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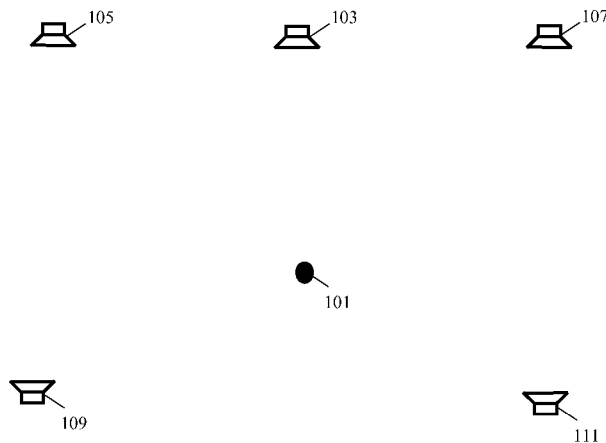
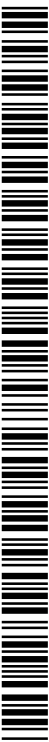


FIG. 1

(57) Abstract: An audio system generates drive signals for sound render channels driving a sound transducer. A user interface (409) receives a user input graphical representation of positions of the sound transducers and a processor (411) determines sound render positions for the sound transducers in response to the user input graphical representation. An input (401) receives a spatial multichannel signal comprising a plurality of spatial channels associated with a nominal sound source position. A signal linker (413) determines a set of associations between the spatial channels and the sound render channels in response to the sound render positions and the nominal sound source positions where an association between a spatial channel and a sound render channel indicates that the sound render channel is to be used for rendering the spatial channel. A driver (403) then generates drive signals for the sound render channels from input signals of the spatial channels in response to the set of associations.



An audio system and method of operating therefor

FIELD OF THE INVENTION

The invention relates to an audio system and a method of operation therefor, and in particular, but not exclusively, to generation for drive signals for loudspeakers of spatial surround sound system.

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BACKGROUND OF THE INVENTION

Spatial sound reproduction beyond simple stereo has become commonplace through applications such as home cinema systems. Typically such systems use loudspeakers positioned at specific spatial positions relative to a listening position. For example, a 5.1
10 home cinema system provides spatial sound via five loudspeakers being positioned with one speaker directly in front of the listening position (the center channel), one speaker to the front left of the listening position, one speaker to the front right of the listening position, one speaker to the rear left of the listening position, and one speaker to the rear right of the listening position. In addition, a non-spatial low frequency speaker is provided.

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Such conventional systems are based the reproduction of audio signals at specific nominal positions relative to the listening position. One speaker is typically provided for each audio channel and therefore speakers must be positioned at positions corresponding to the predetermined or nominal positions for the system. However, the requirement for loudspeakers to be in specific positions is often found to be highly undesirable to users and is
20 particularly inconvenient in the consumer market.

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Although users are expected to position speakers approximately at nominal positions relative to the listening position, deviations will occur in real use cases in consumers' homes. In particular, the angle and distance to the loudspeakers from the listening position varies from one home cinema setup to another. In order to address such variations, automatic optimization procedures have been developed. Typically, such
procedures are based on positioning a microphone at the listening position and radiating test signals from the loudspeakers. The test signals are received by the microphone and the system adapts the processing of the audio channels dependent on the received test signals.

For example, the volume for each individual channel may be adjusted based on the measured test signal for the corresponding loudspeakers.

However, although such compensation may improve the spatial listening experience and may provide some additional compensation for variations in the speaker setup, the loudspeakers are still required to be positioned in approximately the nominal configuration. Indeed, typically the compensation algorithm will fail if the actual loudspeaker positions deviate too much from the assumed nominal positions/angles.

Hence, an improved audio system would be advantageous and in particular a system allowing increased flexibility, facilitated operation, increased freedom in sound transducer placement, improved perceived audio quality, improved audio quality, an improved spatial user experience and/or improved performance would be advantageous.

SUMMARY OF THE INVENTION

Accordingly, the Invention seeks to preferably mitigate, alleviate or eliminate one or more of the above mentioned disadvantages singly or in any combination.

According to an aspect of the invention there is provided an audio system for generating drive signals for a plurality of sound render channels, each sound render channel providing a drive signal for a sound transducer; the audio system comprising: a user interface for receiving a user input graphical representation of positions of the sound transducers; a processor for determining sound render positions for the sound transducers in response to the user input graphical representation; an input for receiving a spatial multichannel signal comprising a plurality of spatial channels, each spatial channel being associated with a nominal sound source position; a signal linker for determining a set of associations between the spatial channels and the sound render channels in response to the sound render positions and the nominal sound source positions, an association between a spatial channel and a sound render channel indicating that the sound render channel is to be used for rendering the spatial channel; and a driver for generating drive signals for the sound render channels from input signals of the spatial channels in response to the set of associations.

The invention may provide an advantageous audio system for providing spatial audio. A more flexible system may often be provided with an increased freedom and flexibility in the positioning of the physical sound transducers. A low complexity, practical and easy-to-use user interface may allow the user to easily and intuitively provide relevant information for the system to configure the sound reproduction to the specific configuration.

For example, a user of a home cinema system may more freely and flexibly position speakers. The speaker positions may then be indicated to the system by the user inputting a graphical representation of the speaker position with the system subsequently selecting and adjusting the signals sent to the individual speakers such that the spatial sound presentation is adapted to the specific transducer positions.

The signal linker may for each spatial input channel select a subset of the sound render channels with the signal of the spatial input channel then being used to generate the drive signals for the selected sound render channels. For example, the right front input channel may be linked with one or more sound render channels having positions towards the right and front of the (nominal) listening position.

The use of a graphical representation allows a particularly advantageous user experience as it provides an intuitive means for indicating sound source positions. Thus, the interface to the user may be simple, easy to use, and highly intuitive.

The approach may allow an improved configuration and adaptation of the system since the graphical representation may provide information that e.g. is not available from simple measurements by a test-microphone at a listening position.

In some embodiments, the graphical representation may indicate a listening position which can be adjusted by the user. In such embodiments, the signal linker may further determine the set of associations in response to the listening position.

In accordance with an optional feature of the invention, the signal linker is arranged to associate a first spatial channel with a first sound render channel if the first sound render channel has a sound render position being a closest sound render position to a nominal position of the first spatial channel.

This may provide an improved spatial experience in many scenarios, and may in particular in many scenarios allow a perception of the first spatial channel originating from a position close to the nominal position for the first spatial channel. The approach may further in many scenarios provide a low complexity implementation and/or operation.

In accordance with an optional feature of the invention, the set of associations may associate more than one sound render channel with one spatial channel.

This may allow improved flexibility and may in many scenarios provide an improved audio experience. The approach may relax the relation between the number and assumed/nominal positions of spatial channels and the actual number and positions of sound transducers used for the audio rendering. A single sound transducer may thus be used by a plurality of input channels, e.g. to generate virtual sound positions for the spatial channels.

In accordance with an optional feature of the invention, the driver is arranged to generate drive signals for at least two sound render channels from an input signal of a first spatial channel to provide a virtual sound source position for the first spatial channel closer to a nominal position of the first spatial channel than sound render positions of the at least two sound render channels.

