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

(11) **EP 2 963 950 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
23.11.2016 Bulletin 2016/47

(51) Int Cl.:
H04S 7/00 *(2006.01)*

(21) Application number: **15151166.4**

(22) Date of filing: **14.01.2015**

(54) Modal response compensation

Kompensation for modale Raumantwort

Compensation de réponse modale

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **04.07.2014 DK 201400364**

(43) Date of publication of application:
06.01.2016 Bulletin 2016/01

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EP 2 963 950 B1

Printed by Jouve, 75001 PARIS (FR)

Description

Field of the invention

[0001] The present invention relates to a method for compensating for a modal response of a listening room on an acoustic output from an audio system including at least a first and a second loudspeaker.

Background of the invention

[0002] A typical listening room exhibits, as part of its acoustical characteristics, modal frequencies that are dependent on the dimensions of the room. It is common amongst room compensation algorithms in loudspeaker systems to use filters that have the reciprocal of the magnitude responses of this modal behavior. In other words, where the room mode creates an increase in the signal at a location in a listening room (due to resonating standing waves) the audio system includes a filter that reduces the signal by the same amount.

[0003] Figure 1 shows a conceptual drawing of the behavior of standing waves in one dimension of a room. Note that the lowest modal frequency (the top curve with a frequency of (1f) has an opposite polarity on either side of the room. The next modal frequency (2f) has the same polarity on either side of the room. This pattern continues - odd numbered modes have opposite polarity, even-numbered modes have similar polarity.

[0004] Figure 2 shows a simplified magnitude response of the modal response in one dimension of a listening room with a single sound source.

[0005] In current filtering systems that are intended to compensate for a listening room's acoustical behavior, loudspeakers in a system are considered to be independent sources. They are therefore measured as such using some version of the following method:

[0006] A microphone (or microphones) is used to measure the behavior of a loudspeaker in a given position or positions in a room. The calculated response (in the time domain or the frequency domain) is used to create a filter that, in some way, is the reciprocal of the room's behavior. The response of the filter may be calculated in the frequency or time domain and it may or may not be smoothed. Various techniques are currently employed in many different varieties of systems.

[0007] Each loudspeaker in a system is measured using this method, and a filter is created independently for each. Figure 3 shows a typical filtering strategy for compensation of modal behavior in a room, and figure 4 shows a typical filtering magnitude response for compensation of modal behavior in a room with a single source. Note that this is the inverse of the modal response shown in Figure 2.

[0008] A problem with current systems is that the loudspeakers are considered as independent sources. However, in a typical situation, the loudspeakers are playing correlated (or negatively correlated) signals. In fact, they are very rarely used to play uncorrelated signals when used to play typical program material such as music. Consequently, their behavior in conjunction with the listening room's acoustical behavior should not be considered independently of each other.

General disclosure of the invention

[0009] It is an object of the present invention to improve existing filtering implementations.

[0010] This and other objects are achieved by a method for compensating for a modal response of a listening room on an acoustic output from an audio system including at least a first and a second loudspeaker, the method comprising receiving a left channel input signal and a right channel input signal, transforming the left channel signal and the right channel signal to a mid channel signal and a side channel signal, applying a mid channel filter to the mid channel signal, to provide a filtered mid channel signal, applying a side channel filter to the side channel signal, to provide a filtered side channel signal, retransforming the filtered mid channel signal and the filtered side channel signal to a left channel output and a right channel output, applying the filtered left channel output to the first loudspeaker, and applying the filtered right channel output the second loudspeaker. The mid channel filter is created by applying correlated signals to the first and the second loudspeakers, measuring a correlated modal response of the listening room, creating the mid channel filter to have a modal response substantially equal to an inverse of the correlated modal response. The side channel filter is created by applying negatively correlated signals to the first and the second loudspeakers, measuring a negatively correlated modal response of the listening room, and creating the side channel filter to have a modal response substantially equal to an inverse of the negatively correlated modal response.

[0011] The invention is based on the realization that the measurement procedure, regardless of the method, should use the two loudspeakers as positively correlated and negatively correlated sources, instead of independent left and right sources. The resulting filters are then applied to the summed "mid" (or 'M') and difference "side" (or'S') channels formed from the right and left channels and compensated right and left channels are formed from the filtered M and S channels.

[0012] The resulting filtering is more efficient, as it avoids applying filtering to musical signals that do not require correction due to the interaction (or lack thereof) between the signals (as a result of their correlation coefficient) and the listening room's resonant behavior.

[0013] The method consists of performing the loudspeaker measurements using the same stimuli and computational method as desired and as is currently in use with existing systems. Consequently, the actual implementation of the filters themselves (both how they are created and how they are implemented) is independent of this invention. This invention can be applied to any

prior art (or future) filtering method that is designed for a single loudspeaker in a multi-loudspeaker configuration.

[0014] The difference lies in the presentation of the stimulus during the measurement procedure. First, the loudspeaker+room response of both loudspeakers playing *correlated signals* is measured and a filter is created using the method of the user's choice. This filter is referred to as the Filter for Positively Correlated Signals, F_{pos}. Then, the loudspeaker+room response of both loudspeakers playing *negatively correlated signals* is measured and a filter is created using the method of the user's choice. This filter is referred to as the Filter for Negatively Correlated Signals, F_{neg}.

[0015] One additional advantage of this system is that the same filtering is applied to the correlated signals in both loudspeakers. Thus, there is no impact on phantom images panned to be localized directly between the two loudspeakers. Similarly, negatively correlated signals are also filtered similarly, thus maintaining their negative correlation and consequently their perceived spatial impression at the listening position.

Brief description of the drawings

[0016] The present invention will be described in more detail with reference to the appended drawings, showing currently preferred embodiments of the invention.

Figure 1 shows a conceptual drawing of the behavior of standing waves in one dimension of a room.

Figure 2 shows a simplified magnitude response of the modal response in one dimension of a listening room with a single sound source.

Figure 3 shows a typical filtering strategy for compensation of modal behavior in a room.

Figure 4 shows a typical filtering magnitude response for compensation of modal behavior in a room with a single source.

Figure 5 shows the behavior of standing waves in one dimension of a room being activated by two loudspeakers playing positively correlated signals.

Figure 6 shows a simplified magnitude response of the modal response in one dimension of a listening room with two sound sources playing correlated signals.

Figure 7 shows an example of the desired filtering magnitude response for compensation of the modal response in Figure 6.

Figure 8 shows the behavior of standing waves in one dimension of a room being activated by two loudspeakers that are playing negatively correlated signals.

Figure 9 shows a simplified magnitude response of the modal response in one dimension of a listening room with two sound sources playing negatively correlated signals.

Figure 10 shows an example of the desired magnitude response for compensation of the modal response in figure 9.

Figure 11 shows a block diagram of an implementation according to a first embodiment of the present invention.

Figure 12 shows a block diagram of an implementation according to a second embodiment of the present invention.

Detailed description of preferred embodiments

[0017] When two loudspeakers are placed in opposite sides of one dimension of a listening room and are playing correlated signals, they have the same polarity at all times. This directly conflicts with the odd-numbered modal frequencies in the room, which, as is shown in Figure 1, are opposite in polarity on either side of the room. Consequently, these modes are not activated in the room, since they are being actively cancelled by the signals from the two loudspeakers. This is illustrated in figures 5- 6. Figure 7 shows the desired filter magnitude response required to compensate for the modal response in figure 6. Note that this is the inverse of the modal response in Figure 6.

