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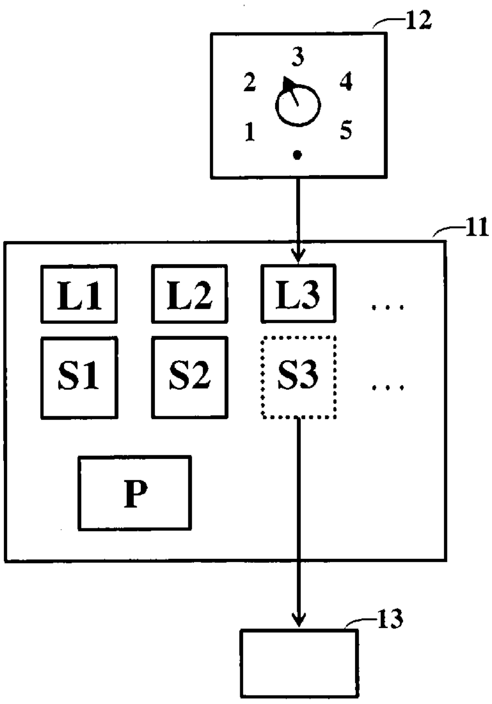


**Fig. 1**

**(57) Abstract**: The invention concerns a system capable of controlling multichannel signals which comprise a plurality of n channels. The system comprises a controller (11) with a processor (*P*), a first magnitude level (*L*1) and an associated first set of channel values (*S*1) comprising n channel values ($S1_i$), and a second magnitude level (*L*2) and an associated second set of channel values (*S*2) comprising n channel values ($S2_i$). The controller (11) is adapted to receive a third magnitude level (*L*3). The processor (*P*) is configured to determine a third set of channel values (*S*3) which is associated with the third magnitude level (*L*3) and which comprises n channel values ($S3_i$). The third set of channel values (*S*3) is determined by determining a channel value ($S3_i$) for each channel $i$ = 1,..., n of the third set of channel values (*S*3) based on the corresponding channel value ($S1_i$) of the first set of channel values (*S*1), the corresponding channel value ($S2_i$) of the second set of channel values (*S*2), the first magnitude level (*L*1), the second magnitude level (*L*2), and the third magnitude level (*L*3). Moreover, the invention concerns a method for controlling multichannel signals and a data structure with computer-executable instructions for controlling multichannel signals.

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# Controlling Multichannel Signals

The invention refers to a system, a method and a data structure for controlling multichannel signals.

Multichannel signals are present in various technical applications. For example, an audio signal (e.g. of hi-fi systems or musical instruments) can consist of different channels corresponding to different frequency ranges (or bandwidths). High quality audio systems typically allow controlling and/or adjusting the values of each of said channels individually with help of equalizers. In this way a better sound can be achieved.

The overall volume of such an multichannel audio signal is typically controlled by a main volume control, meaning that the volume of all channels is controlled by a single volume control. In such a case, following problem could arise: for a given equalizer setting of the channels the sound is good at a low volume, but the sound is still not good or even worse at a high volume (e.g. due to undesired resonances). If, however, the equalizer setting of the channels would produce a good sound at the high volume, then it is possible that the sound is poor (e.g. flat) at said low volume.

The above mentioned type of problem could be avoided by adjusting the equalizer setting each time the volume is changed. In this way, an optimized sound could be achieved at any volume (e.g. minimum, low, middle, high, and maximum volume). Adjusting the equalizer setting each time the volume is changed, however, would be very cumbersome (and therefore, this is usually not done). Therefore, there is a need for a better way of controlling multichannel signals.

Another problem arises, when an audio system (e.g. amplifier and/or speakers) produces for different volumes non-linear responses at different frequencies. For instance, it could happen that at a low volume the response of low frequencies is lower than the response of high frequencies, and that at a high volume the response of low frequencies is higher than the response of high frequencies. Again, such a situation would require adjusting an equalizer setting each time the volume is changed in order to produce a good sound for the whole range of possible volumes.

Other examples for multichannel signals are video signals, where similar problems can arise. For example, the user of a computing device might prefer a rather warm tone for a light signal with a low brightness (intensity) and a colder (more brilliant) tone for a light signal with a high brightness (intensity). In order to have the desired tone for any particular brightness the user would have to recalibrate the (RGB) video signal each time the brightness (intensity) is changed. Recalibrating the (RGB) video signal each time the brightness (intensity) is changed, however, would be impractical. Again, there is a need for a better way of controlling multichannel signals.

A problem to be solved by the invention is to control multichannel signals in such a way that the quality of the multichannel signal is as high as possible. At the same time, the way of controlling multichannel signals should be as convenient as possible.

The above mentioned problem is solved by the system according to claim 1, the method according to claim 4, and the data structure according to claim 15. Additional embodiments of the invention are specified in the dependent claims.

A multichannel signal comprises a plurality of channels (e.g. 2, 3, 4, 5, 6, 7 or more than 7 channels). For example, an audio signal may comprise two channels, namely a "left" channel and a "right" channel. An example for a three-channel signal is an RGB video signal which comprises a "red" channel, a "green" channel and a "blue" channel. Further, the channels of a multichannel signal may represent frequencies or frequency ranges of an audio signal. There are plenty of additional examples for multichannel signals, where, for instance, the channels represent different light sources, different sound sources (e.g. speakers) different heating and/or cooling sources, or different mechanical and/or electrical parts of a device. In a multichannel signal each channel has assigned a channel value as is described in context with Fig. 6. When a multichannel signal is changed, this means that at least one (or more) of the channel values is changed.

A spectrum may be a continuous spectrum or a discrete spectrum. An example for a continuous spectrum is $S(x)$, where $x$ can be any value of the whole range (or a value between a lower bound and an upper bound, respectively) of the spectrum $S(x)$. Thus, a continuous spectrum can be represented by an analytical function or a parametrization, respectively. An example for a discrete spectrum is $S_i$ with $i = 1, ..., n$, where $n$ is the number of discrete values of the spectrum $S_i$. Hence, a discrete spectrum can be represented by a vector or a list, respectively.

Both, a continuous spectrum and a discrete spectrum may be represented by a set of channels $S$. In case of a discrete spectrum each discrete spectrum value may be represented by a corresponding channel. A continuous spectrum may comprise a set of intervals (e.g. without gaps in between neighboring intervals), where each interval may be represented by a corresponding channel. If a continuous spectrum does not consist of intervals, the spectrum may be converted into an aforementioned continuous spectrum consisting of a set of intervals by partitioning the spectrum into intervals and thus, such a spectrum may be represented by a set of channels, too. Another possibility is to parameterize a continuous spectrum and to represent said spectrum by a set of channels, where each parameter (of the spectrum parametrization) corresponds to a channel. Therefore, discrete spectra and/or continuous spectra may be represented by sets of channels.

In the following description it is referred to sets of channels ($S$) and to sets of channel values ($S1$, $S2$, $S3$, ...) where a spectrum is represented by a set of channels (e.g. "red", "green" and "blue") and by the corresponding set of channel values (e.g. 0.5, 0.2 and 0.9). Another example is a sound spectrum, which is represented by a set of channels with frequency intervals (e.g. [50 Hz, 100 Hz], [100 Hz, 200 Hz], ...) and by a set of channel values with signal strengths or gains, respectively (e.g. 5 dB, 3 dB, ...). Furthermore, each channel of a set of channels has a corresponding channel value in a set of channel values, as is described in more detail in context with Fig. 6.

The overall signal strength of one set of channel values may be represented by one magnitude level. For instance, a magnitude level may be the average signal strength value of all channel values of an associated set of channel values, or a magnitude level may be a signal strength value of one particular channel of an associated set of channel values (e.g. the minimum or maximum signal strength value of the set of channel values).

Another possibility is to assign for a given set of channel values an arbitrary (or independent) value to the magnitude level. For instance, a first magnitude level for a first set of channel values is assigned with the value 1 (e.g. representing a low volume), and a second magnitude level for a second set of channel values is assigned with the value 10 (e.g. representing a high volume), where the scales of the magnitude levels and of the sets of channel values are different (e.g. the the channel values vary between -1 and 1).

