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(54) **AUDIO SIGNAL DISTRIBUTION**

(57) An audio signal distribution system and method comprise receiving an audio source signal ($X_L(j\omega)$, $X_R(j\omega)$) to be reproduced by a loudspeaker (104, 105) disposed at a first position; providing to the loudspeaker a loudspeaker signal that represents the audio source signal ($X_L(j\omega)$, $X_R(j\omega)$) to be reproduced by the loudspeaker (104, 105); and providing to two speakers (107, 108) of a headphone, disposed at a second position and a third position, two headphone signals ($S_L(j\omega)$ [$+Y_L(j\omega)$], $S_R(j\omega)$ [$+Y_R(j\omega)$]) which comprise the loudspeaker signals filtered with electrical domain transfer functions (C_{LL}, C_{LR}, C_{RL}, C_{RR}). The electrical domain transfer functions are configured to model acoustic domain transfer functions (H_{LL}, H_{LR}, H_{RL}, H_{RR}) representing the acoustic paths between the first position and each of the second position and third position so that at the second position and third position sound acoustically broadcasted by the loudspeaker (104, 105) is reduced or cancelled by sound broadcasted by the respective speaker (107, 108) of the headphone.

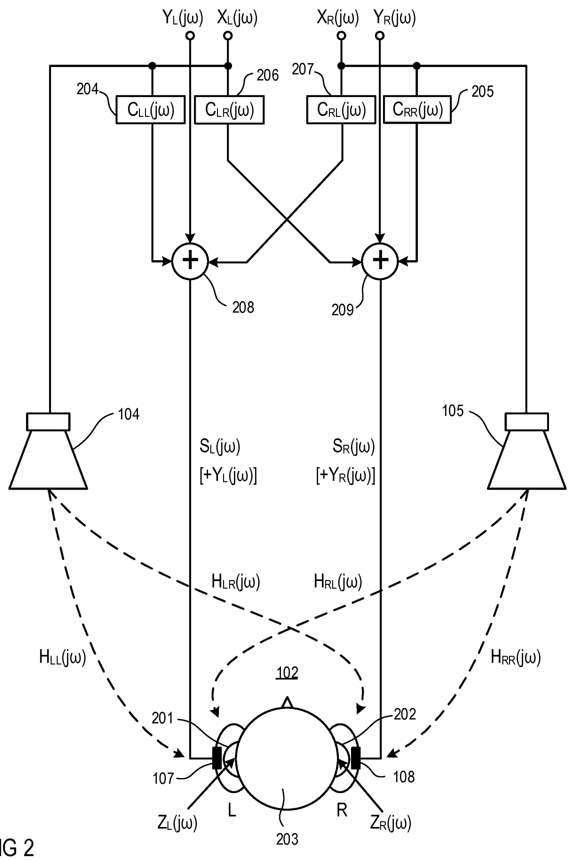

FIG 2

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Description

BACKGROUND

1. Technical Field.

[0001] The disclosure relates to a system and method (generally referred to as a "system") for distributing an audio signal.

2. Related Art.

[0002] Headphone listening is becoming increasingly popular due to the propagation of portable audio players. Even mobile phones now also allow music playback over headphones. Headphones are also increasingly used in rear-seat entertainment systems to allow people sitting in the back of the car to listen to music or watch videos without being disturbed by audio content being played on the main car audio installation, and without disturbing the front passengers. Another trend is the growing use of active noise control (ANC) headphones which isolate the user from the ambient sound such as car engine noise, fan noise or audio content played on the main car audio installation by means of anti-sound played through the headphone speakers. The anti-sound is calculated from sound picked up by microphones placed on or in the headphone. However, the ambient noise may be insufficiently picked up by the microphones so that the noise control performance of the whole system deteriorates.

SUMMARY

[0003] An audio signal distribution system is configured to receive an audio source signal to be reproduced by a loudspeaker disposed at a first position, to provide to the loudspeaker a loudspeaker signal that represents the audio source signal to be reproduced by the loudspeaker, and to provide to two speakers of a headphone, disposed at a second position and a third position, two headphone signals which comprise the loudspeaker signals filtered with electrical domain transfer functions. The electrical domain transfer functions are configured to model acoustic domain transfer functions representing the acoustic paths between the first position and each of the second position and third position so that at the second position and third position sound acoustically broadcasted by the loudspeaker is reduced or cancelled by sound broadcasted by the respective speaker.

[0004] An audio signal distribution method comprises receiving an audio source signal to be reproduced by a loudspeaker disposed at a first position, and providing to the loudspeaker a loudspeaker signal that represents the audio source signal to be reproduced by the loudspeaker. The method further comprises providing to two speakers of a headphone, disposed at a second position and a third position, two headphone signals which comprise the loudspeaker signals filtered with electrical domain transfer functions. The electrical domain transfer functions are configured to model acoustic domain transfer functions representing the acoustic paths between the first position and each of the second position and third position so that at the second position and third position sound acoustically broadcasted by the loudspeaker is reduced or cancelled by sound broadcasted by the respective speaker of the headphone.

[0005] A program code of processing audio data, when being executed by a processor, is configured to carry out or control the method described above.

[0006] Other systems, methods, features and advantages will be, or will become, apparent to one with skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features and advantages be included within this description, be within the scope of the invention, and be protected by the following claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The system may be better understood with reference to the following drawings and description. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like referenced numerals designate corresponding parts throughout the different views.

Figure 1 is a block diagram of an exemplary arrangement of loudspeakers and headphone in connection with an in-car entertainment system.
Figure 2 is a signal flow diagram of an audio signal distribution used in the arrangement shown in Figure 1.
Figure 3 is a block diagram illustrating an exemplary in-car multimedia entertainment system.
Figure 4 is a block diagram illustrating a wireless headphone connection.
Figure 5 is a signal flow diagram illustrating the arrangement shown in Figure 1, which additionally employs headtrack-

ing.

Figure 6 is a process chart illustrating an exemplary audio signal distribution method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0008] In an exemplary audio arrangement shown in Figure 1, two different stereophonic audio contents such as, for example, two different pieces of music are to be reproduced at two different positions 101 and 102 in the interior of an automobile 103 (or any other room). Position 101 may be the front left seat position and position 102 may be the rear right seat position in the interior of automobile 103. The content intended to be played at position 101 is reproduced by way of two loudspeakers 104 and 105 arranged in front and to the left and right of position 101, and the content intended to be played at position 102 is reproduced by way of a headphone 106 with two headphone speakers 107 and 108. While sound radiated by the headphone speakers 107 and 108 is under most circumstances not or not significantly audible at position 101, particularly when loudspeakers 104 and 105 radiate sound, sound radiated by loudspeakers 104 and 105 is under most circumstances audible at position 102 even when a user wears the headphone 106. Further loudspeakers such as, for example, loudspeakers 109 and 110 disposed on the rear shelf of automobile 103 may be employed but for the sake of simplicity only loudspeakers 104 and 105 are looked at more closely in the following description. However, the behavior of loudspeakers 109 and 110 with regard to a user (listener) sitting at position 102 can be described in a similar manner to that of loudspeakers 104 and 105.

