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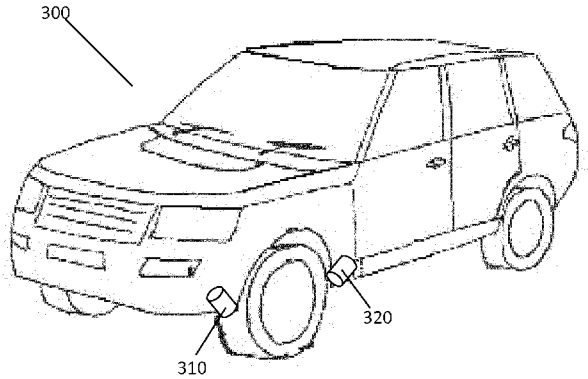


Fig 3

(57) Abstract: Embodiments of the present invention provide a noise cancellation controller (410), comprising a noise cancellation means (110, 410) arranged to receive a first noise signal (135, 425) indicative of noise associated with a predetermined first tyre horn (210), wherein the noise cancellation means is arranged to generate a first noise cancellation signal 145, 435 for in-vehicle noise cancellation by processing the first noise signal with an algorithm having one or more parameters associated with the first tyre horn (210).

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# APPARATUS AND METHOD FOR NOISE CANCELLATION

## TECHNICAL FIELD

The present disclosure relates to an apparatus and method for noise cancellation. Aspects of the invention relate to a noise cancellation controller, a noise cancellation system, a method of generating a noise cancellation signal, and to a vehicle comprising a noise cancellation system.

## BACKGROUND

Noise, especially within a vehicle, is troublesome for occupants the vehicle. Noise within the vehicle may distract a driver of the vehicle and may be tiring for the occupants of the vehicle, for example. Mechanical measures have been used to reduce noise within vehicles. However such measures are bulky and heavy. The use of active noise cancellation has been suggested. Active noise cancellation involves the generation of a sound wave to cancel with a noise sound wave thus making the environment quieter for a listener.

It is an object of embodiments of the invention to at least mitigate one or more of the problems of the prior art.

## SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide a noise cancellation controller, a noise cancellation system, a method of generating a noise cancellation signal, and a vehicle comprising a noise cancellation system as claimed in the appended claims.

According to an aspect of the invention, there is provided a noise cancellation controller comprising a noise cancellation means for receiving a noise signal associated with a predetermined tyre horn. The noise cancellation means processes the first noise signal according to a configuration associated with the tyre horn. Advantageously the noise signal is processed in a predetermined way bespoke for the tyre horn to effectively reduce noise from the tyre horn.

According to an aspect of the invention, there is provided a noise cancellation controller comprising a noise cancellation means arranged to receive a first noise signal indicative of noise. The noise may be associated with a predetermined first tyre horn, wherein the noise cancellation means is arranged to generate a first noise cancellation signal for in-vehicle

noise cancellation by processing the first noise signal with an algorithm having one or more parameters associated with the first tyre horn. Noise cancellation may be used to reduce the noise experienced by one or more occupants within the vehicle. Advantageously noise within the vehicle arising from the first tyre horn is reduced.

A noise cancellation controller as described above, wherein:

said noise cancellation means is one or more processing devices arranged to execute the algorithm to process the first noise signal.

Optionally, the noise cancellation means is arranged to receive a second noise signal indicative of noise associated with a predetermined second tyre horn and to generate a second noise cancellation signal for in-vehicle noise cancellation by processing the second noise signal with an algorithm having one or more parameters associated with the second tyre horn. Advantageously an influence on noise experienced within the vehicle associated with the respective tyre horns is addressed. That is, each tyre horn differently influences the noise within the vehicle. Furthermore, each tyre horn may have an associated different influence on noise experienced at each of a plurality of positions within the vehicle. In some embodiments the noise cancellation controller is arranged to generate a noise cancellation signal for in-vehicle noise cancellation by processing each respective noise signal according to one or more parameters associated with the respective noise source.

In an embodiment of the invention, the one or more parameters associated with the first tyre horn define a first noise transfer function associated with the first tyre horn. Optionally, the parameters associated with the second tyre horn define a second noise transfer function associated with the second tyre horn. Advantageously noise from each tyre horn is differently processed according to characteristics of the respective tyre horn.

Optionally, the first and second noise transfer functions are different. Advantageously each transfer function provides different processing of the tyre horns according to characteristics of the respective tyre horn.

The one or more parameters may be associated with a filter applied to the noise signal. Optionally, the one or more parameters are filter coefficients.

Optionally each noise transfer function defines one or both of a reference transfer function (RTF) or a speaker transfer function (STF).

In some embodiments the first noise cancellation signal is associated with a first noise cancellation zone. The noise cancellation means may be arranged to generate a second noise cancellation signal associated with a second noise cancellation zone by processing the first noise signal with an algorithm having one or more second parameters associated with the first tyre horn. Advantageously, noise arising in each zone from the respective tyre horns is addressed.

The first noise signal may be received from a first noise input means directed to the first tyre horn. Optionally, the first noise input means is an audio input means for audibly detecting the first tyre horn and outputting the first noise signal based thereon. Optionally, the first noise input means is a microphone directed to the first tyre horn. Optionally, the microphone is a directional microphone. Advantageously the noise input means are configured to receive a signal from the associated tyre horn. Furthermore, in some embodiments, noise from other tyre horns is supressed. The microphone may be an omnidirectional microphone arranged about a vehicle at a location associated with a predetermined tyre horn.