If there are two sets of channel values $S1$ and $S2$, wherein $S1$ is associated with a first magnitude level $L1$ and where $S2$ is associated with a second magnitude level $L2$, a third set of channel values $S3$ may be determined for an associated third magnitude level $L3$. The new set of channel values $S3$ may be obtained by interpolating (or extrapolating) between the sets of channel values $S1$ and $S2$ using magnitude levels $L1$, $L2$ and $L3$. It is noted that determining a set of channel values basically means determining the value (or parameter) of each channel of the set of channel values.

The sets of channel values $S1$, $S2$ and $S3$ each comprise $n$ values, where $n$ is the number of channels and the number of channel values, respectively. Therefore, the determination of the third set of channels may be performed for each channel in the following way:

$$S3_i = \left(1 - \frac{L3 - L1}{L2 - L1}\right) \cdot S1_i + \left(1 - \frac{L2 - L3}{L2 - L1}\right) \cdot S2_i \quad \text{with } i = 1, ..., n \qquad (1)$$

where $n$ is the number of channels of each set of channel values ($S1$, $S2$ and $S3$). In Equation 1 each channel value $S3_i$ is determined based on the corresponding channel value $S1_i$ and on the corresponding channel value $S2_i$ ($S1_i$, $S2_i$ and $S3_i$ have all the same index $i$). Further, the determination of each channel value $S3_i$ is based on the magnitude levels $L1$, $L2$ and $L3$. It is pointed out that the magnitude levels $L1$, $L2$ and $L3$ do not carry indices and therefore, each magnitude level is the same for all channels.

In addition to Equation 1 the third set of channel values may be determined in one of the following ways:

$$S3_i = L1 \cdot \left(1 - \frac{L3 - L1}{L2 - L1}\right) \cdot S1_i + L2 \cdot \left(1 - \frac{L2 - L3}{L2 - L1}\right) \cdot S2_i \quad \text{with } i = 1, ..., n \qquad (2)$$

or

$$S3_i = L3 \cdot \left(1 - \frac{L3 - L1}{L2 - L1}\right) \cdot S1_i + L3 \cdot \left(1 - \frac{L2 - L3}{L2 - L1}\right) \cdot S2_i \quad \text{with } i = 1, ..., n \qquad (3)$$

In Equations 2 and 3 the third set of channel values $S3$ is proportional to one or a combination of the magnitude levels $L1$, $L2$ and $L3$ (meaning that in the third set of channel values $S3$ magnitude levels are reflected, too). Equations 2 and 3 lead to similar results. The results of Equations 2 and 3, however, are generally not exactly the same.

Equations 1 to 3 may be expressed in the following short way:

$$S3_i = F1 \cdot S1_i + F2 \cdot S2_i \qquad (4.1)$$

$$S3_i = L1 \cdot F1 \cdot S1_i + L2 \cdot F2 \cdot S2_i \qquad (4.2)$$

$$S3_i = L3 \cdot F1 \cdot S1_i + L3 \cdot F2 \cdot S2_i \qquad (4.3)$$

where $F1 = 1-(L3-L1)/(L2-L1)$ and $F2 = 1-(L2-L3)/(L2-L1)$ are dimensionless factors which each are functions of the magnitude levels $L1$, $L2$ and $L3$. In case $L$ and $S_i$ are quantities that should be combined by addition (e.g. logarithmic quantities), Equations 1 to 3 or Equations 4, respectively, may have the following form:

$$S3_i = F1 \cdot S1_i + F2 \cdot S2_i \qquad (5.1)$$

$$S3_i = F1 \cdot (L1 + S1_i) + F2 \cdot (L2 + S2_i) \qquad (5.2)$$

$$S3_i = L3 + F1 \cdot S1_i + F2 \cdot S2_i \qquad (5.3)$$

with the same dimensionless factors as above. Whereas in Equations 4.1 and 5.1 the channel values $S3_i$ depend only on the two dimensionless factors $F1$ and $F2$ (which are not proportional to any magnitude level), in Equations 4.2, 4.3, 5.2 and 5.3 the channel values $S3_i$ depend additionaly on the magnitude level $L1$ and $L2$, or $L3$, respectively. This means that in case of Equations 4.2, 4.3, 5.2 and 5.3 at least one magnitude level is reflected (by addition and/or by multiplication) in the third set of channel values $S3$.

It becomes clear (e.g. from Equation 1) that an actual interpolation can only be performed, if the magnitude levels $L1$ and $L2$ are different from each other. In the case $L1$ and $L2$ have been chosen (by accident) to be the same, for example, the averages $S3_i = \frac{1}{2} \cdot (S1_i + S2_i)$ may be used instead.

If, for instance, the magnitude level $L3$ is equal to the magnitude level $L1$, the new set of channel values $S3$ is the same as $S1$ according to Equation 1. In such a case the interpolation may be simplified or even omitted, and less than the full set of input information ($S1$, $S2$, $L1$, $L2$ and $L3$) may be needed in order to obtain $S3$. (In this example $L1$, $L3$, and $S1$ would be sufficient in order to be able to determine $S3$.) An analogue situation arises if the magnitude levels $L3$ and $L2$ are equal. Moreover, if the channel values $S1_i$ and $S2_i$ with the same index $i$ are equal, it follows from Equation 1 that $S3_i = S1_i = S2_i$ and therefore, in this case the interpolation may also be simplified or omitted, respectively.

It is noted that Equations 1 to 5 may be written in different ways, such that the resulting set of channel values $S3$ is identical. Further, other techniques may be used in order to obtain the third set of channel values $S3$, such as for instance, weighting techniques and/or averaging techniques.

A first embodiment of the invention concerns a system capable of controlling multichannel signals. A multichannel signal comprises a plurality of $n$ channels, such as for instance, 2, 3, 4, 5, or more than 5 channels. The syatem comprises a controller with a processor, a first magnitude level $L1$ and an associated first set of channel values $S1$ comprising $n$ channel values $S1_i$, and a second magnitude level $L2$ and an associated second set of channel values $S2$ comprising $n$ channel values $S2_i$. The controller is adapted to receive a third magnitude level $L3$. And the processor is configured to determine a third set of channel values $S3$ which is associated with the third magnitude level $L3$. The third set of channel values $S3$ comprises $n$ channel values $S3_i$. For each channel $i = 1, ..., n$ a channel value $S3_i$ of the third set of channel values $S3$ is determined based on the channel value $S1_i$

(with the same index $i$) of the first set of channel values $S1$, the channel value $S2_i$ (with the same index $i$) of the second set of channel values $S2$, said first magnitude level $L1$, said second magnitude level $L2$, and said third magnitude level $L3$.

The determination of each channel values of the third set of channel values $S3$ may be based on one or more corresponding channel values (with the same index $i$) of one or more additional sets of channel values (e.g. a fourth set of channel values $S4$) and on one or more additional magnitude levels (e.g. a fourth magnitude level $L4$) which are associated with the corresponding one or more additional sets of channel values.

Optionally, the system of the first embodiment comprises means for selecting one or more magnitude levels, wherein the one or more magnitude levels comprise (at least) the third magnitude level $L3$, and/or wherein the means for selecting one or more magnitude levels is capable of transmitting the one or more magnitude levels to the controller. The means for selecting one or more magnitude levels may be a user interface allowing a user to select and/or change the one or more magnitude levels. Alternatively, the means for selecting one or more magnitude levels is a (computing) device which is configured to automatically select and/or change the one or more magnitude levels.

As a further option the system of the first embodiment comprises means for receiving at least the third set of channel values $S3$ from the controller and/or for generating one or more output signals. An output signal may comprise $n$ output signal values $O_i$. The output signal may be generated by determining an output signal value $O_i$ for each channel $i = 1, ..., n$ based on the corresponding channel value $S3_i$ of the third set of channel values $S3$. Said generation of an output signal may comprise scaling each channel value $S3_i$ of the third set of channel values $S3$ and/or performing a digital to analog conversion for each channel value $S3_i$ of the third set of channel values $S3$. The one or more output signals may be audio signals and/or the one or more output signals may be video signals.