[0009] Figure 2 illustrates electrical and acoustic paths present in the audio arrangement shown in Figure 1, in which binaural (stereo) signals are picked up by the left ear 201 and the right ear 202 of a user 203 sitting at position 102. The signals broadcasted by loudspeakers 104 and 105 may be input electrical stereo audio signals $X_L(j\omega)$ and $X_R(j\omega)$ which represent a first audio content to be audible at position 101 but not at position 102. For illustration purposes, the signals $X_L(j\omega)$ and $X_R(j\omega)$ are frequency domain signals that correspond with time domain signals. The left electrical input (audio) signal $X_L(j\omega)$ and the right electrical input (audio) signal $X_R(j\omega)$, which may be provided by any suitable audio signal source such as a radio receiver, music player, telephone, navigation system or the like, are, on one hand, supplied to the loudspeakers 104 and 105, and on the other hand, are filtered by inverse filters 204-207 before they are supplied to headphone speakers 107 and 108. Filters 204 and 206 filter signal $X_L(j\omega)$ with transfer functions $C_{LL}(j\omega)$ and $C_{LR}(j\omega)$, respectively, and filters 205 and 207 filter signal $X_R(j\omega)$ with transfer functions $C_{RR}(j\omega)$ and $C_{RL}(j\omega)$, respectively, to provide inverse filter output signals. The filter output signals provided by filters 204 and 206 are combined by an adder 208 and inverse filter output signals provided by filters 205 and 207 are combined by an adder 209 to form combined signals $S_L(j\omega)$ and $S_R(j\omega)$. In particular, signal $S_L(j\omega)$ supplied to the left headphone speaker 107 can be expressed as:

$$S_L(j\omega) = C_{LL}(j\omega)\cdot X_L(j\omega)+C_{RL}(j\omega)\cdot X_R(j\omega), \tag{1}$$

and the signal $S_R(j\omega)$ supplied to the right headphone speaker 108 can be expressed as:

$$S_R(j\omega) = C_{LR}(j\omega)\cdot X_L(j\omega)+C_{RR}(j\omega)\cdot X_R(j\omega). \tag{2}$$

[0010] The headphone speakers 107 and 108 radiate the combined signals $S_L(j\omega)$ and $S_R(j\omega)$ to the left ear 201 and right ear 202 of the user 203 with transfer functions which are neglected in the following considerations due to their minor significance. The loudspeakers 104 and 105 receive the input electrical stereo audio signals $X_L(j\omega)$ and $X_R(j\omega)$ and convert them into sound signals which are transferred via respective acoustic paths with transfer functions $Hij(j\omega)$ to the left ear 201 and right ear 202 of the user 203. The sound signal present at the left ear 201 and right ear 202 is denoted as $Z_L(j\omega)$ and $Z_R(j\omega)$, in which

$$Z_L(j\omega) = H_{LL}(j\omega)\cdot X_L(j\omega)+H_{RL}(j\omega)\cdot X_R(j\omega)+S_L(j\omega), \tag{3}$$

$$Z_R(j\omega) = H_{LR}(j\omega)\cdot X_L(j\omega)+H_{RR}(j\omega)\cdot X_R(j\omega)+S_R(j\omega). \tag{4}$$

[0011] In equations 3 and 4, the transfer functions $Hij(j\omega)$ denote the room impulse response (RIR) in the frequency domain, i.e. the transfer functions from the loudspeakers 104 and 105 to the left ear 201 and right ear 202 of the user 203. Index i is "L" when it refers to the left loudspeaker 104 and "R" when it refers to the right loudspeaker 105. Index j is "L" when it refers to the left ear 201 and "R" when it refers to the right ear 202.

[0012] Inserting equations 1 and 2 into equations 3 and 4 leads to equations 5 and 6:

$$Z_L(j\omega) = H_{LL}(j\omega)\cdot X_L(j\omega)+H_{RL}(j\omega)\cdot X_R(j\omega)+C_{LL}(j\omega)\cdot X_L(j\omega)+C_{RL}(j\omega)\cdot X_R(j\omega), \quad (5)$$

$$Z_R(j\omega) = H_{LR}(j\omega)\cdot X_L(j\omega)+H_{RR}(j\omega)\cdot X_R(j\omega)+C_{LR}(j\omega)\cdot X_L(j\omega)+C_{RR}(j\omega)\cdot X_R(j\omega). \quad (6)$$

When the inverse filters 204-207 have transfer functions that are the inverse of transfer functions Hij(jω), which means that $C_{LL}(j\omega) = -H_{LL}(j\omega)$, $C_{LR}(j\omega) = -H_{LR}(j\omega)$, $C_{RL}(j\omega) = -H_{RL}(j\omega)$, and $C_{RR}(j\omega) = -H_{RR}(j\omega)$, equations 5 and 6 can be rewritten as follows:

$$Z_L(j\omega) = H_{LL}(j\omega)\cdot X_L(j\omega)+H_{RL}(j\omega)\cdot X_R(j\omega)+-H_{LL}(j\omega)\cdot X_L(j\omega)+-H_{RL}(j\omega)\cdot X_R(j\omega) = 0, \quad (7)$$

$$Z_R(j\omega) = H_{LR}(j\omega)\cdot X_L(j\omega)+H_{RR}(j\omega)\cdot X_R(j\omega)+-H_{LR}(j\omega)\cdot X_L(j\omega)+-H_{RR}(j\omega)\cdot X_R(j\omega) = 0. \quad (8)$$

