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(54) SPEAKER SYSTEM

(57) A speaker system capable of providing a listening environment without giving audience the feeling of wrongness is described. A speaker system **(100)** includes a first speaker unit configured to include first and second speakers **(101)** and **(102),** the first and second speakers **(101)** and **(102)** being arranged in symmetry each other with respect to a first standard plane **(d)** including a first listening point. The speaker system **(100)** further includes a second speaker unit configured to include third and fourth speakers **(103)** and **(104),** the third and fourth speakers being arranged in symmetry each other with respect to a second reference plane **(c)** including a second listening point, and to be arranged in symmetry with the first speaker unit with respect to a predetermined median plane **(e).**

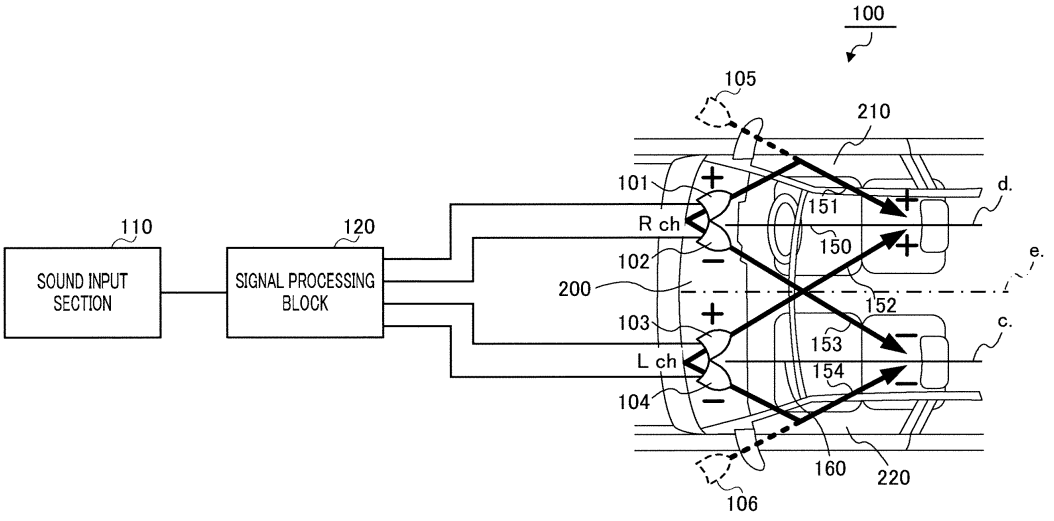

FIG.1

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Description

Technical Field

[0001] The present invention relates to a speaker system that includes two pairs of speaker units each including at least two speakers.

Background Art

[0002] A conventional speaker system includes, for example, an L channel speaker unit, an R channel speaker unit and a center speaker unit (for example, see Patent Document 1). Each of the above three speaker units is arranged in the center of positions ahead of the driver' s seat and passenger seat of a vehicle. The L channel speaker unit is directed toward a direction in which the directivity axis of the L channel speaker unit is rotated counterclockwise in the horizontal direction with respect to the traveling direction of the vehicle and in which the directivity axis is inclined at a predetermined angle to the vertical direction with respect to the traveling direction of the vehicle. The R channel speaker unit is directed toward a direction in which the directivity axis of the R channel speaker unit is rotated clockwise in the horizontal direction with respect to the traveling direction of the vehicle and in which the directivity axis is inclined at a predetermined angle in the vertical direction with respect to the traveling direction of the vehicle. The center speaker unit outputs an -L-R signal obtained by adding an -L signal which is a reverse phase signal of an L channel signal and an -R signal which is a reverse phase signal of the R channel signal.

Patent Document 1: Japanese Patent Application Laid-Open No.2004-289341

Disclosure of Invention

Problems to be Solved by the Invention

[0003] With such a conventional speaker system mounted in a vehicle, given that a difference (path length difference) is caused between the lengths of the paths for the L and R channel signals through which the Both signals reaches the listener in the driver' s seat, a phase difference and delay are caused between the both channel signals before they reach the listener. The same applies to the listener in the front passenger seat. There is a problem that listeners feel a sense of discomfort listening to audio due to the above phase difference and delay.

[0004] In view of the above, it is therefore an object of the present invention to provide a speaker system that makes it possible to provide a listening environment which does not give a sense of discomfort to a plurality of listeners.

Means for Solving the Problem

[0005] To realize the above object, A speaker system includes: a first speaker unit configured to include first and second speakers, the first and second speakers being arranged in symmetry each other with respect to a first reference plane including a first listening point; and a second speaker unit configured to include third and fourth speakers, the third and fourth speakers being arranged in symmetry each other with respect to a second reference plane including a second listening point, and to be arranged in symmetry with the first speaker unit with respect to a predetermined median plane.

Advantageous Effect of the Invention

[0006] Thanks to the symmetry of speakers according to the present invention, it is easier to provide sound without a phase difference and delay to the first and second listening points. Consequently, it is possible to provide a listening environment which does not give a sense of discomfort to listeners at the first and second listening points.

Brief Description of Drawings

[0007]

FIG.1 shows the interior of a vehicle mounting a speaker system from above, according to an embodiment of the present invention;
FIG.2 shows the lateral side of the driver's seat in the speaker system, according to the above embodiment;
FIG.3 shows a configuration of a signal processing block of the speaker system according to the embodiment;
FIG.4 is a plan view illustrating positions of the speaker unit of the speaker system and the listener according to the

embodiment; and

FIG.5 is a schematic view illustrating the relationship between the direction of the speaker unit of the speaker system and the position of the listener according to the embodiment.

Best Mode for Carrying Out the Invention

[0008] An embodiment of the present invention will be described in detail below with reference to the drawings.

[0009] FIG.1 shows an interior of a vehicle mounting the speaker system from above, according to the embodiment of the present invention and FIG.2 shows the lateral side of the driver's seat.

[0010] In FIG.1, a speaker system **100** includes a first R channel speaker **101,** a second R channel speaker **102,** a the third L channel speaker **103** and a fourth L channel speaker **104** that each output sound of the middle and high frequency band (about 200 Hz to 20 kHz).

[0011] The first R channel speaker **101** is substantially arranged in front of the driver's seat of the vehicle (for example, in/on a dashboard **200)** and outputs sound based on an in-phase signal of the R channel signal (hereinafter referred to as "in-phase signal (R)") from a sound source.

[0012] Further, the second R channel speaker **102** is arranged in a location in symmetry with the first R channel speaker **101** with respect to the first virtual plane and is substantially arranged in front of the driver's seat, and outputs sound based on the reverse phase signal (hereinafter referred to as "reverse phase signal (R)") that inverts has a reverse phase with respect to above in-phase signal (R).