This may allow improved flexibility and may in many scenarios provide an improved audio experience. In particular, it may allow the sound rendered from the first channel to be perceived to originate from approximately the nominal position without requiring any physical sound transducers to be positioned at or necessarily close to that position.

In accordance with an optional feature of the invention, the set of associations may associate more than one spatial channel with one sound render channel.

This may allow improved flexibility and may in many scenarios provide an improved audio experience. The approach may relax the relation between the number and assumed/nominal positions of spatial channels and the actual number and positions of sound transducers used for the audio rendering.

In accordance with an optional feature of the invention, the driver is arranged to adjust at least one of an audio level and a delay of at least one of the drive signals in response to the sound render positions.

The audio system may provide an improved adaptation of the reproduced sound to the specific sound transducer setup. Specifically, the variations in the characteristics from the sound propagation from sound transducers to a listener as a function of the relative positions may be at least partially compensated. As a result an improved spatial experience may be provided.

In accordance with an optional feature of the invention, the user interface comprises: a display for displaying the user input graphical representation with icons representing positions of the sound transducers; an input interface for moving the icons on the display in response to a user input.

This may provide a particularly advantageous user interface for inputting sound transducer setup information.

In accordance with an optional feature of the invention, the input interface is operable to receive a user selection of an icon representing a position of a sound transducer; and wherein the audio system further comprises an audio generator for providing a test drive signal to the sound render channel corresponding to the selected icon.

This may facilitate operation and/or may allow a more flexible setup. For example, it may mitigate or avoid the requirement for predetermined associations between sound transducers and nominal positions and/or between the sound transducers and icons on the user interface. The approach may allow facilitated identification of corresponding icons and sound transducers.

For example, when a user touches an icon representing a sound transducer/sound transducer position on a touch screen display, a test drive signal may be generated for the corresponding sound render channel resulting in the corresponding sound transducer radiating sound. At the same time all other sound transducers may be kept silent (or the test signal may be a recognizable signal, such as a single tone). The process may provide an efficient feedback to a user and substantially facilitate the user input.

The feature may in particular allow a very flexible and user friendly system allowing the user to freely and randomly connect or couple the different sound transducers (specifically loudspeakers) to the different output channels of the multi-channel system. As a specific example, wires from loudspeakers may randomly be connected to the outputs from an amplifier without any consideration of any matching between the loudspeakers and outputs. Any loudspeaker may be connected to any output.

In accordance with an optional feature of the invention, the audio generator is arranged to adjust a volume of the test drive signal in response to a distance between a nominal listening position and the sound render position of the sound render channel corresponding to the selected icon.

This may further facilitate the user input and/or may improve the accuracy of the graphical representation. In particular, it may allow improved distance information to be provided.

In accordance with an optional feature of the invention, the audio system further comprises: a microphone input for receiving a microphone signal; and a calibrator for setting at least one of a delay, volume and sound render direction for at least one of the drive signals in response to the microphone signal.

This may provide improved audio quality and/or performance in many environments. The calibrator may perform a setup or configuration process based on the graphical representation. This may in particular allow a closer adaptation to specific conditions of the audio environment.

A close interworking between adaptation based on user input and on (e.g. automatic) calibration based on a microphone signal may provide improved performance in

many scenarios. For example, the microphone based calibration may be used to fine tune parameters having approximate values determined from the graphical representation.

In accordance with an optional feature of the invention, the audio system further comprises an initializer for initializing a calibration by the calibrator in response to the sound render positions.

This may provide improved audio quality and/or performance in many environments. For example, many automatic calibration/ configuration processes are based on finding local optimizations for the relevant parameters. By initializing such a calibration or configuration based on the graphical representation, the probability that the nearest local optimization is also a global optimization can be substantially increased. In addition, a much faster calibration can often be achieved.

In accordance with an optional feature of the invention, the user interface is part of a portable device operable to be remote from the driver.

This may provide a particularly advantageous user experience. The portable device may for example be a remote control or a mobile phone.

In accordance with an optional feature of the invention, the user input graphical representation further comprises an indication of a characteristic of a listening environment, and the driver is arranged to generate the drive signals in response to the indication.

This may provide improved quality of the audio or spatial experience. The characteristics may for example include positions of walls, furniture, etc.

In accordance with an optional feature of the invention, the user input graphical representation comprises an indication of a listening position, and the driver is arranged to generate the drive signals in response to the listening position.

This may provide a particularly advantageous system, and in particular may provide a practical, feasible, user friendly, and high performance system which can quickly and easily adapt and/or optimize the sound reproduction at different positions/areas.

In some embodiments, the driver may be arranged to adapt a direction of sound radiation for at least one sound render channel in response to the characteristic.

This may provide increased flexibility in sound transducer setup and/or may provide an improved spatial experience from the specific positions. E.g. the approach may be used to provide a sound reaching the listening position from a direction at which no sound transducer has been positioned.

According to an aspect of the invention there is provided a method of generating drive signals for a plurality of sound render channels, each sound render channel providing a drive signal for a sound transducer; the method comprising: receiving a user input graphical representation of positions of the sound transducers; determining sound render positions for the sound transducers in response to the user input graphical representation; receiving a spatial multichannel signal comprising a plurality of spatial channels, each spatial channel being associated with a nominal sound source position; determining a set of associations between the spatial channels and the sound render channels in response to the sound render positions and the nominal sound source positions, an association between a spatial channel and a sound render channel indicating that the sound render channel is to be used for rendering the spatial channel; and generating drive signals for the sound render channels from input signals of the spatial channels in response to the set of associations.

These and other aspects, features and advantages of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be described, by way of example only, with reference to the drawings, in which

Figures 1-3 illustrate examples of loudspeaker setups for spatial audio provision;

Figure 4 illustrates an example of an audio system in accordance with some embodiments of the invention;

Figure 5 illustrates an example of a graphical representation of an audio system in accordance with some embodiments of the invention;

Figure 6 illustrates an example of a portable device of an audio system in accordance with some embodiments of the invention;

Figure 7 illustrates an example of elements of a portable device of an audio system in accordance with some embodiments of the invention; and

Figure 8 illustrates an example of elements of a driver circuit of an audio system in accordance with some embodiments of the invention.

DETAILED DESCRIPTION OF SOME EMBODIMENTS OF THE INVENTION

The following description focuses on embodiments of the invention applicable to a surround sound home cinema system, and in particular to a five channel surround sound home cinema system. However, it will be appreciated that the invention is not limited to this application but may be applied to many other spatial audio systems.

5 Home cinema systems provide a spatial experience using a plurality of loudspeakers positioned at or close to nominal positions. Thus, a spatial multi-channel signal is provided with a signal for each of the nominal positions of a loudspeaker. Fig. 1 illustrates an example of a nominal setup for a five channel surround sound system.

10 In the example, the loudspeakers are assumed to be positioned around a listening position 101 with a speaker directly in front of the listening position 101 (the center speaker 103), a speaker to the front left of the listening position (the front left speaker 105), a speaker to the front right of the listening position (the front right speaker 107), a speaker to the rear left of the listening position (the left surround speaker 109), and a speaker to the rear right of the listening position (the right surround speaker 111).

