



- (51) International Patent Classification:
H04S 3/00 (2006.01) *G10K 15/04* (2006.01)
G11B 20/10 (2006.01)
- (21) International Application Number: PCT/IB2011/052638
- (22) International Filing Date: 17 June 2011 (17.06.2011)
- (25) Filing Language: English
- (26) Publication Language: English
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- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:
— with international search report (Art. 21(3))

(54) Title: AUTOMATIC SOUND ADAPTATION FOR AN AUTOMOBILE

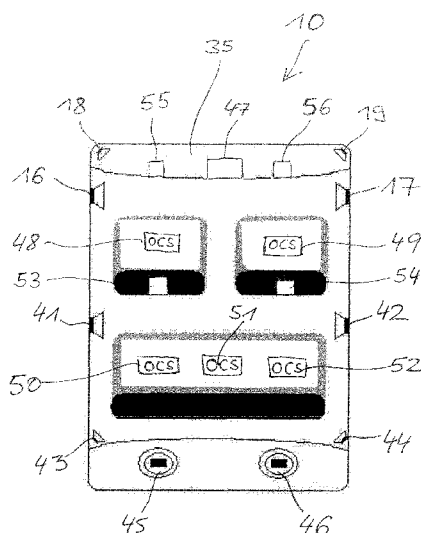


Fig. 2

(57) Abstract: The application provides a sound adaptation module for a passenger car which comprises an input connection for receiving a passenger occupation pattern of the passenger car, an audio input connection for receiving audio signals from an audio source and a database with predetermined sound profiles. Moreover, the sound adaptation module comprises a selection means for selecting a sound profile from the predetermined sound profiles based on the passenger occupation pattern and adaptation means for adapting the audio signals according to the sound profile and output connections for transmitting the adapted audio signals from the adaptation means to at least two loud-speakers.

AUTOMATIC SOUND ADAPTATION FOR AN AUTOMOBILE

This application relates to a sound system for a vehicle, such as a passenger car, van, caravan, minibus, a bus or even covered two and three wheelers.

Automotive vehicles are commonly equipped with radios for receiving wireless broadcast radio frequency (RF) signals. These radios process the received RF signals and then broadcast audio sounds together with other information to passengers in the vehicles while the automotive vehicles travel amongst various locations.

From the US 20050105744 it is known to improve speaker sound quality by adjusting relative output pressures and inclination angles of speakers within a passenger compartment of a passenger car.

It is an object of the application to provide an improved sound adaptation module, an improved sound adaptation system for a vehicle and a method for operating those.

To this end the application discloses a sound adaptation module for a passenger car which comprises an input connection for receiving a passenger occupation pattern of the passenger car via a bus or other communication cable And an audio input connection for receiving audio signals from an audio source such as a radio, a cd/dvd player, a player for a tape or other storage medium for sound a passenger information system a telephone etc. Furthermore, the sound adaptation module comprises a database with predetermined sound profiles, a selection means for selecting a sound profile from the predetermined sound profiles based on the passenger occupation pattern, adap-

tation means for adapting the audio signals according to the sound profile and output connections for transmitting the adapted audio signals from the adaptation means to at least two loudspeakers.

The passenger detection sensors are provided below the seating area of a passenger seat or at a lower part of the passenger seat and allow to detect if the passenger seat is occupied. In particular, the occupation sensors may be provided as sensor mats which allow to detect bone patterns which can be used to make a distinction between child and adult.

For example, the adaptation means may comprise a digital signal processor which is adapted to apply a digital filter to loudspeaker output signals, wherein the filter is based on the selected sound profile.

A loudspeaker configuration of the sound adaptation system comprises at least two loudspeakers. A typical configuration comprises at least two front tweeters and two front main speakers. Furthermore the loudspeaker configuration may also comprise a center speaker which can be integrated in a centre console, for example. A further extended configuration for better sound on the rear seats further comprises two rear tweeters and two rear main speakers which may be at door and/or behind rear seats. Additional loudspeakers may be provided, especially for automobiles with more than two rows of seats.

The automatic selection of a sound profile according to the application allows the driver to concentrate on driving while providing a sound experience which is pre-tuned to the specific acoustic response of a car's interior to

provide an approximately flat frequency response by compensating for resonances and/or attenuations and also reflections.

In a further extended embodiment, the selection of the sound pattern may be coupled to the degree of opening of windows, of a cloth top on the roof or of a retractable roof which is derived from sensors on the passenger car. A sound profile comprises parameters which determine the output of the loudspeakers in relation to an input from an audio device. In particular, the sound profile may comprise a loudspeaker activation pattern, a frequency dependent amplification characteristics or equalizer pattern. The amplification characteristics may be provided separately for front right and left speakers and rear right and left speakers or even for individual speakers.

The sound adaptation module may furthermore comprise means for narrowing down the number of available sound patterns by user selection or it may comprise means for selecting a sound characteristic which modifies the selected sound pattern, for example characteristic sound patterns for pop, classic and speech signals. The user selection may also override the automatic selection. The sound adaptation system may also comprise a computer readable memory for storing user preferences.

In particular, the sound profiles may comprise a loudspeaker activation pattern or frequency dependent amplification characteristics. The frequency dependent amplification patterns can be attributed to a subset of loudspeakers or even to individual loudspeakers.

Furthermore, the application discloses an audio device with a sound adaptation module according to one of the preceding claims. By integrating the sound adaptation module in an audio device such as a radio, a cd player or a separate amplifier, a compact design is achieved.

Moreover, the application discloses a sound adaptation system for a passenger car, comprising an occupant classification system for determining a passenger occupation pattern of the passenger car. The occupant classification system comprises passenger detection sensors which are integrated into seats of the passenger car and means for deriving the passenger occupation pattern from output signals of the passenger detection sensors.

The sound adaptation system further comprises an audio source, at least two loudspeakers and a sound adaption module according to the application, wherein a first input of the sound adaptation module is connected to the audio device, a second input of the sound adaptation module is connected to the means for deriving the passenger occupation pattern

The sound adaptation system may further comprise motion detection sensors such as pyroelectric sensors and motion evaluation means. The motion evaluation means is adapted to determine an event of passengers entering or leaving the car through a car door and the sound adaptation system is configured to trigger a selection of a sound profile based on the event. The selection of a sound profile can be triggered by the movement sensors. In particular, the triggering can be made such that a reselection is only triggered when passenger enter or leave the car.

Furthermore, a sound adaptation system according to the application can comprise height detection sensors which are integrated in the seats, for example as sensor mats, and/or in the panel. The selection means is adapted to select a predetermined sound pattern based on output signals of the height detection sensors. The height detection sensors allow to better estimate a position of the passengers' ears and to better differentiate between child and adult. The selected sound profile may be adapted to the estimated ear positions.

The passenger detection sensors may comprise weight sensors. In particular, a sound adaptation system according to the application can be configured to detect a child passenger from output signals of the height detection sensors and the weight sensors, for example from hip bone position and blade bone positions. The selection means is adapted to select a corresponding sound profile, for example to tune down the speakers to direct sound away from the child passenger.

Furthermore, the sound adaptation system may comprises height actuators for adjusting heights of high pitch loudspeakers on pillars of the passenger car. The adaptation means of the sound adaptation module is configured to send signals to the height actuators according to the passenger occupation pattern, wherein the passenger occupation may also comprise passenger heights.

The tweeter loudspeakers may be movable along the larger portion of a column height or even along substantially the entire column height. Specifically, there may be a high, mid and low position of the tweeters. A loudspeak-

er configuration with tweeters has at least two front tweeters and optionally also two rear tweeters.

Furthermore, the application provides a method for adapting a sound pattern of passenger car loudspeakers, which comprises steps of deriving a passenger occupation pattern from output signals of passenger detection sensors, selecting a predefined sound profile based on the passenger occupation pattern, adapting a sound pattern of passenger car loudspeakers based on the predefined sound profile, wherein a sound pattern refers to a relation of an input from an audio source to a loudspeaker signal. The step of adapting comprises adapting a sound pattern of at least two loudspeakers.

Furthermore, the method may comprise reading out signals of door sensors, reading out signals of motion detection sensors and evaluating the signals of the door sensors and the signals of the motion detection sensors. If an open door is detected and a motion is detected, based on the evaluation of the signals from the door sensors and from the motion detection sensors the steps of deriving the passenger occupation pattern, selecting the sound profile and adapting the sound pattern are triggered

In particular, the method may comprise a step of adapting the sound pattern comprises adjusting the heights of tweeter loudspeakers to get an even better directivity of the signal.

Furthermore, the method may comprise detecting a passenger height from an output signal of a height detection sensor, wherein the step of selecting the sound profile comprises selecting the sound profile based on the pas-

senger height and optionally also adjusting the heights of the tweeter loudspeakers.

Specifically, the step of adapting may comprise attributing frequency amplification relationship(s) to one or more loudspeakers according to the selected sound profile and a step of deriving one or more loudspeaker output signal(s) from an audio source input signal according to the frequency amplification relationship.

Furthermore, the method may comprise a step of activating or deactivating loudspeakers according to a loudspeaker activation matrix of the selected sound profile. For example, the method may comprise a step of switching on of at least two rear main speakers which are provided behind a seat back row and switching off of other rear speakers if only the first row of passenger seats is occupied and switching off of the rear main speakers and switching on of additional rear speakers if at least one row of rear seats is at least partially occupied. The rear main speakers are located behind the back seat row while the additional rear speakers are provided at the left and right sides.

The method may furthermore comprise a step of switching off or reducing an amplification of a loudspeaker in response to a detected infant or child.

The step of adapting may furthermore comprise attributing a delay pattern to one or more loudspeakers according to the selected sound profile.

A method according to the application may also comprise a user based selection of pitch/bass biased sound profiles e.g. according to music style or environment noise.

In summary, the application provides a sound adaptation system for adapting the sound of an entertainment system in a passenger car. The system includes a sound production system and an Occupant Classification System (OCS) for providing number and location of seated passengers in the vehicle.

Furthermore, the application also provides a method of adapting the sound of the entertainment system.

According to the application, an automobile is provided which includes an automated sound adaptation module and a sound configuration data base module. The sound adaptation module comprises seat sensors and/or pyroelectric sensors.

The automobile comprises front and rear speakers, wherein the front speakers and the rear speakers comprise tweeters and lower frequency speakers. The lower frequency speakers may be designed as woofers, for example. One tweeter and one woofer can be integrated into one unit or they can be provided as separate units or components. A woofer component can be integrated into a door of the automobile.

According to a special embodiment, the front tweeters are adjustably mounted on front pillars of the automobile while the rear speakers are adjustable mounted on rear pillars of the automobile. The pillars are also referred to as posts. The pillars connected a roof of the automo-

bile to a lower part of the automobile. The front pillars are also called A-pillars while the rear pillars are called C-pillars. Specifically, the front and the rear tweeters may be adjustable to a high position, to a mid position, and to a low position. The positions of tweeter speakers are adjusted on the front pillar may be adjusted according to the number of the seated passenger or according to the passenger height for obtaining better sound directivity and phase to the passengers.