[0013] Furthermore, the above first virtual plane will be referred to as the "first reference plane **c"** in the following description. With the present embodiment, this first reference plane **c** is parallel or substantially parallel to longitudinal median plane **e** of the vehicle, includes a listening point (hereinafter referred to as "the first listening point") for the listener sitting in the driver's seat and passes the center of the first and second R channel speakers **101** and **102.** Further, in the present embodiment, the first listening point is exemplarily determined in advance around the head of the listener sitting in the driver's seat.

[0014] Furthermore, the third L channel speaker **103** is substantially arranged in front of the front passenger seat next to the driver's seat (for example, in/on dashboard **200),** and outputs sound based on the in-phase signal of the L channel signal (hereinafter referred to as "in-phase signal (L)") from the same sound source as above.

[0015] The fourth L channel speaker **104** is arranged in a location in symmetry with the third L channel speaker **103** with respect to the second virtual plane and is substantially arranged in front of the front passenger seat, and outputs sound based on the reverse phase signal (hereinafter "reverse phase signal (L)") that has a reverse phase with respect to the above in-phase signal (L).

[0016] The above second virtual plane will be referred to as the "second reference plane **d"** in the following description. With the present embodiment, this second reference plane **d** is parallel or substantially parallel to the longitudinal median plane **e** of the vehicle, includes the listening point for the listener sitting in the front passenger seat (hereinafter referred to as "the second listening point") and passes the center of third and fourth L channel speakers **103** and **104.** Further, in the present embodiment, the second listening point is exemplarily determined in advance around the head of the listener sitting in the front passenger seat.

[0017] As described above, the first R channel speaker **101** outputs sound based on the in-phase signal (R) and the second R channel speaker **102** outputs sound based on the reverse phase signal (R). Consequently, above and near the first reference plane **c,** sound based on the in-phase signal (R) and sound based on the reverse signal (R) cancel each other and the listener sitting in the driver's seat feels like sound does not come from the front. Given that the same phenomenon occurs in the first L channel speaker **103** and the second L channel speaker **104,** the listener sitting in the front passenger seat feels like sound does not come from the front of the listener.

[0018] Further, the speaker system **100** includes a sound input section **110** in which a sound source composed of two-channel signal (composed of L channel and R channel), and a signal processing block **120** for applying signal processing to the two-channel signal from the sound input section **110** to generate an in-phase signal (R), a reverse phase signal (R), a in-phase signal (L) and a reverse phase signal (L). The in-phase signal (R), the reverse phase signal (R), the in-phase signal (L) and the reverse phase signal (L) generated, are outputted to the first R channel speaker **101,** the second R channel speaker **102,** the third L channel speaker **103** and the fourth L channel speaker **104,** respectively.

[0019] The sound input section **110** is an input terminal in which a sound source from an audio device and a speech input device, the audio device being one of a CD player, DVD player, MD player, cassette deck, radio, television receiver and semiconductor memory audio device and a speech input apparatus being a microphone, for example. Further, the sound input section **110** as such may be an audio device or speech input apparatus.

[0020] As shown in FIG.2, the speaker system **100** includes a low band (less than about 200 Hz) speaker (woofer) **180** under dashboard **200** of the driver's seat side. Further, although not shown in FIG.2, a low band speaker **181** (see FIG.3) similar to the speaker **180,** is provided under dashboard **200** of the front passenger seat side.

[0021] The directivity axes of the low band speakers 180 and **181** are not directed toward the listener **P1** in the driver's seat (i.e. driver) and the listener in the front passenger seat. Preferably, the low band speakers 180 and **181** are installed so as to be directed downward from the respective locations of installation. Consequently, the sounds having a low frequency band radiated from the low band speakers **180** and **181** do not reach the listeners directly, and, instead reflected sounds reach the listeners.

[0022] Further, the first R channel speaker **101,** the second R channel speaker **102,** the third L channel speaker **103** and the fourth L channel speaker **104** reproduce sound of a middle and high frequency band and the low band speakers **180** and **181** reproduce sound of a low frequency band. Consequently, to the middle and high band speakers **101, 102, 103** and **104,** middle and high band audio signals obtained by performing band division of the audio signal from the sound source are supplied as the in-phase signal (R), the reverse phase signal (R), the in-phase signal (L) and the in-phase signal (L), respectively. Supplied to the low band speakers **180** and **181** are the low band audio signals obtained by performing band division of the audio signal from the above sound source.

[0023] A pair of the first R channel speaker **101** and the second R channel speaker **102** compose speaker unit **SP1** (see FIG.2) for the driver' s seat, and a pair of the third L channel speaker **103** and the fourth L channel speaker **104** compose a speaker unit **SP2** (not shown) for the front passenger seat. In this way, the speaker units **SP1** and **SP2** are arranged in the driver's seat side and in the front passenger seat of dashboard **200,** respectively. Further, the first R channel speaker **101** and the third L channel speaker **103** compose a speaker set for the listener (i.e. driver) in the driver' s sea, and the second R channel speaker **102** and the fourth L channel speaker **104** compose another speaker set for the listener in the front passenger seat.

[0024] The first R channel speaker **101** and the second R channel speaker **102** are mounted in dashboard **200** of the driver's seat side such that an opening angle and elevation angle as described below are formed. Similarly, the third L channel speaker **103** and the fourth L channel speaker **104** are mounted in the dashboard **200** of the front passenger seat side such that an opening angle and elevation angle described below are formed.

[0025] (1) The first speaker unit **SP1** is arranged in a location where an extension line of a bisector 150 of the opening angle, formed by the directivity axis of the first R channel speaker **101** and the directivity axis of the second R channel speaker **102,** is parallel or substantially parallel to the longitudinal median line of the vehicle and passes the first listening point. Note that the extension line of the bisector 150 is included in the first reference plane **c** where the in-phase signal (R) and reverse phase signal (R) cancel each other. Similarly, the second speaker unit **SP2** is arranged in a location where an extension line of a bisector **160** of the opening angle, formed by the directivity axis of the third L channel speaker **103** and the directivity axis of the fourth L channel speaker **104,** is parallel or substantially parallel to the longitudinal median line of the vehicle and passes the second listening point. The extension line of the bisector **160** is included in the second reference plane **d** where the in-phase signal (L) and reverse phase signal (L) cancel each other. By this means, the first R channel speaker **101** and the second R channel speaker **102** are arranged in front of the driver, and the third L channel speaker **103** and the fourth L channel speaker **104** are arranged in front of the listener in the front passenger seat. Consequently, as described above, each listener sitting in the driver's seat and the front passenger seat feels like sound does not come from the front.