[0018] Simultaneously, the negatively correlated signals in the two loudspeakers actively cancel the even-numbered modal frequencies which have similar polarities on either side of the room. The even-numbers modes are not activated, since the loudspeakers are negatively correlated and the modal behavior from the locations of the loudspeakers has the same polarities. This is illustrated in figures 8-9. Figure 10 shows the desired filter magnitude response required to compensate for the modal response in figure 9. Note that this is the inverse of the modal response in Figure 9.

Main embodiment

[0019] In a first embodiment, illustrated in figure 11, the filters F_{pos} and F_{neg} are created and applied in a central unit 2 of an audio system 1, with access to both left and right audio channels (L, R). This is referred to as a "central" system. Typically, but not necessarily, the central unit 2 is the same unit that receives and amplifies the audio source signal. The central unit is connected to a left speaker 3 and a right speaker 4.

[0020] The central unit 2 here includes circuitry 10 for creating, storing and applying the filters F_{pos} 11 and F_{neg} 12. The central unit 2 further has a L/R-to-M/S converter 13, the summed or "M" output being connected to the F_{pos} filter 11 and the difference or "S" output being connected to the F_{neg} filter 12. The filtered outputs M_{filter}, S_{filter} of the filters 11, 12 are each connected to a M/S-toR converter 14 and a M/S-to-L converter 15, respectively. The outputs L_{out}, Rout from these converters 14, 15 are connected to the left and right speakers 3, 4, respectively. It is noted that the converters 14, 15 may be integrated as one M/S-to-L/R converter. The unit 2 is also connected to at least one microphone 9, which provides

input to the circuitry 10.

[0021] The operation of the system will be described in the following.

[0022] During an initiation phase, the circuitry 10 controls the audio system to output correlated signals on each loudspeaker 3, 4. The resulting audio signals are received by the microphone(s) 9, and supplied to the circuitry 10. The circuitry then determines a first room response, referred to as a room response for correlated signals. The first room response is used to define and create the filter 11. Then, the circuitry controls the audio system to output negatively correlated signals on each loudspeaker 3, 4. Again, the resulting audio signals are received by the microphone(s) 9, and supplied to the circuitry 10. The circuitry then determines a second room response, referred to as a room response for negatively correlated signals. This second room response is used to define and create the filter 12.

[0023] It is noted that the determination of room response can be performed using conventional measurement techniques. Also, the filters can be created using conventional techniques.

[0024] When used with room compensation systems that employ a target magnitude response, it should be remembered that the target responses of the Positively Correlated signals and the Negatively Correlated signals should be different.

[0025] During playback, the left and right channel input signals L, R are supplied to the converter 13, where the M and S channel signals M, S are formed according to M = L + R, S = L - R. The mid channel signal M is then supplied to the filter 11, while the side channel signal S is supplied to the filter 12. The filtered outputs from each filter 11, 12 are each connected to the converters 14, 15, where left and right channel output signals L_{out}, R_{out} can be calculated according to $L_{out} = 0.5x(M_{filter} + S_{filter})$, Rout = $0.5x(M_{filter} - S_{filter})$. The left and right channel output signals Lout, Rout are applied to the left and right speakers 3, 4 respectively, where they are applied to electro-acoustic transducers.

[0026] In an alternative embodiment, illustrated in figure 12, the filters F_{pos} and F_{neg} are created and applied in each speaker 103, 104 of an audio system 101. This is referred to as a "distributed" system. Also in this case, a central unit 2 has access to both left and right audio channels (L, R), and is connected to a left speaker 103 and a right speaker 104.

[0027] In this case, however, each loudspeaker 103, 104 will have a set of the filters F_{pos} 111 and F_{neg} 112, and also includes circuitry 110a, 110b for creating, storing and applying the filters F_{pos} 111 and F_{neg} 112. Each loudspeaker further includes a R/L-to-M/S converter 113, the M output being connected to the F_{pos} filter 111 and the S output being connected to the F_{neg} filter 112. Each loudspeaker 103, 104 is also connected to at least one microphone 109a, 109b, which provides input to the circuitry 110a, 110b.

[0028] The left speaker further includes a M/S-to-L converter 114, connected to the filtered outputs M_{filter}, S_{filter} of the filters 111, 112, and a transducer connected to the output Lout from the converter 114.

[0029] The right speaker further includes a M/S-to-R converter 115, connected to the filtered outputs M_{filter}, S_{filter} of the filters 111, 112, and a transducer connected to the output Rout from the converter 115.

[0030] The operation of the system according to this embodiment is similar to that described in relation to figure 11, except for where the various steps take place.

[0031] During an initiation phase, the circuitry 110a, 110b first interact to control the audio system to output correlated signals on each loudspeaker 103, 104. The resulting audio signals are received at the central unit by the microphone(s) 109, and supplied to each circuitry 110a, 110b. Each circuitry 110a, 110b then determines a first room response, referred to as a room response for correlated signals. The first room response is used to define and create the filter 111 in each circuitry 110a, 110b, independently of each other.

[0032] Secondly, the circuitry 110a, 110b controls the audio system to output negatively correlated signals on each loudspeaker 103, 104. Again, the resulting audio signals are received at the central unit by the microphone(s) 109, and supplied to each circuitry 110a, 110b. Each circuitry 110a, 110b then determines a second room response, referred to as a room response for negatively correlated signals. This second room response is used to define and create the filter 112 in each circuitry 110a, 110b, independently of each other.

[0033] During playback, the left and right channel input signals L, R are supplied to each loudspeaker 103, 104, where the converters 113 generate mid and side channel signals M, S according to M = L + R, S = L - R. The M channel signal M is then supplied to the filters 111, while the S channel signal S is supplied to the filters 112. The filtered outputs from each filter 111, 112 are each connected to the converters 114, 115, where left and right channel output signals L_{out}, R_{out} can be calculated according to Lout = $0.5x(M_{filter} + S_{filter})$, Rout = $0.5x(M_{filter} - S_{filter})$. The left and right channel output signals Lout, Rout are applied to the transducers in the left and right speakers 103, 104 respectively.

[0034] The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims.

[0035] For example, the correlation of the measurements (both positive and negative) can be performed by summing and subtracting the time measurements (impulse responses) of the two loudspeakers. This can be done instead of playing the signals from both loudspeakers simultaneously. Both methods are equivalent.

[0036] Although this method is described for a two-channel system considering only one dimension of a listening room, it is applicable to systems with more than two loudspeakers and rooms with more than one dimen-

sion. The system can be applied to any pair of loudspeakers in a loudspeaker system that contains more than two loudspeakers.

[0037] In systems where a gain and delay can be applied to the loudspeaker outputs to compensate for incorrect listener placement, these compensation elements should be applied to the Left and Right input signals before the M/S filtering takes place. In this way, the effects of the mismatched gains and delays on the room's acoustical behavior will be compensated for in the filtering. Placing the gains and delays after the filter blocks will result in an incorrect effect. One recommended implementation is shown in Figure 13, showing the correct placement of the delay and gain used for listener placement compensation. Note that the Gain and Delay blocks are placed before the M/S Filtering stages.

Claims

1. A method for compensating for a modal response of a listening room on an acoustic output from an audio system including at least a first and a second loudspeaker, the method comprising:

    receiving a left channel input signal and a right channel input signal;
    transforming said left channel signal and said right channel signal to a mid channel signal and a side channel signal;
    applying a mid channel filter (F_{pos}) to said mid channel signal to provide a filtered mid channel signal;
    applying a side channel filter (F_{neg}) to said side channel signal to provide a filtered side channel signal;
    retransforming said filtered mid channel signal and said filtered side channel signal to a left channel output and a right channel output;
    applying said filtered left channel output to said first loudspeaker; and applying said filtered right channel output said second loudspeaker;

    wherein said mid channel filter is created by:

    applying correlated signals to said first and said second loudspeakers,
    measuring a correlated modal response of said listening room,
    creating said mid channel filter to have a modal response substantially equal to an inverse of said correlated modal response; and

    wherein said side channel filter is created by:

    applying negatively correlated signals to said first and said second loudspeakers,
    measuring a negatively correlated modal response of said listening room, and
    creating said side channel filter to have a modal response substantially equal to an inverse of said negatively correlated modal response.