This means that sound radiated by the loudspeakers 104 and 105 is not audible to the user 203 who wears the headphone 106. When adding signals $Y_L(j\omega)$ and $Y_R(j\omega)$, which represent another audio content, to signals $S_L(j\omega)$ and $S_R(j\omega)$, the resulting sum signals $YL(j\omega)+S_L(j\omega)$ and $Y_R(j\omega)+S_R(j\omega)$ interfere, after being radiated by headphone speakers 107 and 108, with the signals $H_{LL}(j\omega)\cdot X_L(j\omega)$, $H_{RL}(j\omega)\cdot X_R(j\omega)$, $H_{LR}(j\omega)\cdot X_L(j\omega)$ and $H_{RR}(j\omega)\cdot X_R(j\omega)$ according to:

$$Z_L(j\omega) = H_{LL}(j\omega)\cdot X_L(j\omega)+H_{RL}(j\omega)\cdot X_R(j\omega)+C_{LL}(j\omega)\cdot X_L(j\omega)+C_{RL}(j\omega)\cdot X_R(j\omega)+Y_L(j\omega), \quad (9)$$

$$Z_R(j\omega) = H_{LR}(j\omega)\cdot X_L(j\omega)+H_{RR}(j\omega)\cdot X_R(j\omega)+C_{LR}(j\omega)\cdot X_L(j\omega)+C_{RR}(j\omega)\cdot X_R(j\omega)+Y_r(j\omega), \quad (10)$$

so that $Z_L(j\omega) = Y_L(j\omega)$ and $Z_R(j\omega) = Y_R(j\omega)$, which means that only the desired content is presented to the user 203.

[0013] An in-car multimedia entertainment system used in the arrangement described above in connection with Figures 1 and 2 is shown in Figure 3. As its primary components, the automotive multimedia entertainment system includes an audio system 301, the headphone 106, a two-way wired (alternatively: wireless) communication link 302, a set of front speakers including the loudspeakers 104 and 105, and a set of rear speakers (not shown in Figure 3). The audio system 301 can receive audio input signals from multiple audio input devices, for example a CD player 303, a cassette player 304, a radio tuner 305, a DVD player 306, and other auxiliary devices 307. The audio input signals are received by a multiplexer 308 of the audio system 301 and selected in accordance with two selection signals from program switches 316 and 317 to provide two different audio contents, a first audio content and a second audio content. The multiplexer 308 can provide each of the two audio contents from any of the audio input devices 303-307 across a stereo channel 309 transmitting the first audio content to be reproduced by loudspeakers 104 and 105 and across a stereo channel 310 transmitting the second audio content to be reproduced by the headphone 106 to an audio processor 315. The audio processor 315 may, for example, be operated to perform the functions of the filters 204-207 and the adders 208, 209 described above in connection with Figure 2 in which audio signals $X_L(j\omega)$ and $X_R(j\omega)$ represent the first audio content to be audible at position 101 and reproduced by loudspeakers 104 and 105, and signals $Y_L(j\omega)$ and $Y_R(j\omega)$ represent the second audio content to be audible at position 102 and reproduced by headphone 106.

[0014] The signals $X_L(j\omega)$ and $X_R(j\omega)$ and the signals $Y_L(j\omega)$ and $Y_R(j\omega)$ can be attenuated by way of attenuators 318 and 319. Amplifiers 311 and 312 are connected downstream of the audio processor 315 and upstream of the loudspeakers 104 and 105. Amplifiers 313 and 314 are connected downstream of the audio processor 315 and upstream of the headphone 106. The attenuator 318 allows, for example, the front seat passenger to control the volume of the signals $X_L(j\omega)$ and $X_R(j\omega)$ and may be mounted in the instrument panel or integrated into the steering wheel together with the program switch 316. The attenuator 319 allows, for example, the user wearing the headphone 106 to control the volume of the signals $Y_L(j\omega)$ and $Y_R(j\omega)$ and may be mounted in the arm rest of the rear seats which may also house the program switch 317 and a connector jacket for the headphone in case of a wired connection 302. The audio system, including the multiplexer 308 and the audio processor 315, may be in the form of an embedded system and controlled by software.

[0015] If a wireless connection 402 is used instead of wired connection 302, a transceiver 401 may be included in the audio system 301 as shown in Figure 4. The transceiver 401 is adapted to establish a two-way wireless communication link 402 with a transceiver 403 connected to the headphone 106. Transceivers 401 and 403 may be implemented using infrared or radio frequency transceivers, e.g., according to a Bluetooth® or near field communication (NFC) standard. Transceiver 403 and/or a set of controls (not shown) may be integrated in the headphone106 for configuring program and audio parameters associated with, e.g., audio channel 310 shown in Figure 3. A power "on" control 404 may be integrated into the headphone 106. When the power "on" control is activated and the headphone is switched on, this may be reported to the audio system 301 which then deactivates the rear speakers and connects audio channel 310 to the headphone 106. A similar mechanism may be used with wired connection 302 when it is detected that the headphone is connected by wire to the audio system 301.

[0016] Referring now to Figure 5, a head tracking system 501 may be included in the audio system shown in Figure 2 to determine a rotation angle of the head of the user 203 wearing the headphone 106 with respect to a reference direction (e.g., the direction to the front of the car), which may also be dependent on a movement of the user 203. Here the movement of a user should be understood as an act or process of moving including e.g. changes of position or posture, such as leaning back or settling into the seat. The head tracking system 501 may include a sensing device (not shown), such as an array of video cameras, for measuring a head movement to provide a measurement representing the head movement, and a processing circuit (not shown) for deriving the rotation angle of the head of the user with respect to the reference direction from the measurement. The reference direction used in the processing circuit may be fixed or dependent on the linear movement of the user. Alternatively, a multitude of other (known) head tracking systems (mainly consumer headphone or gaming applications) may be employed which use e.g. ultrasonic technology, infrared technology, transmitters/receivers, gyroscopes, or multiple sensors. For example, these head tracking systems may determine the head position relative to an environment, either by using a fixed reference with a stable (invariant) position relative to the environment (e.g. an infrared 'beacon, or using the earth magnetic field), or by using sensor technology that, once calibrated, does not drift significantly during the listening session (e.g. by using high-accuracy gyroscopes). Other implementations may include one or more cameras whose video signals are evaluated with adequate software.