A second embodiment of the invention concerns a method for controlling multichannel signals. Multichannel signal are signals with a plurality of $n$ channels (e.g. $n \geq 2$ channels). In a first step a first magnitude level $L1$ and a first set of channel values $S1$ which is associated with the first magnitude level $L1$ is received, where the first set of channel values $S1$ comprises one channel value $S1_i$ for each channel $i = 1, ..., n$. In a second step a second magnitude level $L2$ and a second set of channel values $S2$ which is associated with the second magnitude level $L2$ is received, where the second set of channel values $S2$ comprises one channel value $S2_i$ for each channel $i = 1, ..., n$. In a third step a third magnitude level $L3$ is received. And in a fourth step a third set of channel values $S3$ which is associated with the third magnitude level $L3$ is determined. In said fourth step for each channel $i = 1, ..., n$ a channel value $S3_i$ of the third set of channel values $S3$ is determined based on the corresponding channel value $S1_i$ of the first set of channel values $S1$, the corresponding channel value $S2_i$ of the second set of channel values $S2$, the first magnitude level $L1$, the second magnitude level $L2$, and the third magnitude level $L3$.

In the second embodiment the steps of receiving a third magnitude level $L3$ and determining a third set of channel values $S3$ may be repeated (at least) a second time. Moreover, the first magnitude level $L1$, the first set of channel values $S1$, the second magnitude level $L2$, and the second set of channel values $S2$ may be updated (received) typically fewer times than the third magnitude level $L3$ and the third set of channel values $S3$ are updated (e.g. $L1$, $L2$, $S1$ and $S2$ are updated each time an audio device is set up at a new location, whereas $L3$ and $S3$ are updated each time the volume $L3$ of said audio device is changed). The method of the second embodiment may be performed employing the system of the first embodiment.

A third embodiment of the invention concerns a data structure comprising computer-executable instructions for controlling multichannel signals. The data structure is, for instance a computer-readable medium (e.g. a compact disk, a floppy disk, or a hard disk), a file (for download) or data stream. Further, the controller of the first embodiment may comprise the data structure of the third embodiment and/or the processor of the first embodiment may employ the data structure of the third embodiment. Moreover, the data structure of the third embodiment may comprise instructions for performing one or more methods of the second embodiment.

Regarding any of the above mentioned embodiments, controlling a multichannel signal means determining a set of channel values for a selected magnitude level. Further, each channel value $S3_i$ of the third set of channel values $S3$ may be determined with the same algorithm as all the other values $S3_i$ of the third set of channel values $S3$. Moreover, each channel value $S3_i$ of the third set of channel values $S3$ may be determined by performing an interpolation and/or an extrapolation and/or a weighted averaging (method). Typically, the lower magnitude level of $L1$ and $L2$ is in the lowest quarter of the whole range of possible magnitude levels, and the higher magnitude level of $L1$ and $L2$ is in the highest quarter of the whole range of possible magnitude levels. For example, if the whole range is between 0 and 10, then the lower magnitude level (e.g. $L1$) would typically be below 2.5 and the higher magnitude level (e.g. $L2$) would typically be above 7.5. It is possible, however, that the magnitude levels of $L1$ and $L2$ are closer to each other (e.g. $L1 = 4$ and $L2 = 6$). In the latter case, Equations 1 to 5 could be used, too, in order to determine the third set of channel values $S3$. If, however, $L1$ and $L2$ have (accidentally) been chosen to be the same, for example, the averages $S3_i = \frac{1}{2} \cdot (S1_i + S2_i)$ may be used instead of an interpolation technique.

Regarding any of the above mentioned embodiments, a channel value $S3_i$ of the third set of channel values $S3$ may be determined for each channel $i = 1, ..., n$ according to the equation $S3_i = F1 \cdot S1_i + F2 \cdot S2_i$. Alternatively, a channel value $S3_i$ of the third set of channel values $S3$ may be determined for each channel $i = 1, ..., n$ according to one of the following equations: $S3_i = L1 \cdot F1 \cdot S1_i + L2 \cdot F2 \cdot S2_i$, $S3_i = F1 \cdot (L1 + S1_i) + F2 \cdot (L2 + S2_i)$, $S3_i = L3 \cdot F1 \cdot S1_i + L3 \cdot F2 \cdot S2_i$ or $S3_i = L3 + F1 \cdot S1_i + F2 \cdot S2_i$. In all of the above mentioned equations $S1_i$ is the corresponding channel value of the first set of channel values $S1$, $S2_i$ is the corresponding channel value of the second set of channel values $S2$, $L1$ is the first magnitude level, $L2$ is the second magnitude level, $L3$ is the third magnitude level, $F1$ and $F2$ are dimensionless factors. Each of the dimensionless factors depends the first magnitude level $L1$, the second magnitude level $L2$ and the third magnitude level $L3$. In particular, the dimensionless factors may be defined as $F1 = 1 - (L3 - L1)/(L2 - L1)$ and $F2 = 1 - (L2 - L3)/(L2 - L1)$. It is noted that the dimensionless factors may be defined differently in such a way that the determination of a channel value $S3_i$ of the third set of channel values $S3$ leads to similar (or even identical) results.

Regarding any of the above mentioned embodiments, the multichannel signals may be sound signals and/or audio signals and/or light signal and/or video signals. Further, each set of channel values (e.g. $S1$, $S2$ and $S3$) may represent a characteristics of a frequency spectrum. For instance, each channel $i = 1, ..., n$ represents a frequency or a frequency range of a frequency spectrum, and each channel value $S3_i$ of the third set of channel values $S3$ represents an amplitude (e.g. a volume, gain, or intensity) of said frequency spectrum. Said frequency spectrum may be a sound spectrum or a light spectrum.

Regarding any of the above mentioned embodiments, the multichannel signal may be an audio signal which is controlled with an equalizer (e.g. a digital equalizer) and a volume control, wherein the first set of channel values $S1$ and the second set of channel values $S2$ each corresponds to an equalizer setting, and wherein the first magnitude level $L1$, the second magnitude level $L2$ and the third magnitude level $L3$ each corresponds to a setting of the volume control. Further, the third set of channel values $S3$ may represent an equalizer setting (where each channel value $S3_i$ is determined according to, for instance, Equation 4.1 or 5.1). Alternatively, the third set of channel values $S3$ may represent an equalizer setting and the current setting of the volume control (where each channel value $S3_i$ is determined according to, for instance, Equation 4.2, 4.3, 5.2 or 5.3). Thus, when the setting of the volume control is changed the overall volume and the sound (corresponding to a particular equalizer setting which is determined automatically) of the audio signal are changed.

Further aspects of possible embodiments of the invention become clear from Figs. 1, 2, 3, 4, 5 and 6:

Fig. 1 shows a system which is capable of controlling multichannel signals.

Fig. 2 shows a flow chart of a method for controlling multichannel signals.

Fig. 3 shows a first example of a determined multichannel signal.

Fig. 4 shows a second example of a determined multichannel signal.

Fig. 5 shows a third example of a determined multichannel signal.

Fig. 6 shows an exemplary representation of a multichannel signal.

In Fig. 1 a system is illustrated which can be used to control multichannel signals. Controller 11 comprises a processor $P$ and information which can be used by the processor $P$. The information comprises magnitude levels (e.g. $L1$, $L2$ and $L3$) and corresponding sets of channel values (e.g. $S1$, $S2$ and $S3$). Although only magnitude levels $L1$, $L2$ and $L3$, and sets of channel values $S1$, $S2$ and $S3$ are shown, said information may comprise additional magnitude levels and/or additional sets of channel values and/or processor-executable instructions, for example.