2. The method according to claim 1, wherein said step of transforming said left channel signal and said right channel signal to a mid channel signal and a side channel signal is performed by a L/R-to-M/S converter (13) in a central unit (2) connected to said first and second loudspeaker.

3. The method according to claim 2, wherein said step of retransforming said filtered mid channel signal and said filtered side channel signal to a left channel output and a right channel output is performed by M/S-to-R/L converter(s) (14, 15) in said central unit (2).

4. The method according to claim 1, wherein said step of transforming said left channel signal and said right channel signal to a mid channel signal and a side channel signal is performed by a L/R-to-M/S converter (113a) in said first loudspeaker and by a L/R-to-M/S converter (113b) in said second loudspeaker.

5. The method according to claim 4, wherein said step of retransforming said filtered mid channel signal and said filtered side channel signal to a left channel output is performed by a M/S-to-L converter (114) in said first loudspeaker, and said step of retransforming said filtered mid channel signal and said filtered side channel signal to a right channel output is performed by M/S-to-R converter (115) in said second loudspeaker.

6. The method according to claim 1, wherein the steps of:

    measuring a correlated modal response of said listening room,
    creating said mid channel filter to have a modal response substantially equal to an inverse of said correlated modal response,
    measuring a negatively correlated modal response of said listening room, and
    creating said mid channel filter to have a modal response substantially equal to an inverse of said negatively correlated modal response,

    are performed by microphone(s) (9) and circuitry (10) in a central unit (2) connected to said first and second loudspeakers (3, 4).

7. The method according to claim 1, wherein the steps of:

    measuring a correlated modal response of said listening room, and

creating said mid channel filter to have a modal response substantially equal to an inverse of said correlated modal response,

are performed by microphone(s) (109a) and circuitry (110a) in or connected to said first loudspeaker (103),
and wherein the steps of :

measuring a negatively correlated modal response of said listening room, and
creating said mid channel filter to have a modal response substantially equal to an inverse of said negatively correlated modal response,

are performed by microphone(s) (109b) and circuitry (110b) in or connected to said second loudspeaker (104).

8. An audio system in a listening room, comprising:

a first and a second loudspeaker (3, 4; 103, 104);
circuitry (10) for applying, in a first sequence, correlated signals to said first and said second loudspeakers, and, in a second sequence, negatively correlated signals to said first and said second loudspeakers,
at least one microphone (109; 109a, 109b) for measuring, in said first sequence, a correlated modal response of said listening room, and, in said second sequence, a negatively correlated modal response of said listening room,
circuitry (10) for creating a mid channel filter (F_{pos}) with a modal response substantially equal to an inverse of said correlated modal response; and creating a side channel filter (F_{neg}) with a modal response substantially equal to an inverse of said negatively correlated modal response;
L/R-to-M/S converting circuitry (13; 113) for transforming a left channel signal and a right channel signal to a mid channel signal and a side channel signal;
circuitry (10; 110a, 110b) for applying said mid channel filter to said mid channel signal to provide a filtered side channel signal, and for applying a side channel filter to said side channel signal to provide a filtered side channel signal;
L/R-to-M/S converting circuitry (14, 15; 114, 115) for retransforming said filtered mid channel signal and said filtered side channel signal to a left channel output and a right channel output,
wherein said filtered left channel output is applied to said first loudspeaker (3; 103); and said filtered right channel output is applied to said second loudspeaker (4; 104);

9. The audio system in claim 8, wherein said L/R-to-M/S converting circuitry (13) is provided in a central unit (2) connected to said first and second loudspeaker (3, 4).

10. The audio system in claim 9, wherein said L/R-to-M/S converting circuitry (14, 15) is provided in said central unit (2).

11. The audio system in claim 8, wherein said circuitry (10) is provided in said central unit (2).

12. The audio system in claim 8, wherein said L/R-to-M/S converting circuitry comprises a first L/R-to-M/S converter (113) provided in said first loudspeaker (3) and a second L/R-to-M/S converter (113) provided in said second loudspeaker (4).

13. The audio system in claim 11, wherein said L/R-to-M/S converting circuitry comprises a M/S-to-L converter (114) in said first loudspeaker, and a M/S-to-R converter (115) in said second loudspeaker.

14. The audio system in claim 8 , wherein said circuitry (110a, 110b) is provided in said first loudspeaker (103) and in said second loudspeaker (104), respectively.

Patentansprüche

1. Verfahren zum Kompensieren einer modalen Antwort eines Hörraums auf einen akustischen Ausgang von einem Audiosystem, das zumindest einen ersten und einen zweiten Lautsprecher enthält, das Verfahren umfassend:

Empfangen eines linken Kanaleingangssignals und eines rechten Kanaleingangssignals;
Transformieren des linken Kanalsignals und des rechten Kanalsignals zu einem mittleren Kanalsignal und einem seitlichen Kanalsignal;
Anwenden eines Mittelkanalfilters (F_{pos}) an dem mittleren Kanalsignal, um ein gefiltertes mittleres Kanalsignal vorzusehen;
Anwenden eines Seitenkanalfilters (F_{neg}) an dem seitlichen Kanalsignal, um ein gefiltertes seitliches Kanalsignal vorzusehen;
Umtransformieren des gefilterten mittleren Kanalsignals und des gefilterten seitlichen Kanalsignals zu einem linken Kanalausgang und einem rechten Kanalausgang;
Anlegen des gefilterten linken Kanalausgangs an den ersten Lautsprecher; und
Anlegen des gefilterten rechten Kanalausgangs an den zweiten Lautsprecher;

wobei der Mittelkanalfilter gestaltet ist durch:

Anlegen korrelierter Signal an den ersten und den zweiten Lautsprecher,
Messen einer korrelierten modalen Antwort des Hörraums,
Gestalten des Mittelkanalfilters, so dass er eine modale Antwort hat, die im Wesentlichen gleich einem Inversen der korrelierten modalen Antwort ist; und

wobei der Seitenkanalfilter gestaltet ist durch:

Anlegen negativ korrelierter Signale an den ersten und zweiten Lautsprecher,
Messen einer negativ korrelierten modalen Antwort des Hörraums und
Gestalten des Seitenkanalfilters, so dass er eine modale Antwort hat, die im Wesentlichen gleich einem Inversen der negativ korrelierten modalen Antwort ist.

2. Verfahren nach Anspruch 1, wobei der Schritt zum Transformieren des linken Kanalsignals und des rechten Kanalsignals zu einem mittleren Kanalsignal und einem seitlichen Kanalsignal durch einen L/R-M/S-Wandler (13) in einer Zentraleinheit (2) ausgeführt wird, die an den ersten und zweiten Lautsprecher angeschlossen ist.

3. Verfahren nach Anspruch 2, wobei der Schritt zum Umtransformieren des gefilterten mittleren Kanalsignals und des gefilterten seitlichen Kanalsignals zu einem linken Kanalausgang und einem rechten Kanalausgang durch (einen) M/S-R/L-Wandler (14, 15) in der Zentraleinheit (2) ausgeführt wird.

4. Verfahren nach Anspruch 1, wobei der Schritt zum Transformieren des linken Kanalsignals und des rechten Kanalsignals zu einem mittleren Kanalsignal und einem seitlichen Kanalsignal durch einen L/R-M/S-Wandler (113a) im ersten Lautsprecher und durch einen L/R-M/S-Wandler (113b) im zweiten Lautsprecher ausgeführt wird.