The seat sensors are installed below or inside passenger seats of the automobile and can be part of an Occupant Classification System (OCS), as shown in patent US7597011 B2). According to the application, the sound adaptation system can make use of preexisting seat sensors which are provided for altering the passenger to fasten their seat belts, for example. The pyroelectric sensors are installed at a front dashboard and/or at the back of front seats of the automobile, especially on the back of the head rests of the front seats.

In operation, the sound enhancement module is used for improving sound produced by the sound entertainment system for the passengers of the automobile.

The seat sensors are used to detect and to obtain data of the seated passengers. The data include location information, weight information, and number information of the seated passengers.

The weight information is used to classify the passenger as adult, child or infant. The seat sensor may also comprise sensor mats such that a bone location can be identified and used for the age discrimination of a passen-

ger. The detection of bone patterns allows to differentiate between children and people of short stature. The differentiation result can be used in various ways, for example to determine a required airbag pressure. The sensor mats may comprise capacitive sensors, strain gauges or other types of weight sensitive elements.

The pyroelectric sensors are used to detect motions of the passengers. In particular, the pyroelectric sensors are used to detect difference in passenger body infrared emitted signals, which in turn detect discrete recognition of the height of the passengers. The pyroelectric sensors that are installed at the back of the front seats are used for detecting motions of the back seat passengers. In contrast, the pyroelectric sensors that are installed at the front dashboard are used for detecting motions of the front seat passengers. A method of tracking movements with pyroelectric sensors is shown in patent W0/2006/105094, for example

A sound adaptation module according to the application provides

- information regarding the number of the seated passengers from seat sensors,
- information regarding the seat location of the passengers from the seat sensors,
- information regarding the classification of the passengers according to the weight information from the seat sensors, and
- information regarding the heights of the passengers from height sensors.

The database module is used for storing different sound system configurations. The sound system configurations include different sets of sound system settings.

The passenger information is used for selecting the appropriate sound system configuration from the database module.

A loudspeaker configuration according to the application may comprise only the front speakers, only the rear speakers, or both front and rear speakers. In other words, the embodiment can be applied to an automobile in which the front speakers are actuated while the rear speakers are not actuated. The embodiment can also be applied to an automobile in which the rear speakers are actuated while the front speakers are not actuated. The embodiment can also be applied to an automobile in which both the rear speakers and the front speakers are actuated.

According to the application, a sound tuning with calibrated profiles is done with respect to the automobile interior environment. These profiles are then saved into the entertainment system. For example, they are stored in a flash based system which may be referred to as a sound tuning profile database. As soon as the system and automobile is started, the OCS and sensors within the interior of the automobile provide the necessary information about the seated passenger from their module via CAN bus protocol or any automobile electrical communication into the entertainment system. The entertainment system will then process this information to decide, based on which configuration of seated passengers, which profile to select. The selected profiles which fit the

detect number of passengers can also include options for the end user to select more dynamic choices like for example bass emphasis or treble emphasis for specific types of sound data. These profiles are pre-tuned to provide the best align sound listening experiences.

The subject of this application builds on the following concepts:

- 1) An initial sound tuning calibration is done for all types of automobiles,
- 2) An existing occupation classification system is used to determine the location and position of the seated passenger/s.

The application comprises, among others, the following aspects:

- a) An automatic adjustment of calibrated sound profiles with respect to the number of seated passenger without manual intervention.
- b) Additional sensors, such as capacitive sensor mats and pyroelectric sensors, to detect the height and movement of the seated passengers determine the right sound calibrated profile to use.
- c) A dynamic movement of the tweeter speakers of the automobile along the front and rear pillars provides the right projection of sound close to and direct to the passenger in accordance to the height and number of passengers.

An adjustment of sound could also be done manually by a front passenger of the automobile who adjusts controls of the entertainment system. However, with an adaptation system according to the application a desired sound can be obtained with an adjustment that is both easy and fast. In this way, the driver is less distracted and can concentrate on driver. Furthermore, according to the application, a driver may select an adjusted sound which is suitable for other passengers of the automobile.

A sound adaptation method according to the application uses sensors in the automobile to first detect a number of seated passengers in the automobile. This is followed by automatically adjusting sound tuning parameters of a sound entertainment system of the automobile according to the number of the passengers for providing desired sound effects. The method may also comprise moving speakers of the sound entertainment system to enhance further reception of the sound by the different passengers.

The subject of the application will now be explained in further detail with reference to the following figures in which

- Fig. 1 illustrates a perspective view of the front part of a passenger compartment with an entertainment system,
- Fig. 2 illustrates a top view of sensor and loudspeaker locations,
- Fig. 3 illustrates a side view of sensor and loudspeaker locations,
- Fig. 4 shows an amplification curve for a first occupation pattern,

- Fig. 5 shows an amplification curve for a second occupation pattern,
- Fig. 6 shows a first loudspeaker activation pattern,
- Fig. 7 shows a second loudspeaker activation pattern,
- Fig. 8 shows an extended loudspeaker configuration,
- Fig. 9 shows an arrangement of rear speakers,
- Fig. 10 shows a loudspeaker configuration with flat panel speakers as front tweeters,
- Fig. 11 shows a cross section through an A-pillar with a flat panel speaker,
- Fig. 12 shows an embodiment with movable front tweeters,
- Fig. 13 shows an embodiment with movable rear tweeters,
- Fig. 14 illustrates an occupation pattern detection,
- Fig. 15 illustrates a sound profile selection, and
- Fig. 16 illustrates a sound profile tuning.

In the following description, details are provided to describe embodiments of the application. It shall be apparent to one skilled in the art, however, that the embodiments may be practiced without such details.

Some parts of the embodiments, which are shown in the Figs. below, have similar parts. The similar parts may have the same names or the similar part numbers. The description of such similar parts also applies by reference to other similar parts, where appropriate, thereby reducing repetition of text without limiting the disclosure.

Fig. 1 shows a passenger compartment 10 of a passenger car. An audio entertainment system 11 is installed in the passenger compartment. The audio entertainment system 11 comprises a car radio 12 with a CD/DVD player 13 and a

cassette player 14 which are installed in a centre console of the passenger compartment 10. The car radio 12 and the cassette player 14 are connected to an amplifier. The amplifier is not shown in Fig. 1. It may be part of the car radio 12, for example. Loudspeakers are connected to the amplifier via a sound adaptation unit, which is not shown in Fig. 1. The sound adaptation unit may be realized as a separate component or within components of the audio entertainment system 11.

The loudspeakers comprise front and rear loudspeakers, which are also referred to as front and rear speakers. The front speakers are shown in Fig. 1. They comprise a front left main speaker 16, a front right main speaker 17, a front left treble speaker 18, a front right treble speaker 19 and a front centre speaker 20. The treble speakers are also referred to as "tweeters".

The front left main speaker 16 is provided in an opening of a left front door 20 below a left armrest 22 and the front right main speaker 17 is provided in an opening of a right front door 23 below a right armrest 24. The left tweeter 18 is provided in an upper region of a left A-pillar 25 and the right front tweeter is provided in an upper region of a right A-pillar 26. The front centre speaker is provided in a lower area 27 of the centre console 15.

Furthermore, Fig. 1 shows a lower part of a left front seat 28 and a lower part of a right front seat 29. Passenger detection sensors, which are not shown in Fig. 1, are provided in the lower parts of the front seats 28, 29. The passenger detection sensors are connected to the sound adaptation unit.

Further parts of the passenger cell 10 which are shown in Fig. 1 include a left door opener 30, a right door opener 31, a left exterior mirror 32, a right exterior mirror 33, a hand brake 34 a front window 40 and a dashboard 35. The dashboard 35 comprises, among others, an upper surface 36, ventilation openings 37 and an instrument cluster 38. A steering wheel 39 is mounted to a steering column which is provided below the instrument cluster 38.

Fig. 2 shows a schematic upper view of a sound adaptation system inside the passenger cell 10. The loudspeakers of the passenger cell 10 comprise the front left tweeter 18, the front main speaker 16, the front right tweeter 19, the front main speaker 17, a rear left door main speaker 41, a rear right door main speaker 42, a rear left tweeter 43, a rear right tweeter 44, a rear left main speaker 45 and a rear right main speaker 46.

A car entertainment system 47 comprises the car radio 12 and the cassette recorder 14 of Fig. 1 as well as the adaptation unit. The adaptation unit of the car entertainment system 47 is connected to passenger detection sensors which are provided at lower parts of the passenger seats. The passenger detection sensors comprise a front left passenger detection sensor 48, a front right passenger detection sensor 49, a rear left passenger detection sensor 50, a rear center passenger detection sensor 51 and a rear right passenger detection sensor 52.

Furthermore, a left height detection sensor 53 is provided in an upper part of a front left seat and a right height detection sensor 54 is provided in an upper part of a front right seat. A front left motion sensor 55 is

integrated into a left side of the dashboard 35 while a front right motion sensor 56 is integrated into a right side of the dashboard 35.

Fig. 3 shows a schematic diagram that illustrates the respective position of the sensors and their connection to the car entertainment system 47. Fig. 3 shows a side view from a left side in which a front left seat of a front row 58 and a rear left seat of a back row 59 is visible. The seats of the front row 58 and of the back row 59 comprise a lower portion 60, a back portion 61 and a head rest 62. The lower portion 60 of the front seats in the front row 59 is also shown in Fig. 1 as lower portion 28 and 29.

The height detection sensors 53, 54 are provided in upper areas of the back portions 61 of the front seats, respectively.

Fig. 4 shows amplification curves 64, 65, 66, 67 for an occupation pattern in which the first row of seats 58 is occupied and the second row of seats 59 is not occupied. The curves refer to amplifications of respective input signals in decibel. A front left amplification curve 64 determines an amplification of a front left input signal to a front left output signal, a front right amplification curve 65 determines an amplification of a front right input signal to a front right output signal, a rear left amplification curve 66 determines an amplification of a rear left input signal to a rear left output signal and a rear right amplification curve 67 determines an amplification of a rear right input signal to a rear right output signal.

The respective input signals are derived from output signals of an audio source. For example, for a stereophonic output with a left and right channel, the front left and rear left input signals may be equal to a left channel signal and the front right and rear right input signals may be equal to a right channel signal. The front left, rear left, front right and rear right input signals may also be obtained by mixing of the right and left channel signals, for example to obtain a pseudo-quadrophonic sound.

The front left, front right, rear right and rear left output signals are sent to front left, front right, rear right and rear left speakers or groups of speakers. For example, a front left group of speakers may comprise a front left bass speaker and a front left tweeter in which case the front left output signal is split up with an audio crossover into an input signal of the front left bass speaker and an input signal of the front left tweeter.

In the example of Fig. 4, the amplification curves 64 and 65 of the front speakers have a high amplification of up to 12 dB in a low frequency range that extends from the lower hearing threshold of 50 Hz to up to about 150 Hz, a low amplification in a range from 200 to 300 Hz, a medium amplification of up to about 5 dB around 500 Hz and several amplification peaks of more than 8 dB in a range between 2 kHz and the upper hearing threshold of 20 kHz.

The high amplification can compensate a high damping of the car's interior. By contrast, a low amplification can compensate a resonance of the car's interior.