Processor $P$ may be configured to determine the third set of channel values $S3$ using $L1$, $S1$, $L2$, $S2$ and $L3$. Since said determination is based on $L1$, $S1$, $L2$, $S2$ and $L3$, this information has to be present before $S3$ can be determined. The third set of channel values $S3$ does not need to be present before said determination of $S3$. It is possible, however, that an old set of channel values $S3$ is present and said old set of channel values $S3$ is overwritten with a new set of channel values $S3$ (once the new set of channel values $S3$ has been determined). Typically, a new set of channel values $S3$ is determined each time the magnitude level $L3$ is updated.

Further, Fig. 1 shows means 12 for selecting one or more magnitude levels. In particular, the means 12 are suitable for selecting the magnitude level $L3$. Other magnitude levels (e.g. $L1$ and $L2$) may either be selected by the same means 12 or may be selected by different means (similar to means 12). Means 12 may either be a user interface (e.g. a control or dial) or mans 12 may be a (computing) device that is configured to select magnitude levels automatically. Component 12 is capable of transmitting one or more magnitude levels to controller 11. Further, component 12 may comprise an analog to digital converter (e.g. in case digital signals are desired for further processing).

Once a new set of channel values $S3$ has been determined Controller 11 may transmit the new set of channel values $S3$ to component 13 which is configured to receive the new set of channel values $S3$. Further, component 13 may be configured to further process (e.g. scale up or down) the set of channel values $S3$. For example, component 13 may comprise a digital to analog converter (e.g. for generating an analog output signal). Moreover, component 13 may be configured to generate one or more output signals. Output signals may be (stereo) audio and/or video signals, for instance.

It is noted that the components 12 and/or 13 are optional. Further, components 11, 12 and 13 may be located in the same physical device. Moreover, each component may be located in a separate physical device. Other possibilities are that components 11 and 12 are located in the same physical device and that component 13 is located in a separate physical device, or that components 11 and 13 are located in the same physical device and that component 12 is located in a separate physical device. Moreover, components 12 and 13 may be located in the same physical device and controller 11 is located in a separate physical device. The latter combination may be used in cases where an existing system is upgraded (or extended) with a controller 11 such that the new system is better capable of controlling multichannel signals.

In Fig. 2 a flowchart of a method for controlling multichannel signals is illustrated. The method starts at step 20. In step 21 a first magnitude level $L1$ and a first set of channel values $S1$ which is associated with the first magnitude level $L1$ are received. Further, in step 22 a second magnitude level $L2$ and a second set of channel values $S2$ which is associated with the second magnitude level $L2$ are received. Furthermore, a third magnitude level $L3$ is received in step 23. Alternatively, steps 21, 22 and 23 may be carried out in a single step. Moreover, the magnitude levels $L1$, $L2$ and $L3$ and the sets of channel values $S1$ and $S2$ may be received in a different order.

Then, in step 24 a third set of channel values $S3$, which is associated with the third magnitude level $L3$ is determined. Determining $S3$ typically means that channel values $S3_i$ are determined for each channel $i = 1, ..., n$. Said determination of the third set of channel values $S3$ is based on the magnitude levels $L1$, $L2$ and $L3$, and the sets of channel values $S1$ and $S2$. For example, the third set of channel values $S3$ is determined by performing an interpolation, extrapolation or weighted averaging (e.g. according to any of Equations 1 to 5). The representation of sets of channel values (e.g. $S1$, $S2$ and $S3$) is described in context with Fig. 6.

After step 24 the method is done. Alternatively, the method proceeds to step 25. At step 25 it is determined whether an update of the magnitude level $L3$ is accepted or not. If no update of $L3$ is accepted, the method proceeds to the end 26. If, however, an update of $L3$ is accepted, the method proceeds to step 23, where a new magnitude level $L3$ may be received. Alternatively, if an update of $L3$ is accepted, the method may wait for an update of $L3$ and then proceed to step 23. Such a situation is when a user updates the magnitude level $L3$ by changing the control of selector 12, for instance. If updates of $L1$ and/or $L2$ and/or $S1$ and/or $S2$ are to be used for the determination of $S3$, then typically all method steps are repeated, but parts of steps 21, 22 and 23 may be omitted.

An optional step (not shown) may be to check (e.g. after step 22) whether the magnitude levels $L1$ and $L2$ are different from each other or not, and in case $L1$ and $L2$ are not different from each other to repeat steps 21 and/or 22 (until magnitude levels $L1$ and $L2$ are received that are actually different from each other).

For example, the above described method may be carried out by the processor $P$ of controller 11, shown in Fig. 1. Further, the above described method may be carried out for any number of channels of a set of channel values (e.g. 2, 3, 4, 5 or more than 5). The number of channels is the same for each of the sets of channel values $S1$, $S2$ and $S3$.

A first example of controlling a multichannel signal is shown in Fig. 3. In this particular example, a first characteristics 31 of a first set of channel values $S1$ is associated with a magnitude level $L1 = 2$ (not shown), and a second characteristics 32 of a second set of channel values $S2$ is associated with a magnitude level $L2 = 10$ (not shown). Starting from the aforementioned information any third set of channel values $S3$ can be determined for a given third magnitude level $L3$ (not shown). In this example, the third set of channel values $S3$ is determined for the magnitude level $L3 = 5.5$ according to Equation 1. The resulting third set of channel values $L3$ has the characteristics 33. It is noted that, for instance, the magnitude levels $L1 = 4$, $L2 = 20$ and $L3 = 11$ would result in exactly the same characteristics 33.

The example, illustrated in Fig. 3, may be used to control a multichannel signal of an equalizer (of an audio system), for instance, where the sets of channel values $S1$, $S2$ and $S3$ each consist of 10 channels. Each set of channel values may correspond to a frequency spectrum with 10 adjacent frequency ranges which may add up to a continuous overall frequency spectrum (e.g. in the range of 20 Hz to 20 kHz). In the example of Fig. 3, the number of channels is exemplary. In general, the number of channels may be higher or lower than 10.

The third set of channel values $S3$ (with characteristics 33) may be determined with the system and/or with the method which are described in context with Figs. 1 and 2, respectively. In this particular example, Equation 1 is used to determine each cannel value of the set of channel values $S3$ with characteristics 33.

If, however, the magnitude level $L3$ would be chosen closer to the magnitude level $L1$

than in the example illustrated in Fig. 3 then the characteristics 33 would be closer (closer in magnitude and closer in shape) to the characteristics 31 (using the same algorithm). Similarly, if the magnitude level $L3$ would be chosen closer to the magnitude level $L2$ (than in the example illustrated in Fig. 3 and using the same algorithm) then the magnitude and shape of characteristics 33 would be closer to the magnitude and shape of the characteristics 32. Further, if the the magnitude level $L3$ was selected to be the average $L3 = \frac{1}{2}\cdot(L1+L2)$ of $L1$ and $L2$, then each channel value of $S3$ would be the average of the corresponding channel values of $S1$ and $S2$, namely $S3_i = \frac{1}{2}\cdot(S1_i+S2_i)$ with $i = 1, 2, ..., 10$ in case of 10 channels. Furthermore, the characteristics 33 and 31 would be identical for $L3 = L1$, and the characteristics 33 and 32 would be identical for $L3 = L2$. (The latter three cases can be verified by replacing $L3$ with $\frac{1}{2}\cdot(L1 + L2)$, $L1$ or $L2$ in Equation 1.)

A second example of controlling a multichannel signal is shown in Fig. 4. Each set of channel values comprises three channel values labeled with $a$, $b$ and $c$. These three channel values could correspond to "low", "mid" and "high" channels of an audio signal, for example. In another example, these three channels could correspond to "red", "green" and "blue" channels of a video signal. The values 41 represent the first set of channel values $S1$, the values 42 represent the second set of channel values $S2$, and the values 43 represent the third set of channel values $S3$. In this particular example of Fig. 4, the third set of channel values is determined based on the first set of channel values $S1$, the second set of channel values $S3$ and the three magnitude levels $L1$, $L2$ and $L3$ according to Equation 1 with the level choices $L1 = 0.1$, $L2 = 0.9$, and $L3 = 0.5$ (not shown).