[0026] (2) The directions of the first R channel speaker **101** and the third L channel speaker **103** (preferably, the directions of the directivity axis) are determined such that the distance of a path **151** through which sound is reflected by a right side glass **210** and reaches from the first R channel speaker **101** the right ear of the driver and the distance of a path 152 through which sound reaches from the third L channel speaker **103** directly the left ear of the driver, are equal. Similarly, the directions of the third L channel speaker **103** and the fourth L channel speaker **104** (preferably, the directions of the directivity axes) are determined such that the distance of a path **153** through which sound reaches from the second R channel speaker **102** directly the right ear of the listener in the front passenger seat and the distance of a path 154 through which sound is reflected by a left side glass **220** and reaches from the fourth L channel speaker **104** the left ear of the driver, are equal.

[0027] (3) The first speaker unit **SP1** and the second speaker unit **SP2** are arranged in locations in symmetry with each other with respect to the longitudinal median plane **e** including the longitudinal median line of the vehicle.

[0028] Depending on the size of the interior of the vehicle, the location of the seat and the shape of the dashboard, there are cases where all of the above (1) to (3) arrangement requirements are not necessarily satisfied. In these cases, the first R channel speaker **101,** the second R channel speaker **102,** the third L channel speaker **103** and the fourth L channel speaker **104** are mounted by adjusting the arrangement and directions such that the above (1) to (3) arrangement conditions are satisfied as much as possible. What important matters to hearing is the requirement (2) that the distance of the path through which sound is reflected by the side glasses **210** and **220** and reaches the listener and the distance of the path through which sound reaches directly the listener are equal. To prioritize this requirement, a method of arranging the first R channel speaker **101** and the second R channel speaker **102** and the third L channel speaker **103** and the fourth L channel speaker **104** on the dashboard **200** by shifting these speakers slightly to the right, left, forward or backward with respect to the front of the driver or the listener in the front passenger seat, may be adopted. In this case, a set of the first R channel speaker **101** and the second R channel speaker **102** and a set of the third L channel

speaker **103** and the fourth L channel speaker **104** may not face the listener in the driver's seat (i.e. driver) and the listener in the front passenger seat, respectively.

[0029] If the first R channel speaker **101,** the second R channel speaker **102,** the third L channel speaker **103** and the fourth L channel speaker **104** are suitably arranged on the dashboard **200** such that the above (1) and (2) arrangement requirements are satisfied, the driver does not hear the sound from the first channel speaker **101** directly but hears the sound reflected by the side glass **210.** Consequently, the listener feels like sound based on the in-phase signal (R) comes from a virtual image **105** of the first R channel speaker **101** at the front right outside the vehicle. The listener sitting in the driver' s seat feels like the virtual image **105** of the first R channel speaker **101** is in a location in symmetry with the third L channel speaker **103** with respect to the first reference plane **c.** By hearing sound from the virtual image **105** of the first R channel speaker **101** and sound from the third L channel speaker **103,** the listener sitting in the driver' s seat is able to hear sound wide stereo feeling in the narrow space in the vehicle in which installation of speakers is considerably restricted.

[0030] Given that the second speaker unit **SP2** is arranged in a location in symmetry with the first speaker unit **SP1** with respect to the longitudinal median plane **e** of the vehicle, the listener in the front passenger seat recognizes that there is a virtual image **106** of the fourth L channel speaker **104** at the front left outside the vehicle. Consequently, the listener sitting in the front passenger seat is able to hear sound with wide stereo feeling, like the listener sitting in the driver's seat.

[0031] In this way, the speaker system **100** includes the speaker unit **SP1** composed of the first R channel speaker **101** that radiates the in-phase signal of the R channel signal and the second R channel speaker **102** that radiates the reverse phase signal of the R channel signal, and the speaker unit **SP2** composed of the third L channel speaker **103** that radiates the in-phase signal of the L channel signal and the fourth L channel speaker **104** that radiates the reverse phase signal of the L channel signal. In the speaker unit **SP1,** the first R channel speaker **101** and the second R channel speaker **102** are in symmetry with respect to the first reference plane **c** including the listening point for the listener, and are arranged such that sound outputted from the first R channel speaker **101** is reflected by the side glass **210** and reaches to the first listening point. The speaker unit **SP2** is arranged in a location in symmetry with the first speaker unit **SP1** with respect to the longitudinal median plane **e** of the vehicle, the third L channel speaker **103** and the fourth L channel speaker **104** are in symmetry with respect to the second reference plane **d** including the listening point for the listener and are arranged such that sound outputted from the fourth L channel speaker **104** is reflected by the side glass **220** and reaches to the second listening point.

[0032] Further, the first R channel speaker **101** and the third L channel speaker **103** are arranged such that the distance through which sound outputted from the first R channel speaker **101** is reflected by the side glass **210** and reaches the first listening point and the distance through which sound outputted from the third L channel speaker **103** reaches directly the first listening point, are equal. The second R channel speaker **102** and the fourth L channel speaker **104** are arranged according to the same relationship between the positions of the first R channel speaker **101** and the third L channel speaker **103.**

[0033] As described above, it is possible to provide to the listeners, the sound of the R channel and the sound of the L channel with substantially no phase difference and delay. The listeners do not feel a sense of discomfort listening to audio. Further, the listener sitting in the front passenger seat is able to hear sound with wide stereo feeling like the listener sitting in the driver's seat.

[0034] FIG.3 shows a configuration of the signal processing block **120.**

[0035] In FIG.3, the signal processingblock **120** includes amplifiers **301** to **304,** inverters **311** to **314,** delay units **321** to **324** and band division sections **325** to **328.**

[0036] The amplifiers **301** and **302** adjust the levels of the R and L channel signals from a sound source (not shown), respectively. Further, the amplification factors in amplifiers **301** and **302** are set such that, for example, as to the levels of the first R channel speaker **101** and the third L channel speaker **103,** a listener at the first listening point hears sounds therefrom with the same levels each other. The inverters **311** and **312** invert the R and L channel signals from the sound source (not shown) to adjust the level thereof, respectively. Further, the amplification factors in the amplifiers **311** and **312** are set such that, for example, as to the levels of the second R channel speaker **102** and the fourth L channel speaker **104,** another listener at the second listening point hears sounds outputted therefrom with the same levels each other.

