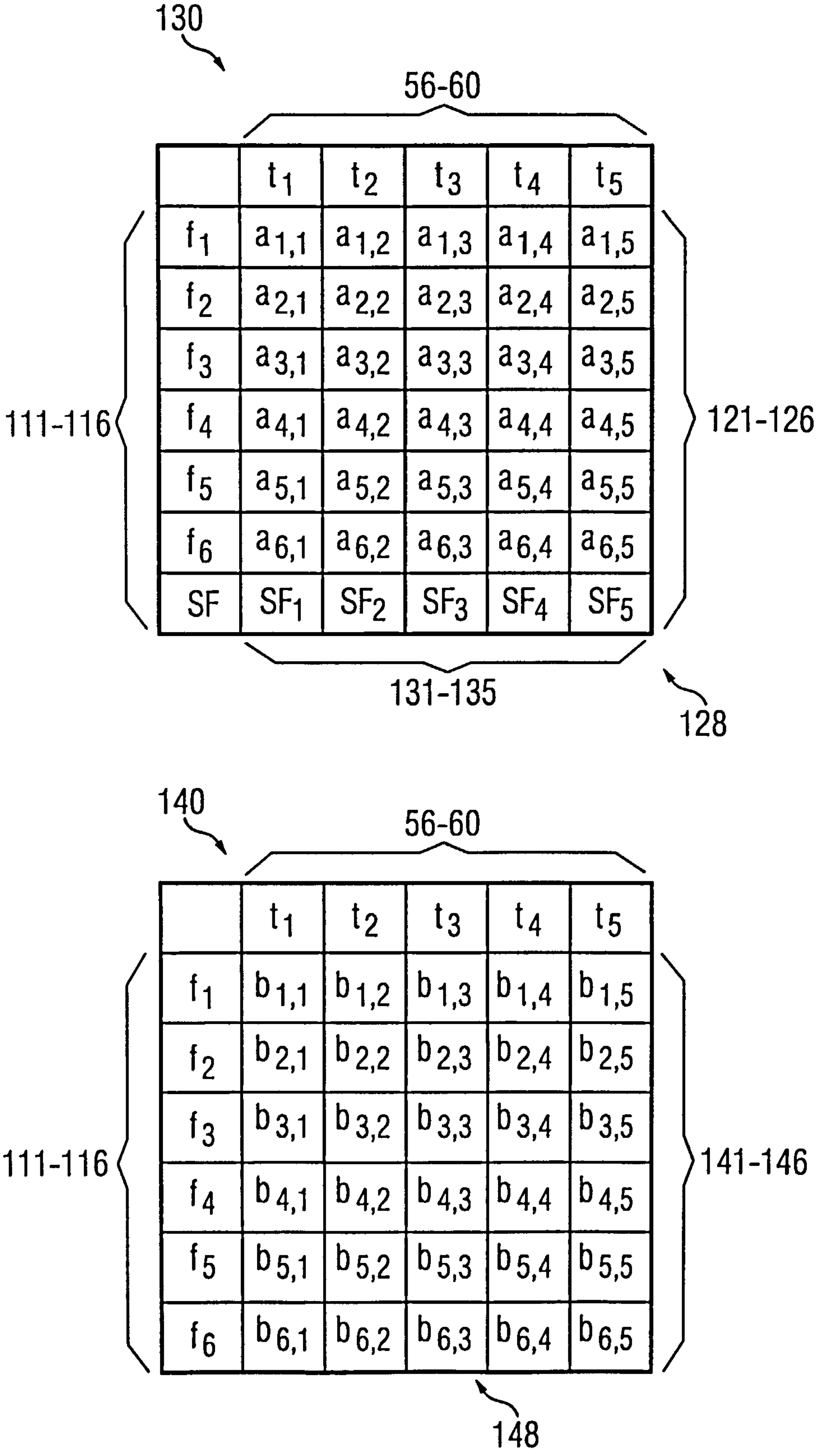

105
121-126
122
124
123
125
126
106
121
f1 f2 f3 f4 f5 f6 f
111-116
121-126
123
125
107
122
121
124
126
f1 f2 f3 f4 f5 f6 f
111-116
121-126
124
125
108
122
123
121
126
f1 f2 f3 f4 f5 f6 f
111-116
121-126
125
109
121
124
126
122
123
f1 f2 f3 f4 f5 f6 f
111-116
121-126
123
126
110
122
125
121
124
f1 f2 f3 f4 f5 f6 f
111-116