15 The spatial audio signal is generated to provide the desired spatial experience when the loudspeakers are positioned in accordance with the nominal setup relative to the listening position. Accordingly, users are required to position their speakers at specific locations relative to the listening position in order to achieve the optimum spatial experience. However, in practice this is inconvenient and in many cases impossible or at least
20 unacceptable to do. Therefore, typical surround sound setups only approximate the nominal setup resulting in a degraded spatial experience.

Indeed, the restrictions on speaker positioning is considered one of the main disadvantages of spatial audio systems. Indeed, users would prefer to be able to position speakers at positions reflecting the specific preferences and requirements in the individual
25 environment.

In the following, an audio system will be described which is arranged to provide a spatial experience yet to provide additional freedom in the positioning of loudspeakers and/or a facilitated loudspeaker set-up. Indeed, the system adapts to specific loudspeaker setups, and seeks to provide an approach where a user may position speakers
30 relatively freely with the system then adapting its operation to the specific speaker setup. Thus, rather than requiring the positioning of the speakers to be adapted to the spatial audio, the approach seeks to adapt the audio system to the specific speaker setup.

The system may provide a very advantageous spatial experience in many scenarios. For example, a user may freely position speakers to surround the listening position

but without being at predetermined or nominal positions. The audio system then adapts to the speaker positions to provide a spatial experience that still relatively closely corresponds to that which would have been provided by a direct rendering of the received multi-channel signal from loudspeakers at the nominal positions. Examples of possible loudspeaker setups are illustrated in Figs. 2 and 3.

In contrast to conventional systems where each output channel is statically and fixedly linked to a an input spatial channel so that the corresponding speaker must be placed at the corresponding nominal position, the system described in the following implements a dynamic linking between the spatial input channels and the output channels. Thus each output channel is not associated with a specific position and is not predetermined to correspond to a specific input channel. This is in direct contrast to conventional approaches wherein the audio system merely amplifies each input signal to generate an output signal that directly corresponds to the input spatial channel, and thus is for a speaker that must be positioned at the nominal position to provide the desired spatial effect.

In the system described in the following, sound transducers and specifically loudspeakers may be positioned by the user in the audio environment without consideration of which input channel is to be rendered by the speaker. The sound transducer may specifically be a loudspeaker, and the following description will for clarity and brevity assume that each sound transducer is a loudspeaker (e.g. comprising a plurality of drivers). In the system, the user may position loudspeakers without considering the link to the input channels. The audio system may then proceed to adapt the processing such that the implemented speaker setup provides a spatial experience corresponding to that which would be achieved for a conventional setup with speakers at the nominal positions. Thus, rather than require a close correlation between the actual speaker positions and the nominal positions, the audio system allows a large variation in the actual speaker positions with the system adapting itself to reflect the specific speaker setup.

Fig. 4 illustrates an example of an audio system in accordance with some embodiments of the invention.

The audio system comprises a receiver 401 which receives a spatial multichannel signal. The multichannel signal comprises a plurality of spatial channels, each of which is associated with a nominal sound source position. The input signal is thus a signal where each channel is intended to be rendered from a specific nominal position relative to the listening position. In the specific example, the input signal is a five channel surround sound system with a nominal speaker setup as illustrated in Fig. 1. Thus, the input signal comprises

a center channel, a front left channel, a front right channel, a surround left channel and a surround right channel. It will be appreciated that the input signal may also comprise non-spatial signals, such as a Low Frequency Effects (LFE) channel.

In the example, the receiver 401 demultiplexes the received multichannel
5 signal to provide the individual spatial channel signals. In some embodiments, the input signal may be an encoded signal and the receiver 401 may include a decoder for generating the signals of the individual spatial channels. In some embodiments, the multichannel signal may be provided as a downmixed signal wherein the spatial channels are downmixed to a lower number of channels (e.g. to a mono or stereo signal). In such embodiments, the
10 receiver 401 may include functionality for upmixing, or equivalently the multichannel signal may be considered to be received by the receiver 401 from an internal or external upmixing unit.

The audio system generates drive signals for a number of sound render channels. Each sound render channel provides one drive signal for a sound transducer which
15 in the specific example is a loudspeaker. Hence, each sound render channel (output channel) corresponds to a specific sound source position in the listening environment, namely to the position of the loudspeaker driven by the drive signal. Thus, the audio system generates the loudspeaker drive signals from the spatial input signals. However, in the system, the link/association between the input channels and loudspeakers (and loudspeaker positions) is not
20 predetermined or fixed but is dynamically updated and determined for the individual loudspeaker setup.

In the system of Fig. 4, the receiver 401 is coupled to a driver 403 which generates a drive signal for each sound render channel from the input signals. Thus, the driver 403 receives the signals of all the spatial input signals and in response generates the
25 drive signals for each loudspeaker. Fig. 4 illustrates an amplifier 405 and a loudspeaker 407 for each sound render channel, but it will be considered that these elements may be considered external to or as part of the audio system. The amplifiers 405 amplify the signal of each sound render channel to the appropriate levels for the loudspeakers 407.

In the specific example, the loudspeakers 407 are coupled to the audio system
30 via physical wires, and in this example the amplifiers 405 may be included in a suitable device together with the receiver 401 and the driver 403. The device may for example be a home cinema amplifier. However, in the example, the device does not have any predetermined relationship between the sound render channel outputs (i.e. speaker outputs) and assumed positions of the corresponding loudspeakers. Rather, the device merely provides

a number of outputs that may be connected to speakers at any position. Thus, the user needs not consider which speaker output to use for a specific speaker but can rather use any of the outputs for any of the speakers. Thus, the user can simple connect the speaker wires freely to the different speaker outputs. This simplifies the setting up of e.g. a home cinema system which for many users in especially the consumer market is considered to otherwise be complex and cumbersome.

In other embodiments, the signal may e.g. be fed wirelessly to the speakers and the amplifiers 405 may be implemented together with the speakers 407 rather than in the driver unit. For example, the connections between a centralized audio device and the individual speakers may be implemented over a shared wireless network. The loudspeakers may register with the centralized audio device and be assigned a network address. Each loudspeaker may be treated in exactly the same way and without any considerations of positions when the address is assigned. This may allow for a very simple, flexible and efficient set up process.

Thus, in the system of Fig. 4, the audio system does not have any predetermined knowledge and assumption about positions of speakers. Rather, it is initially only known that a number of speakers are connected to the system but there is no spatial assumption or information associated with the individual speaker outputs (and thus with the sound render channels).

Accordingly it is not possible for the system to use a predetermined allocation of input channels to sound render channels. For example, it is not known which output (sound render channel) is connected to a speaker which is positioned to best provide a perception of a sound source directly in front of the listening position. It is therefore not possible to determine which output (sound render channel) should be fed the input signal received for the center channel.

Instead, the system is arranged to dynamically adapt and select the links between the input channels and the sound render channels. In particular, the driver 403 generates the drive signals for the render channels from input signals of the spatial channels based on a set of associations between the input spatial channels and the sound render channels.