5. Verfahren nach Anspruch 4, wobei der Schritt zum Umtransformieren des gefilterten mittleren Kanalsignals und des gefilterten seitlichen Kanalsignals zu einem linken Kanalausgang durch einen M/S-L-Wandler (114) im ersten Lautsprecher ausgeführt wird und der Schritt zum Umtransformieren des gefilterten mittleren Kanalsignals und des gefilterten seitlichen Kanalsignals zu einem rechten Kanalausgang durch M/S-R-Wandler (115) im zweiten Lautsprecher ausgeführt wird.

6. Verfahren nach Anspruch 1, wobei die Schritte zum:

Messen einer korrelierten modalen Antwort des Hörraums,
Gestalten des Mittelkanalfilters, so dass er eine modale Antwort hat, die im Wesentlichen gleich einem Inversen der korrelierten modalen Antwort ist,
Messen einer negativen korrelierten modalen Antwort des Hörraums und
Gestalten des Mittelkanalfilters, so dass er eine modale Antwort hat, die im Wesentlichen gleich einem Inversen der negativen korrelierten modalen Antwort ist,

durch (ein) Mikrofon(e) (9) und einen Schaltkreis (10) in einer Zentraleinheit (2) ausgeführt werden, die an den ersten und zweiten Lautsprecher (3, 4) angeschlossen ist.

7. Verfahren nach Anspruch 1, wobei die Schritte zum:

Messen einer korrelierten modalen Antwort des Hörraums und
Gestalten des Mittelkanalfilters, so dass er eine modale Antwort hat, die im Wesentlichen gleich einem Inversen der korrelierten modalen Antwort ist,

durch (ein) Mikrofon(e) (109a) und einen Schaltkreis (110a) im oder angeschlossen an den ersten Lautsprecher (103) ausgeführt werden und wobei die Schritte zum:

Messen einer negativen korrelierten modalen Antwort des Hörraums und
Gestalten des Mittelkanalfilters, so dass er eine modale Antwort hat, die im Wesentlichen gleich einem Inversen der negativen korrelierten modalen Antwort ist,

durch (ein) Mikrofon(e) (109b) und einen Schaltkreis (110b) im oder angeschlossen an den zweiten Lautsprecher (104) ausgeführt werden.

8. Audiosystem in einem Hörraum, umfassend:

einen ersten und zweiten Lautsprecher (3, 4; 103; 104);
einen Schaltkreis (10) zum Anlegen, in einer ersten Abfolge, korrelierter Signale an den ersten und den zweiten Lautsprecher und, in einer zweiten Abfolge, negativ korrelierter Signale an den ersten und den zweiten Lautsprecher,
zumindest ein Mikrofon (109; 109a; 109b) zum Messen, in der ersten Abfolge, einer korrelierten modalen Antwort des Hörraums und, in der zweiten Abfolge, einer negativ korrelierten modalen Antwort des Hörraums,
einen Schaltkreis (10) zum Gestalten eines Mittelkanalfilters (F_{pos}) mit einer modalen Antwort, die im Wesentlichen gleich einem Inversen der

korrelierten modalen Antwort ist;
und Gestalten eines Seitenkanalfilters (F_{neg}) mit einer modalen Antwort, die im Wesentlichen gleich einem Inversen der negativ korrelierten modalen Antwort ist;
einen L/R-M/S-Wandlerschaltkreis (13; 113) zum Transformieren eines linken Kanalsignals und eines rechten Kanalsignals zu einem mittleren Kanalsignal und einem seitlichen Kanalsignal;
einen Schaltkreis (10; 110a, 110b) zum Anwenden des Mittelkanalfilters am mittleren Kanalsignal, um ein gefiltertes seitliches Kanalsignal vorzusehen, und zum Anwenden des seitlichen Seitenkanalfilters an dem seitlichen Kanalsignal, um ein gefiltertes seitliches Kanalsignal vorzusehen;
einen L/R-M/S-Wandlerschaltkreis (14, 15; 114, 115) zum Umtransformieren des gefilterten mittleren Kanalsignals und des gefilterten seitlichen Kanalsignals zu einem linken Kanalausgang und einem rechten Kanalausgang,
wobei der gefilterte linke Kanalausgang an den ersten Lautsprecher (3; 103) angelegt wird; und der gefilterte rechte Kanalausgang an den zweiten Lautsprecher (4; 104) angelegt wird.

9. Audiosystem nach Anspruch 8, wobei der L/R-M/S-Wandlerschaltkreis (13) in einer Zentraleinheit (2) vorgesehen ist, die an den ersten und zweiten Lautsprecher (3, 4) angeschlossen ist.

10. Audiosystem nach Anspruch 9, wobei der L/R-M/S-Wandlerschaltkreis (14, 15) in der Zentraleinheit (2) vorgesehen ist.

11. Audiosystem nach Anspruch 8, wobei der Schaltkreis (10) in der Zentraleinheit (2) vorgesehen ist.

12. Audiosystem nach Anspruch 8, wobei der L/R-M/S-Wandlerschaltkreis einen ersten L/R-M/S-Wandler (113) umfasst, der im ersten Lautsprecher (3) vorgesehen ist, und einen zweiten L/R-M/S-Wandler (113), der im zweiten Lautsprecher (4) vorgesehen ist.

13. Audiosystem nach Anspruch 11, wobei der L/R-M/S-Wandlerschaltkreis einen M/S-L-Wandler (114) im ersten Lautsprecher und einen M/S-R-Wandler (115) im zweiten Lautsprecher umfasst.

14. Audiosystem nach Anspruch 8, wobei der Schaltkreis (110a, 110b) im ersten Lautsprecher (103) bzw. im zweiten Lautsprecher (104) vorgesehen ist.

Revendications

1. Procédé de compensation de réponse modale d'une salle d'écoute sur une sortie acoustique à partir d'un système audio comprenant au moins un premier et un second haut-parleur, le procédé comprenant :

la réception d'un signal d'entrée de canal gauche et d'un signal d'entrée de canal droit ;
la transformation dudit signal d'entrée de canal gauche et dudit signal d'entrée de canal droit en un signal de canal central et un signal de canal latéral ;
l'application d'un filtre de canal central (F_{pos}) audit signal de canal central pour fournir un signal de canal central filtré ;
l'application d'un filtre de canal latéral (F_{neg}) audit signal de canal latéral pour fournir un signal de canal latéral filtré ;
la retransformation dudit signal de canal central filtré et dudit signal de canal latéral filtré vers une sortie de canal gauche et une sortie de canal droite ;
l'application de ladite sortie de canal gauche filtrée sur ledit premier haut-parleur et l'application de ladite sortie de canal droite filtrée sur ledit second haut-parleur ;

dans lequel ledit filtre de canal central est créé par :

l'application de signaux corrélés auxdits premier et second haut-parleurs,
la mesure d'une réponse modale corrélée de ladite salle d'écoute,
la création dudit filtre de canal central pour avoir une réponse modale essentiellement égale à un inverse de ladite réponse modale corrélée ; et

dans lequel ledit filtre de canal latéral est créé par :

l'application de signaux corrélés négativement auxdits premier et second haut-parleurs,
la mesure d'une réponse modale corrélée négativement de ladite salle d'écoute, et
la création dudit filtre de canal latéral pour avoir une réponse modale essentiellement égale à un inverse de ladite réponse modale corrélée négativement.