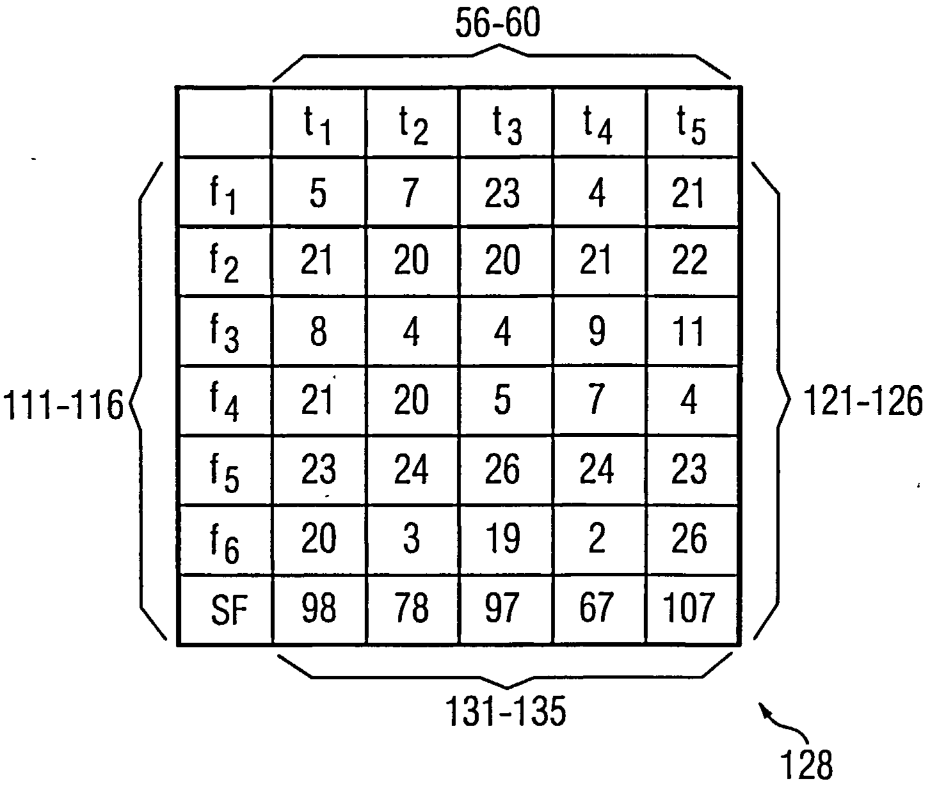
FIG 2C



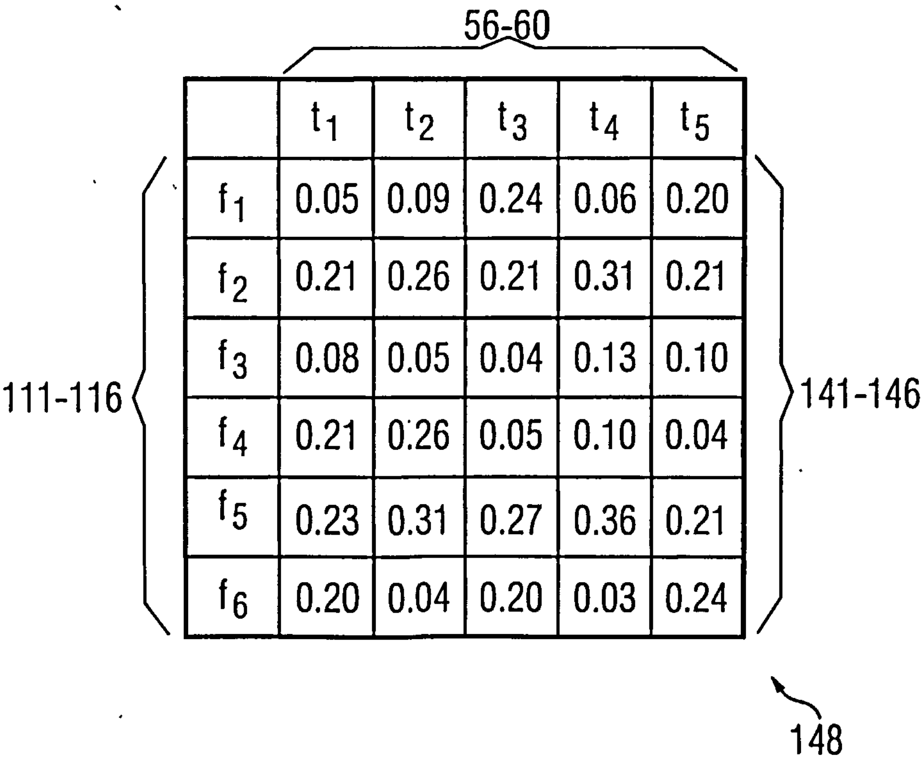
	t_1	t_2	t_3	t_4	t_5
f_1	$a_{1,1}$	$a_{1,2}$	$a_{1,3}$	$a_{1,4}$	$a_{1,5}$
f_2	$a_{2,1}$	$a_{2,2}$	$a_{2,3}$	$a_{2,4}$	$a_{2,5}$
f_3	$a_{3,1}$	$a_{3,2}$	$a_{3,3}$	$a_{3,4}$	$a_{3,5}$
f_4	$a_{4,1}$	$a_{4,2}$	$a_{4,3}$	$a_{4,4}$	$a_{4,5}$
f_5	$a_{5,1}$	$a_{5,2}$	$a_{5,3}$	$a_{5,4}$	$a_{5,5}$
f_6	$a_{6,1}$	$a_{6,2}$	$a_{6,3}$	$a_{6,4}$	$a_{6,5}$
SF	SF_1	SF_2	SF_3	SF_4	SF_5

	t_1	t_2	t_3	t_4	t_5
f_1	$b_{1,1}$	$b_{1,2}$	$b_{1,3}$	$b_{1,4}$	$b_{1,5}$
f_2	$b_{2,1}$	$b_{2,2}$	$b_{2,3}$	$b_{2,4}$	$b_{2,5}$
f_3	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	$b_{3,4}$	$b_{3,5}$
f_4	$b_{4,1}$	$b_{4,2}$	$b_{4,3}$	$b_{4,4}$	$b_{4,5}$
f_5	$b_{5,1}$	$b_{5,2}$	$b_{5,3}$	$b_{5,4}$	$b_{5,5}$
f_6	$b_{6,1}$	$b_{6,2}$	$b_{6,3}$	$b_{6,4}$	$b_{6,5}$

FIG 3



	t_1	t_2	t_3	t_4	t_5
f_1	5	7	23	4	21
f_2	21	20	20	21	22
f_3	8	4	4	9	11
f_4	21	20	5	7	4
f_5	23	24	26	24	23
f_6	20	3	19	2	26
SF	98	78	97	67	107



	t_1	t_2	t_3	t_4	t_5
f_1	0.05	0.09	0.24	0.06	0.20
f_2	0.21	0.26	0.21	0.31	0.21
f_3	0.08	0.05	0.04	0.13	0.10
f_4	0.21	0.26	0.05	0.10	0.04
f_5	0.23	0.31	0.27	0.36	0.21
f_6	0.20	0.04	0.20	0.03	0.24