For example, an association may indicate that a first render channel is suitable for providing the perception of a sound source originating from in front of the listening position, and the drive signal for that sound render channel will therefore be generated from the input center channel. Another association may indicate that a second sound render

channel is suitable for providing the perception of a sound source originating from the right and front of the listening position, and the drive signal for that sound render channel will therefore be generated from the front right channel. Typically associations will be provided for all input channels but in some embodiments or scenarios, one or more input channels may not have any associations and therefore may not be rendered.

In the system, the determination of suitable associations is based on a graphical representation of the loudspeaker setup provided by a user.

Specifically, the audio system of Fig. 4 comprises a user interface 409 which receives a user input graphical representation of the positions of the sound transducers.

The user interface 409 in the example of Fig. 4 comprises a touch screen wherein a graphical representation of the listening environment is displayed. In the example, the graphical representation is a simple and stylized representation of the environment with a graphical element (icon) representing the listening position and a graphical element (icon) for each sound render channel. An example of such a graphical representation is illustrated in Fig. 5.

The user may in this example simply move the icons representing the loudspeakers to positions that reflect the positions of the loudspeakers in the environment. Thus, the user can move the graphical elements representing the speakers (in the example of Fig. 5 represented by dark circles) to correspond to the physical location of the speakers relative to the user. In the example, the top of the screen corresponds to the position directly in front of the user/listening position.

In the example, the graphical representation is presented on a display which is a touch screen display. Accordingly, the user can simply touch the icons representing the loudspeaker positions and move them to the desired position in the graphical representation.

Thus, a very simple and intuitive, user interface is provided.

The user interface is coupled to a position processor 411 which receives data describing the graphical representation. The position processor 411 proceeds to determine sound render positions for the sound transducers in response to the graphical representation. Thus, the position processor 411 determines position values for the loudspeakers based on the graphical representation. The position values may for example determine a distance and angle from the listening position to the individual speakers. The distances may either be absolute or relative values. Additionally or alternatively, the positions may be determined as coordinates in a two dimensional representation of the listening environment.

In a simple embodiment, the positions of the loudspeakers in the listening environment may simply be determined by scaling of the relative distances between the icons in the graphical representation.

5 The position processor 411 is coupled to a linker 413 which proceeds to determine the set of associations between the input spatial channels and the output sound render channels based on the positions determined for the loudspeakers and on the nominal sound source positions. The linker 413 generates a number of associations where each association represents a signal path link from the corresponding spatial channel to the corresponding sound render channel. The association between a spatial channel and a sound
10 render channel indicating that the sound render channel is to be used for rendering the spatial channel. An association between a spatial channel and a sound render channel may specifically be indicative of a weight of the spatial channel in the drive signal for the sound render channel. A zero weight corresponds to no association, i.e. to a scenario where the sound render channel contains no contribution from the spatial channel.

15 The set of associations are fed to the driver 403 which proceeds to generate drive signals for the output sound render channels based on the set of the associations.

As a low complexity example, the linker 413 may generate one association for each input spatial channel. In this example, one loudspeaker is used to render each input spatial channel. The linker may select the associations between loudspeakers and spatial
20 channels such that the speaker indicated by the graphical representation to be closest to the nominal position for a given spatial channel is associated with the sound render channel for that speaker.

In such an example, the driver 403 may simply correspond to a switch matrix that can switch the input signals of the spatial signals to the best suited output sound render
25 channel.

In such a system, the central audio device may be provided with simple speaker outputs that are not labeled but rather are merely provided as identical and non-specific speaker outputs. The user can then place the speakers and connect them to the device using any speaker output for any speaker. The user then moves the graphical elements
30 representing the speakers on the touch screen display to represent their physical location relative to the user. The audio system in response proceeds to switch the input channels to the appropriate speaker outputs to provide a suitable spatial experience.

The user interface may in many scenarios be provided as a portable device which can be operated remotely from the central speaker drive unit. For example, the user interface may be provided as an application on a mobile phone or by a remote control.

Fig. 6 shows an example where the user interface is provided in a mobile phone and Fig. 7 illustrates elements of a remote portable device for providing the user interface. The portable device comprises a display 701 which is driven by a display controller 703 which presents the graphical representation on the display. The display 701 is in the example a touch screen which is coupled to an input 705 that can detect and interpret the touches on the screen. The portable device comprises a user interface controller 707 which receives the signal from the input 705 and provides data describing the graphical representation to the display controller 703. When a user operates the screen, this is detected by the user interface controller 707 which accordingly adjusts the graphical representation. The user interface 707 is further coupled to a transceiver 709 which communicates with the central audio device. The communication may for example be via a wireless communication, such as for example using a BluetoothTM connection. The transceiver 709 transmits data describing the graphical representation to the central audio device which proceeds to determine the transducer positions and the associations.

It will be appreciated that the exact functionality distribution between the central audio unit and the portable device may depend on the preferences and requirements of the individual embodiment. For example, the position processor 411 and possibly the linker 413 may be implemented in the portable device or in the central audio device.

In the previous example, the routing between input channels (the spatial channels) and the output channels (the sound render channels) is determined based on the user input graphical representation. This may substantially facilitate the setting up by non-expert users and may provide a much improved user experience.

However, in addition, the user input graphical representation may also be used to adapt signal processing characteristics of the system. In particular, an audio level and/or delay for the drive signals may be set in response to the sound render positions determined from the graphical interface. In particular, the delay and sound level may be increased for an increasing distance from the loudspeakers to the listening position. Thus, the system may on the basis of the graphical representation compensate for different propagation delays and attenuations thereby providing an improved audio experience.

In some embodiments, each spatial channel may be rendered in a single sound render channel and each sound render channel may render only one spatial channel.

However, in other embodiments, a spatial channel may be rendered in a plurality of channels and/or a sound render channel may comprise contributions from a plurality of channels. Further, the number of sound render channels may be different from the number of spatial channels.

5 Each association between a spatial channel and a sound render channel indicates that a signal path exists from the spatial channel to the sound render channel. The set of associations generated by the linker may comprise a plurality of associations for a spatial channel and/or a plurality of associations for a sound render channel. Thus, in some embodiments, the set of associations may associate more than one sound render channel with
10 one spatial channel and/or may associate more than one spatial channel with one sound render channel.

 Indeed, the system may be arranged to render a spatial channel through a plurality of sound transducers such that the combined effect results in a perceived sound source of the spatial channel to be closer to the nominal position of the spatial channel than
15 of the positions of the loudspeakers rendering the sound. Thus, the system uses the information of the loudspeaker positions to generate virtual sound positions in between the loudspeakers.

 As a low complexity example, the linker 413 may for each spatial channel determine the two sound transducers that are closest to the nominal position on each side.
20 The signal of the spatial channel may then be rendered by these two loudspeakers using amplitude panning to provide a perception of the sound source being in between the two loudspeakers. For example, if the nominal position is in the middle of the two loudspeaker positions, the gain for the two drive signals are equal and if the nominal position is closer to one of the loudspeakers, the gain for this loudspeaker will be set higher than for the other
25 loudspeaker. Furthermore, the overall gain may be set dependent on the distance from the listening position to the two loudspeaker relative to the distance to the nominal position and/or relative to the distance to loudspeakers used for other channels.