[0017] The determined position and the rotation angle of the head 203 of the user wearing headphone 106 is used to control the transfer functions of filters 204-207. All possible (discrete) positions of the head 203 are associated with specific transfer functions $H'_{LL}(j\omega)$, $H'_{RL}(j\omega)$, $H'_{LR}(j\omega)$ and $H'_{RR}(j\omega)$ that vary with the head position. When adjusting variable transfer functions $C'_{LL}(j\omega)$, $C'_{RL}(j\omega)$, $C'_{LR}(j\omega)$ and $C'_{RR}(j\omega)$ of the filters 204-207 so that for each particular position the transfer functions $C'_{LL}(j\omega)$, $C'_{RL}(j\omega)$, $C'_{LR}(j\omega)$ and $C'_{RR}(j\omega)$ are the inverse of the transfer functions $H'_{LL}(j\omega)$, $H'_{RL}(j\omega)$, $H'_{LR}(j\omega)$ and $H'_{RR}(j\omega)$, the situation outlined above in connection with Figure 2 is true for every possible head position. The adjustments may be made, for example, by way of look-up tables which provide for each (discrete) position detected by the head tracking system 501 the transfer functions $C'_{LL}(j\omega)$, $C'_{RL}(j\omega)$, $C'_{LR}(j\omega)$ and $C'_{RR}(j\omega)$. The transfer functions $C'_{LL}(j\omega)$, $C'_{RL}(j\omega)$, $C'_{LR}(j\omega)$ and $C'_{RR}(j\omega)$ correspond to the actual transfer functions $H'_{LL}(j\omega)$, $H'_{RL}(j\omega)$, $H'_{LR}(j\omega)$ and $H'_{RR}(j\omega)$. Alternatively, the transfer functions $C'_{LL}(j\omega)$, $C'_{RL}(j\omega)$, $C'_{LR}(j\omega)$ and $C'_{RR}(j\omega)$ may be calculated from the detected positions using models or equation systems.

[0018] Referring to Figure 6, an exemplary audio signal distribution method may include receiving audio source signals to be reproduced by loudspeakers disposed at a first and fourth position (procedure 601), providing to the loudspeakers loudspeaker signals that represent the audio content to be reproduced by the loudspeakers (procedure 602), and providing to two speakers of a headphone, disposed at a second position and a third position, two headphone signals (procedure 603). The headphone signals comprise the loudspeaker signals filtered with electrical domain transfer functions (procedure 604). The electrical domain transfer functions may be configured to model acoustic domain transfer functions representing the acoustic paths between each of the first and fourth position and each of the second and third position so that at the second position and third position sound acoustically broadcasted by the loudspeakers is reduced or cancelled by sound broadcasted by the respective speaker of the headphone. The audio signal distribution method may further include receiving two audio source signals to be reproduced by the headphone (procedure 605). The two audio source signals to be reproduced by the headphone are combined with the loudspeaker signals filtered with electrical domain transfer functions to form the two headphone signals (procedure 606).

[0019] At least one additional audio source signal to be reproduced by at least one additional loudspeaker disposed at additional positions may be received (procedure 606) and at least one additional loudspeaker signal that represents the at least one additional audio source signal to be reproduced by the at least one additional loudspeaker may be provided to the at least one additional loudspeaker. The two headphone signals provided to the two speakers may further comprise the at least one additional loudspeaker signal filtered with additional electrical domain transfer functions, in which the additional electrical domain transfer functions may be configured to model acoustic domain transfer functions representing the acoustic paths between each additional position and each of the second position and third position so that at the second position and third position sound acoustically broadcasted by the at least one additional loudspeaker is reduced or cancelled by sound broadcasted by the related speaker. The position(s) of the loudspeaker(s), the positions of the speakers of the headphone (and maybe additional positions) are spatially constant and the related electrical domain transfer functions are timely constant. The method may further include receiving a headtracking signal indicative of the actual speaker positions (procedure 607), and, if the first position positions of the loudspeaker(s) are spatially constant and the positions of the speakers of the headphone are spatially variable, controlling the related electrical domain transfer functions according to the actual speaker positions (procedure 608).

[0020] While various embodiments of the invention have been described, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible within the scope of the invention. Accordingly, the invention is not to be restricted except in light of the attached claims and their equivalents.

Claims

1. An audio signal distribution system configured to:

receive an audio source signal to be reproduced by a loudspeaker disposed at a first position;
provide to the loudspeaker a loudspeaker signal that represents the audio source signal to be reproduced by the loudspeaker; and
provide to two speakers of a headphone, disposed at a second position and a third position, two headphone signals which comprise the loudspeaker signals filtered with electrical domain transfer functions, the electrical domain transfer functions configured to model acoustic domain transfer functions representing the acoustic paths between the first position and each of the second position and third position so that at the second position and third position sound acoustically broadcasted by the loudspeaker is reduced or cancelled by sound broadcasted by the respective speaker.

2. The audio signal distribution system of claim 1, further configured to receive at least one audio source signal to be reproduced by the headphone, the at least one audio source signal to be reproduced by the headphone is combined with the loudspeaker signals filtered with electrical domain transfer functions to form the two headphone signals.

3. The audio signal distribution system of claim 1or 2, further configured to:

receive at least one additional audio source signal to be reproduced by at least one additional loudspeaker disposed at additional positions; and
provide to the at least one additional loudspeaker at least one additional loudspeaker signal that represents the at least one additional audio source signal to be reproduced by the at least one additional loudspeaker; wherein the two headphone signals provided to the two speakers further comprise the at least one additional loudspeaker signal filtered with additional electrical domain transfer functions, the additional electrical domain transfer functions configured to model acoustic domain transfer functions representing the acoustic paths between each additional position and each of the second position and third position so that at the second position and third position sound acoustically broadcasted by the at least one additional loudspeaker is reduced or cancelled by sound broadcasted by the related speaker.

4. The audio signal distribution system of any of claims 1to 3, further configured to provide a wireless connection to the headphone.

5. The audio signal distribution system of any of claims 1to 4, wherein the first position, the second position and the third position and/or the additional positions are spatially constant and the related electrical domain transfer functions are timely constant.

6. The audio signal distribution system of any of claims 1to 4, further configured to receive a headtracking signal indicative of the actual speaker positions, wherein the first position and/or the additional positions are spatially constant, the second position and the third position are spatially variable, and the system is further configured to control the related electrical domain transfer functions according to the actual speaker positions.

7. The audio signal distribution system of any of claims 1to 6, further comprising at least one additional loudspeaker that is switched off when the headphone is in use.

8. An audio signal distribution method comprising:

receiving an audio source signal to be reproduced by a loudspeaker disposed at a first position;
providing to the loudspeaker a loudspeaker signal that represents the audio source signal to be reproduced by the loudspeaker; and
providing to two speakers of a headphone, disposed at a second position and a third position, two headphone

signals which comprise the loudspeaker signals filtered with electrical domain transfer functions, the electrical domain transfer functions configured to model acoustic domain transfer functions representing the acoustic paths between the first position and each of the second position and third position so that at the second position and third position sound acoustically broadcasted by the loudspeaker is reduced or cancelled by sound broadcasted by the respective speaker of the headphone.