[0037] The amplifiers **303** and **304** adjust the level of the center signal to be applied to R channel speakers **101** and **102** from the sound source (not shown), respectively. The inverters **311** and **312** invert the center signal to be applied to L channel speakers **103** and **104** to adjust the levels thereof, respectively. The center signal of the present embodiment is a center channel signal used for multi-channel signals use such as 5.1 ch signals. For example, voices of actors/actresses in the center of a movie reproduced with DVD are assigned in the center channel. Alternatively, the vocal sound is assigned in the center channel in case that the source is music.

[0038] A signal, in which the output signal of the amplifier **301** and the output signal of the amplifier **303** are combined, is applied to the delay unit **321** and given a predetermined delay in the delay unit **321.** The output signal of the delay

unit **321** is inputted to the band division section **325.** The band division section **325** includes ahighpass filter and lowpass filter (not shown), and the high pass filter passes the signal components of the signal inputted to the band division section **325,** included in a passband of about 200 Hz to about 20 kHz. The output signal of this high band filter includes the above-described in-phase signal (R) and is applied to the first R channel speaker **101.** Further, the low pass filter passes the signal components of the input signal to the band division section **325,** included in a passband of about 200 Hz or lower. The output signal of the low pass filter is applied to the low band speaker **180.**

[0039] A signal, in which the output signal of the inverter **311** and the output signal of the amplifier **304** are combined, is applied to the delay unit **322,** given a predetermined delay in the delay unit **322** and then is inputted to the band division section **326.** The band division section **326** includes a high pass filter (not shown), and the high pass filter passes signal components of the signal inputted to the band division section **326,** included in a passband of about 200 Hz to about 20 kHz. The output signal of this high band filter includes the above-described reverse phase signal (R) and is applied to the second R channel speaker **102.**

[0040] Further, a signal, in which the output signal of the amplifier **302** and the output signal of the inverter **313** are combined, is applied to the delay unit **323,** given a predetermined delay in the delay unit **323** and then is inputted to the band division section **327.** The band division section **327** includes a high pass filter (not shown), and the high pass filter passes signal components of the signal inputted to the band division section **327,** included in a passband of about 200 Hz to about 20 kHz. The output signal of this high band filter includes the above-described in-phase signal (L) and is assigned to the third L channel speaker **103.**

[0041] A signal, in which the output signal of the inverter **312** and the output signal of the inverter **314** are multiplexed, is applied to the delay unit **324,** and given a predetermined delay in the delay unit **324.** The output signal of the delay unit **324** is inputted to the band division section **328.** The band division section **328** includes a high pass filter and low pass filter (not shown), and the high pass filter passes signal components of the signal inputted to the band division section **328,** included in a passband of about 200 Hz to about 20 kHz. The output signal of this high band filter includes the above-described reverse phase signal (L) and is applied to the fourth L channel speaker **104.** Further, the low pass filter passes signal components of the signal inputted to the band division section **328,** included in the passband of about 200 Hz or lower. The output signal of the low pass filter is applied to the low band speaker **181.**

[0042] The amplifiers **301** to **304** and the inverters **311** to **314** have functions as level adjusters that adjust the output levels to the speakers by adjusting gain, and the output levels for speakers **101** to **104** can be adjusted by the amplifiers **301** to **304** and the inverters **311** to **314.** In this case, the level of the center signal applied to speakers **101** to **104** can be adjusted by the amplifiers **303** and **304** and the inverters **313** and **314,** respectively.

[0043] Further, the in-phase signals of the center signals are added through the amplifiers **303** and **304** to the signals toward the first R channel speaker **101** and the second R channel speaker **102,** respectively. The reverse signal of the center signals are added through the inverters **313** and **314** to the signals toward the third L channel speaker **103** and the fourth L channel speaker **104,** respectively. By this means, it is possible to locate sound image of the center channel in the front of the listener in the driver's seat (i.e. driver) and the listener in the front passenger seat.

[0044] The delay units **321** to **324** can give different phase shifts between the outputs of the first R channel speaker **101** and the second R channel speaker **102** or between the outputs of the third L channel speaker **103** and the fourth L channel speaker **104.** As described above, the first R channel speaker **101** that makes the in-phase sound of the R channel signal reach to the right ear of the driver via reflection using the right side glass **210,** the second R channel speaker **102** that makes the reverse phase sound of the R channel signal reach directly to the right ear of the listener in the front passenger seat, the third L channel speaker **103** that makes the in-phase sound of the L channel signal reach directly the left ear of the driver, and the fourth L channel speaker **104** that makes the reverse phase sound of the L channel signal reach the left ear of the listener in the front passenger seat via reflection using the left side glass **220,** are provided, so that the in-phase and reverse phase of the R channel signal can cancel each other in the locations of the listener in the driver's seat (driver) and the in-phase and reverse phase of the L channel signal can cancel each other in the locations of the listener in the passenger seat. It is possible to finely adjust the angle, at which silence occurs, by adjusting the phase difference with the delay units **321** and **324.**

[0045] FIG.4 is a plan view illustrating the positions of the speaker unit and the listener, employing an example of the relationship between the positions of the speaker unit **SP1** of the driver's seat side and the listener **P1** in the driver's seat (i.e. driver).

[0046] As shown in FIG.4, the speaker unit **SP1** and the listener **P1** in the driver's seat face each other. Further, reference numeral **"a"** is assigned to the directivity axis of the first R channel speaker **101** that radiates sound based on the in-phase signal (R) and reference numeral **"b"** is assigned to the directivity axis of the second R channel speaker **102** that radiates sound based on the reverse phase signal (R). Reference numeral **"c"** is assigned to the above-described first reference plane. Further, assuming that the angle formed by the directivity axis **a** and the first reference plane **c** is **rv1** and the angle formed by the directivity axis **b** and the first reference plane **c** is **rv2,** the condition of following equation (1) for providing an effect that the listener **P1** sitting in the driver's seat feels like sound does not come from the front, is formed.

[0047]

$$rv1=rv2 \quad \ldots \quad (1)$$

Note that the speaker unit **SP1** and the listener **P1** need not to face each other if above equation (1) is satisfied.

[0048] Although the positions of the speaker unit **SP1** of the driver's seat side and the listener **P1** in the driver's seat (i.e. driver) have been described above, the same applies to the listener in the front passenger seat and the speaker unit **SP2** of the passenger seat side, that is, the in-phase signal (L) and reverse phase signal (R).

[0049] FIG. 5 is a schematic view showing the relationship between the direction of the speaker unit and the position of the listener, employing an example of the relationship between the positions of the speaker unit **SP1** of the driver's seat side and the listener **P1** in the driver's seat (i.e. driver) and the listener **P2** of the passenger seat side.