 In such an embodiment, each spatial channel is thus rendered by two sound transducers and each sound transducer may render more than one spatial channel.

30 In a more general implementation, each drive signal may be generated as a weighted combination of the input spatial channels, i.e. each sound render channel may possibly comprise contributions from all spatial channels. For example, for five spatial channels and four sound transducers (and thus four sound render channels), the output drive signals may be determined as:

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} c_{11} & c_{21} & c_{31} & c_{41} & c_{51} \\ c_{12} & c_{22} & c_{32} & c_{42} & c_{52} \\ c_{13} & c_{23} & c_{33} & c_{43} & c_{53} \\ c_{14} & c_{24} & c_{34} & c_{44} & c_{54} \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix}$$

5

where x_n represents input spatial channel n , y_m represents output sound render channel m , and $c_{k,l}$ represents the association between input spatial channel k and output sound render channel. If no association exists the value of the corresponding matrix coefficient is zero.

For five spatial channels and six sound transducers, the output drive signals

10 may be determined as:

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \end{bmatrix} = \begin{bmatrix} c_{11} & c_{21} & c_{31} & c_{41} & c_{51} \\ c_{12} & c_{22} & c_{32} & c_{42} & c_{52} \\ c_{13} & c_{23} & c_{33} & c_{43} & c_{53} \\ c_{14} & c_{24} & c_{34} & c_{44} & c_{54} \\ c_{15} & c_{25} & c_{35} & c_{45} & c_{55} \\ c_{16} & c_{26} & c_{36} & c_{46} & c_{56} \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix}$$

15

In this example, the output drive signals may thus be generated from a gain matrix which provides associations between input spatial channels and output sound render channels. Typically, a large number of the coefficients of the gain matrix will be zero corresponding to there being no association between the corresponding input spatial channel and output sound render channel.

20

In some embodiments, the signal paths may also include other compensations or signal processing such as e.g. frequency compensations (e.g. filtering). In particular, the signal paths may include a delay which specifically may compensate for differences in the distance between the sound transducers and the listening position.

25

As an example, the driver 403 may for each spatial channel provided the functionality illustrated in Fig. 8. Thus, a signal path with a variable gain and delay may be provided to each of the sound render channels. The values of the gain and delay may be determined fully or partially based on the graphical representation. If no association is

provided between a spatial channel and a sound render channel, the corresponding gain will be zero. It will be appreciated that the delays will typically be the same for all spatial channels for a given sound render channel, and that a single delay may accordingly be applied to the drive signal generated by combining the individual contributions from the different spatial channels.

The system may accordingly provide a very flexible setup. A user may simply connect (e.g. directly, or using a wireless or network based connections) as many speakers as he would like to use. The speakers may be positioned freely but may preferably be situated to surround the listening position. The user then uses his portable device to quickly and easily generate a graphical representation of the speaker setup, e.g. simply by sliding some icons to appropriate positions on a touch screen. In response, the system automatically adapts to provide an appropriate spatial experience, and may specifically proceed to generate virtual sound sources from positions corresponding to (or approximating) the nominal positions of the received spatial multi-channel signal. The user may freely select how many speakers to use and may position these freely. Increasing the number of speakers used, and providing a more even distribution of the loudspeakers around the listening position, may typically increase the accuracy of the virtual sound source positioning and the resulting spatial experience. However, in some embodiments it may be more attractive to reduce cost and complexity, and therefore the number of loudspeakers may be kept low. Thus, the user has a high degree of flexibility in both how many and where to position loudspeakers, and the same audio system may be used as it can easily adapt to the individual configuration.

In some embodiments, the system may be arranged to generate a sound from a sound transducer in response to a selection of the corresponding icon on the display. For example, when the user touches an icon corresponding to a sound source position on the display, this icon may e.g. change color to indicate that it has been selected. In response to the selection, an audio generator may provide a test drive signal on the corresponding sound render channel resulting in the loudspeaker connected to the output of that sound render channel rendering the corresponding sound.

The test drive signal may typically represent a distinct and detectable sound such as a pure tone or a white noise signal. Thus, when the icon is selected, the user will immediately hear a characteristic and distinct sound coming from the corresponding loudspeaker. He may then easily slide or move the icon to a position corresponding to the position of the loudspeaker radiating the sound. Thus a low complexity and intuitive approach is achieved for the user allowing him to easily identify which speaker is associated

with which icon. No predetermined information or correlation between loudspeaker positions and the sound render channels is required, and specifically any output can be used with any loudspeaker.

5 In some embodiments, the generated test signal, and thus the rendered test audio, may have a volume that is adjusted in response to the distance from the nominal listening position to the position of the icon for the sound transducer position on the display. Specifically, the volume may be increased as the icon is moved further away and decreased when it is moved closer. This may assist the user in positioning the icons to reflect the actual sound positions, and may compensate for differences in the distances and thus in attenuation
10 of the sound from the different loudspeakers.

In some embodiments, the processing of the audio system may be setup based only on the graphical representation. However, in many embodiments, the system may further be arranged to perform an automatic or semi-automatic calibration based on a microphone signal.

15 Specifically, the system may comprise a microphone input which is coupled to a microphone that can be positioned at the listening position. A calibrator may then receive the microphone signal and adjust a characteristic of the signal processing dependent on the microphone signal. Specifically, a delay, volume and/or sound render direction of the drive signals may be adjusted dependent on the microphone signal.

20 For example, a test generator may generate a test signal which is fed to one of the sound transducers. The time difference between the generated test signal and the received signal by the microphone may be used to determine the propagation delay from the sound transducer to the listening position. This may be performed for all sound render channels and the appropriate relative delays may be applied to ensure that sound is received substantially
25 simultaneously.

Thus, the approach may combine the approach of calibrating/adapting the system based on the graphical representation with a microphone based calibration/adaptation. An improved performance may be achieved by combining the two approaches. For example, the calibration based on the graphical representation may provide a coarse
30 adaptation/calibration with some parameters being fine-tuned using the microphone measurement.

Specifically, the sound render positions determined from the graphical representation may be used to initialize the calibration process based on the microphone signal. For example, the graphical representation may be used to determine initial estimates

for delay and volume as well as to setup the virtual sound source positioning. The calibration based on the microphone signal may then proceed based on these initial values. Calibration processes may often determine local optimizations and by initializing the calibration with approximate initial values, the chance of the determined local optimum is also the global optimum is also substantially increased.

Furthermore, the graphical representation can be used to determine or adapt to characteristics that are typically not addressed by a microphone calibration. For example, the angle of the sound reaching the listening position may be estimated based on the graphical representation. Further, the virtual sound source positioning may be determined based on the graphical representation with the subsequent microphone calibration being used to calibrate characteristics of the virtual sound source.

In some embodiments, the user input graphical representation may comprise an indication of a characteristic of a listening environment. This additional information may then be used to adapt the signal processing of the driver 403.

For example, the graphical representation may be enhanced to allow different listening positions to be indicated, such that the drive signal generation may compensate for differences in the listening position.

As another example, the user may be able to indicate the presence of walls or other obstacles in the listening environment. This may specifically indicate sound reflections.