2. Procédé selon la revendication 1, dans lequel ladite étape de transformation dudit signal de canal gauche et dudit signal de canal droit vers un signal de canal central et un signal de canal latéral est effectuée par un convertisseur L/R vers M/S (13) dans une unité centrale (2) reliée auxdits premier et second haut-parleur.

3. Procédé selon la revendication 2, dans lequel ladite

étape de retransformation desdits signal de canal central filtré et signal de canal latéral filtré vers une sortie de canal gauche et une sortie de canal droite est effectuée par un/des convertisseur(s) M/S vers R/L (14, 15) dans ladite unité centrale (2).

4. Procédé selon la revendication 1, dans lequel ladite étape de transformation desdits signal de canal gauche et signal de canal droit vers un signal de canal central et un signal de canal latéral est effectuée par un convertisseur L/R vers M/S (113a) dans ledit premier haut-parleur et un convertisseur L/R vers M/S (113b) dans ledit second haut-parleur.

5. Procédé selon la revendication 4, dans lequel ladite étape de retransformation desdits signal de canal central filtré et signal de canal latéral filtré vers une sortie de canal gauche est effectuée par un convertisseur M/S vers L (114) dans ledit premier haut-parleur, et ladite étape de retransformation dudit signal de canal central filtré et dudit signal de canal latéral filtré vers une sortie de canal droite est effectuée par un convertisseur M/S vers R (115) dans ledit second haut-parleur.

6. Procédé selon la revendication 1, dans lequel les étapes de :

mesure d'une réponse modale corrélée de ladite salle d'écoute,
création dudit filtre de canal central pour avoir une réponse modale essentiellement égale à un inverse de ladite réponse modale corrélée,
mesure d'une réponse modale corrélée négativement de ladite salle d'écoute, et
création dudit filtre de canal central pour avoir une réponse modale essentiellement égale à un inverse de ladite réponse modale corrélée négativement,

sont effectuées par un/des microphone(s) (9) et une circuiterie (10) dans une unité centrale (2) reliés auxdits premier et second haut-parleurs (3, 4).

7. Procédé selon la revendication 1, dans lequel les étapes de :

mesure d'une réponse modale corrélée de ladite salle d'écoute,
création d'un filtre de canal central pour avoir une réponse modale essentiellement égale à un inverse de ladite réponse modale corrélée,
sont effectuées par des un/des microphone(s) (109a) et une circuiterie (110a) dans ledit ou reliés audit premier haut-parleur (103),

et dans lequel les étapes de :

mesure d'une réponse modale corrélée négativement de ladite salle d'écoute, et
création dudit filtre de canal central pour avoir une réponse modale essentiellement égale à un inverse de ladite réponse modale corrélée négativement,

sont effectuées par un/des microphone(s) (109b) et une circuiterie (110b) dans ledit ou reliés audit second haut-parleur (104).

8. Système audio dans une salle d'écoute, comprenant :

un premier et un second haut-parleur (3, 4 ; 103, 104) ;
une circuiterie (10) pour appliquer, dans une première séquence, des signaux corrélés vers lesdits premier et second haut-parleurs et, dans une seconde séquence, des signaux corrélés négativement vers lesdits premier et second haut-parleurs,
au moins un microphone (109 ; 109a, 109b) pour mesurer, dans ladite première séquence, une réponse modale corrélée de ladite salle d'écoute, et dans ladite seconde séquence, une réponse modale corrélée négativement de ladite salle d'écoute,
une circuiterie (10) pour créer un filtre de canal central (F_{pos}) avec une réponse modale essentiellement égale à un inverse de ladite réponse modale corrélée ; et la création d'un filtre de canal latéral (F_{neg}) avec une réponse modale essentiellement égale à un inverse de ladite réponse modale corrélée négativement ;
un circuit de conversion L/R vers M/S (13 ; 113) pour transformer un signal de canal gauche et un signal de canal droit en un signal de canal central et un signal de canal latéral ;
une circuiterie (10 ; 110a, 110b) pour appliquer ledit filtre de canal central audit signal de canal central pour fournir un signal de canal latéral filtré, et pour appliquer un filtre de canal latéral audit signal de canal latéral pour fournir un signal de canal latéral filtré ;
une circuiterie de conversion L/R vers M/S (14, 15 ; 114, 115) pour retransformer ledit signal de canal central filtré et ledit signal de canal latéral filtré vers une sortie de canal gauche et une sortie de canal droite,
dans lequel ladite sortie de canal gauche filtrée est appliquée audit premier haut-parleur (3 ; 103) et ladite sortie de canal droite filtrée est appliquée audit second haut-parleur (4 ; 104).

9. Système audio selon la revendication 8, dans lequel ladite circuiterie de conversion L/R vers M/S (13) est prévue dans une unité centrale (2) reliée audit pre-

mier et second haut-parleur (3, 4).

10. Système audio selon la revendication 9, dans lequel ladite circuiterie de conversion L/R vers M/S (14, 15) est prévue dans ladite unité centrale (2).

11. Système audio selon la revendication 8, dans lequel ladite circuiterie (10) est prévue dans ladite unité centrale (2).

12. Système audio selon la revendication 8, dans lequel ladite circuiterie de conversion L/R vers M/S comprend un premier convertisseur L/R vers M/S (113) prévu dans ledit premier haut-parleur (3) et un second convertisseur L/R vers M/S (113) prévu dans ledit second haut-parleur (4).

13. Système audio selon la revendication 11, dans lequel ladite circuiterie de conversion L/R vers M/S comprend un convertisseur M/S vers L (114) dans ledit premier haut-parleur et un convertisseur M/S vers R (115) dans ledit second haut-parleur.

14. Système audio selon la revendication 8, dans lequel ladite circuiterie (110a, 110b) est prévue dans ledit premier haut-parleur (103) et dans ledit second haut-parleur (104) respectivement.