[0050] In FIG.5, the speaker unit **SP1** of the driver's seat side is installed on the dashboard **200** shown in FIG.1 and FIG.2. Further, the reflection plane **A** of FIG.5 is the side glass **210** of FIG.1. This interior space of the vehicle is defined with **X** and **Y** coordinates. In the width **X** in the interior space of the vehicle, to the reference point of the reflection plane **A,** there are the distance **x3** from the speaker unit **SP1** of the driver's seat side, the distance **X1** from the listener **P1** in the driver's seat and the distance **x2** from the listener **P2** in the front passenger seat. Further, in the depth **Y** in the interior space of the vehicle, there are the distance **y1** from the listener **P1** in the driver's seat to the reference point of the speaker unit **SP1** and the distance **y2** from the listener **P2** in the front passenger seat to the reference point of the speaker unit **SP1.**

[0051] Reference numeral "α" (see the dotted line) is assigned to the path through which the sound outputted from the first R channel speaker **101** composing the speaker unit **SP1** (the in-phase signal (R)) is reflected by the reflection plane **A** and reaches the listener **P1** in the driver's seat, and reference numeral "β" (see the dotted line) is assigned to the path through which the sound outputted from the second R channel speaker **102** (the reverse phase signal (R)) reaches directly the listener **P2** in the front passenger seat. Further, in case of FIG.5, the speaker unit **SP1** and the listener **P1** in the driver's seat face each other as described in FIG.4, and, given that sounds radiated from the first R channel speaker **101** and the second R channel speaker **102** cancel each other near the first reference plane **c,** the listener **P1** sitting in the driver's seat feels like sound does not come from the front.

[0052] In the interior space of the vehicle defined with **X** and **Y** coordinates, the distance **y1** to the listener **P1** in the driver's seat and the distance **y2** to the listener **P2** in the front passenger seat are equal. The distance of the path α through which sound is reflected by the reflection plane **A** and reaches the listener **P1** in the driver's seat from the first R channel speaker **101** of the speaker unit **SP1** and the distance of the path β through which sound reaches directly the listener **P2** in the front passenger seat from the second R channel speaker **102** are equal. These relationships can be represented as follows.

[0053] Condition 1: y1 = y2 = y

Condition 2: path α = path β

$$Path\ 1 = ((x1 + x3)^2 + (y1)^2)^{0.5} \quad \ldots \quad (2)$$

$$Path\ 2 = ((x2 - x3)^2 + (y2)^2)^{0.5} \quad \ldots \quad (3)$$

Following equation (4) can be derived from the condition 2 and above equations (2) and (3). Equation (5) can be obtained by applying the condition 1 to equation 4 and figuring out **x3.**

[0054]

$$((x1 + x3)^2 + (y1)^2)^{0.5} = ((x2 - x3)^2 + (y2)^2)^{0.5} \quad \ldots \quad (4)$$

$$x3 = 0.5 * (x2 - x1) \quad \ldots (5)$$

According to above equation (5), the speaker unit **SP1** needs to be preferably arranged at the distance **x3** which is apart from the wall **A** by a half of the distance between the two listeners **P1** and **P2.**

[0055] Although the positions of the speaker unit **SP1** of the driver's seat side, the listener **P1** in the driver's seat and the listener **P2** in the front passenger seat are described above, the same applies to the arrangement of the speaker unit **SP2** of the front passenger seat side.

[0056] The positions of the speaker units **SP1** and **SP2,** the listener **P1** in the driver's seat and the listener **P2** in the front passenger seat in the horizontal direction have been described. Next, the elevation angle formed by the speaker units **SP1** and **SP2,** the listener **P1** in the driver's seat and the listener **P2** in the front passenger seat will be described with reference to FIG.2.

[0057] As shown in FIG.2, it is preferable to mount the speaker unit **SP1** with the elevation angle **rh** such that the directivity axis **a** of the first R channel speaker **101** (that radiates reflected sound to the listener **P1**) of the speaker units **SP1** and **SP2** (in FIG.2, speaker unit **SP1** and the listener **P1** are represented and shown) come at the height of the ears of the listener **P1**. By setting the elevation angle **rh** in this way, the listener **P1** would hear the sound radiated from the speakers **101** and **102** better.

[0058] As described above in detail, according to the present embodiment, the speaker system **100** includes the speaker unit **SP1** composed of the first R channel speaker **101** that radiates the in-phase R channel signal and the second R channel speaker **102** that radiates the reverse phase R channel signal and the speaker unit **SP2** composed of the third L channel speaker **103** that radiates the in-phase L channel signal and the fourth L channel speaker **104** that radiates the reverse phase L channel signal, and the first R channel speaker **101** and the second R channel speaker **102** are in symmetry with respect to the first reference plane **c** including the first listening point for the listener and are arranged such that sound from the first R channel speaker **101** is reflected by the side glass **210** which is the reflection plane and reaches the first listening point. The same relationship holds between the third L channel speaker **103** and the fourth L channel speaker **104.**

[0059] Further, speakers composing the speaker units **SP1** and **SP2** are arranged such that the distance through which sound from one speaker is reflected by the side glasses **210** and **220** and reaches the listeningpoint for the listener and the distance through which sound from the other speaker reaches directly the listening point for the listener, are equal. Further, the listening point for the listener is arranged on the axis in which the in-phase sound signal from above one speaker and the sound signal from the above other speaker cancel each other. By this means, it is possible to realize a speaker system that makes it possible to provide a listening environment that does not give a sense of discomfort to listeners. That is, in an environment in which there are two listeners in the interior of the vehicle, it is possible to produce excellent effects that, at the same time, (1) the sound image is located in the front, (2) the opening angles of the left side and the right side are the substantially same each other and (3) the sound paths of the left side and the right side are the substantially same each other, for the two listeners, so that an optimal acoustic environment is possible.

[0060] Further, in the above description, the first and second listening points are determined in advance and are located near the heads of the listeners sitting in the driver's seat and the front passenger seat. More preferably, in case where the vehicle is a car with a right-hand steering wheel, the first listening point is set near the left ear of the listener sitting in the driver's seat and the second listening point is set near the right ear of the listener sitting in the front passenger seat. In case where the vehicle is a car with a left-hand steering wheel, the first listening point is set near the right ear of the listener sitting in the driver's seat and the second listening point is set near the left ear of the listener sitting in the front passenger seat.

[0061] The above description is an illustration of a preferred embodiment of the present invention and the scope of the present invention is not limited to this.

[0062] Further, although an example has been described with the present embodiment where the present invention is applied to a speaker system arranged on the dashboard in a vehicle, the speaker system may be mounted in other locations in the vehicle. Furthermore, the present invention is applicable to the speaker system arranged in, for example, a narrow room other than in the passenger compartment.