It is noted, however, that the choices $L1 = c\cdot 0.1$, $L2 = c\cdot 0.9$, and $L3 = c\cdot 0.5$, where $c$ is any constant number that is not equal to zero, would have led to an identical result. Further, it is noted that the magnitude level $L3$ does not have to be in between magnitude levels $L1$ and $L2$, but magnitude level $L3$ could also be below magnitude level $L1$ or above magnitude level $L2$, respectively. In the latter case the values 43 would be below values 41 or above values 42, respectively. Moreover, the closer magnitude level $L3$ would be to magnitude level $L1$, the closer (in shape and in magnitude) values 43 would be to values 41. And the closer magnitude level $L3$ would be to magnitude level $L2$, the closer (in shape and in magnitude) values 43 would be to values 42.

If, for example, in Fig. 4 a video signal is represented (the three channels corresponding to "red", "green" and "blue" of the video signal) then the color of the video signal corresponds to the first set of channel values $S1$ (with RGB values 41) if the magnitude levels $L1$ and $L3$ are equal. In this case the intensity (magnitude) of the video signal would be relatively low. If then the magnitude level $L3$ is increased, the intensity of the video signal is increased, too, and the color becomes closer to the color corresponding to the values 42 of the second set of channel values $S2$. If the magnitude level $L3$ eventually is the same as the magnitude level $L2$, the video signal would have the same intensity and color as is defined by the second set of channel values $S2$ which is associated with the second magnitude level $L2$.

In the example of Fig. 4 the value $43a$ (of $S3$) is determined based on the magnitude levels $L1$, $L2$ and $L3$, and based on the values $41a$ (of $S1$) and $42a$ (of $S2$). Correspondingly, the value $43b$ (of $S3$) is determined based on the magnitude levels $L1$, $L2$ and $L3$, and based on the values $41b$ (of $S1$) and $42b$ (of $S2$), and the value $43c$ (of $S3$) is determined based on the magnitude levels $L1$, $L2$ and $L3$, and based on the values $41c$ (of $S1$) and $42c$ (of $S2$). Thus, each channel $S3_i$ of the set of channel values $S3$ is determined based on the magnitude levels $L1$, $L2$ and $L3$, and based on the corresponding channel values $S1_i$ and $S2_i$ of the sets of channel values $S1$ and $S2$, respectively, for all channels $i = 1, ..., n$, where $n$ is the number of channels.

A third example of controlling a multichannel signal is shown in Fig. 5. Diagram 51 is an illustration of the first set of channel values $S1$, and diagram 52 is an illustration of the second set of channel values $S2$. In this example, the third set of channel values, shown in diagram 53, is determined for the magnitude levels $L1 = 1.0$, $L2 = 9.0$ and $L3 = 6.5$ according to Equation 2. The number of channels is $n = 7$ in this particular case. In contrast to the examples of Figs. 3 and 4 the scale of the third set of channel values $S3$ (diagram 53) is different form the scales of the first and second sets of channels $S1$ and $S2$ (diagrams 51 and 52). Employing Equation 2 allows to determine a third set of channel values $S3$ which reflects (in each channel value $S3_i$ with $i = 1, ..., n$) the magnitude of the magnitude levels $L1$ and $L2$. It is noted that determining the third set of channel values $S3$ using Equation 3 would lead to a similar result. In the latter case, however, the third set of channel values $S3$ would reflect the magnitude of the third magnitude level $L3$ (in each channel value $S3_i$ with $i = 1, ..., n$).

In Fig. 5 the diagrams 51 and 52 may each represent an equalizer setting. Said equalizer settings are defined at the corresponding settings of a volume control (e.g. magnitude levels $L1$ and $L2$). Both diagrams 51 and 52 have a scale from zero to one, whereas diagram 53 has a scale between zero and ten. The scale of diagram 53 is different (in the particular case of Fig. 5) because the third set of channel values $S3$ represents an equalizer setting and a setting of the volume control (e.g. a weighted average of the magnitude levels $L1$ and $L2$).

In Fig. 6 it is illustrated how a multichannel signal (with three different characteristics) may be represented by one set of channels $S$ and (in this particular case) three sets of channel values $S1$, $S2$ and $S3$. As is illustrated in Fig. 6, the number of channels and the number of channel values, respectively, is $n$ for each set. In Fig. 6, individual channel numbers are indicated by the subindices $i = 1, 2, ..., n$. Depending on the particular application $n$ is 2, 3, 4, 5 or more than 5. For one particular application, however, $n$ is the same number for all sets $S$, $S1$, $S2$ and $S3$. Hence, each channel of $S$ has one corresponding channel value ($S1_i$, $S2_i$ and $S3_i$) in each set of channel values $S1$, $S2$ and $S3$. It is noted, that the number of sets of channel values may be more than three.

For example, a light/video signal may be represented with RGB values. Thus the set of channels has three channels, namely the "red", "green" and "blue" channels. Therefore, a corresponding set of channel values has three channel values (e.g. 0.7, 0.4 and 0.9). In the latter example, each set of channel values corresponds to a particular color. Correspondingly, a sound/audio signal may be represented by a set of channels $S$, where each channel represents a frequency range, and where a set of channel values comprises values that may represent gains and/or volumes.

In the present invention a multichannel signal is controlled by determining a third set of channel values $S3$. As is described in context with Equation 1 the third set of channel values $S3$ is determined based on a first set of channel values $S1$, a second set of channel values $S2$ and three magnitude levels $L1$, $L2$ and $L3$. In other words, multichannel signals are controlled by determining sets of channel values. When a multichannel signal is controlled (or manipulated) the number of channels $n$ and/or the channels themselves remain the same during the whole procedure. Thus, for the aforementioned determination of $S3$ the set of channels $S$ is not used directly.

There are various examples of applications, where the above described system and method for controlling multichannel signals may be employed in audio (or sound) systems. Such applications are, for instance, surround sound systems, headphones, telephones, car hi-fi systems, home entertainment systems, audio systems for conference rooms, computing systems, music equipment, musical instruments, and audio recording systems.

Examples of the above mentioned system and method of controlling multichannel signals in applications which are related to video (or light) signals are video systems with different light sources (e.g. theaters, show and/or meeting rooms, cinemas, cars, illumination systems for buildings or parks) and video systems (e.g. involving RGB signals), such as monitors, displays, color light sources, beamers and cameras.

Even though the invention has mainly been discussed in context with audio and video signals, there are other applications possible, too, such as for instance temperature regulating systems or electro-mechanical systems comprising a plurality of parts moved by actuators, where each actuator may correspond to one channel of a set of channels.

A typical use case is an audio system comprising an equalizer (for controlling sets of channel values) and a volume control (for selecting magnitude levels), where a user would like to optimize the sound at different volume levels. Employing the system and/or method for controlling multichannel signals the user starts to optimize the sound of the audio system by adjusting the equalizer channel values $S1$ at a low volume $L1$. Then the user of the audio system optimizes the sound by adjusting the equalizer channel values $S2$ at a high volume $L2$. After these two steps the user can select any volume $L3$, and then the channel values $S3$ are automatically adjusted (by an audio system according to the invention) based on $L1$, $S1$, $L2$, $S2$ and $L3$. The channel values $S3$ may represent equalizer channel values (where each channel value $S3_i$ is determined according to, for instance, Equation 4.1 or 5.1). Further, the channel values $S3$ may represent equalizer channel values and the selected volume (where each channel value $S3_i$ is determined according to, for instance, Equation 4.2, 4.3, 5.2 or 5.3). Automatically adjusting the channel values $S3$ each time the volume $L3$ is updated results in a better sound (e.g. almost free of nonlinearity effects and/or undesired resonances) at any selected volume $L3$. Therefore, the quality of the sound is as high as possible for any selected volume while the way of controlling and optimizing the sound is as convenient as possible.