The amplification curves 66, 67 of the rear speakers have a lower amplification in the low frequency range which decreases from about 6 dB at the lower hearing threshold to about -4 dB at 500 Hz. In the range from 800 Hz to 20 kHz the amplification of the rear speakers resembles the amplification of the front speakers but is generally slightly lower.

Fig. 5 shows amplification curves 64', 65', 66', 67' for an occupation pattern in which the first row of seats 58 and the second row of seats 59 is occupied.

Compared to the front speaker amplification curves of Fig. 4, the amplification curves of the front speakers of Fig. 5 have a lower amplification of no more than 6 dB. Also, the amplification peaks above 2 kHz are smaller with respect to the low frequency amplification and region of low amplification between 500 Hz and 2 kHz is more pronounced.

Compared to the rear speaker amplification curves 66, 67 of Fig. 4, the rear speaker amplification curves 66', 67' of Fig. 5 have a lower amplification of no more than -2dB and the amplification curves are smoother and without pronounced amplification peaks. The amplification dips from about -2 dB at the lower hearing threshold to about -12 dB at about 250 Hz. It then gradually rises to a plateau of about -3 dB between 2 kHz to 10 kHz and it gradually falls off between 10 kHz and 20 kHz. Between 1 kHz and 2 kHz there is a 3 dB dip in amplification.

The amplification curve may be realized by digital filters in a digital signal processor (DSP). The input of the DSP may be derived from a digital output of an audio

source or from an analog output of the audio source which is processed with an analog digital converter. The DSP may be realized as part of an audio device, such as a radio or a CD player, or as a separate component.

Figs. 6 and 7 show loudspeaker activation patterns in which activated loudspeaker are shown and deactivated loudspeakers are not shown.

Fig. 6 shows a loudspeaker activation pattern for an occupation pattern in which the front row 58 is occupied and the back row 59 is not occupied. A front left main speaker 16, a front left tweeter 18, a front right main speaker 17, a front right tweeter 19, a rear left main speaker 45 and a rear right main speaker 46 are activated while a rear left door speaker 41, a rear left tweeter 43, a rear right door speaker 42 and a rear right tweeter 44 are deactivated.

Fig. 6 shows a loudspeaker activation pattern for an occupation pattern of a car in which the front row 58 and the back row 59 are occupied. A front left speaker 16, a front left tweeter 18, a front right speaker 17, a front right tweeter 19, a rear left door speaker 41, a rear right door speaker 42, a rear left tweeter 43 and a rear right tweeter 44 are activated while a rear left main speaker 45 and a rear right main speaker 46 are deactivated.

Fig. 8 shows a further extended speaker configuration of a 5 seater car with a rear center speaker 9 and a centre speaker 20. Herein, the speakers are labeled as follows:

Front left tweeter 18	T_FL
Front right tweeter 19	T_FR
(front) centre speaker 20	T_centre
Front left speaker 16	FL
Front right speaker 17	FR
Rear left speaker 41	RL1
Rear right speaker 42	RR1
Rear left tweeter 43	T_RL
rear right tweeter 44	T_RR
Rear left main speaker 45	RL2
Rear right main speaker 46	RR2
Rear centre speaker 9	T_centre_R

Fig. 9 shows a placement of a rear left speaker 41 in a rear left door, of a rear right speaker 42 in a rear right door and of a rear left main speaker 45 and a rear right main speaker 46 in a hat shelf behind a back row 59.

Table 3 shows an allocation of sound profiles to detected occupation patterns of a 5 seater car. Herein, "A" refers to adult, "C" to child and "I" to infant. An infant refers to a baby or a child of up to 12 months or even up to 3 years, whereas a child refers to human between infancy and puberty.

Car type	1 (driver)	2	3	4	5	Profile
5 seater	A	No	No	No	No	1
5 seater	A	A	I	No	No	3a
5 seater	A	No	No	No	C	5c
5 seater	A	A	A	C	C	3
5 seater	A	C	No	No	No	1

...	A	...	...	...	...	...
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The following table shows a listing of equalizer patterns and phase compensation and delay patterns for a 5 seater car, which are calibrated during a sound calibration procedure. The sound calibration procedure may be carried out at the manufacturer of the sound system for certain predetermined classes of vehicles like 5 seaters, 8 seaters etc. or individually for a given passenger car at a service shop.

The equalizer patterns with the prefix "EQ", and the phase compensation and delay patterns with the prefix "T" are associated to the occupation patterns which are listed in the first column. The occupation patterns include also occupation patterns in which the driver seat is not included. For example, these can be useful in a situation in which the driver is a chauffeur and an owner or a VIP is seated on a back seat.

Table 1 lists sound profiles which comprise phase compensation and delay patterns as well as equalization patterns which correspond to specific tuning targets of a 5 seater car. The sound profiles may be automatically selectable or manually selectable. The automatically selectable sound profiles may allow a manual selection or not. In the given example of Table 1, the sound profiles with detected infants or children do not allow a manual selection. In an actual implementation, the available selection modes may be different from Table 1 or they may be configurable by the driver.

5 seater		Acoustic tuning factors		Remark
Tuning target	Final tuned profile	Phase compensation + delay	EQ setting with gain	Activation method select
1	prof 1	T1	EQ1	Auto/Manual
1+2	prof 2	T2	EQ2	Auto/Manual
1+2+3	prof 3	T3	EQ3	Auto/Manual
1+2+3 (I)	prof 3a	T3a	EQ3a	Auto
1+3	prof 4	T4	EQ4	Auto/Manual
1+5 (C)	prof 5c	T5c	EQ5c	Auto
1+2+3+4+5	prof 6	T6	EQ6	Auto/Manual
3	prof 7	T7	EQ7	Manual
4	prof 8	T8	EQ8	Manual
...	...	...	...	...

Table 2 shows an activation matrix, wherein a loudspeaker is indicated in the header of A-pillar, "1" stands for activation of the loudspeaker, "0" stands for a deactivation of the loudspeaker and a value between 0 and 1 stands for an attenuation of the loudspeaker signal. For example, 0.5 stands for an attenuation of 50%. The numbering of the seats of the 5 seater is shown in Fig. 8.

5 seater												
Target	FL	FR	T_ FL	T_ FR	T_ ctr	RL1	RR1	RL2	RR2	T_ RL	T_ RR	T_R ctr
1	1	1	1	1	0	0	0	1	1	1	1	0
1+2	1	1	1	1	1	0	0	1	1	1	1	0
1+2+3	1	1	1	1	1	1	1	0	0	0	0	0
1+2+3(I)	1	1	1	1	1	0	0	0	0	0	0	0
1+3	1	1	1	1	0	1	1	0	0	0	0	0
1+5(C)	1	1	1	1	0	0.5	0.5	0	0	0	0	0
1+2+3 +4+5	1	1	1	1	1	1	1	0	0	0	0	1
3	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	0	1	1	1	1	1	1	0
1	1	1	1	1	0	1	1	1	1	1	1	0
...	...	...	...	...	...	...	...	...	...	...	...	...

The activation matrix of Table 2 is specially adapted for occupation patterns with children and infants. For example, the fourth row refers to a detected occupation pattern in which adult passengers are detected on the first and the second seat and an infant is detected on the third seat on the back row. All rear loudspeakers are deactivated in order to avoid disturbing the infant. The sixth row refers to an occupation pattern in which an adult passenger is detected on the first seat in the front row and a child is detected on the fifth seat in the back row. Only the left main rear speaker and the right main rear speaker are activated and the sound is attenuated to 50%. In further configurations with detected child and/or infant passengers there may be more activated loudspeakers, for example to play soothing music for the infant or to play an audio book for the child.

In a further embodiment, the loudspeaker amplification may change to a driver centered pattern, if an information message for the driver is transmitted. Alternatively, the adaptation system may send the sound signal of the information message to the loudspeakers that are closest to the driver. The information message may be mixed into a sound signal of a media being played or it may be sent instead of the sound signal.

Fig. 10 shows a further embodiment, wherein a left tweeter 18' and a right tweeter 19' are realized as flat panel speakers 18', 19'.

Fig. 11 shows a cross section A-A of the A-pillar 25 of Fig. 10. The flat panel speaker 18' comprises a speaker panel 70, also known as diaphragm, a coil 71 which is attached to the speaker panel 70, a frame 72 and a magnet 73 which is attached to the frame 72. A first end 74 and a second end 75 of the coil 71 are connected to a cable which is connected to an audio source. For example, the ends may be connected to an inner and an outer part of a coaxial cable.

The frame of the flat panel speaker may also be provided by a part of the carriage, especially of A-pillar, in which the flat panel speaker is integrated. Furthermore, a piezoelectric element may provide the actuation of the speaker panel.

In addition or instead of conventional tweeters or flat panel speakers, transparent film speakers may be used as tweeters as well. The transparent film speakers may be positioned on the windscreen. For example, the film speakers can be used in combination with a head-up dis-

play such that a voice of an information system is coming from the location of the head-up display.

Figs. 12 and 13 show a further embodiment in which the tweeter speakers 18, 19, 43, 44 are movable between a low, mid and high position. Arrows 76 and 77 show up and down movements of the tweeters 18 and 19, respectively. Likewise, arrows 78 and 79 in Fig. 13 show an up and down movement of the tweeters 43 and 44, respectively.

Fig. 14 shows a detection process of a passenger configuration, also referred to as passenger occupation pattern.

After a start step 80, it is determined, in a door checking step 81, if one or more passenger doors of the car are open or at least partially open or ajar. The start step 80 may itself be triggered by an opening of a door. In a movement detection step 82, output signals of pyroelectric sensors are analyzed to detect whether there is any thermal movement that corresponds to passengers entering or leaving the car.

If a thermal movement is detected, a passenger configuration is detected in a configuration detection step 83. The configuration detection step 83 may be repeated until detection sensors give a stable signal. The configuration detection step 83 includes a determination if the passenger is an adult, child or infant. If no thermal movement is detected, the process loops back to the door checking step 81 and the opening status of the passenger doors is checked again.

The detection sensors may comprise capacitive sensing mats and other occupant classification sensors. For exam-

ple, the occupant classification sensors may comprise a weight sensor with a strain gauge that is attached to a deforming part. For example, the deforming part may be realized as a bar which is attached to a passenger seat such that an up/down motion of the passenger seat is converted into a rotation of the bar.

In a transmission step 84, the detected configuration is transferred to other modules, for example to a seat belt detection module and to a sound adaptation module. In a shutdown detection step 85, it is determined if there is a shutdown. In particular, the shutdown may comprise turning off the motor or turning off the radio.

If a shutdown is detected and a closing of the last passenger door, the process terminates in a termination step 86. Otherwise, the process loops back to the door checking step 81 and the opening status of the passenger doors is tested again.

Fig. 15 shows a selection process for a sound profile that comprises frequency profiles which are specific to a loudspeaker or a group of loudspeakers and loudspeaker activation/amplification patterns. In Fig. 15, the lozenge symbols of steps 95 and 99 refer to alternatives with three possible outcomes.

After a start step 90 of the sound adaptation system, it is determined in step 91 if a user selection is requested. If a user selection is requested, a list of available sound profiles is displayed in step 92, wherein the sound profiles relate to a detected occupation pattern or seating pattern. In a step 93, a user selection of a sound profile is received. In a step 94, an activation matrix

and a pre-tuned sound profile is loaded from a database. In step 94, the user selection is stored for later use.