[0063] Further, although the term "speaker system" is used with the present embodiment for ease of description, other terms are certainly possible, including, for example, "audio system," "audio playback system," "speaker apparatus mounted in the vehicle" and "audio devices mounted in the vehicle."

[0064] Furthermore, each circuit section forming the above speaker system , for example, the type, number and connecting method of signal processing sections are not limited to the above described embodiment.

[0065] The disclosure of Japanese Patent Application No.2006-152550, filed on May 31, 2006, including the specification, drawings and abstract, is incorporated herein by reference in its entirety.

Industrial Applicability

[0066] The speaker system according to the present invention is useful as a speaker system installed in the interior of the vehicle. The present invention is also applicable for use in, for example, products having a plurality of speaker units. Further, the present invention is preferable for the speaker system installed in a narrow space other than in the interior of the vehicle.

Claims

1. A speaker system comprising:

a first speaker unit configured to include first and second speakers, the first and second speakers being arranged in symmetry each other with respect to a first reference plane including a first listening point; and
a second speaker unit configured to include third and fourth speakers, the third and fourth speakers being arranged in symmetry each other with respect to a second reference plane including a second listening point, and to be arranged in symmetry with the first speaker unit with respect to a predetermined median plane.

2. The speaker system according to claim 1, wherein:

an in-phase signal from a sound source is inputted to one of the first and second speakers;
a reverse phase signal of the in-phase signal is inputted to the other one of the first and second speakers;
the in-phase signal from the sound source is inputted to one of the third and fourth speakers; and
the reverse phase signal of the in-phase signal from the sound source is inputted to the other one of the third and fourth speakers.

3. The speaker system according to claim 1, wherein:

a directivity axis of the first speaker is configured to be directed toward a first reflection plane;
a directivity axis of the second speaker is configured to be directed toward the second listening point;
a directivity axis of the third speaker is configured to be directed toward the first listening point; and
a directivity axis of the fourth speaker is configured to be directed toward a second reflection plane.

4. The speaker system according to claim 3, wherein:

a path length through which sound outputted from the first speaker is reflected by the first reflection plane and reaches the first listening point, and a path length through which sound outputted from the third speaker reaches the first listening point, are substantially equal; and
a path length through which sound outputted from the second speaker reaches the second listening point, and a path length through which sound outputted from the fourth speaker is reflected by the second reflection plane and reaches the second listening point, are substantially equal.

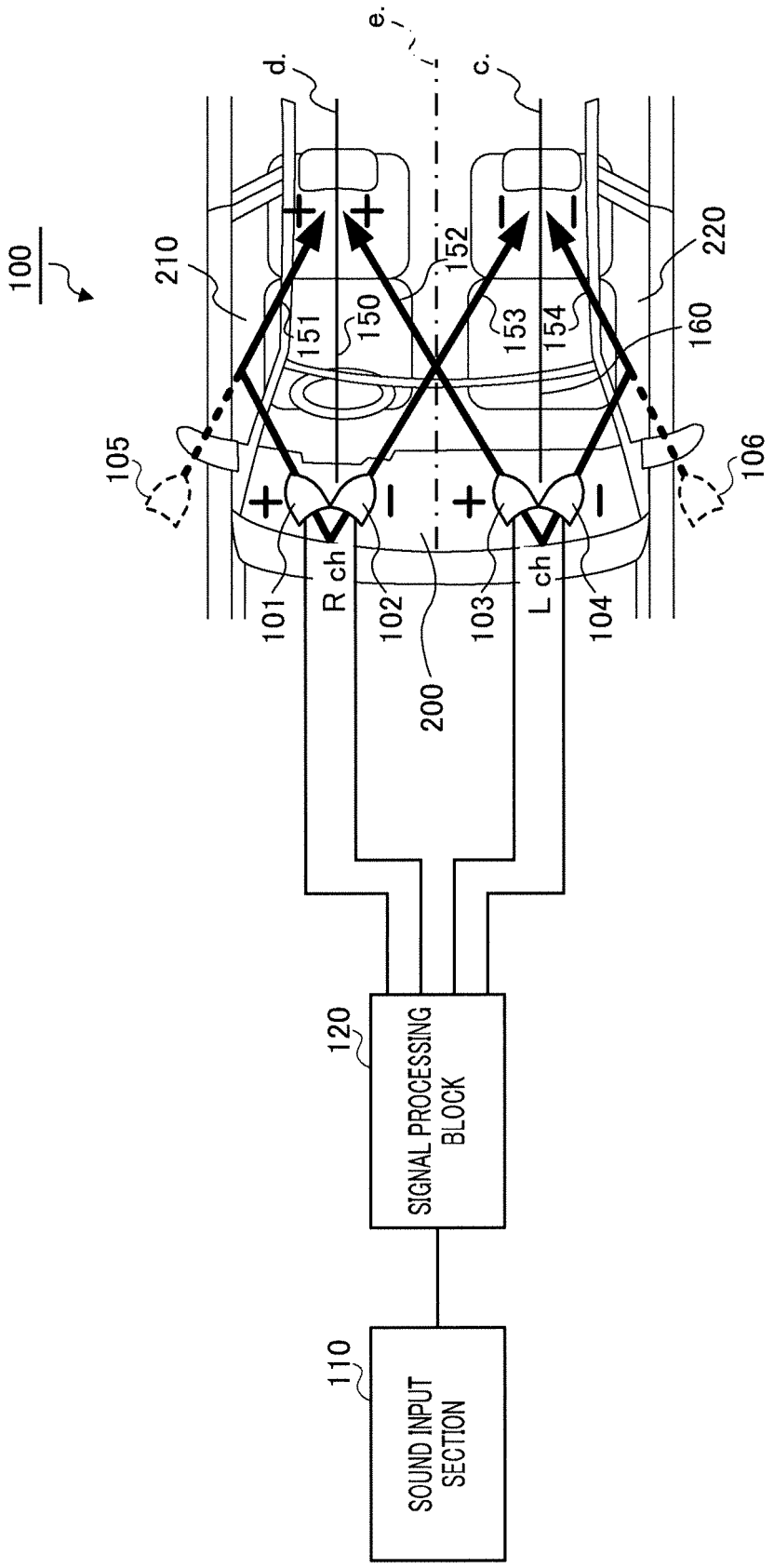
100
210
220
105
106
160
151
150
152
153
154
d.
e.
c.
+
+
−
−
+
−
+
−
R ch
L ch
101
102
103
104
200
120
SIGNAL PROCESSING BLOCK
110
SOUND INPUT SECTION