## Claims

1. A system capable of controlling multichannel signals, wherein a multichannel signal comprises a plurality of $n$ channels, the system comprising:

   a controller (11) comprising a processor ($P$), a first magnitude level ($L1$) and an associated first set of channel values ($S1$) comprising $n$ channel values ($S1_i$), and a second magnitude level ($L2$) and an associated second set of channel values ($S2$) comprising $n$ channel values ($S2_i$);

   wherein the controller (11) is adapted to receive a third magnitude level ($L3$);

   and wherein the processor ($P$) is configured to determine a third set of channel values ($S3$) which is associated with the third magnitude level ($L3$), where the third set of channel values ($S3$) comprises $n$ channel values ($S3_i$), and where for each channel $i = 1, ..., n$ a channel value ($S3_i$) of the third set of channel values ($S3$) is determined based on the corresponding channel value ($S1_i$) of the first set of channel values ($S1$), the corresponding channel value ($S2_i$) of the second set of channel values ($S2$), the first magnitude level ($L1$), the second magnitude level ($L2$), and the third magnitude level ($L3$).

2. The system according to claim 1 further comprising:

   means (12) for selecting one or more magnitude levels, wherein the one or more magnitude levels comprise the third magnitude level ($L3$), and/or wherein the means (12) for selecting one or more magnitude levels is capable of transmitting the one or more magnitude levels to the controller (11).

3. The system according to claim 1 or 2 further comprising:

   means (13) for receiving at least the third set of channel values ($S3$) from the controller (11) and for generating one or more output signals.

4. A method for controlling multichannel signals, wherein a multichannel signal comprises a plurality of $n$ channels, the method comprising:

   receiving (21) a first magnitude level ($L1$) and a first set of channel values ($S1$) which is associated with the first magnitude level ($L1$), wherein the first set of channel values ($S1$) comprises one channel value ($S1_i$) for each channel $i = 1, ..., n$;

   receiving (22) a second magnitude level ($L2$) and a second set of channel values ($S2$) which is associated with the second magnitude level ($L2$), wherein the second set of channel values ($S2$) comprises one channel value ($S2_i$) for each channel $i = 1, ..., n$;

   receiving (23) a third magnitude level ($L3$); and

   determining (24) a third set of channel values ($S3$) which is associated with the third magnitude level ($L3$), wherein for each channel $i = 1, ..., n$ a channel value ($S3_i$) of the third set of channel values ($S3$) is determined based on the corresponding channel value ($S1_i$) of the first set of channel values ($S1$), the corresponding channel value ($S2_i$) of the second set of channel values ($S2$), the first magnitude level ($L1$), the second magnitude level ($L2$), and the third magnitude level ($L3$).

5. The method according to claim 4, wherein the steps of receiving (23) a third magnitude level ($L3$) and determining (24) a third set of channel values ($S3$) are performed at least two times, and/or wherein the first magnitude level ($L1$), the first set of channel values ($S1$), the second magnitude level ($L2$), and the second set of channel values ($S2$) are updated fewer times than the third magnitude level ($L3$) and the third set of channel values ($S3$) are updated.

6. The system/method according to any of claims 1 to 5, wherein each channel value ($S3_i$) of the third set of channel values ($S3$) is determined by performing at least one of: interpolation, extrapolation, and weighted averaging.

7. The system/method according to any of claims 1 to 6, wherein for each channel $i = 1, ..., n$ the channel value ($S3_i$) of the third set of channel values ($S3$) is determined according to

$$S3_i = F1 \cdot S1_i + F2 \cdot S2_i$$

where $S1_i$ is the corresponding channel value of the first set of channel values ($S1$), where $S2_i$ is the corresponding channel value of the second set of channel values ($S2$), and where $F1$ and $F2$ are dimensionless factors.

8. The system/method according to any of claims 1 to 6, wherein for each channel $i = 1, ..., n$ the channel value ($S3_i$) of the third set of channel values ($S3$) is determined according to

$$S3_i = L1 \cdot F1 \cdot S1_i + L2 \cdot F2 \cdot S2_i$$

$$\text{or } S3_i = F1 \cdot (L1 + S1_i) + F2 \cdot (L2 + S2_i)$$

$$\text{or } S3_i = L3 \cdot F1 \cdot S1_i + L3 \cdot F2 \cdot S2_i$$

$$\text{or } S3_i = L3 + F1 \cdot S1_i + F2 \cdot S2_i$$

where $S1_i$ is the corresponding channel value of the first set of channel values ($S1$), where $S2_i$ is the corresponding channel value of the second set of channel values ($S2$), where $L1$ is the first magnitude level, where $L2$ is the second magnitude level, where $L3$ is the third magnitude level, and where $F1$ and $F2$ are dimensionless factors.

9. The system/method according to claims 7 or 8, wherein each of the dimensionless factors ($F1$, $F2$) is a function of the first magnitude level ($L1$), the second magnitude level ($L2$) and the third magnitude level ($L3$).

10. The system/method according to any of claims 1 to 9, wherein the multichannel signals are one or more of the following: sound signals, audio signals, light signals and/or video signals.

11. The system/method according to any of claims 1 to 10, wherein each channel $i = 1, \ldots, n$ represents a frequency or a frequency range of a frequency spectrum, and wherein each channel value ($S3_i$) of the third set of channel values ($S3$) represents an amplitude of said frequency spectrum.

12. The system/method according to any of claims 1 to 11, wherein the multichannel signal is an audio signal which is controlled by an equalizer and a volume control, wherein the first set of channel values ($S1$) and the second set of channel values ($S2$) each corresponds to an equalizer setting, and wherein the first magnitude level ($L1$), the second magnitude level ($L2$) and the third magnitude level ($L3$) each corresponds to a setting of the volume control.

13. The system/method according to claim 12, wherein the third set of channel values ($S3$) represents an equalizer setting.

14. The system/method according to claim 12, wherein the third set of channel values ($S3$) represents an equalizer setting and a current setting of the volume control.

15. A data structure comprising computer-executable instructions for performing one or more methods according to any of claims 4 to 14.