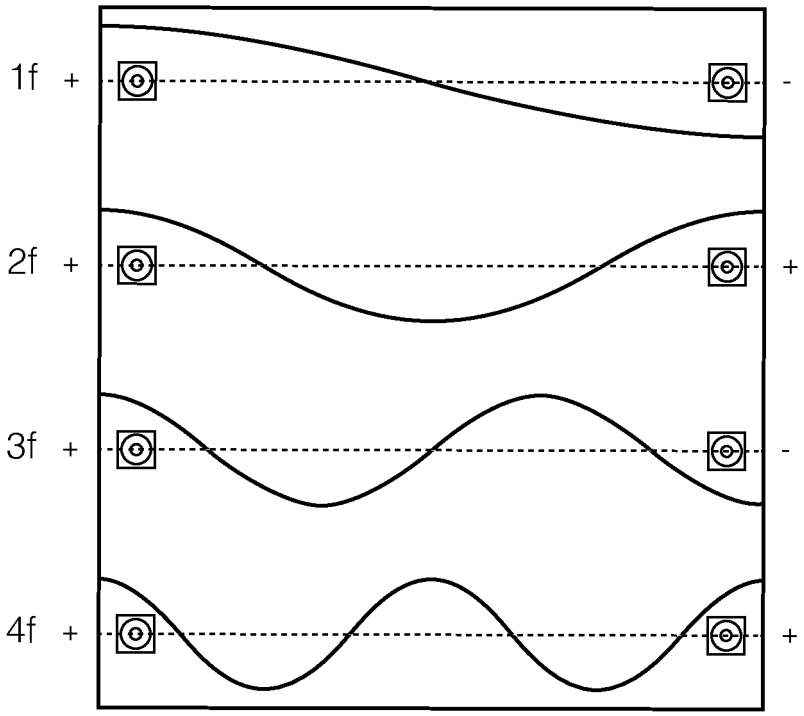

1f
+
-
2f
+
+
3f
+
-
4f
+
+

Fig. 1

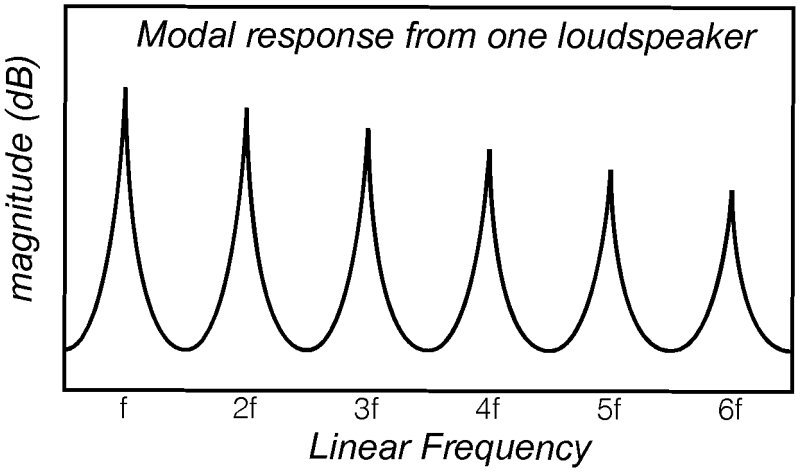

Modal response from one loudspeaker
magnitude (dB)
f
2f
3f
4f
5f
6f
Linear Frequency

Fig. 2

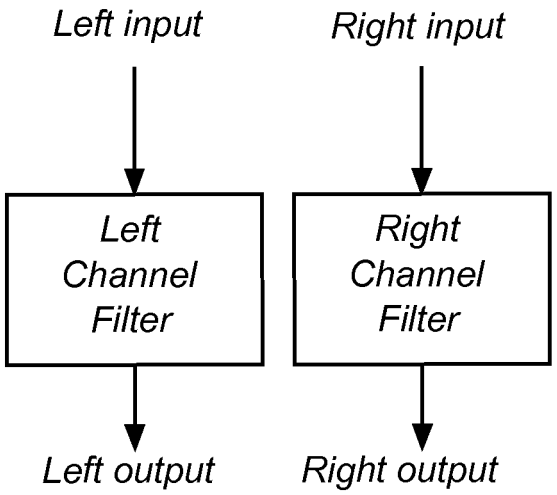

Left input
Right input
Left Channel Filter
Right Channel Filter
Left output
Right output