FIG.1

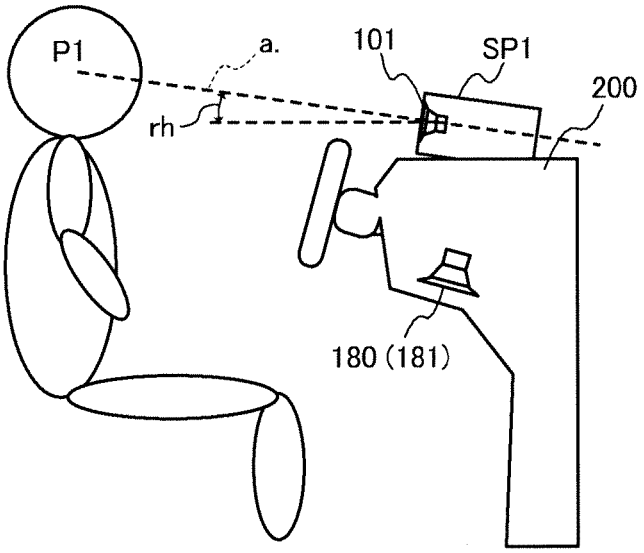

FIG.2

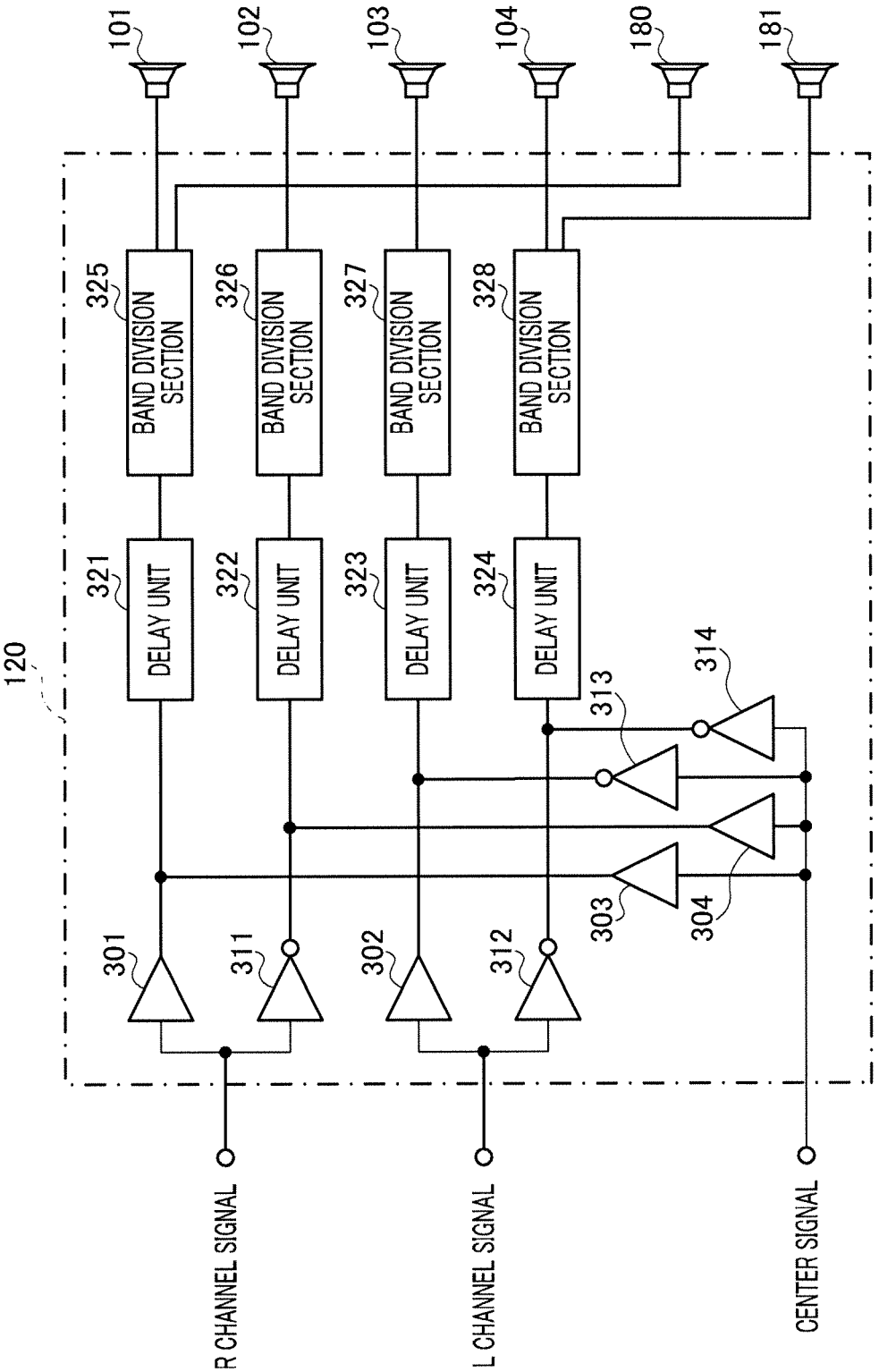
101
102
103
104
180
181
120
325
326
327
328
BAND DIVISION SECTION
321
322
323
324
DELAY UNIT
313
314
303
304
301
311
302
312
R CHANNEL SIGNAL
L CHANNEL SIGNAL
CENTER SIGNAL