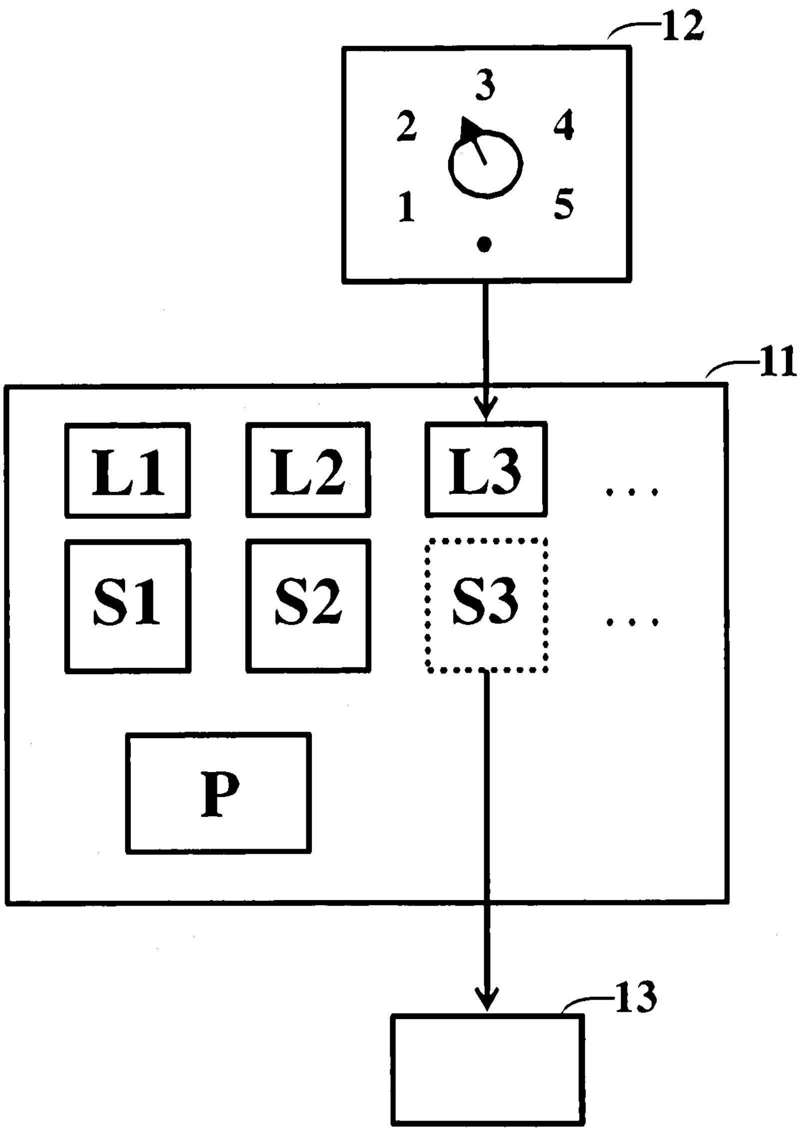



Fig. 1

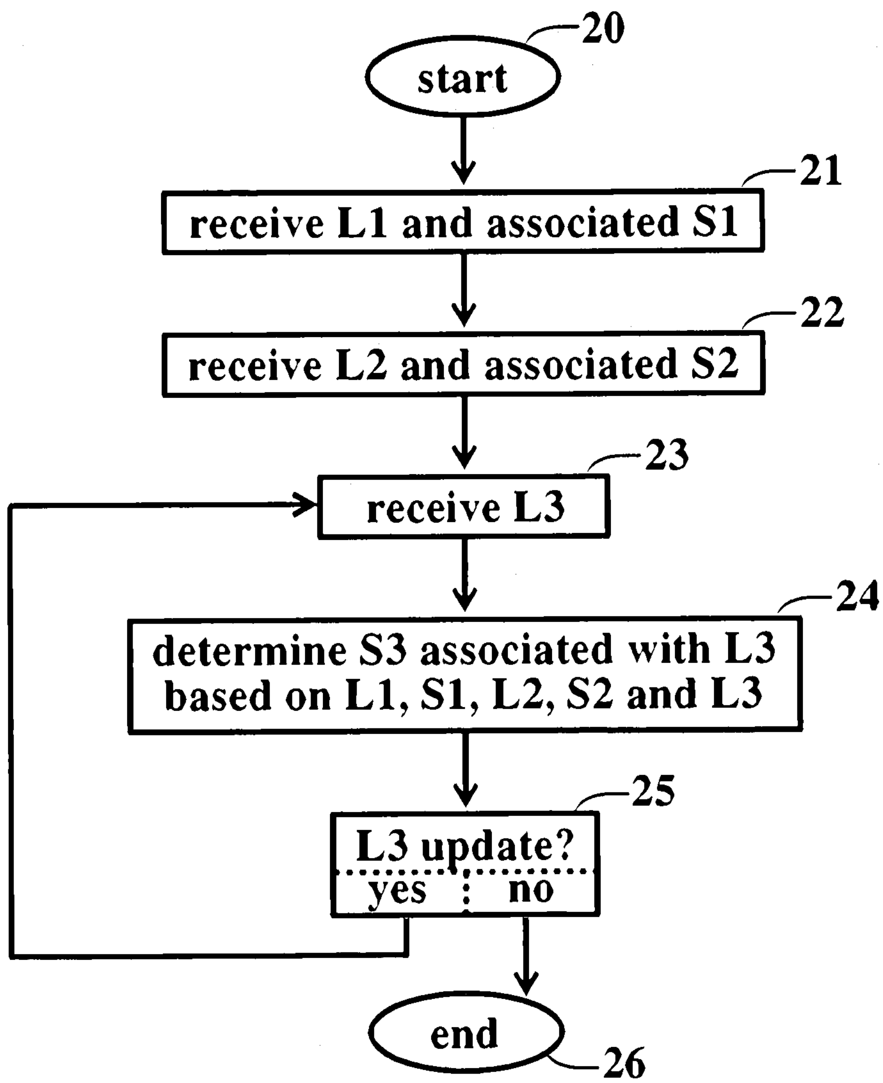

20
start
21
receive L1 and associated S1
22
receive L2 and associated S2
23
receive L3
24
determine S3 associated with L3
based on L1, S1, L2, S2 and L3
25
L3 update?
yes
no
end
26