In an extended embodiment, the user can also make alterations to the sound profile via user input. If the sound profile is altered, the user can save the altered sound profile in a sound profile database.

In a decision step 95, it is determined whether there is a user interrupt or a shutdown. If there is a shutdown, the process ends in a termination step 96. If, on the other hand, there is a user interrupt, the process branches back to step 91 and it is again determined, if a user selection is requested. If there is neither a shutdown nor a user interrupt, the process remains in a waiting state.

If, in the step 91, it is determined that an automatic selection of a sound profile is requested, in a step 97 information is requested from an integrated body control module and from a seating module via a communication bus which is connected to detection sensors and a passenger occupation pattern is determined from the information.

Herein, integrated body control (IBC) module refers to the body of the car. Functions of the integrated body control module may comprise functions of a basic function control module such as the control of the interior and exterior lamps, the wipers and the washing system, the door closing system and the rear-window heater but also functions such as the keyless access control and start system (PASE), the remote locking system (RKE), the welcome lighting, the electronic steering lock as well as a remote engine start. The body control module as well as

other modules, such as the sound adaptation module, may be realized by printed circuit boards with microcontrollers, for example.

In a step 98, the occupation pattern is used to select an activation matrix which corresponds to the occupation pattern and a pre-tuned sound profile which corresponds to the activation matrix. The automatic selection of the sound profile in step 98 may also take into account stored user preferences such as a pop or a classic sound characteristic. The selection of the sound profile is stored in a database.

Similar to decision step 95, it is determined in a decision step 99, if there is a user interrupt or shutdown. In the case of a user interrupt, the process branches back to step 91 in which it is determined whether an automatic selection or a user selection is requested. In the case of a shutdown the process terminates in the process termination step 96. If there is neither a user interrupt nor a shutdown, it is determined, in a decision step 100, if an occupation pattern has changed using the information provided by the IBC module and the seat module.

If the occupation pattern has changed, the process branches back to step 97 in which an occupation pattern is determined. To avoid a frequent reselection of sound patterns, the condition of decision step 100 may comprise a condition, that a passenger door is open or ajar.

Fig. 16 shows a tuning process for obtaining a pre-tuned sound profile as well as a predetermined speaker matrix or activation matrix. The sound tuning process is per-

formed for different types of vehicles and seating patterns. In a production process, a database of a sound adaptation module can then be loaded with sound profiles and activation patterns that are specific to the vehicle type in which the sound adaptation module is integrated and which have been determined during the tuning process of Fig. 16.

It is often advantageous to obtain a flat frequency response to achieve a desired sound uniformity. Herein, flat refers to a sound reproduction with little or no emphasis or attenuation of specific frequency ranges. During the tuning process, equalization patterns, phases and timings are adjusted with respect to the reflection pattern of the automobile structure and/or the passengers.

In a start step 102, the tuning process is initiated. In a step 103, a phase of the speaker output is determined. In a step 104, a predetermined speaker matrix is determined in which occupation patterns are defined. An example of a speaker matrix is shown in table 1. The sound profiles are then associated to the speaker matrix in the steps 106 and 107.

In a step 105 a sound spectrum of the car is determined. In a step 106, an equalization matrix is adapted to a desired frequency response for a given occupation pattern and is stored in a pre-tuned equalization matrix. By way of example, equalization matrices are visualized in Figs. 4 and 5.

In a step 107, an output speaker activation pattern is determined and the activation pattern is stored in an activation matrix database. By way of example, table 2

shows an output speaker activation pattern. In a step 108, the tuning process is terminated.

Although the above description contains much specificity, this should not be construed as limiting the scope of the embodiments but merely providing illustration of the foreseeable embodiments. For example, a position and/or orientation of the loudspeakers may be changed in other ways than shown and the available seats, type of car and loudspeaker configuration may be different from the ones of the embodiments.

The above stated advantages of the embodiments should not be construed especially as limiting the scope of the embodiments but merely to explain possible achievements if the described embodiments are put into practice. Thus, the scope of the embodiments should be determined by the claims and their equivalents, rather than by the examples given.

Patent Claims

1. Sound adaptation module for a passenger car, the sound adaptation module comprising
 - an input connection for receiving a passenger occupation pattern of the passenger car,
 - an audio input connection for receiving audio signals from an audio source,
 - a database with predetermined sound profiles,
 - selection means for selecting a sound profile from the predetermined sound profiles based on the passenger occupation pattern,
 - adaptation means for adapting the audio signals according to a selected sound profile,
 - output connections for transmitting the signals from the adaptation means to at least two loudspeakers.
2. Sound adaptation module according to claim 1, wherein the sound profiles comprise a loudspeaker activation pattern.
3. Sound adaptation module according to claim 1 or claim 2, wherein the sound profiles comprise frequency dependent amplification characteristics.
4. Sound adaptation module according to one of the preceding claims, further comprising
 - means for narrowing down the number of available sound patterns by user selection.
5. Audio device with a sound adaptation module according to one of the preceding claims.

6. Sound adaptation system for a passenger car, comprising
- an occupant classification system for determining a passenger occupation pattern of the passenger car, the occupant classification system comprising
 - passenger detection sensors which are integrated into seats of the passenger car,
 - means for deriving the passenger occupation pattern from output signals of the passenger detection sensors,
- the sound adaptation system further comprising
- an audio source,
 - at least two loudspeakers,
 - a sound adaption module according to one of claims 1 to 4, wherein a first input of the sound adaptation module is connected to the audio device, a second input of the sound adaptation module is connected to the means for deriving the passenger occupation pattern
7. Sound adaptation system according to claim 6, further comprising
- motion detection sensors,
 - motion evaluation means,
- wherein the motion evaluation means is adapted to determine an event of passengers entering or leaving the car through a car door and wherein the sound adaptation system is configured to trigger a selection of a sound profile based on the event.
8. Sound adaptation system according to claim 6 or claim 7, further comprising height detection sensors, wherein the selection means is adapted to se-

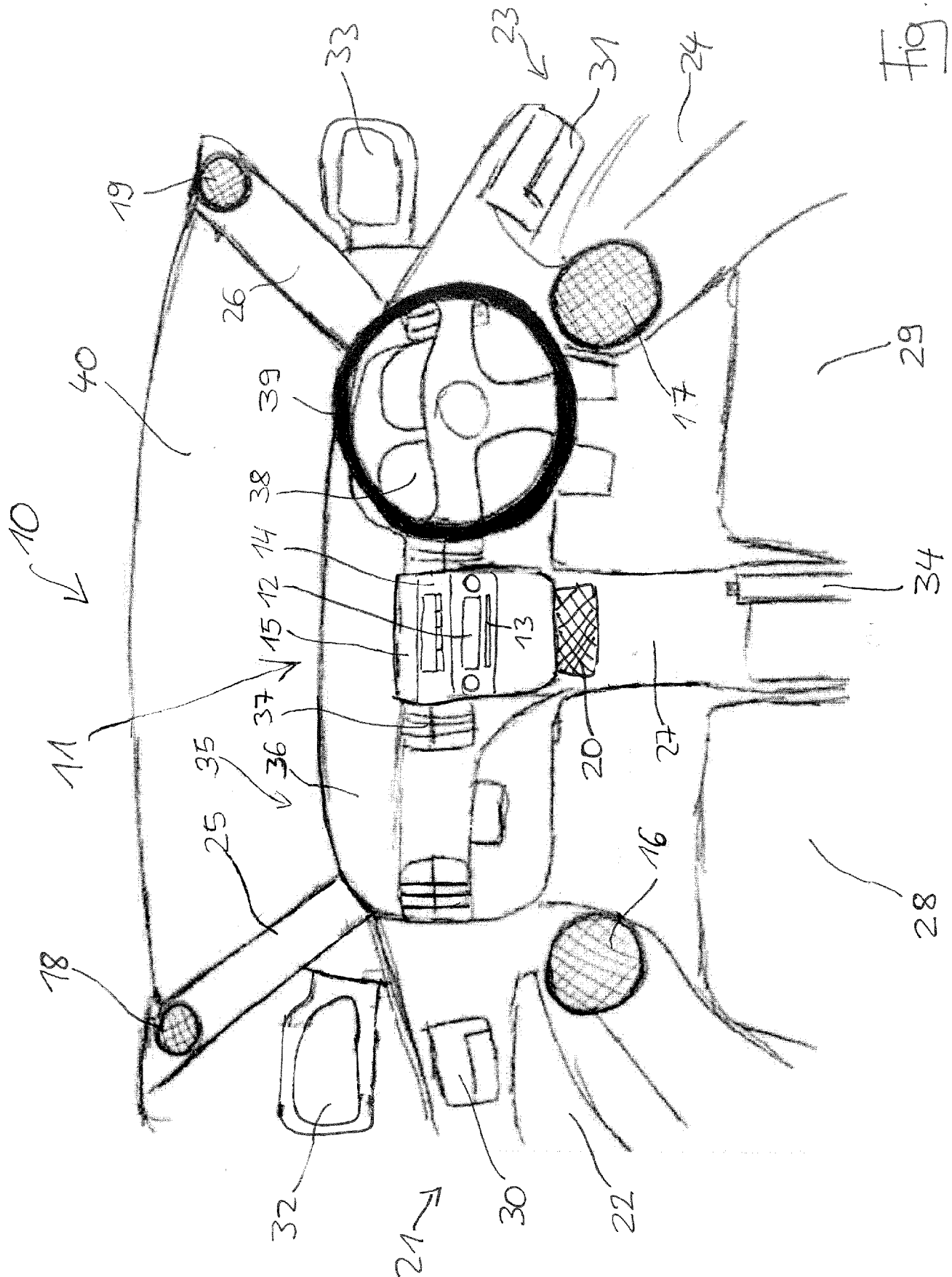
lect a predetermined sound pattern based on output signals of the height detection sensors.

9. Sound adaptation system according to one of claims 6 to 8, wherein the passenger detection sensors comprise weight sensors, wherein the sound adaptation system is configured to detect a child passenger from output signals of the height detection sensors and the weight sensors and wherein the selection means is adapted to select a corresponding sound profile.
10. Sound adaptation system according to claims 6 to 9, further comprising height actuators for adjusting heights of high pitch loudspeakers on a column of the passenger car and wherein the adaptation means of the sound adaptation module is configured to send signals to the height actuators according to the passenger occupation pattern.
11. Method for adapting a sound pattern of passenger car loudspeakers, the method comprising steps of
 - deriving a passenger occupation pattern from output signals of passenger detection sensors,
 - selecting a predefined sound profile based on the passenger occupation pattern,
 - adapting a sound pattern of passenger car loudspeakers based on the predefined sound profile,wherein the step of adapting comprises adapting a sound pattern of at least two loudspeakers.
12. Method according to claim 11, further comprising steps of
 - reading out signals of door sensors,

- reading out signals of motion detection sensors,
 - evaluating the signals of the door sensors and the signals of the motion detection sensors, if an open door is detected and a motion is detected, based on the evaluation of the signals from the door sensors and from the motion detection sensors:
 - triggering the steps of deriving the passenger occupation pattern, selecting the sound profile and adapting the sound pattern.
13. Method according to claim 11 or claim 12, wherein the step of adapting the sound pattern comprises adjusting the heights of tweeter loudspeakers.
14. Method according to one of claims 11 to 13, further comprising a step of
- detecting a passenger height from an output signal of a height detection sensor, wherein the step of selecting the sound profile comprises selecting the sound profile based on the passenger height.
15. Method according to one of claims 11 to 14, wherein the step of adapting comprises attributing a frequency amplification relationship to one or more loudspeakers according to the selected sound profile, the method further comprising a step of
- deriving one or more loudspeaker output signals from an audio source input signal according to the frequency amplification relationship.
16. Method according to one of claims 11 to 15, wherein the step of adapting comprises activating or deac-

tivating loudspeakers according to a loudspeaker activation matrix of the selected sound profile.