Thus, the graphical representation can be used to estimate e.g. a direction in which sound should be radiated from a sound transducer in order to reach the listening position from a reflected direction corresponding to a desired virtual sound source direction. For example, a wall to the rear of the listening position may be indicated on the graphical representation. In response, sound may be radiated towards this wall to provide reflected sound reaching the listening position from behind.

It will be appreciated that the above description for clarity has described embodiments of the invention with reference to different functional circuits, units and processors. However, it will be apparent that any suitable distribution of functionality between different functional circuits, units or processors may be used without detracting from the invention. For example, functionality illustrated to be performed by separate processors or controllers may be performed by the same processor or controllers. Hence, references to specific functional units or circuits are only to be seen as references to suitable means for providing the described functionality rather than indicative of a strict logical or physical structure or organization.

The invention can be implemented in any suitable form including hardware, software, firmware or any combination of these. The invention may optionally be implemented at least partly as computer software running on one or more data processors and/or digital signal processors. The elements and components of an embodiment of the invention may be physically, functionally and logically implemented in any suitable way. Indeed the functionality may be implemented in a single unit, in a plurality of units or as part of other functional units. As such, the invention may be implemented in a single unit or may be physically and functionally distributed between different units, circuits and processors.

Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognize that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term comprising does not exclude the presence of other elements or steps.

Furthermore, although individually listed, a plurality of means, elements, circuits or method steps may be implemented by e.g. a single circuit, unit or processor. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also the inclusion of a feature in one category of claims does not imply a limitation to this category but rather indicates that the feature is equally applicable to other claim categories as appropriate. Furthermore, the order of features in the claims do not imply any specific order in which the features must be worked and in particular the order of individual steps in a method claim does not imply that the steps must be performed in this order. Rather, the steps may be performed in any suitable order. In addition, singular references do not exclude a plurality. Thus references to "a", "an", "first", "second" etc. do not preclude a plurality. Reference signs in the claims are provided merely as a clarifying example shall not be construed as limiting the scope of the claims in any way.

CLAIMS:

1. An audio system for generating drive signals for a plurality of sound render channels, each sound render channel providing a drive signal for a sound transducer; the audio system comprising:

5 a user interface (409) for receiving a user input graphical representation of positions of the sound transducers;

a processor (411) for determining sound render positions for the sound transducers in response to the user input graphical representation;

an input (401) for receiving a spatial multichannel signal comprising a plurality of spatial channels, each spatial channel being associated with a nominal sound source position;

10 a signal linker (413) for determining a set of associations between the spatial channels and the sound render channels in response to the sound render positions and the nominal sound source positions, an association between a spatial channel and a sound render channel indicating that the sound render channel is to be used for rendering the spatial channel; and

15 a driver (403) for generating drive signals for the sound render channels from input signals of the spatial channels in response to the set of associations.

2. The audio system of claim 1 wherein the signal linker (413) is arranged to associate a first spatial channel with a first sound render channel if the first sound render channel has a sound render position being a closest sound render position to a nominal position of the first spatial channel.

3. The audio system of claim 1 wherein the set of associations may associate more than one sound render channel with one spatial channel.

4. The audio system of claim 1 wherein the driver (403) is arranged to generate drive signals for at least two sound render channels from an input signal of a first spatial channel to provide a virtual sound source position for the first spatial channel closer to a

nominal position of the first spatial channel than sound render positions of the at least two sound render channels.

5. The audio system of claim 1 wherein the set of associations may associate
5 more than one spatial channel with one sound render channel.
6. The audio system of claim 1 wherein the driver (403) is arranged to adjust at least one of an audio level and a delay of at least one of the drive signals in response to the sound render positions.
- 10
7. The audio system of claim 1 wherein the user interface (409) comprises:
a display for displaying the user input graphical representation with icons representing positions of the sound transducers;
an input interface for moving the icons on the display in response to a user
15 input.
8. The audio system of claim 7 wherein the input interface is operable to receive a user selection of an icon representing a position of a sound transducer; and wherein the audio system further comprises an audio generator for providing a test drive signal to the
20 sound render channel corresponding to the selected icon.
9. The audio system of claim 8 wherein the audio generator is arranged to adjust a volume of the test drive signal in response to a distance between a nominal listening position and the sound render position of the sound render channel corresponding to the
25 selected icon.
10. The audio system of claim 1 further comprising:
a microphone input for receiving a microphone signal; and
a calibrator for setting at least one of a delay, volume and sound render
30 direction for at least one of the drive signals in response to the microphone signal.
11. The audio system of claim 10 further comprising an initializer for initializing a calibration by the calibrator in response to the sound render positions.

12. The audio system of claim 1 wherein the user interface (409) is part of a portable device operable to be remote from the driver.

13. The audio system of claim 1 wherein the user input graphical representation further comprises an indication of a characteristic of a listening environment, and the driver (403) is arranged to generate the drive signals in response to the indication.

14. The audio system of claim 1 wherein the user input graphical representation comprises an indication of a characteristic of a listening position, and the driver (403) is arranged to generate the drive signals in response to the listening position.

15. A method of generating drive signals for a plurality of sound render channels, each sound render channel providing a drive signal for a sound transducer; the method comprising:

receiving a user input graphical representation of positions of the sound transducers;

determining sound render positions for the sound transducers in response to the user input graphical representation;

receiving a spatial multichannel signal comprising a plurality of spatial channels, each spatial channel being associated with a nominal sound source position;

determining a set of associations between the spatial channels and the sound render channels in response to the sound render positions and the nominal sound source positions, an association between a spatial channel and a sound render channel indicating that the sound render channel is to be used for rendering the spatial channel; and

generating drive signals for the sound render channels from input signals of the spatial channels in response to the set of associations.

1/8

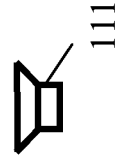
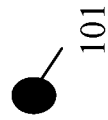