9. The audio signal distribution method of claim 8, further comprising: receiving at least one audio source signal to be reproduced by the headphone, the at least one audio source signal to be reproduced by the headphone is combined with the loudspeaker signals filtered with electrical domain transfer functions to form the two headphone signals.

10. The audio signal distribution method of claim 8 or 9, further comprising:

receiving at least one additional audio source signal to be reproduced by at least one additional loudspeaker disposed at additional positions; and

providing to the at least one additional loudspeaker at least one additional loudspeaker signal that represents the at least one additional audio source signal to be reproduced by the at least one additional loudspeaker; wherein

the two headphone signals provided to the two speakers further comprise the at least one additional loudspeaker signal filtered with additional electrical domain transfer functions, the additional electrical domain transfer functions configured to model acoustic domain transfer functions representing the acoustic paths between each additional position and each of the second position and third position so that at the second position and third position sound acoustically broadcasted by the at least one additional loudspeaker is reduced or cancelled by sound broadcasted by the related speaker.

11. The audio signal distribution method of any of claims 8 to 10, further comprising: providing a wireless connection to the headphone.

12. The audio signal distribution method of any of claims 8 to 11, wherein the first position, the second position and the third position and/or the additional positions are spatially constant and the related electrical domain transfer functions are timely constant.

13. The audio signal distribution method of any of claims 8 to 12, further comprising: receiving a headtracking signal indicative of the actual speaker positions, wherein the first position and/or the additional positions are spatially constant, the second position and the third position are spatially variable, and the method further comprises:

controlling the related electrical domain transfer functions according to the actual speaker positions.

14. The audio signal distribution method of any of claims 8 to 13, further comprising switching off at least one further loudspeaker when the headphone is in use.

15. A program code of processing audio data, which program code, when being executed by a processor, is configured to carry out or control a method according to any of claims 8 to 14.

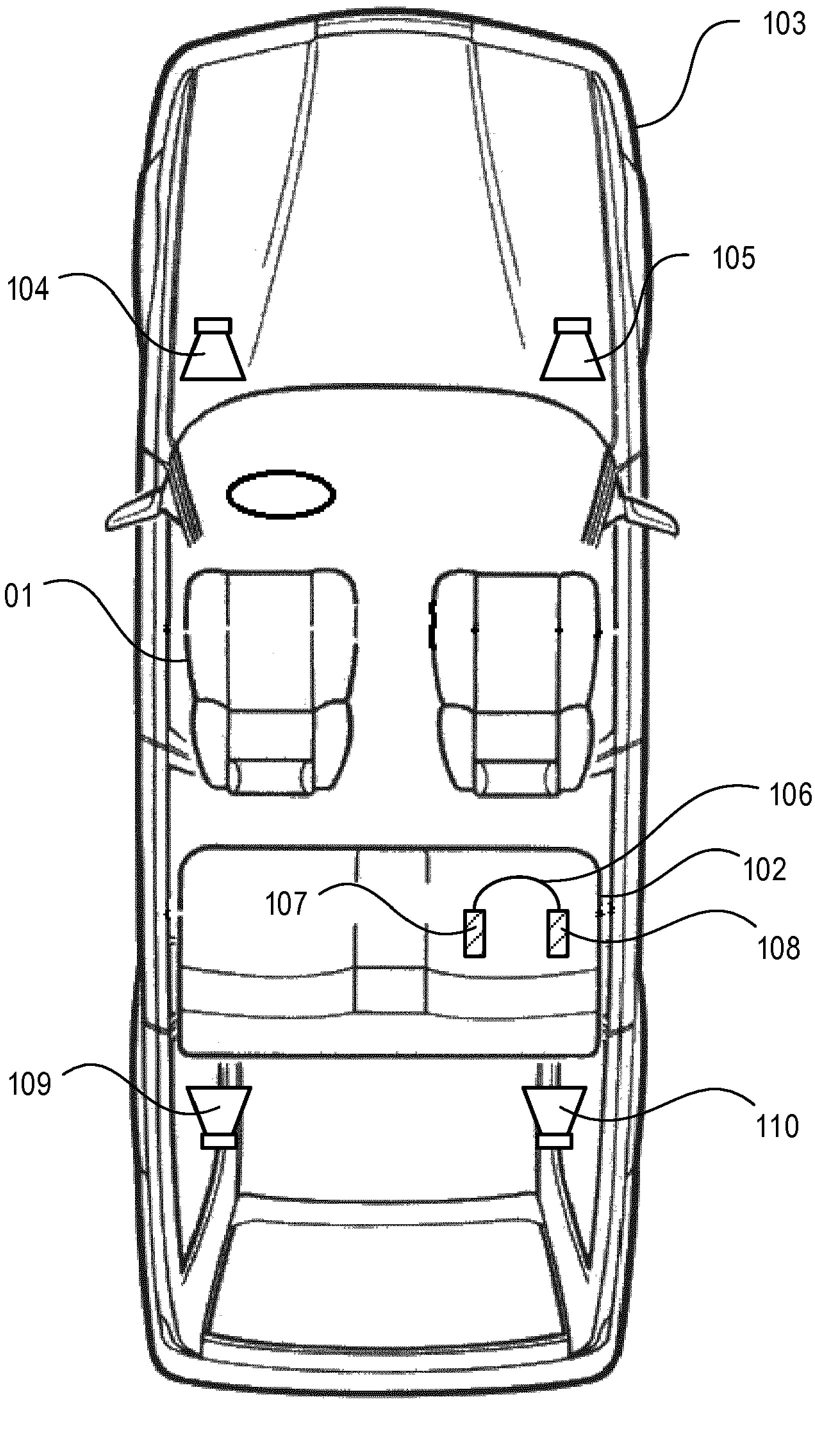
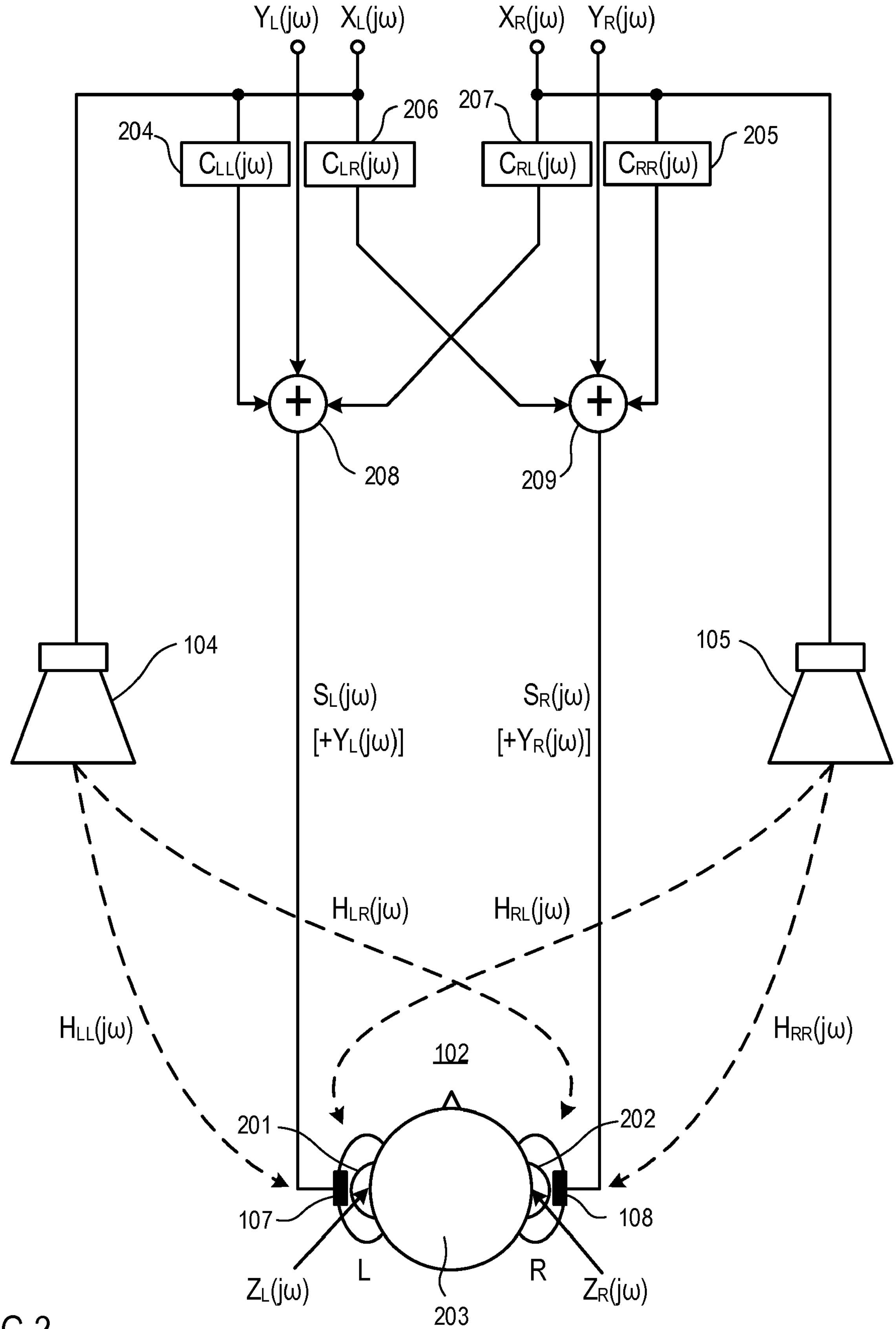