17. Method according to one of claims 11 to 16, further comprising
 - switching on of at least two rear main speakers which are provided behind a seat back row and switching off of other rear speakers if only the first row of passenger seats is occupied,
 - switching off of the rear main speakers and switching on of other rear speakers if at least one row of rear seats is occupied.
18. Method according to one of the claims 11 to 17, further comprising a step of switching off or reducing an amplification of a loudspeaker in response to a detected infant or child.
19. Method according to one of the claims 11 to 18, the step of adapting further comprising attributing a delay pattern to one or more loudspeakers according to the selected sound profile.



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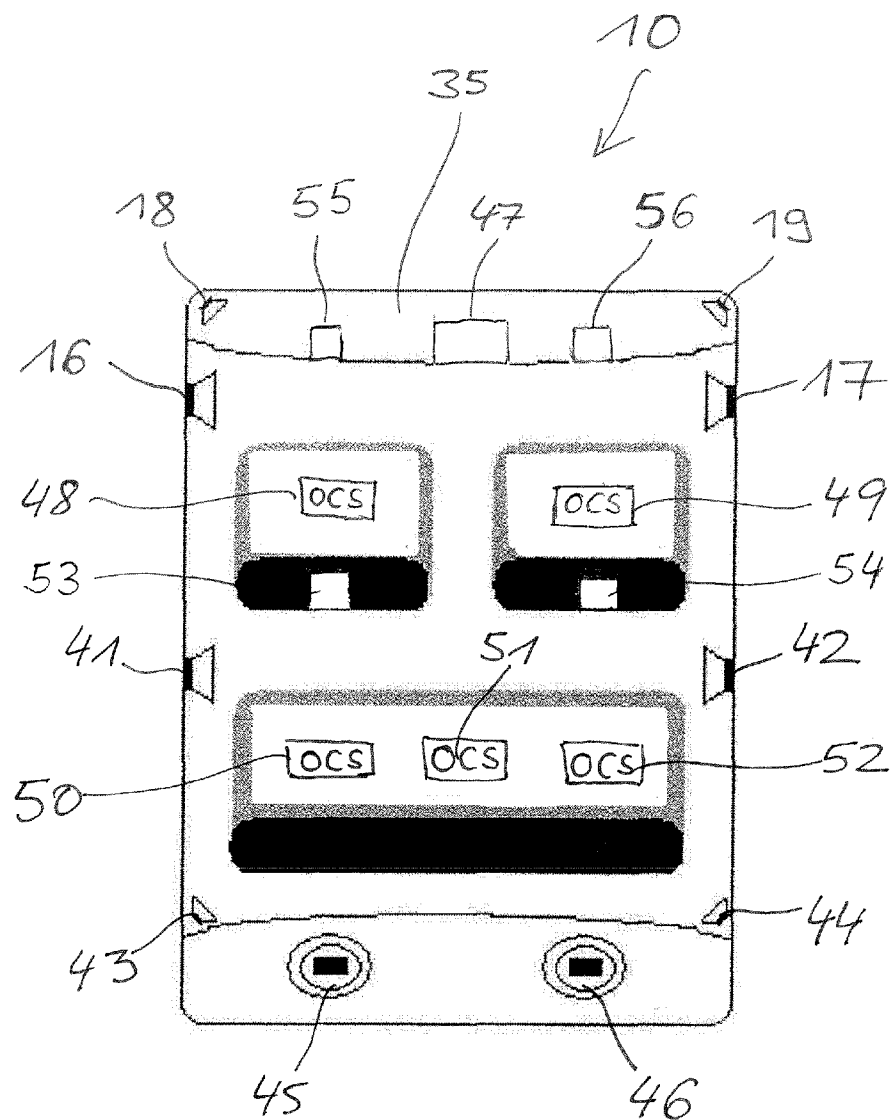