FIG. 1

2/8



FIG. 2

3/8

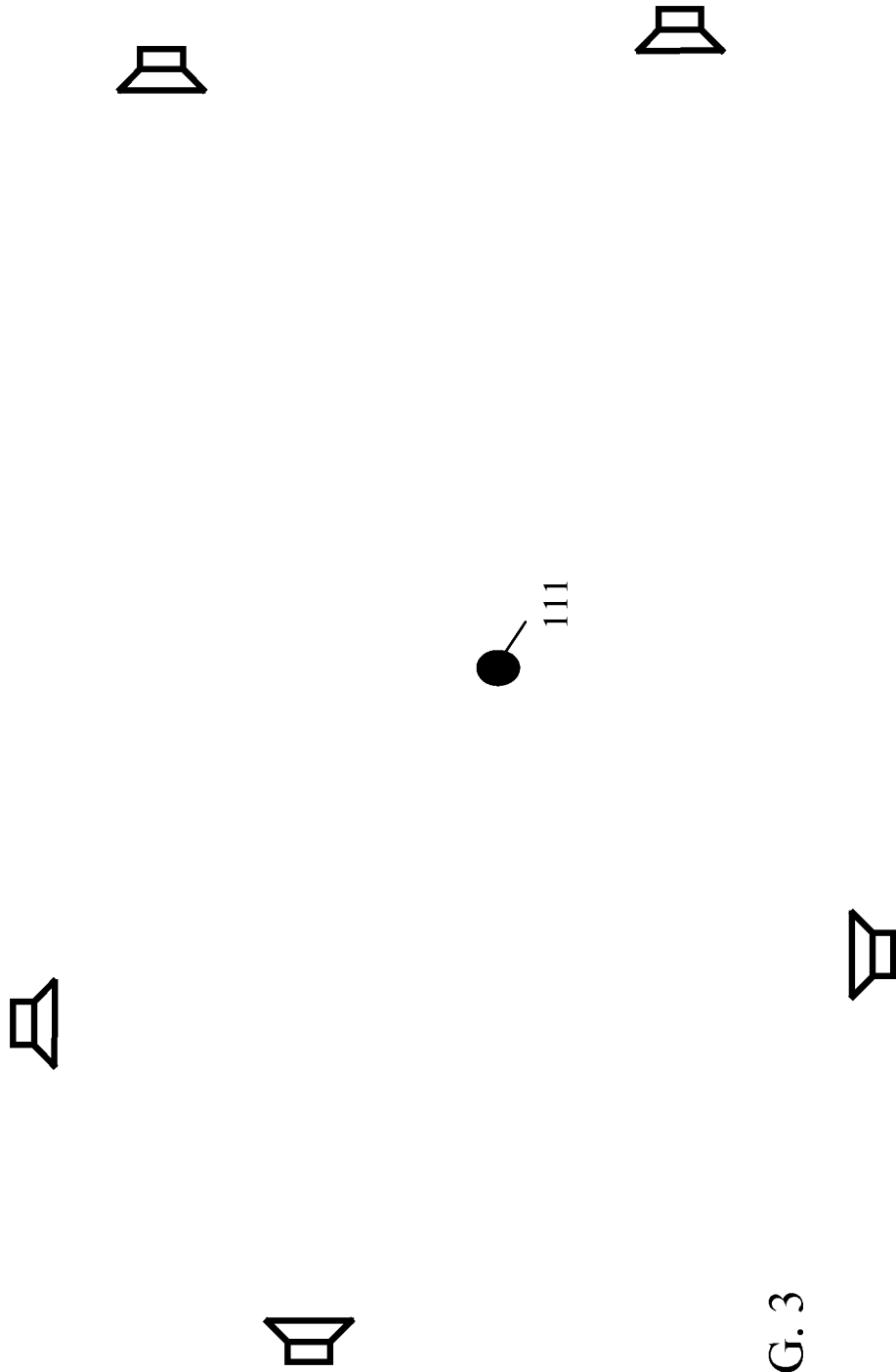


FIG. 3

4/8

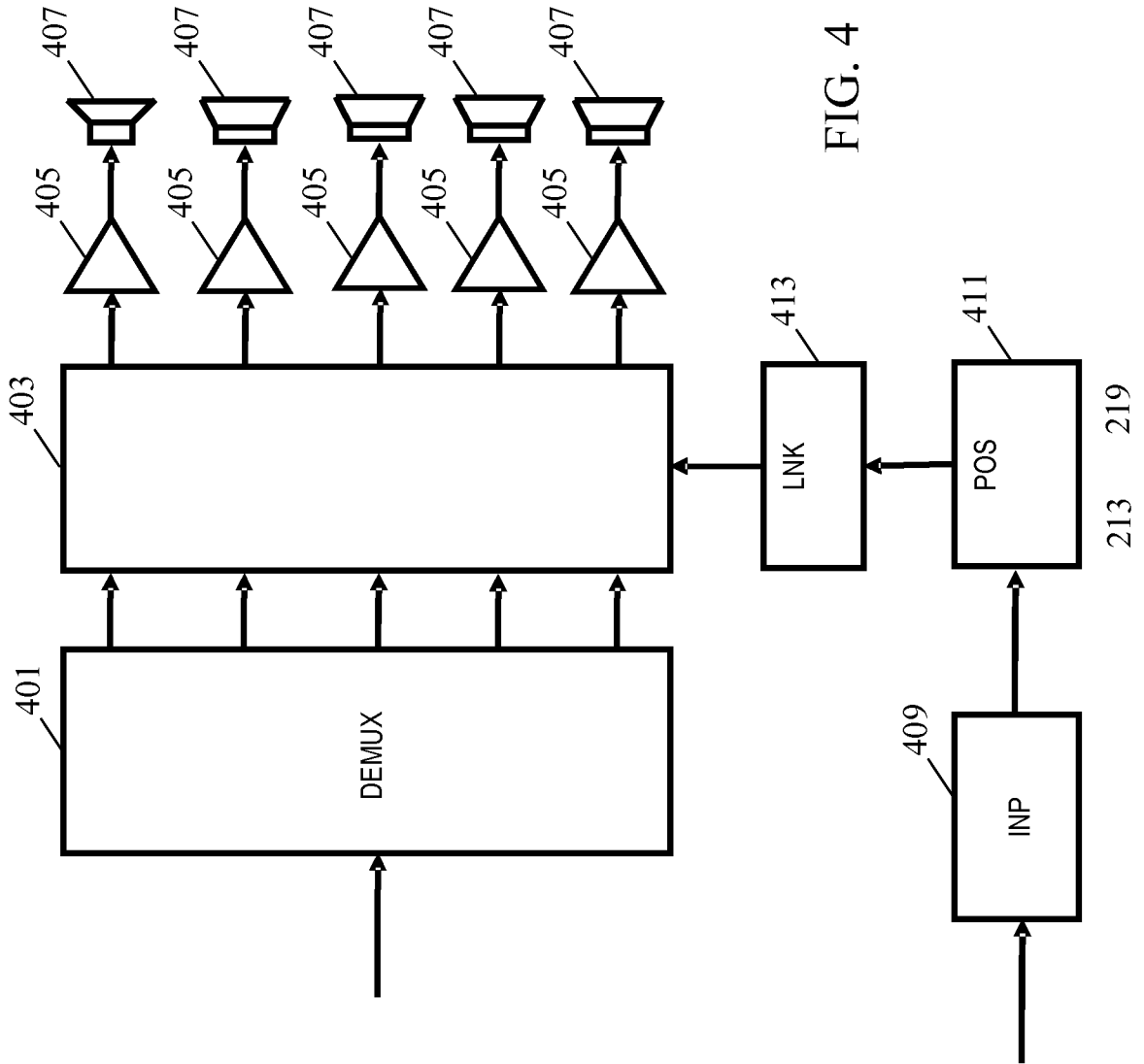


FIG. 4

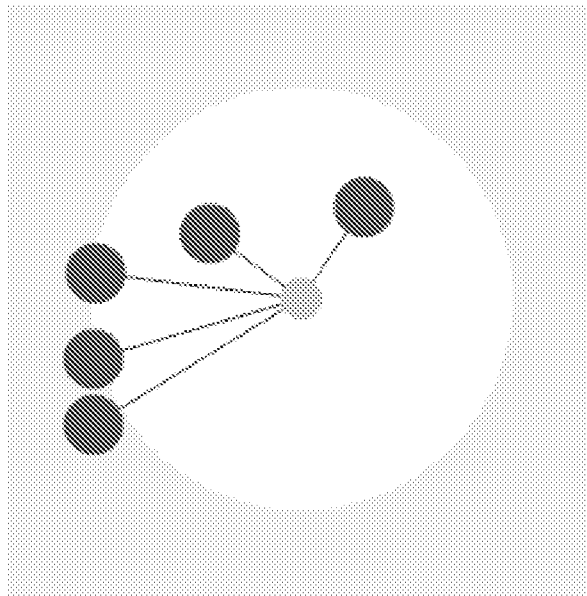


FIG. 5

6/8

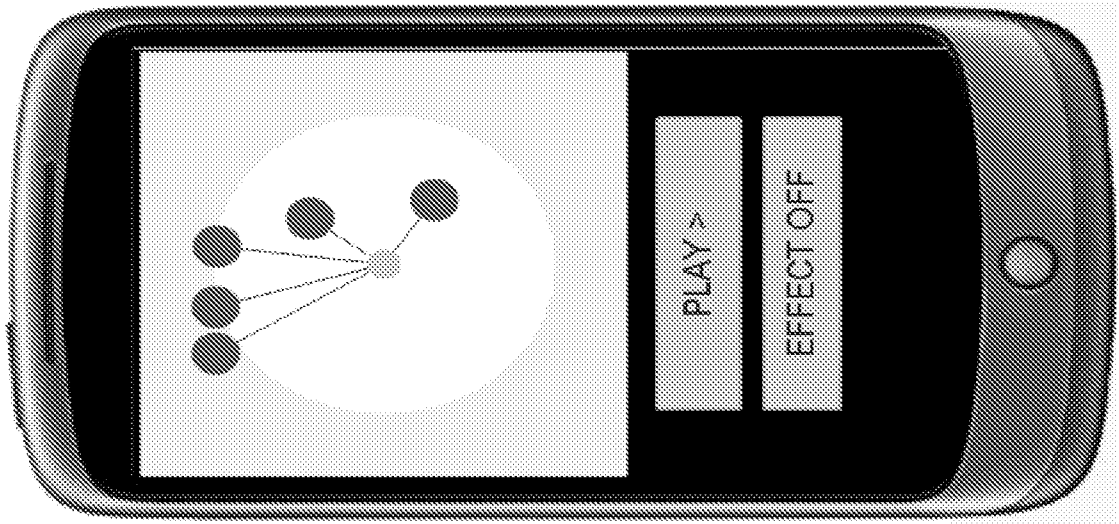
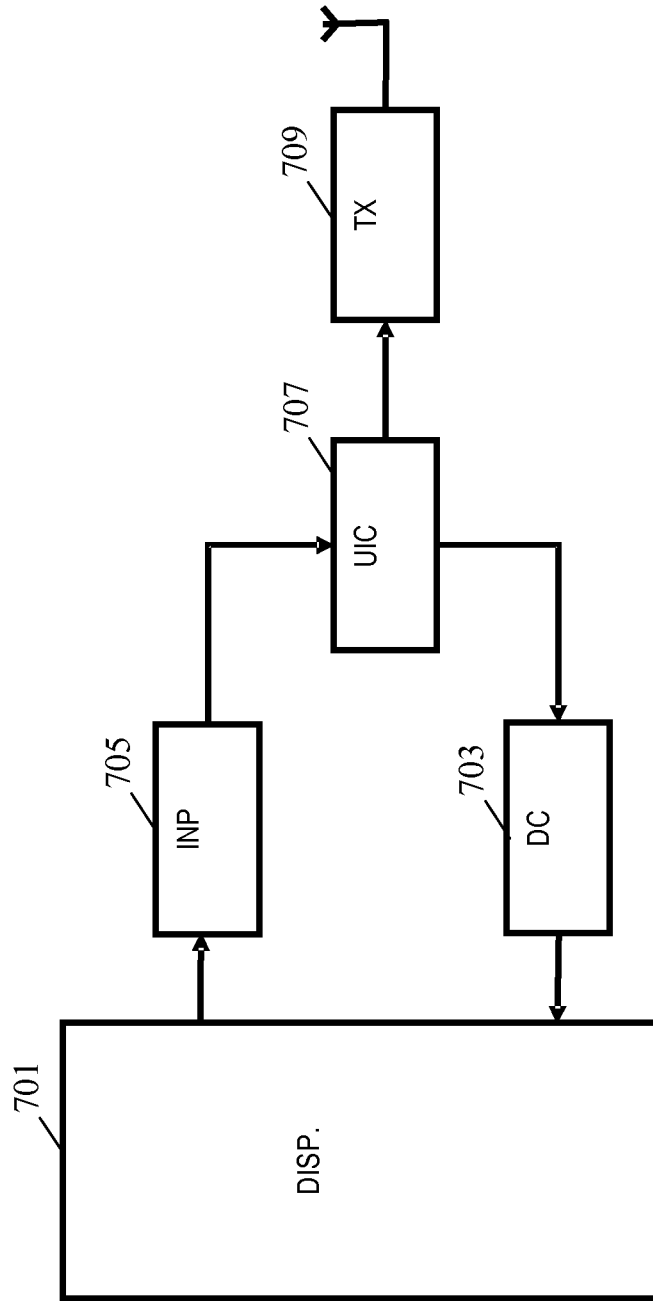


FIG. 6

7/8



409

FIG. 7

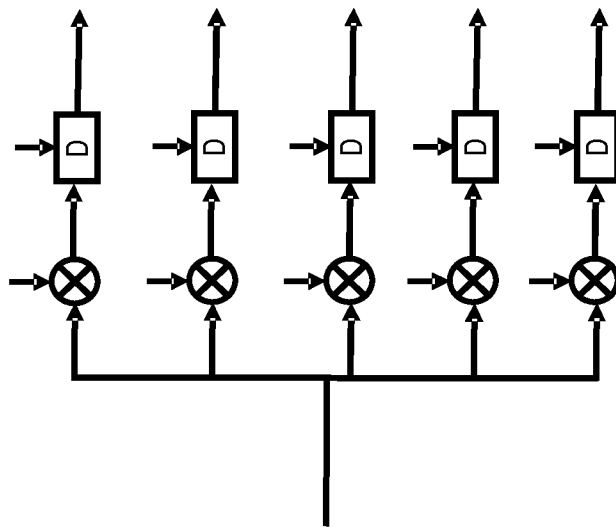


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No PCT/IB2012/052580
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A. CLASSIFICATION OF SUBJECT MATTER INV. H04S7/00 ADD.				
According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H04S				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
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X	US 2004/264704 A1 (HUIN CAMILLE [US] ET AL) 30 December 2004 (2004-12-30) the whole document	1,6,7, 12-15		
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<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;"><input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.</td> <td style="width: 50%; border: none;"><input checked="" type="checkbox"/> See patent family annex.</td> </tr> </table>			<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.	<input checked="" type="checkbox"/> See patent family annex.
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.	<input checked="" type="checkbox"/> 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			
11 September 2012	19/09/2012			
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Scappazzoni, E			

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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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