FIG 1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XL(jω)
XR(jω)
YR(jω)
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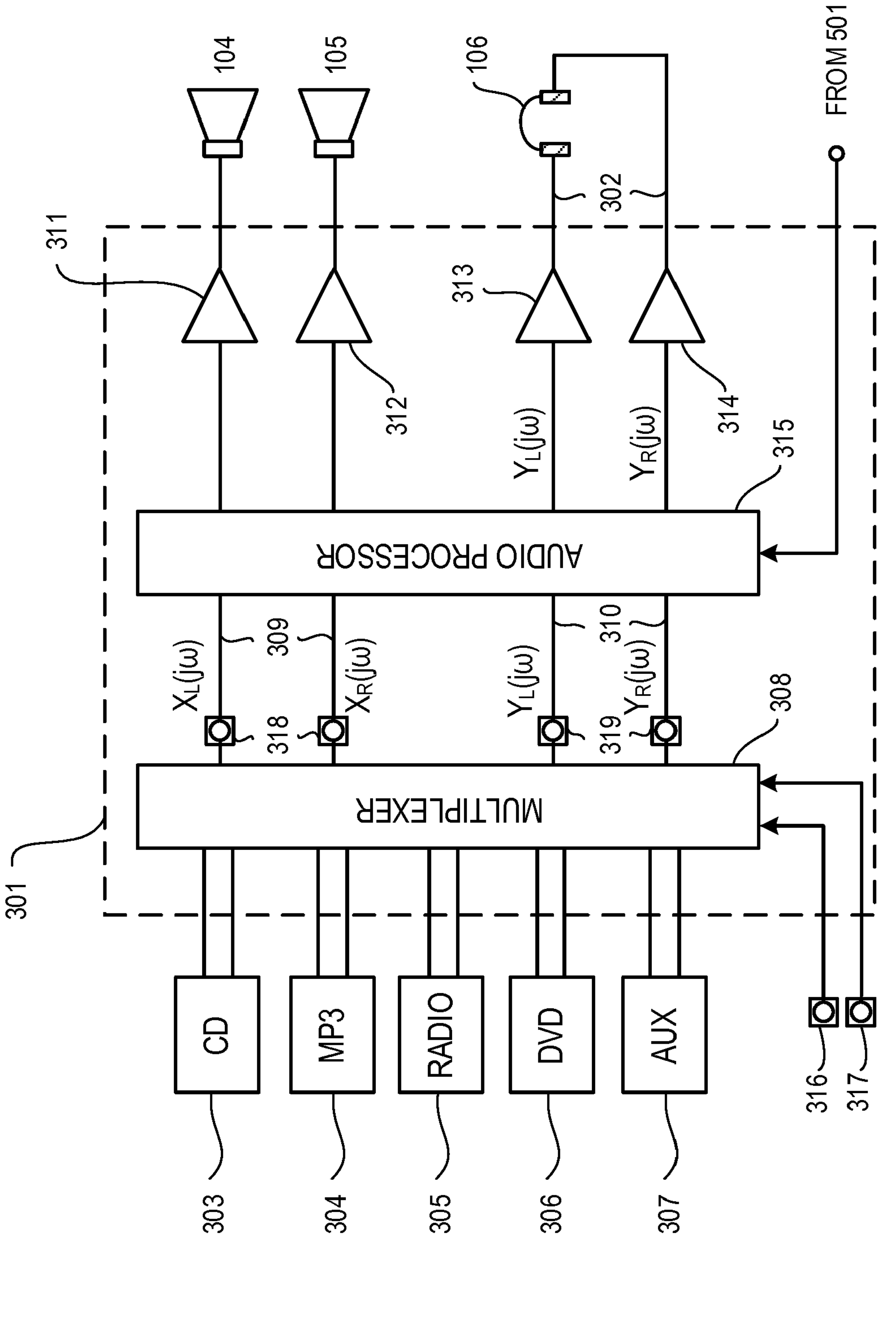
206
207
205
CLL(jω)
CLR(jω)
CRL(jω)
CRR(jω)
208
209
104
105
SL(jω)
[+YL(jω)]
SR(jω)
[+YR(jω)]
HLR(jω)
HRL(jω)
HLL(jω)
HRR(jω)
102
201
202
107
108
L
R
ZL(jω)
ZR(jω)
203