Fig. 2

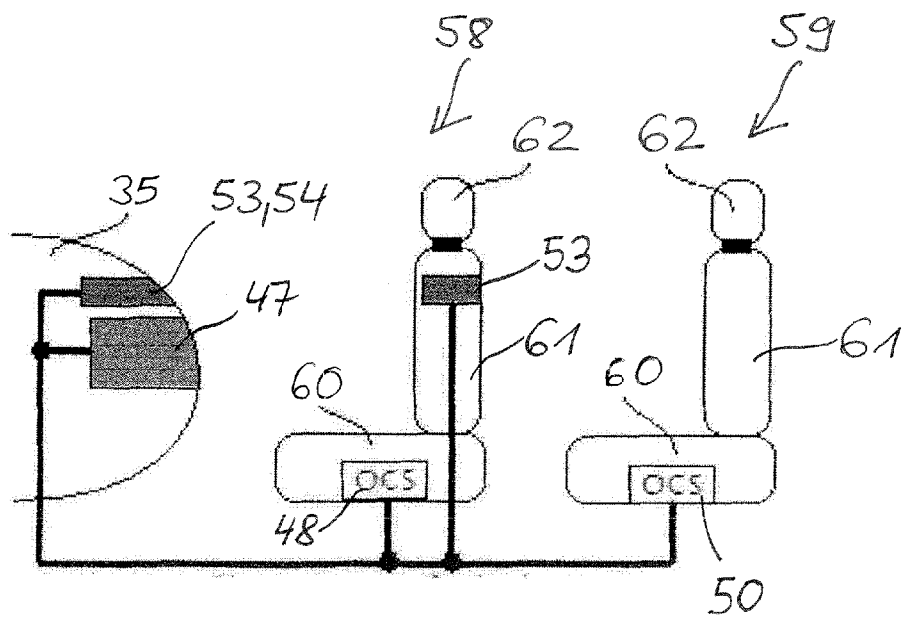


Fig. 3

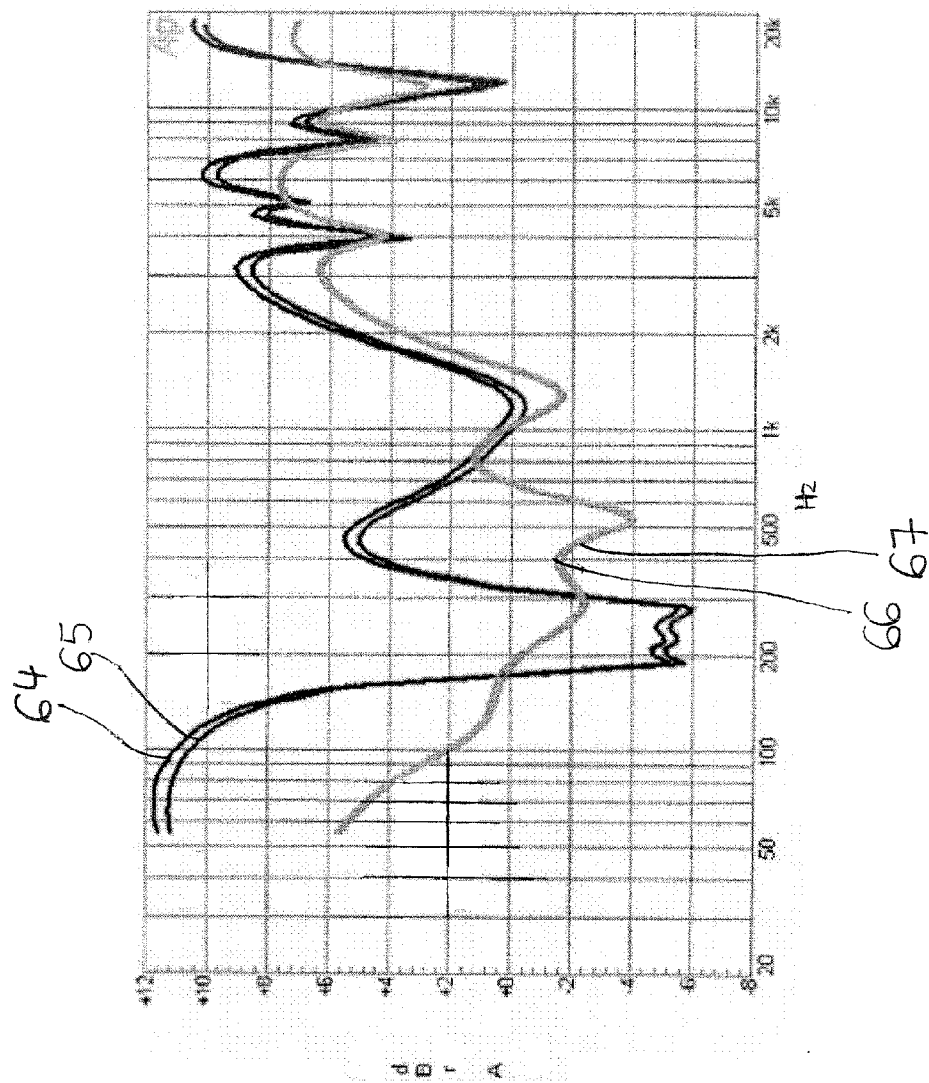


Fig. 4

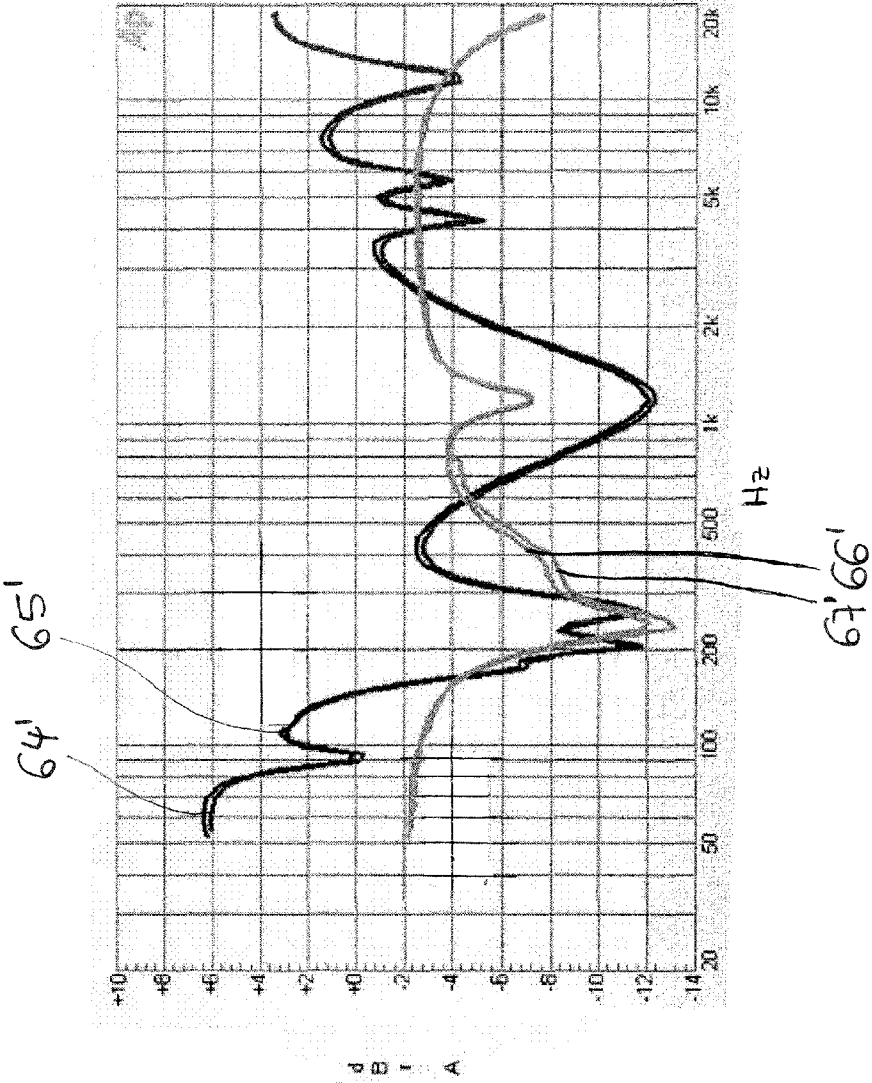
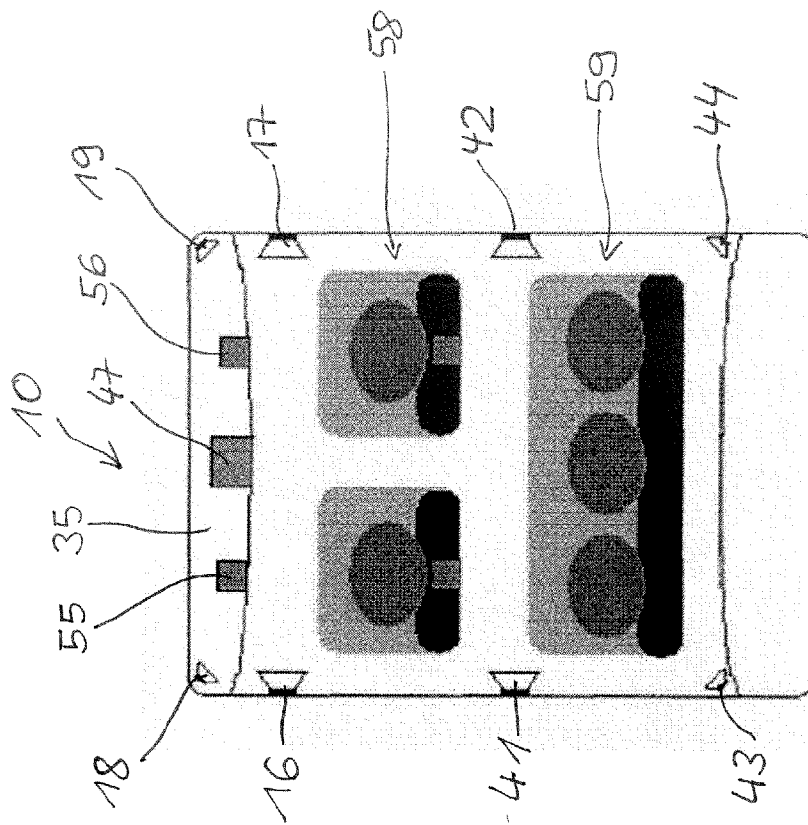
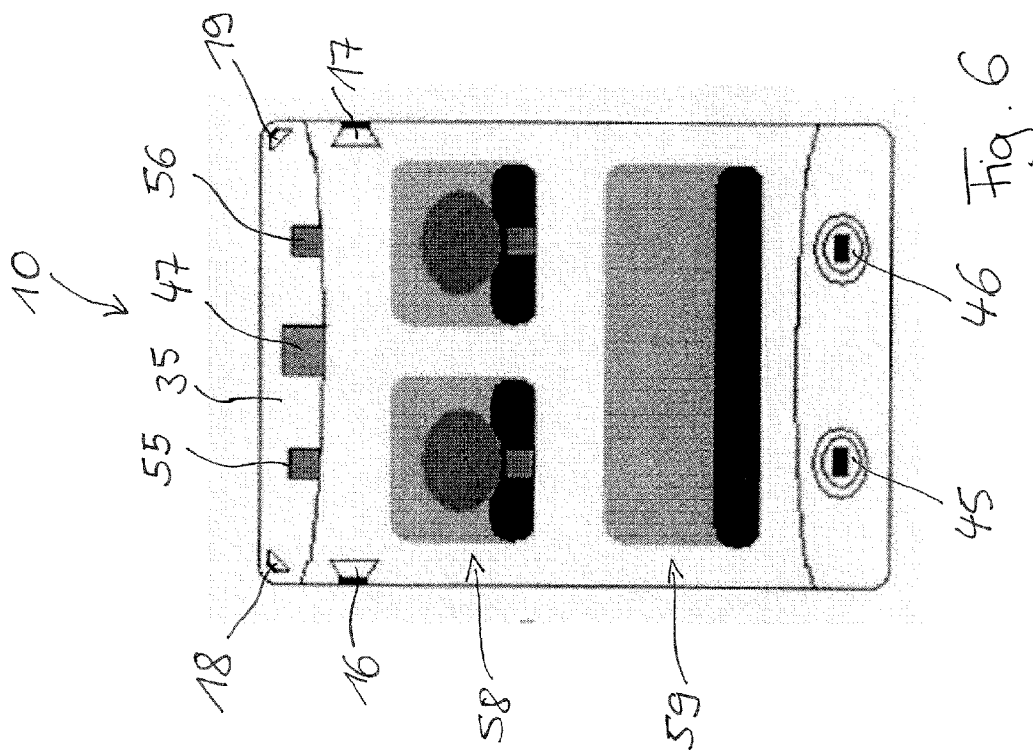


Fig. 5

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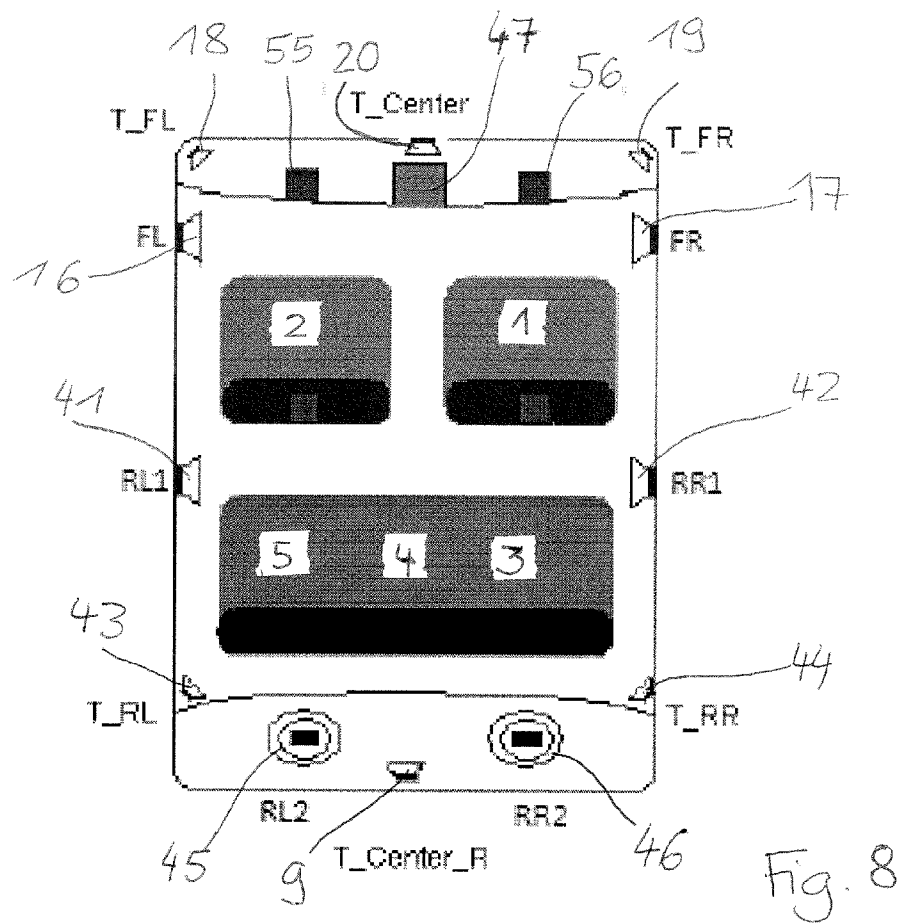