FIG.3

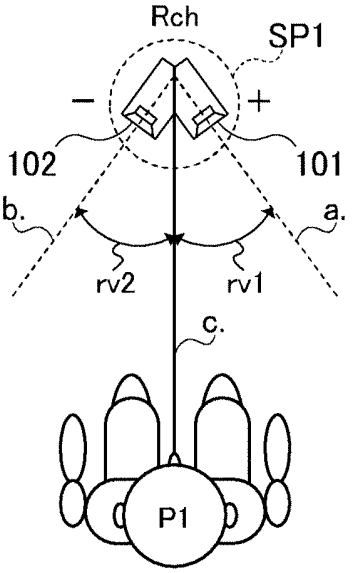
Rch
SP1
−
+
102
101
b.
a.
rv2
rv1
c.
P1

FIG.4

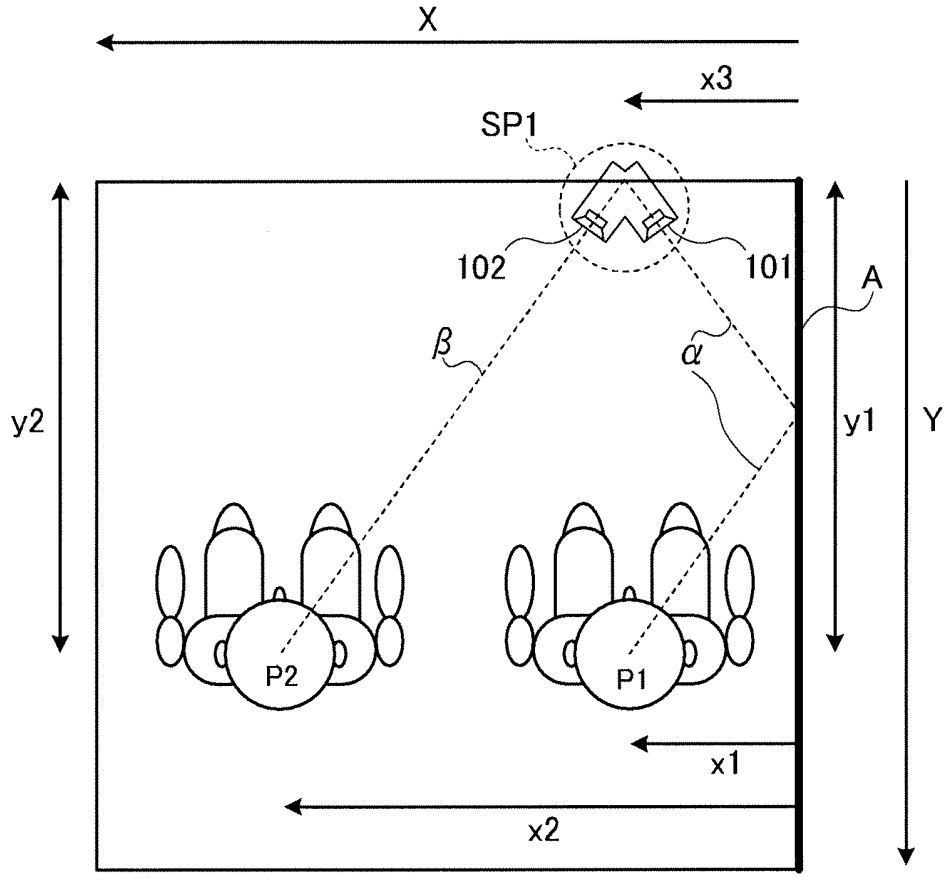
X
x3
SP1
102
101
A
β
α
y2
y1
Y
P2
P1
x1
x2

FIG.5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/060826

A. CLASSIFICATION OF SUBJECT MATTER
H04S1/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04S1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2007
Kokai Jitsuyo Shinan Koho 1971-2007 Toroku Jitsuyo Shinan Koho 1994-2007

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 6-72253 A (Kenwood Corp.), 15 March, 1994 (15.03.94), Par. Nos. [0022] to [0034]; Fig. 1 & US 5389867 A & DE 4300366 A1	1-4
X Y	JP 11-318000 A (Alpine Electronics, Inc.), 16 November, 1999 (16.11.99), Par. Nos. [0002] to [0005]; Fig. 5 (Family: none)	1 2-4
A	JP 62-72300 A (Nissan Motor Co., Ltd.), 02 April, 1987 (02.04.87), Fig. 1 (Family: none)	1-4

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 July, 2007 (10.07.07)	24 July, 2007 (24.07.07)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/060826

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 1-29200 A (Onkyo Corp.), 31 January, 1989 (31.01.89), Page 2, lower left column, line 13 to page 3, upper left column, line 8; Figs. 1, 2 (Family: none)	1-4
A	JP 63-26197 A (Nippon Telegraph And Telephone Corp.), 03 February, 1988 (03.02.88), All pages; all drawings & US 4764960 A & DE 3723409 A1 & FR 2601839 A & CA 1275054 A & KR 9004668 B	1-4

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/060826

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The present international application includes two inventions that do not comply with the requirements for the unity of invention as set forth below:
Main invention: claims 1 and 2
Second invention: claims 3 and 4
The search has been carried out on the assumption that the invention described in the claims 1 and 2 is the originally described invention (main invention).
Since a result of the search shoes that a technical feature of the claim 1 is disclosed ion a document: JP 6-72253 A (Kenwood Corp.), 15 March, 1994 (15.03.94), paragraphs [0022] and [0034], Fig. 1, & US 5389867 A & DE 4300366 A1, (Continue on the extra sheet.)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
the

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, payment of a protest fee..

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/060826

Continuation of Box No.III of continuation of first sheet(3)

it has become clear that the invention is not novel. A first speaker unit including first and second speakers described in the claim 1 is set on a dashboard (3) on extension of a substantially central line of a driver's seat (5) in the document 1 and is described as a first dipole sound source (11) comprised of a horn speaker (11a) of a fist sound source and a horn speaker (11b) of a second sound source that are provided with a back-to-back arrangement. A second speaker unit including third and fourth speakers described in the claim 1 is provided with the same shape and function in the document 1 as for the first dipole sound source (11) and is set on the dashboard (3) on extension of a substantially central line of an assistant's seat (6) and is described as a second dipole sound source (12) comprised of a horn speaker (12a) of a third sound source that is similar to the horn speakers (11a) and (11b) and a horn speaker (12b) of a fourth sound source. The first and second speaker units disposed in plane-symmetry with respect to a prescribed central plane in the claim 1 are described in the document 1 as that the driver's seat side is in symmetry with the assistant's seat in a car room with respect to the central line of the car.

Thus, a technical feature of the claim 1 is not "a special technical feature" in the meaning of PCT 13.2, Second Sentence.

As far as the claim 2 is compared with the above-identified prior art, "the special technical feature" of the main invention is that "a positive phase signal from the sound source is input to either one of the first and second speakers, a reverse phase signal of the positive phase signal is input to the other, a positive phase signal from the same sound source is input to either one of the third and fourth speakers, and a reverse phase signal of the positive phase signal is input to the other.

As far as the claims 3 and 4 (second invention) are compared with the above-identified prior art, "the (tentative) special technical feature" of the second invention is that "a directional axis of the first speaker is directed to a first reflective plane, a directional axis of the second speaker is directed to a second listening point, a directional axis of the third speaker is directed to the first listening point, and a directional axis of the fourth speaker is directed to a second reflective plane".

No technical relationship including one or not less than two identical or corresponding technical features including a special technical feature is deemed to exist among those main and second inventions.

Form PCT/ISA/210 (extra sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2004289341 A **[0002]**
- JP 2006152550 A **[0065]**