Fig. 3

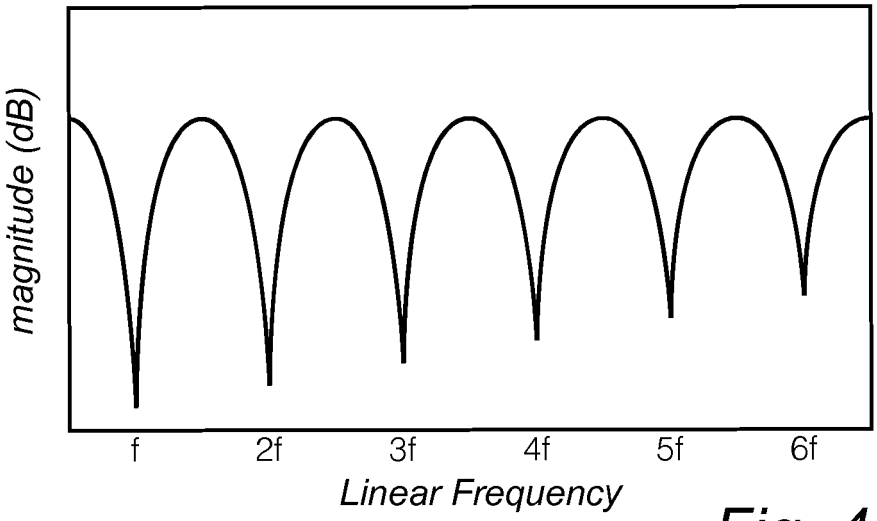

magnitude (dB)
f
2f
3f
4f
5f
6f
Linear Frequency

Fig. 4

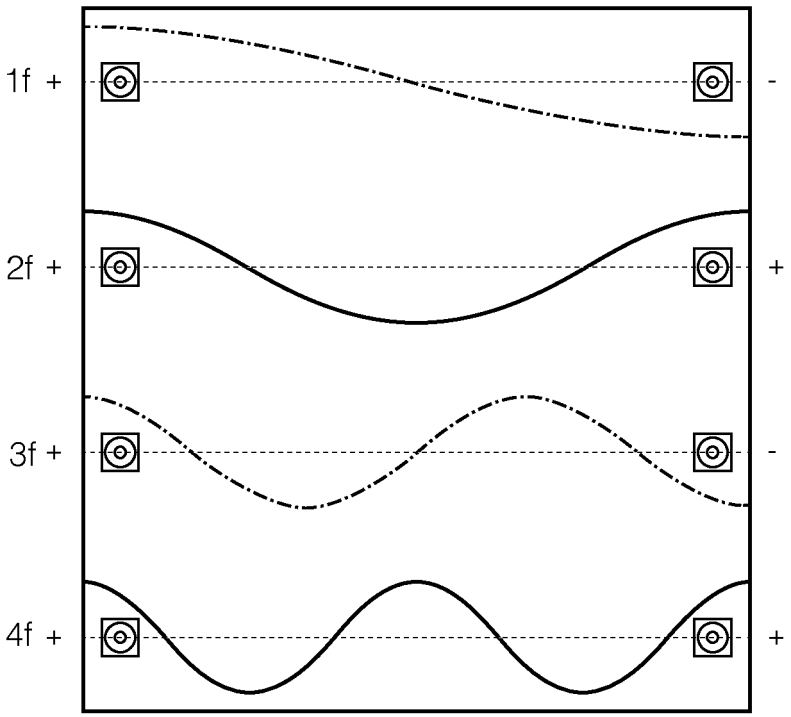


Fig. 5

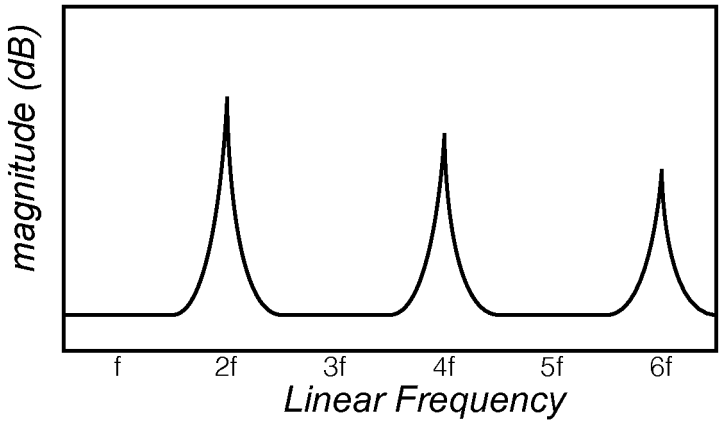


Fig. 6

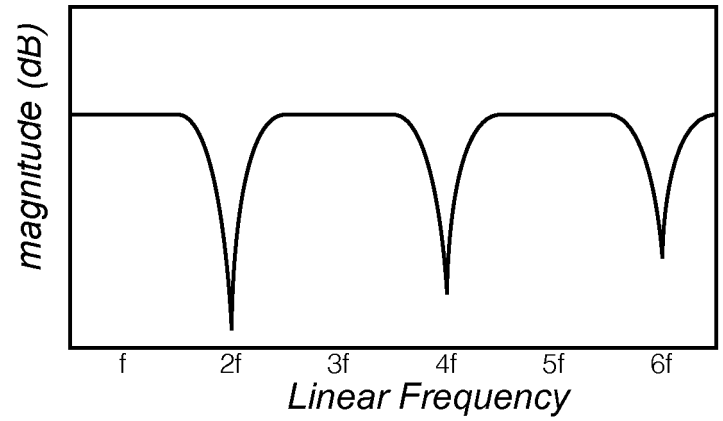


Fig. 7

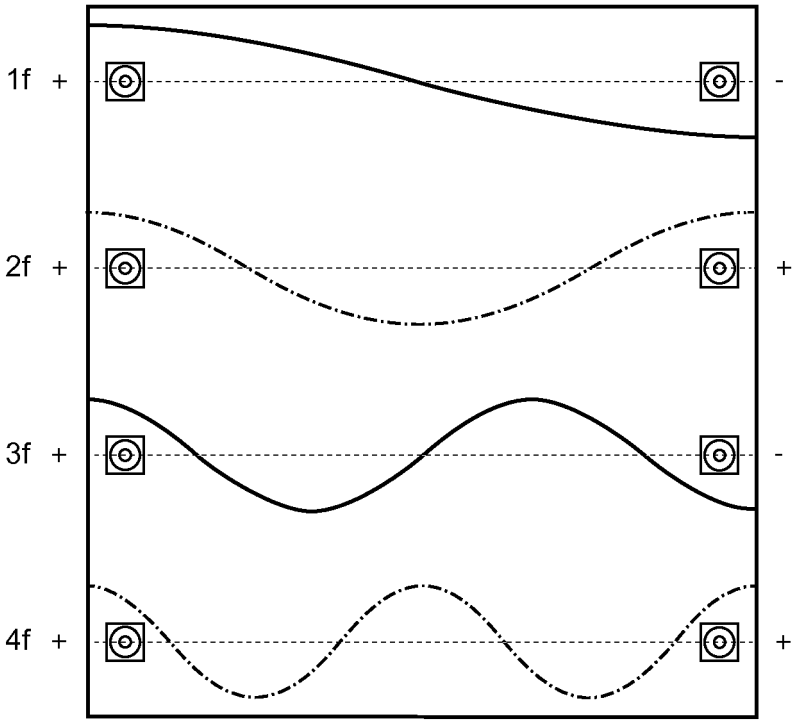


Fig. 8

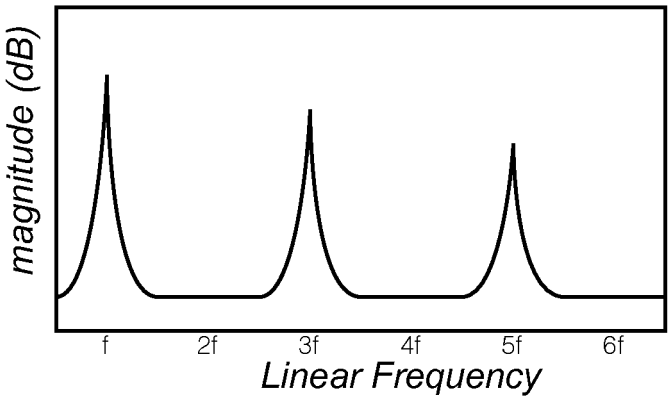


Fig. 9

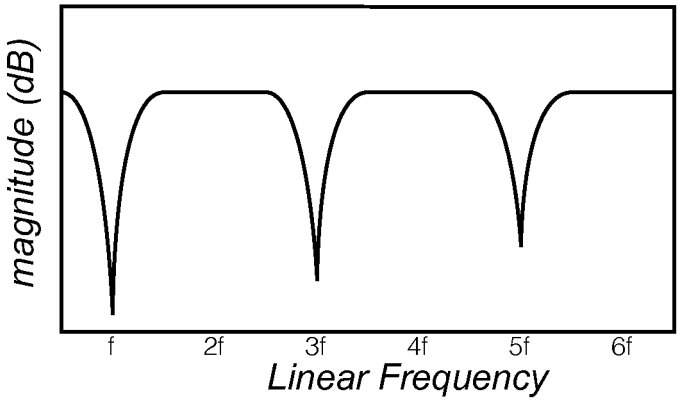


Fig. 10

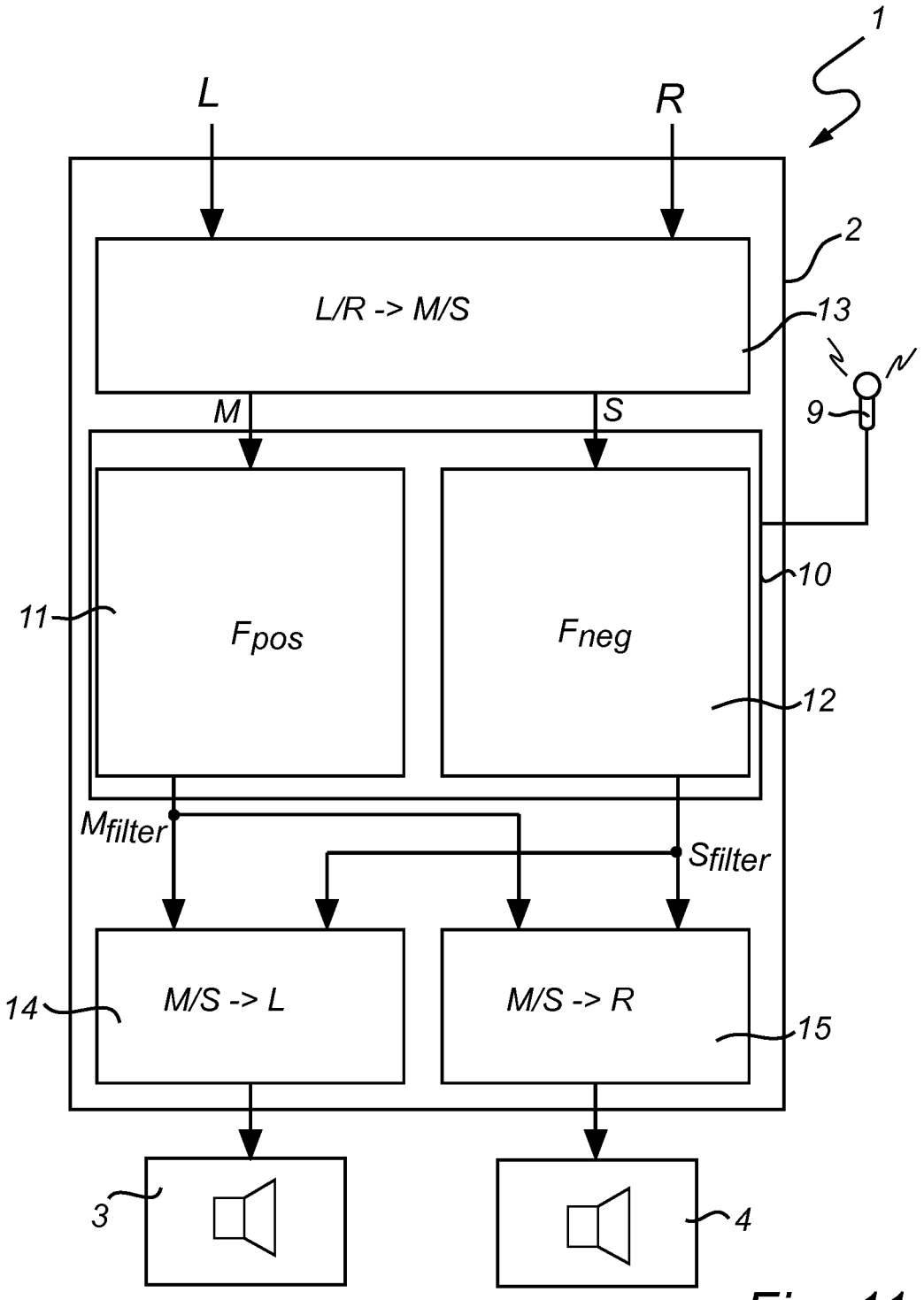

1
L
R
2
L/R -> M/S
13
M
S
9
11