Fig. 8

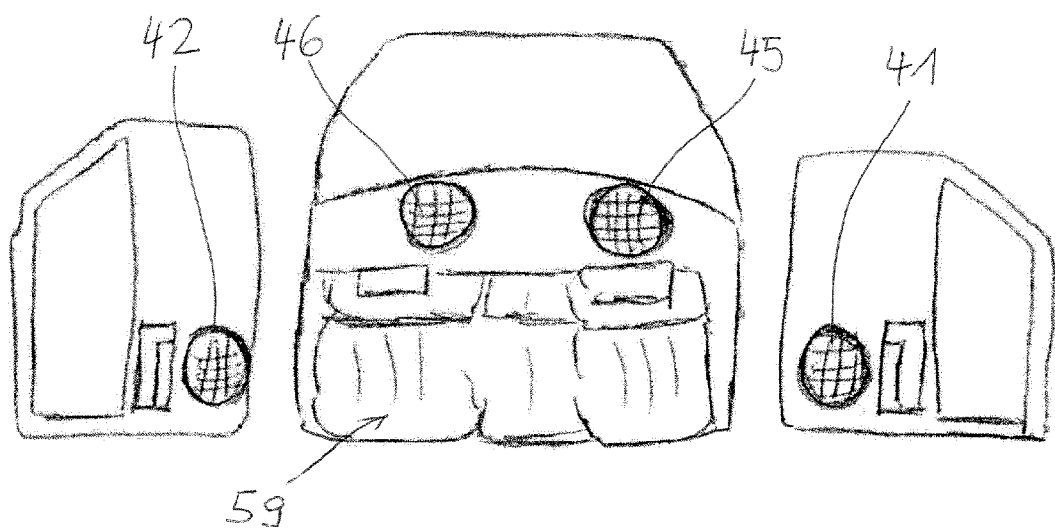


Fig. 9

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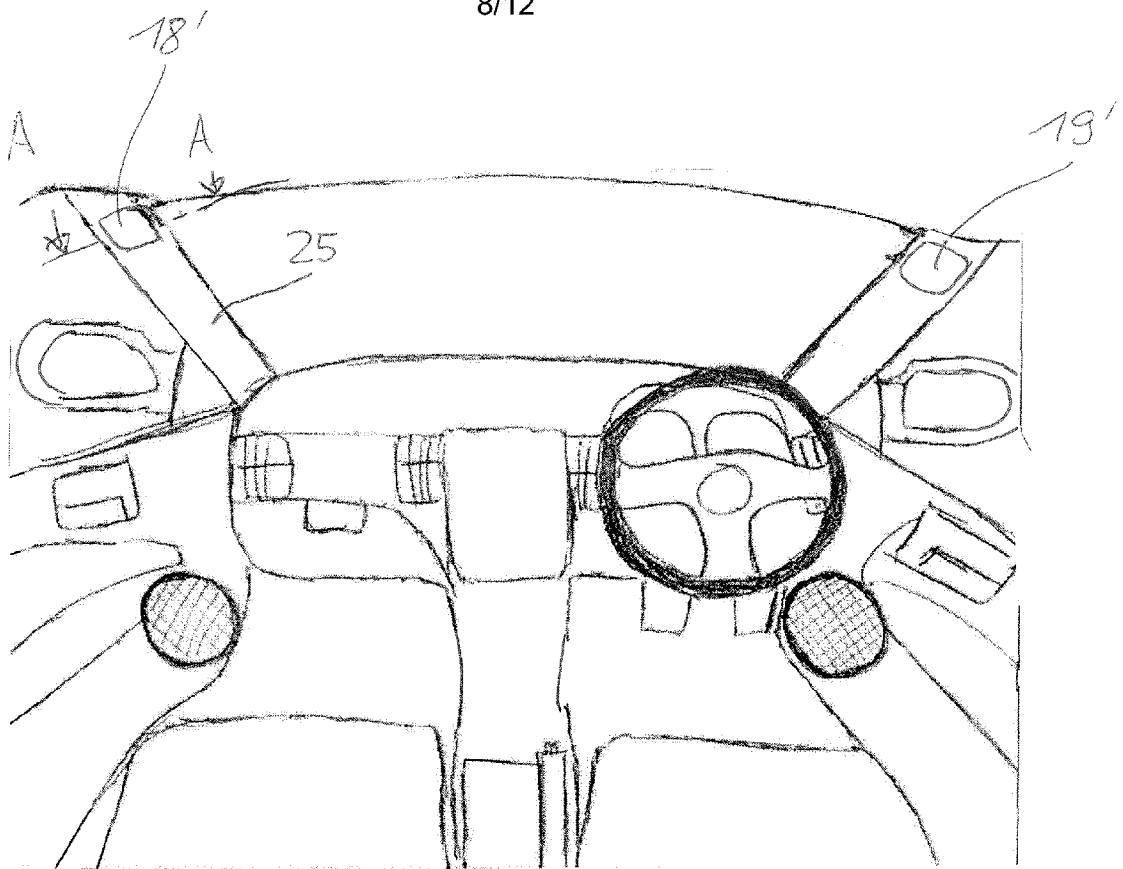


Fig. 10

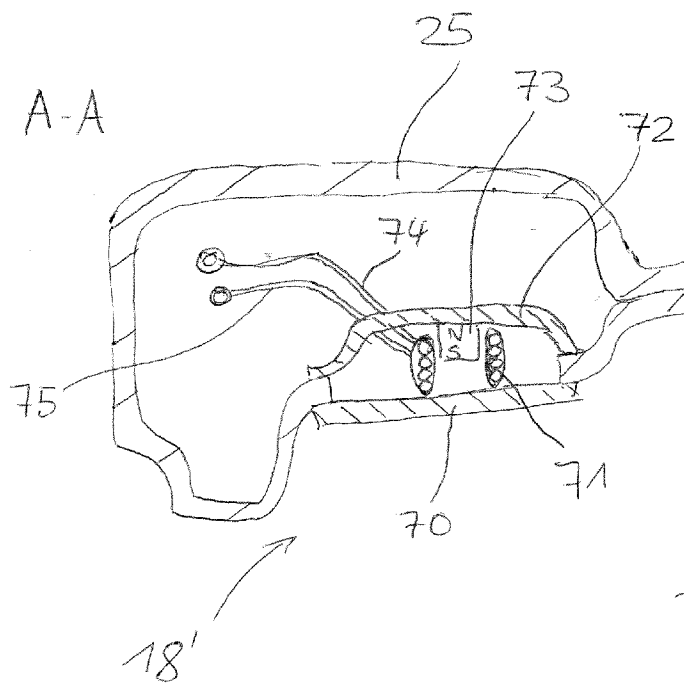


Fig. 11

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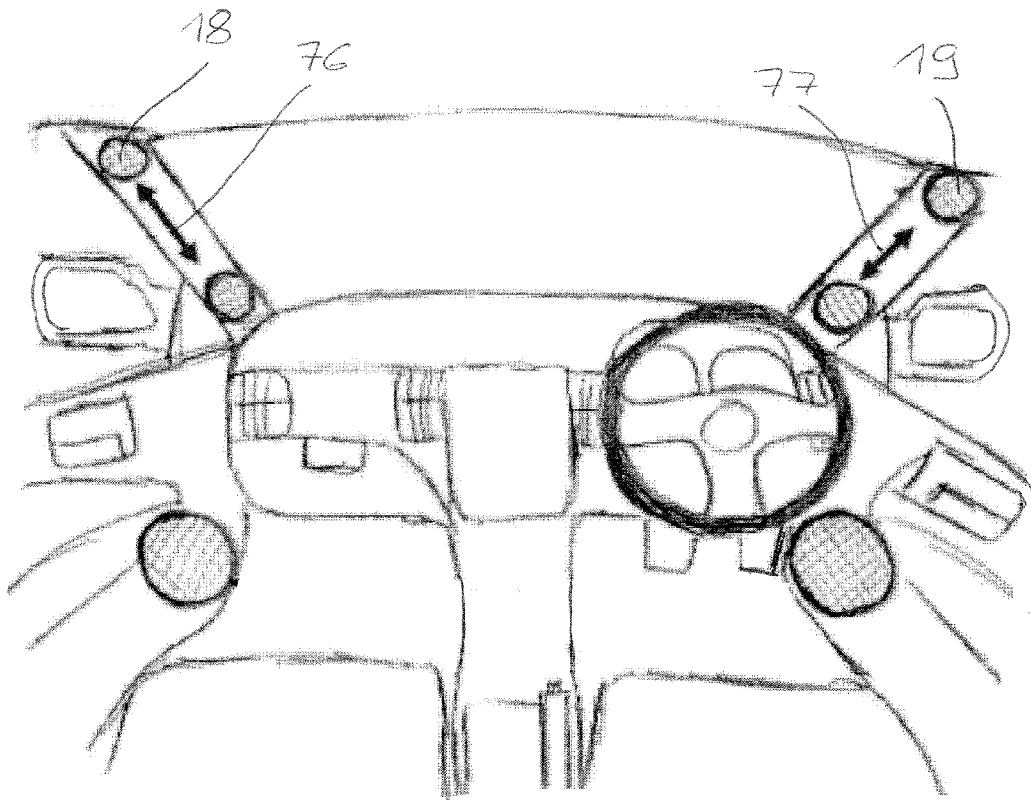