FIG 4A

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	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
f_1	5.00	6.00	6.00	7.00	5.00	6.00	1.00	2.00	5.00	3.00
f_2	54.00	56.00	52.00	54.00	52.00	58.00	59.00	55.00	53.00	51.00
f_3	10.00	20.00	30.00	10.00	20.00	30.00	0.00	20.00	30.00	30.00
f_4	20.00	5.00	25.00	30.00	23.00	5.00	24.00	6.00	23.00	5.00
SF	89.00	87.00	113.00	101.00	100.00	99.00	84.00	83.00	111.00	89.00

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	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
f_1	0.06	0.07	0.05	0.07	0.05	0.06	0.01	0.02	0.05	0.03
f_2	0.61	0.64	0.46	0.53	0.52	0.59	0.70	0.66	0.48	0.57
f_3	0.11	0.23	0.27	0.10	0.20	0.30	0.00	0.24	0.27	0.34
f_4	0.22	0.06	0.22	0.30	0.23	0.05	0.29	0.07	0.21	0.06

FIG 4B

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	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
f_1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
f_2	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
f_3	0.11	0.11	0.11	0.11	0.11	0.30	0.00	0.24	0.24	0.34
f_4	0.22	0.06	0.06	0.30	0.30	0.05	0.29	0.07	0.21	0.06

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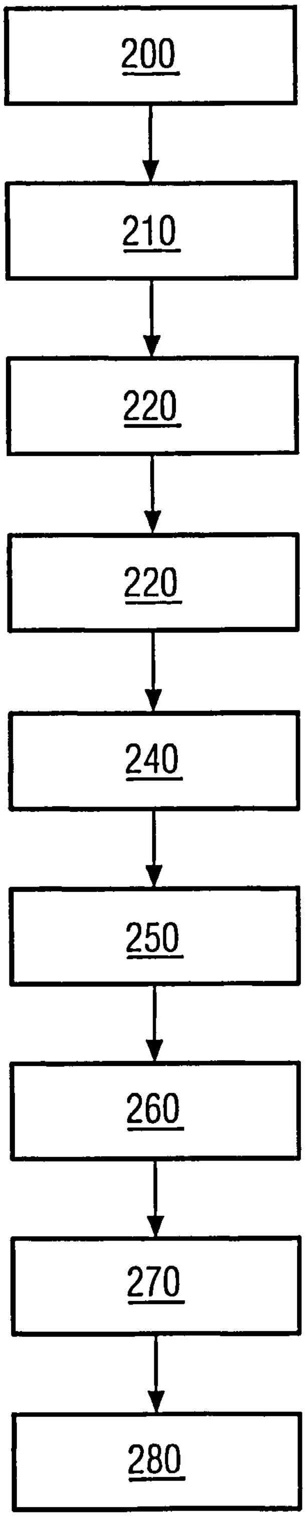
	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
f_1	4.18	4.09	5.31	4.75	4.70	4.65	3.95	3.90	5.22	4.18
f_2	51.26	50.11	65.09	58.18	57.60	57.02	48.38	47.81	63.94	51.26
f_3	9.79	9.57	12.43	11.11	11.00	29.70	0.00	19.92	26.64	30.26
f_4	19.58	5.22	6.78	30.30	30.00	4.95	24.36	5.81	23.31	5.34

FIG 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/RU2012/000211

A. CLASSIFICATION OF SUBJECT MATTER
INV. H03M7/30
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H03M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	SHEKHIREV A V ET AL: "Music files compression based on time-frequency representation of audio signal", STRATEGIC TECHNOLOGIES, 2008. IFOST 2008. THIRD INTERNATIONAL FORUM ON, IEEE, PISCATAWAY, NJ, USA, 23 June 2008 (2008-06-23), pages 340-342, XP031309182, ISBN: 978-1-4244-2319-4 the whole document -----	1,2,4-9, 11,13-15 3,10,12

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search 23 April 2013	Date of mailing of the international search report 03/05/2013
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Winkler, Gregor