FIG 2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105
106
FROM 501
311
312
313
314
315
302
AUDIO PROCESSOR
$Y_L(j\omega)$
$Y_R(j\omega)$
$X_L(j\omega)$
$X_R(j\omega)$
309
310
318
319
308
MULTIPLEXER
301
CD
MP3
RADIO
DVD
AUX
303
304
305
306
307
316
317

FIG 3

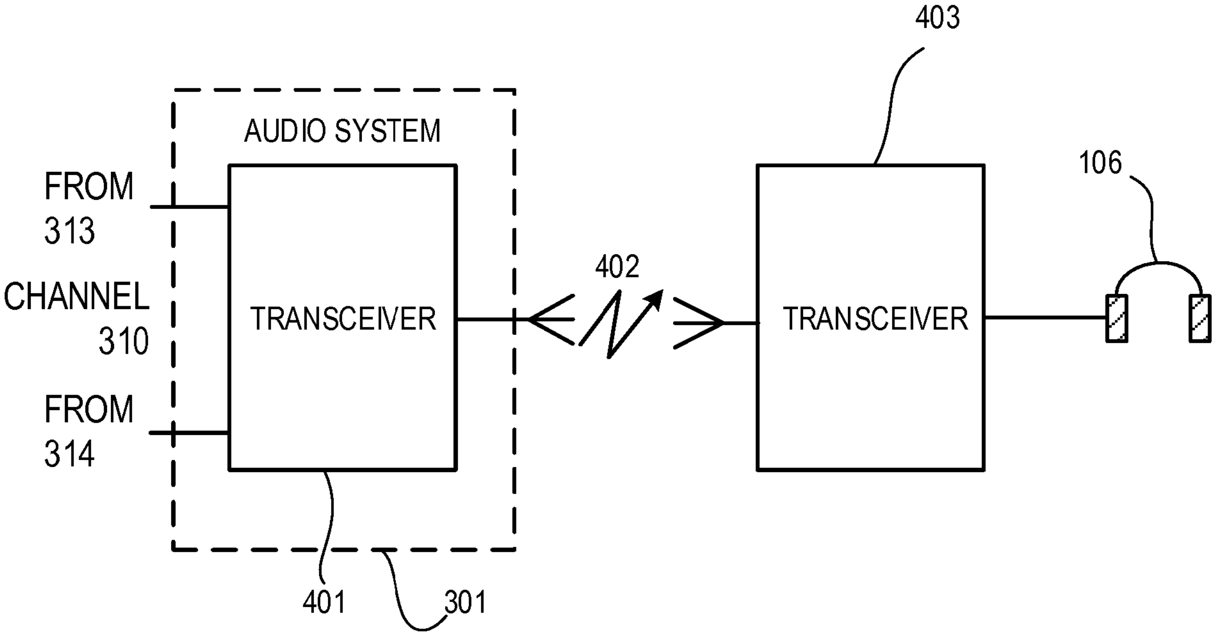
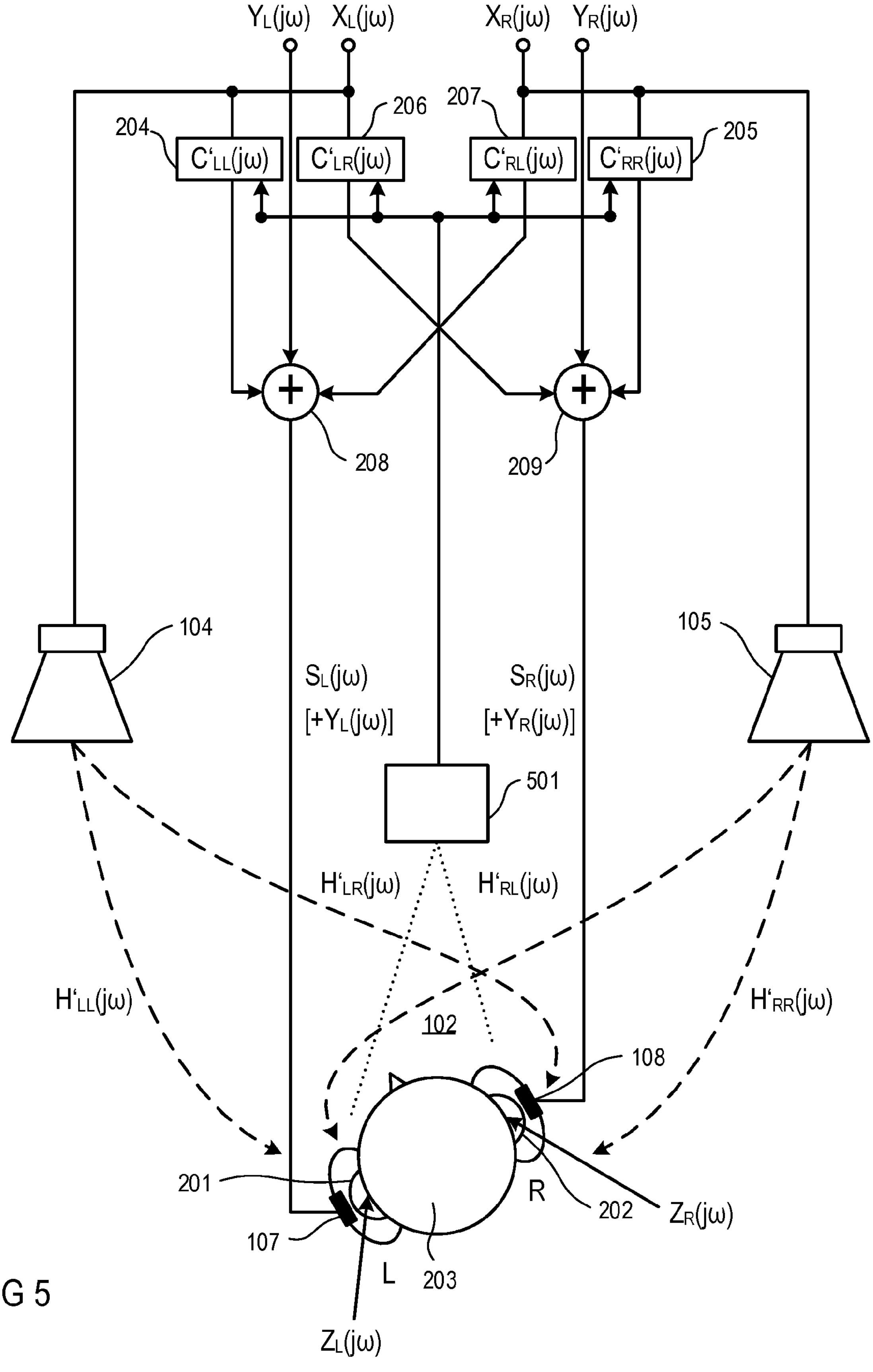