Fig. 2

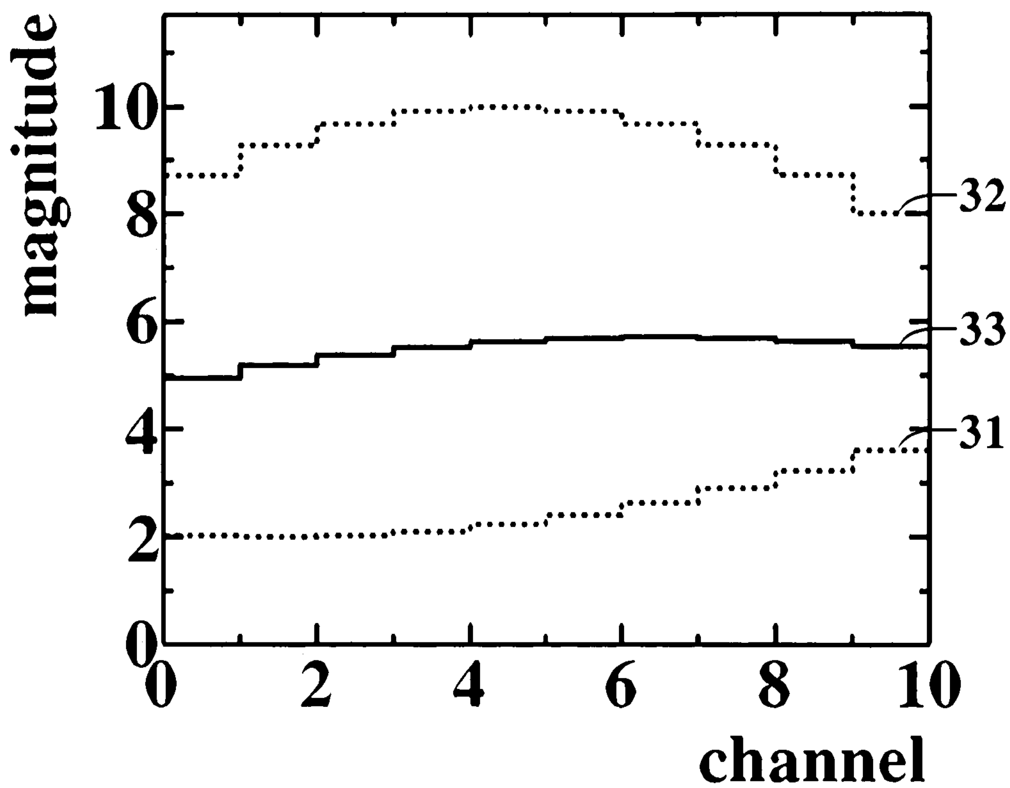



Fig. 3

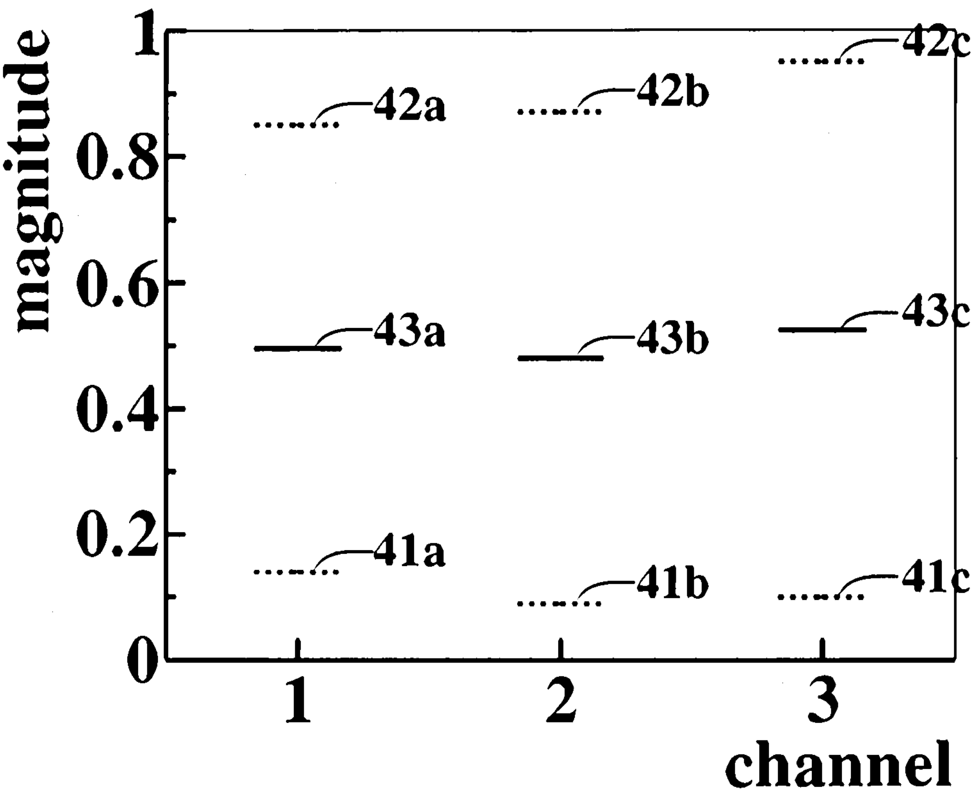
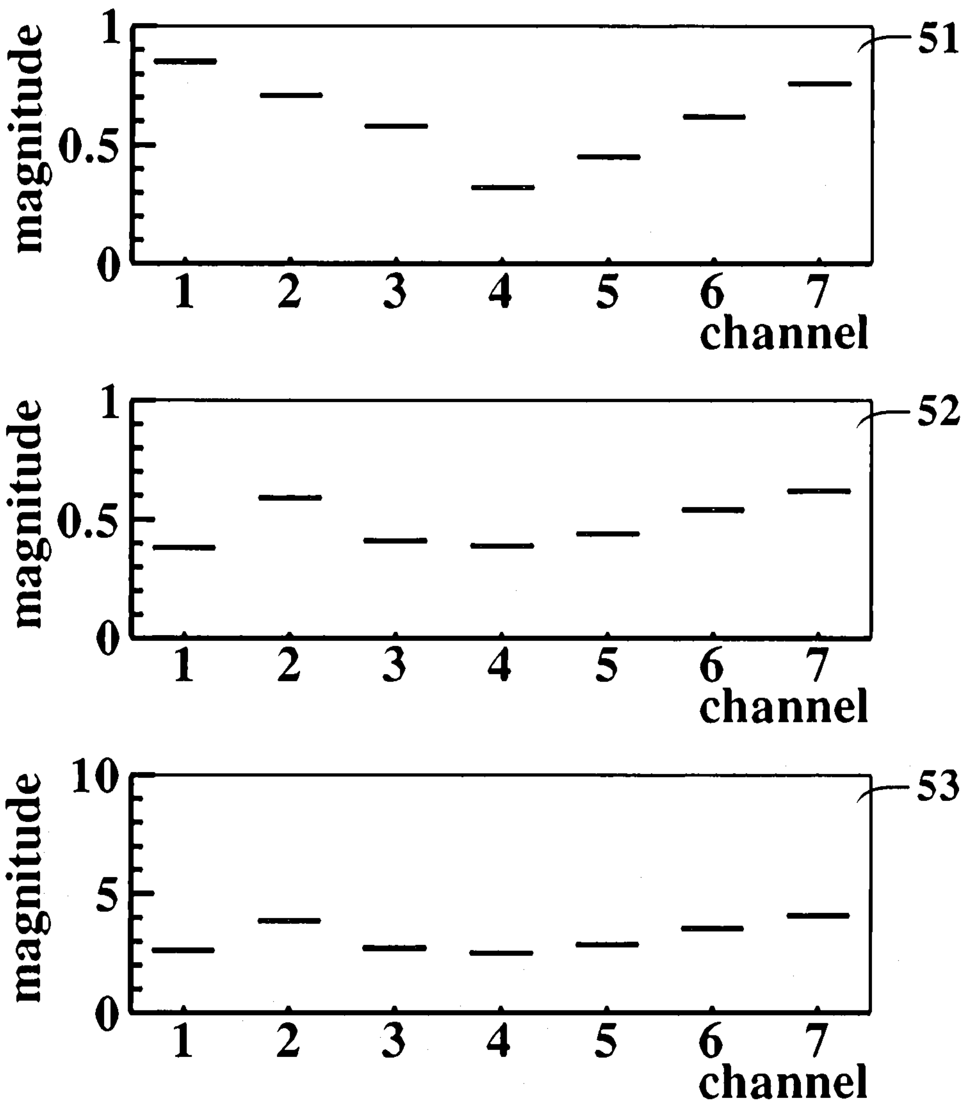

magnitude
1
0.8
0.6
0.4
0.2
0
42a
42b
42c
43a
43b
43c
41a
41b
41c
1
2
3
channel

Fig. 4


magnitude
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0.5
0
1
2
3
4
5
6
7
channel
51
magnitude
1
0.5
0
1
2
3
4
5
6
7
channel
52
magnitude
10
5
0
1
2
3
4
5
6
7
channel
53

Fig. 5

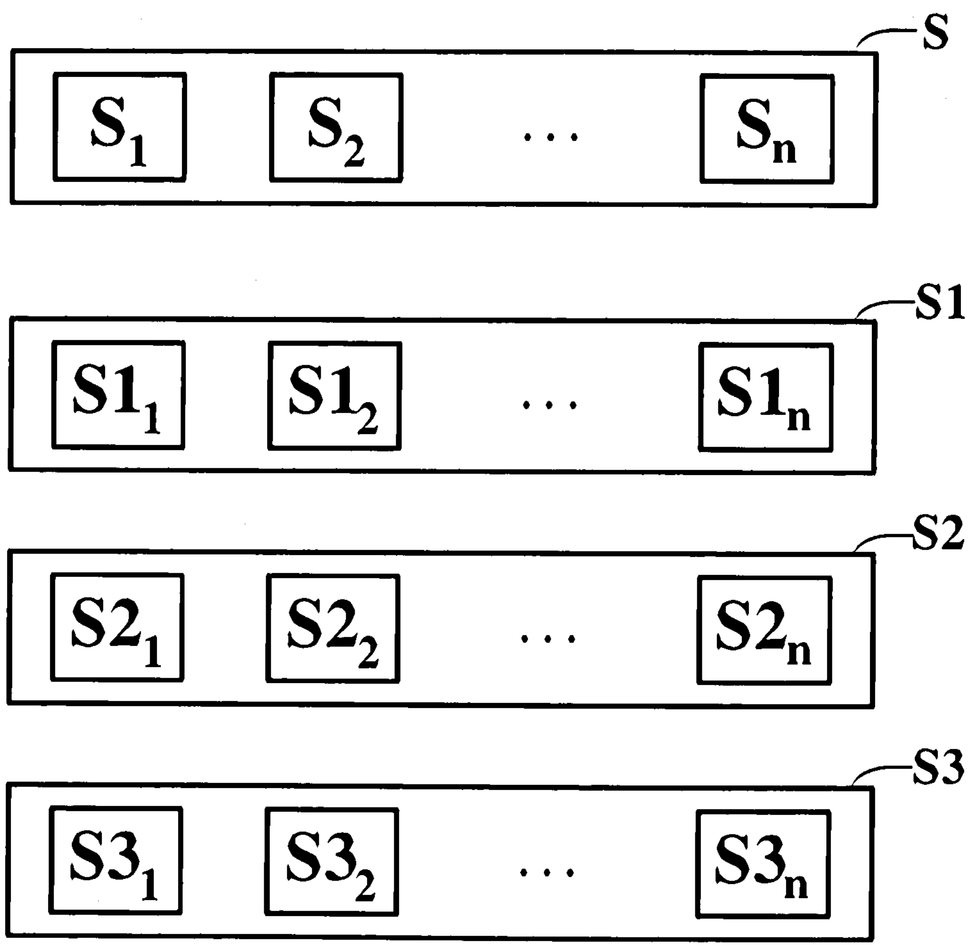


Fig. 6