Fpos
Fneg
10
12
Mfilter
Sfilter
14
M/S -> L
M/S -> R
15
3
4

Fig. 11

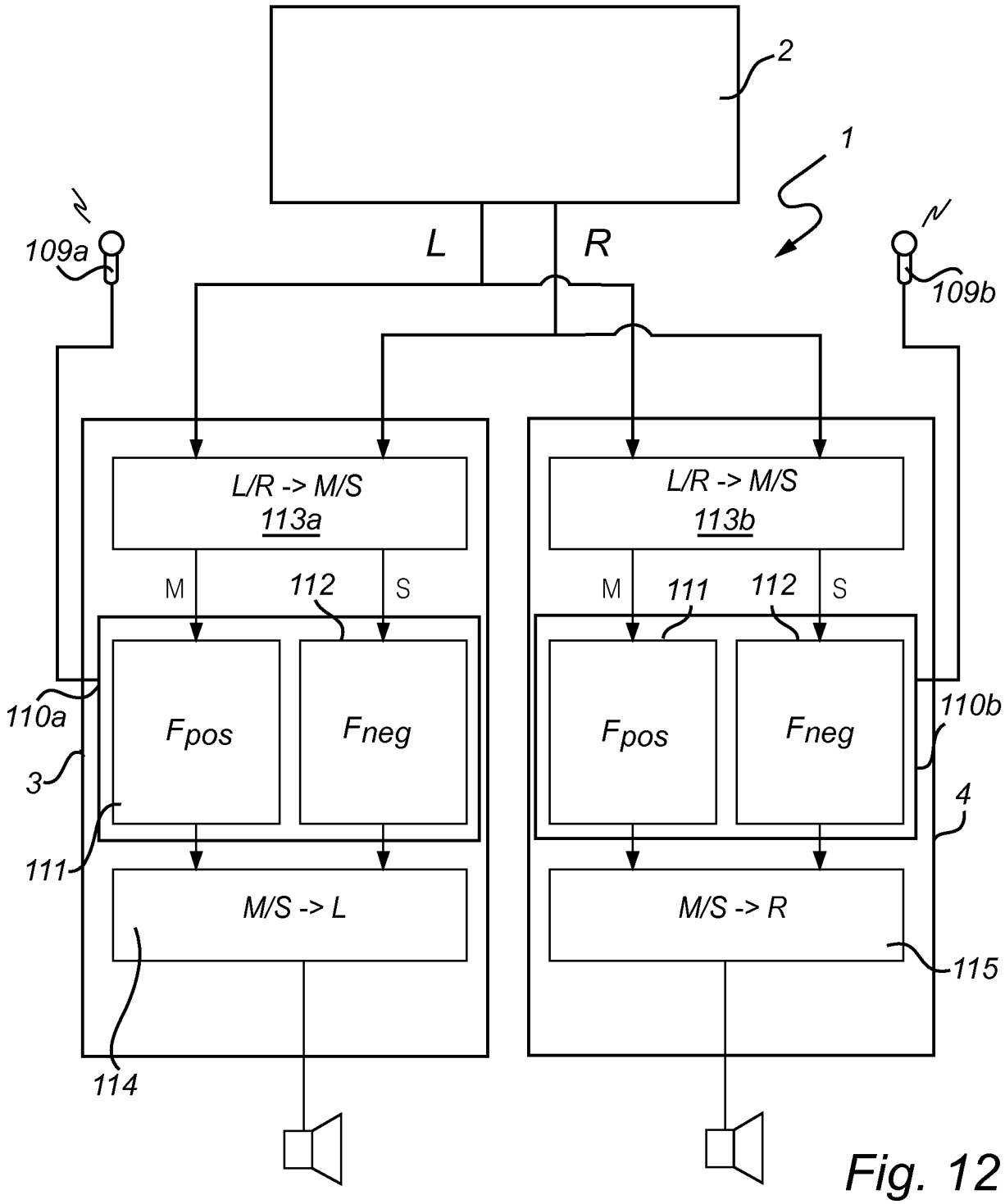

2
1
109a
109b
L
R
L/R -> M/S
113a
L/R -> M/S
113b
M
112
S
M
111
112
S
110a
110b
Fpos
Fneg
Fpos
Fneg
3
4
111
M/S -> L
M/S -> R
115
114

Fig. 12

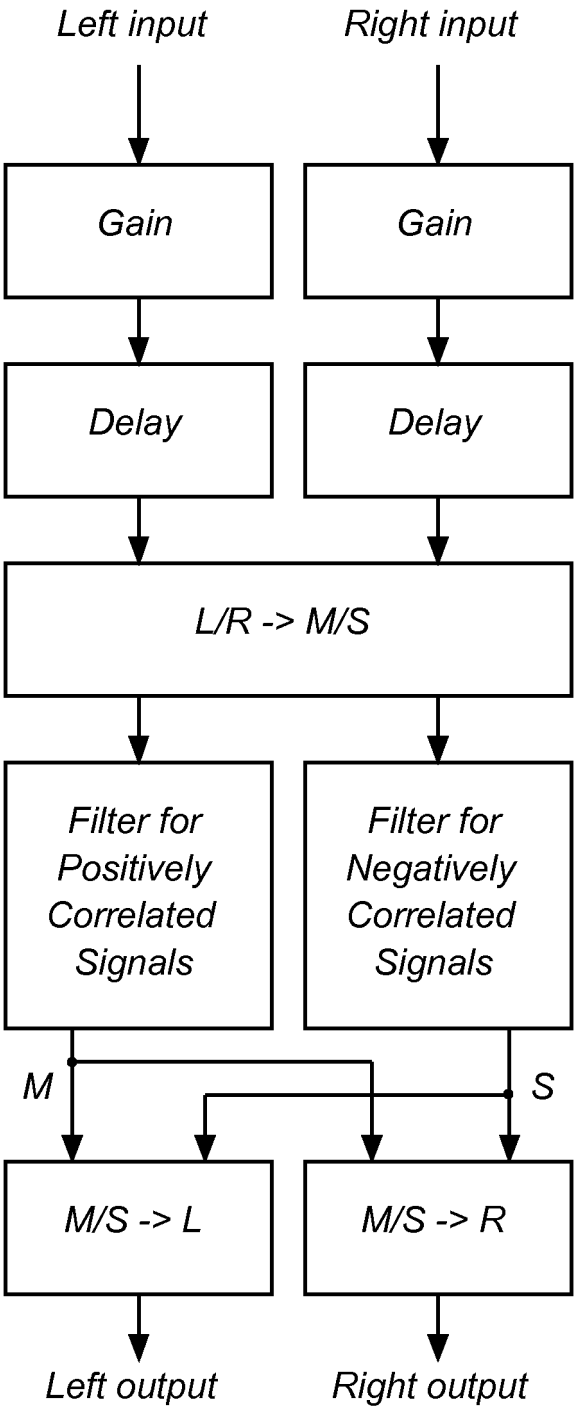

Left input
Right input
Gain
Gain
Delay
Delay
L/R -> M/S
Filter for Positively Correlated Signals
Filter for Negatively Correlated Signals
M
S
M/S -> L
M/S -> R
Left output
Right output

Fig. 13