AUDIO SYSTEM
FROM 313
CHANNEL 310
FROM 314
TRANSCEIVER
402
403
TRANSCEIVER
106
401
301

FIG 4



YL(jω)
XL(jω)
XR(jω)
YR(jω)
204
C'LL(jω)
206
C'LR(jω)
207
C'RL(jω)
205
C'RR(jω)
208
209
104
105
SL(jω)
[+YL(jω)]
SR(jω)
[+YR(jω)]
501
H'LR(jω)
H'RL(jω)
H'LL(jω)
H'RR(jω)
102
108
201
R
202
ZR(jω)
107
L
203
ZL(jω)

FIG 5

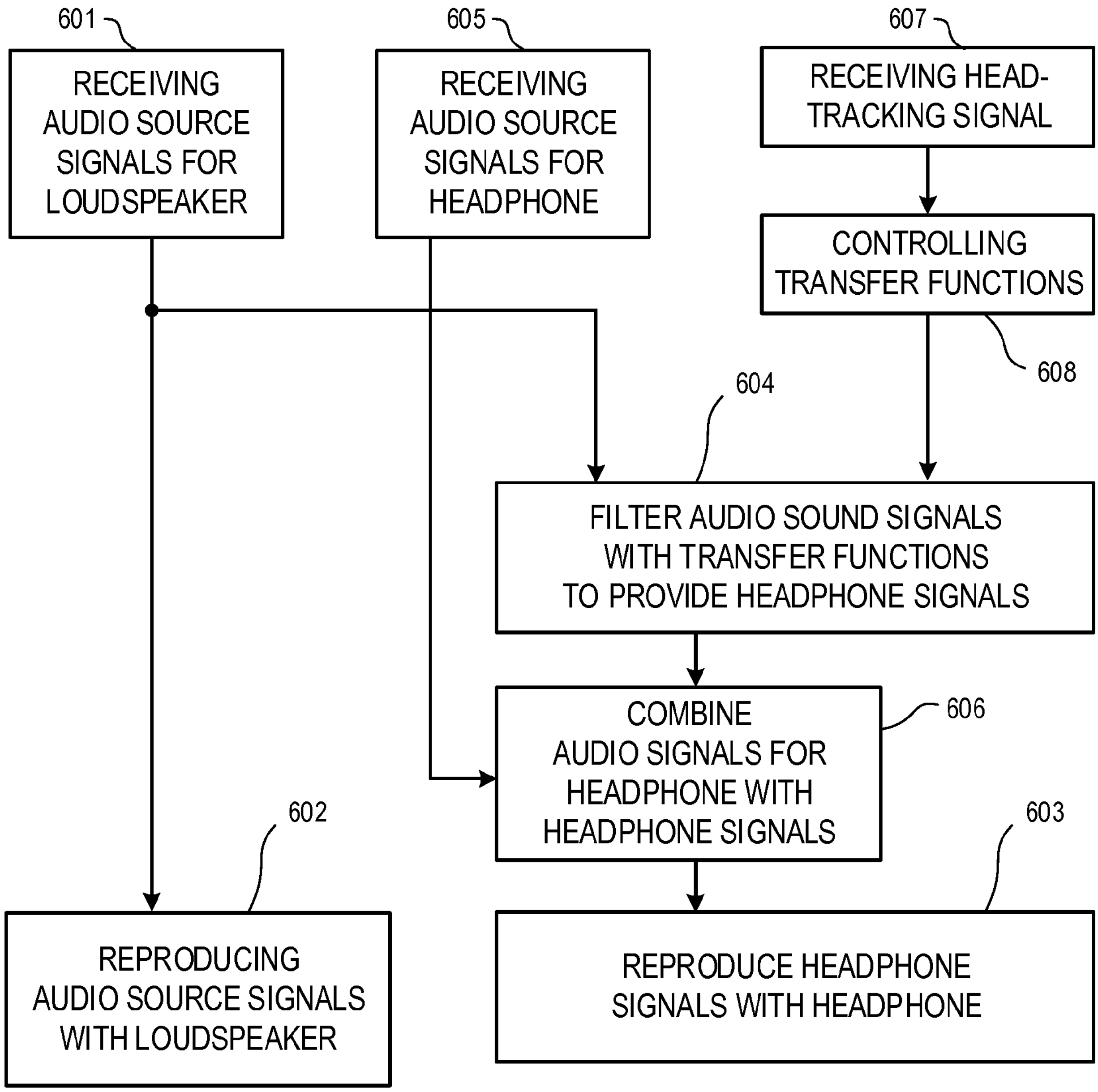

601
RECEIVING AUDIO SOURCE SIGNALS FOR LOUDSPEAKER
605
RECEIVING AUDIO SOURCE SIGNALS FOR HEADPHONE
607
RECEIVING HEAD-TRACKING SIGNAL
CONTROLLING TRANSFER FUNCTIONS
608
604
FILTER AUDIO SOUND SIGNALS WITH TRANSFER FUNCTIONS TO PROVIDE HEADPHONE SIGNALS
COMBINE AUDIO SIGNALS FOR HEADPHONE WITH HEADPHONE SIGNALS
606
602
603
REPRODUCING AUDIO SOURCE SIGNALS WITH LOUDSPEAKER
REPRODUCE HEADPHONE SIGNALS WITH HEADPHONE

FIG 6

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EUROPEAN SEARCH REPORT

Application Number
EP 15 20 0450

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Place of search	Date of completion of the search	Examiner
The Hague	14 April 2016	Lörch, Dominik

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