Fig. 12

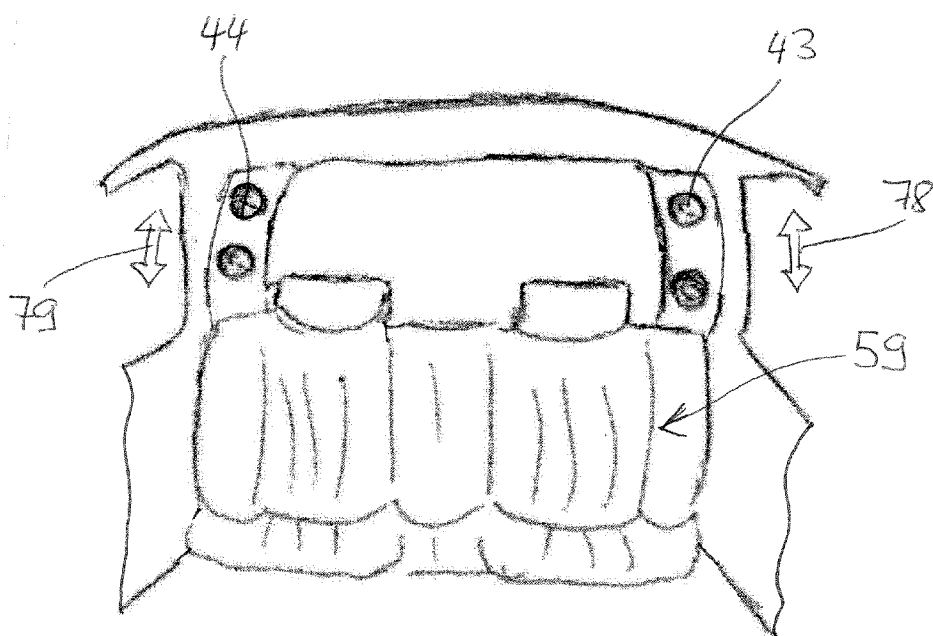


Fig. 13

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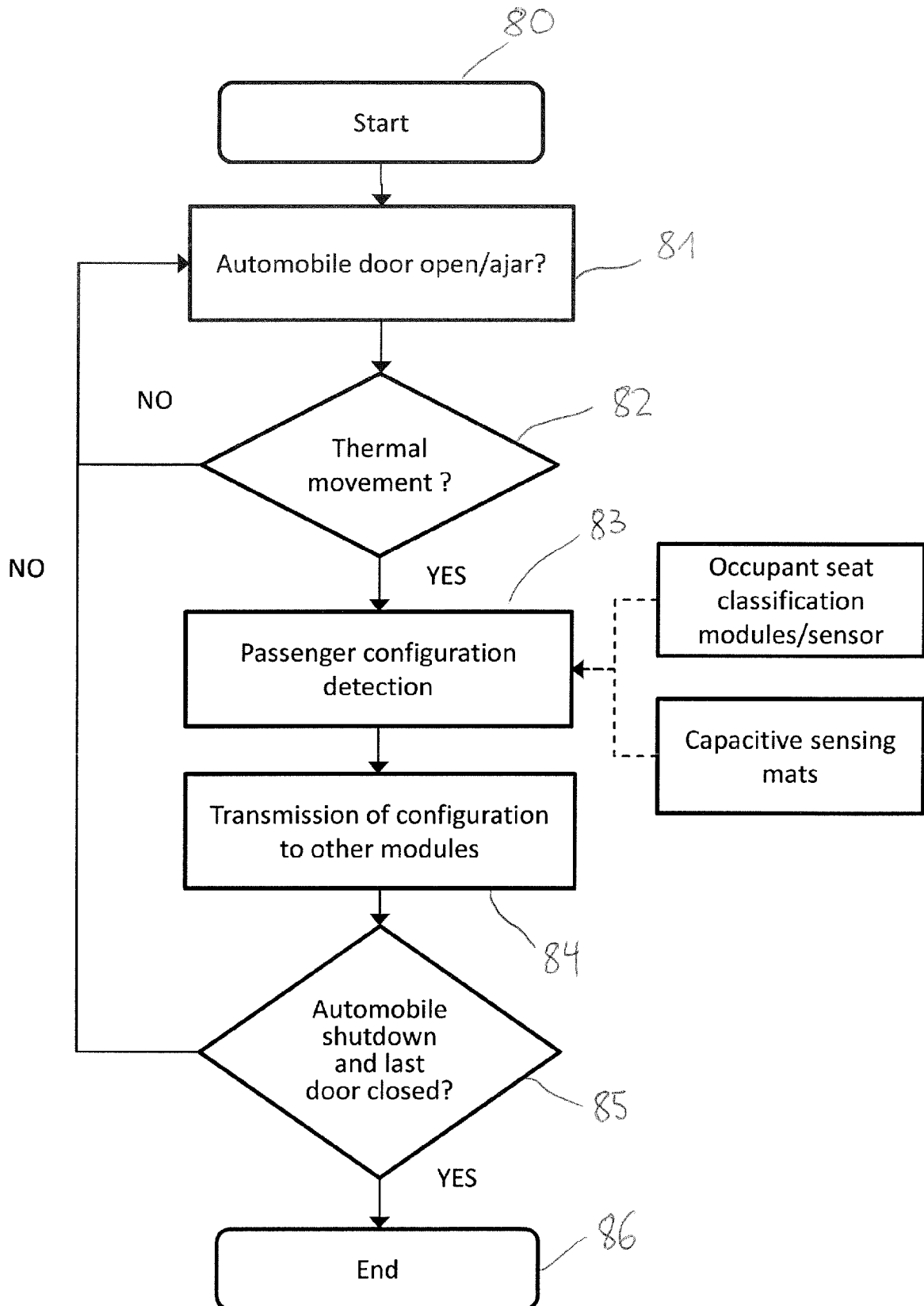
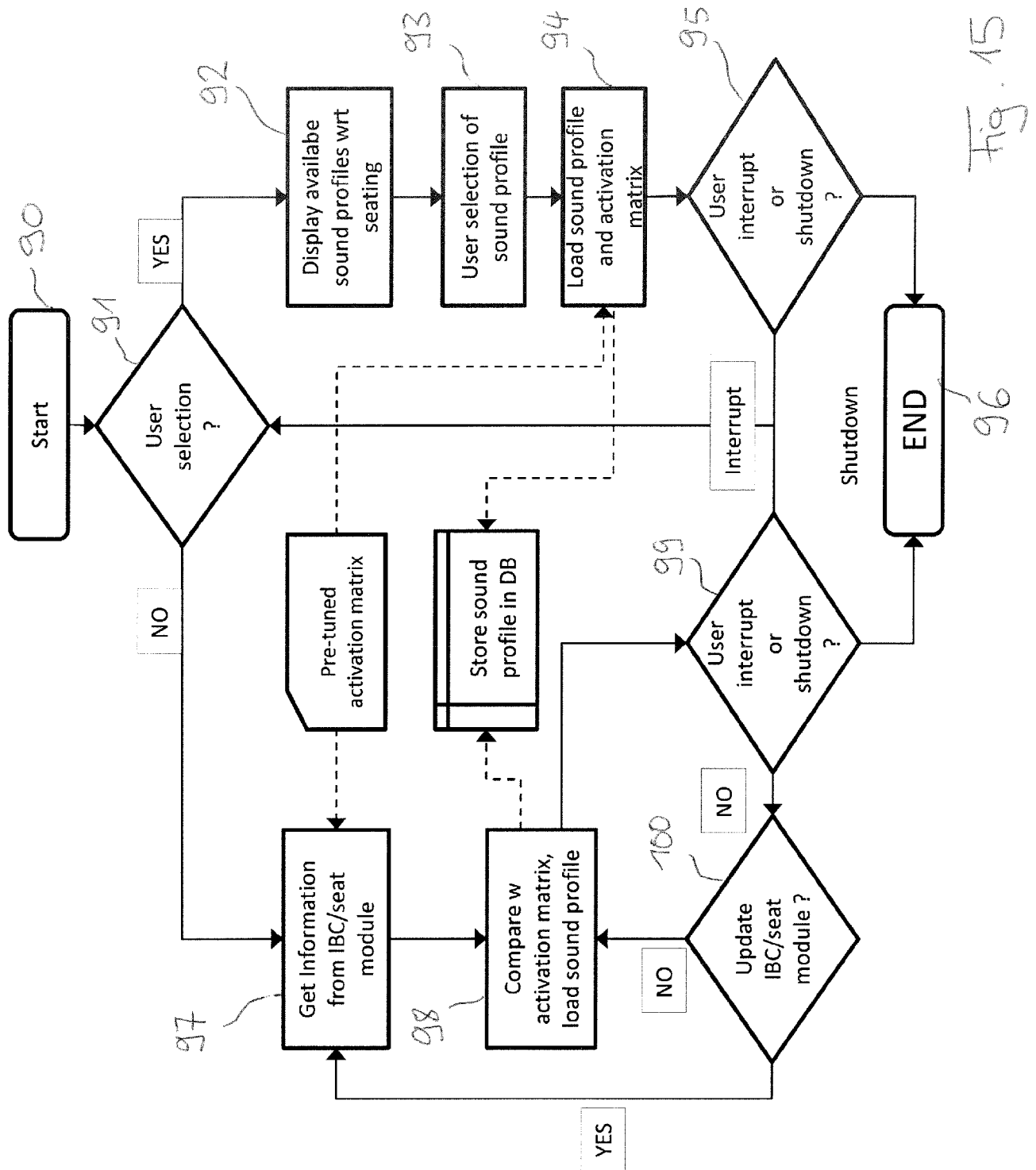


Fig. 14

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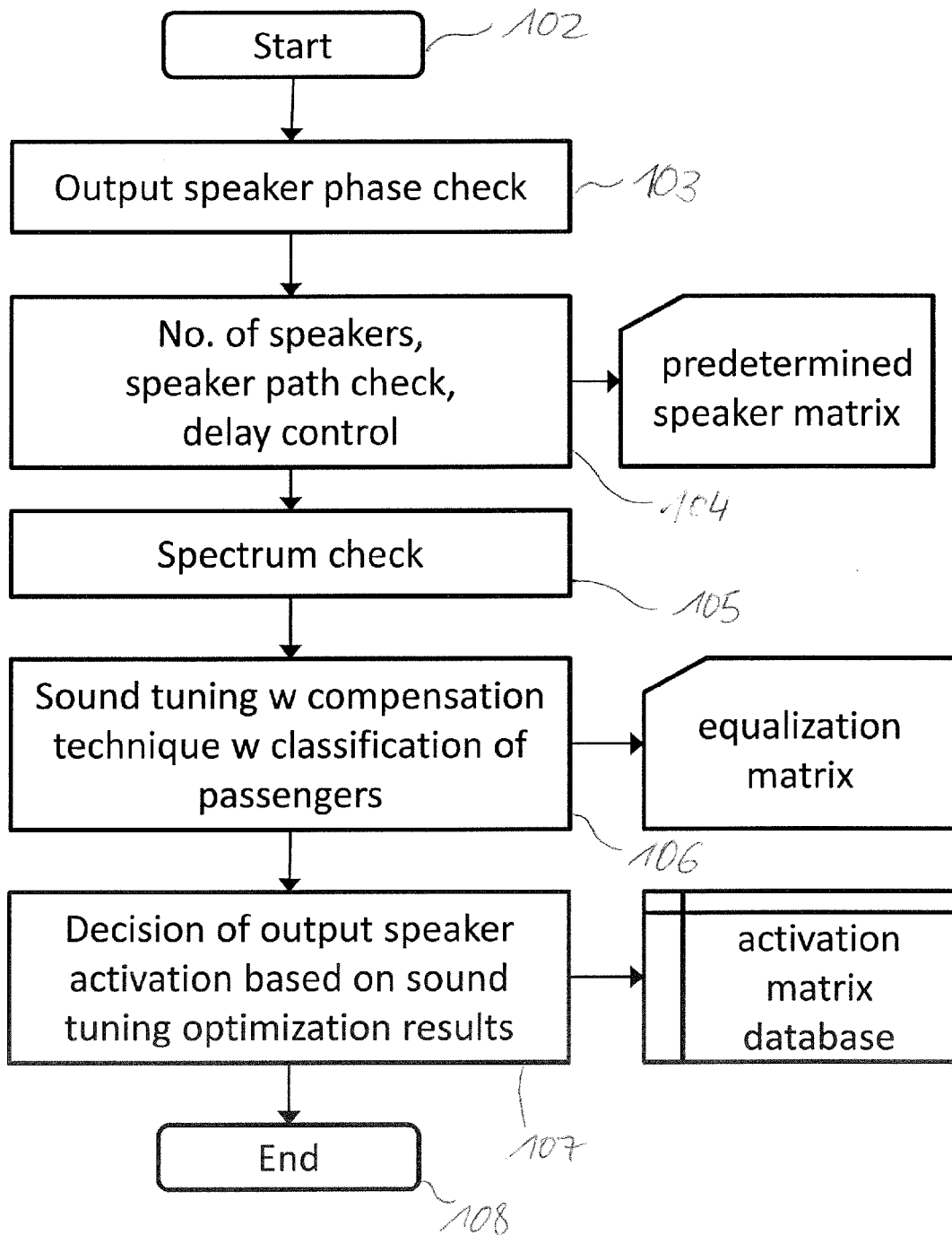


Fig. 16

A. CLASSIFICATION OF SUBJECT MATTER***H04S 3/00(2006.01)i, G11B 20/10(2006.01)i, G10K 15/04(2006.01)i***

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04S 3/00; G10L 13/08; B60R 11/02; G11B 15/02; G10L 21/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords:"car","noise","sound","adapt*"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-2008-0054254 A (DAEWOO IS CORP.) 17 June 2008 See the abstract; claim 1; and figure 1.	1-3, 11-13
A	US 2010-0057465 A1 (KIRSCH DAVID MICHAEL et al.) 04 March 2010 See the abstract; claim 1; and figure 3.	1-3, 11-13
A	KR 10-2007-0019165 A (HYUNDAI AUTONET CO., LTD.) 15 February 2007 See the abstract; claims 1-3; and figure 1.	1-3, 11-13
A	JP 2004-217192 A (SHIMOOKA HIDEHITO) 05 August 2004 See the abstract; claims 1-2; and figure 1.	1-3, 11-13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of 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

19 MARCH 2012 (19.03.2012)

Date of mailing of the international search report

21 MARCH 2012 (21.03.2012)

Name and mailing address of the ISA/KR

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Seo-gu, Daejeon 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

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Telephone No. 82-42-481-8483



INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2011/052638**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 7
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claim 7 is unclear because it refers to multiple dependent claim 6.
3. ☒ Claims Nos.: 4-6,8-10,14-19
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/IB2011/052638

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
KR 10-2008-0054254 A	17.06.2008	None	
US 2010-0057465 A1	04.03.2010	EP 2182511 A1 JP 2010-061137 A	05.05.2010 18.03.2010
KR 10-2007-0019165 A	15.02.2007	None	
JP 2004-217192 A	05.08.2004	None	