According to another aspect of the invention, there is provided a noise cancellation system for a vehicle, comprising a noise cancellation means communicably coupled to first and second noise input means. The first noise input means may be arranged for receiving a first noise signal indicative of noise associated with a predetermined first tyre horn and the second noise input means may be arranged for receiving a second noise signal indicative of noise associated with a predetermined second tyre horn. The noise cancellation means may be arranged to generate a first noise cancellation signal for in-vehicle noise cancellation by processing the first noise signal with an algorithm having one or more parameters associated with the first tyre horn and to generate a second noise cancellation signal by processing the second noise signal with an algorithm having one or more parameters associated with the second tyre horn.

A noise cancellation system as described above, wherein:

said noise cancellation means is one or more processing devices arranged to execute the algorithms to process the first and second noise signals;

said first and second noise input means are first and second noise sensing devices, such as microphones.

According to another aspect of the invention, there is provided a method of in-vehicle noise cancellation, comprising receiving a first noise signal indicative of noise associated with a predetermined first tyre horn and generating a first noise cancellation signal for in-vehicle

noise cancellation by processing the first noise signal with an algorithm having one or more parameters associated with the first tyre horn.

Optionally, the method comprises receiving a second noise signal indicative of noise associated with a predetermined second tyre horn. The method may comprise generating a second noise cancellation signal for in-vehicle noise cancellation by processing the second noise signal with an algorithm having one or more parameters associated with the second tyre horn. Optionally, the parameters associated with the second tyre horn define a second noise transfer function associated with the second tyre horn.

Optionally the one or more parameters associated with the first tyre horn define a first noise transfer function associated with the first tyre horn. Optionally, the first and second noise transfer functions are different.

Each noise transfer function may define one or both of a reference transfer function (RTF) or a speaker transfer function (STF).

In some embodiments of the invention, the one or more parameters are associated with a filter applied to the noise signal. The one or more parameters may be filter coefficients.

The first noise cancellation signal may be associated with a first noise cancellation zone. The method may comprise generating a second noise cancellation signal associated with a second noise cancellation zone by processing the first noise signal with an algorithm having one or more second parameters associated with the first tyre horn.

Optionally the first noise signal may be received from a first noise input means directed to the first tyre horn. Optionally, the first noise input means comprises an audio input means for audibly detecting the first tyre horn and outputting the first noise signal based thereon. The first noise input means may comprise a microphone directed to the first tyre horn. Optionally, the microphone comprises a directional microphone.

According to another aspect of the invention, there is provided a vehicle comprising a noise cancellation system according to an aspect of the invention. Optionally, the first noise input means of the noise cancellation system is a first microphone directed to the first tyre horn. Optionally, the first microphone is a microphone configured to have a directivity pattern directed towards the associated tyre horn. Optionally, the microphone is arranged proximal to a first wheel of the vehicle. Optionally, the vehicle comprises a second microphone

directed to a second tyre horn, wherein the first and second microphones are arranged in non-parallel axes. The axis may, optionally, be at least 45 degrees.

According to another aspect of the invention, there is provided computer software which, when executed by a computer, is arranged to perform a method according to an aspect of the invention. Optionally, the computer software may be stored on a computer readable medium.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

## BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a system according to an embodiment of the invention;

Figure 2 shows an illustration of a tyre footprint and a plurality of sound horns;

Figure 3 shows a vehicle according to an embodiment of the invention; and

Figure 4 shows a noise cancellation system according to an embodiment of the invention.

## DETAILED DESCRIPTION

Figure 1 illustrates a noise cancellation system 100 according to an embodiment of the invention. The system 100 comprises a noise cancellation means 110. The noise cancellation means 110 may be a noise cancellation controller 110 comprising one or more processing devices which are arranged, in use, to determine at least one noise cancellation

signal 145 for reducing noise. The at least one noise cancellation signal 145 is provided to one or more audio output means, generally denoted as 140, as will be explained. The audio output means 141, 142 may be one or more acoustic devices such as speakers 141, 142.

The audio output means 141, 142 are arranged to reduce noise within a vehicle. The noise cancellation system 100 may be used within a vehicle. In an embodiment of the invention the vehicle is a wheeled vehicle comprising a plurality of wheels. The wheels may be pneumatic wheels, although embodiments of the invention may also be used with solid-wheeled vehicles such as trains. The vehicle may be powered by one or more of a combustion engine, such as petrol, diesel or gas, or one or more electric motors which may be driven by battery and/or alternative power source such as hydrogen.

The audio output means 141, 142 may be arranged within an occupant compartment of the vehicle to output audio into the occupant compartment for reducing noise therein. The audio output means 141, 142 outputs audible signals which at least partly cancel with the noise to reduce the noise i.e. the audible signals may be an inverse of the noise at the ear(s) of an occupant of the vehicle. However where there is a desired audio signal such as from an entertainment system within the vehicle the audible signals output by the output means 141, 142 may accommodate the desired audio signal. Hereinafter the noise cancellation means 110 will be referred to as a noise cancellation controller 110.

The noise cancellation signal 145 is determined based upon an input from one or more noise input means generally denoted as 130. The one or more noise input means 131, 132 may be one or more acoustic sensing devices such as microphones or accelerometers 131, 132. Each noise input means 130 is arranged to output a respective noise signal 135 indicative of detected noise to the noise cancellation controller 110.

Noise is a significant issue within vehicles as a noisy environment is detrimental to one or more occupants of the vehicle, such as to enjoyment and comfort of the occupants. For example, the occupants of the vehicle may become tired through exposure to noise within the vehicle. Furthermore, a characteristic of a premium vehicle is that an environment within the vehicle is relatively quiet. Noise cancellation may be used to reduce the noise experienced by one or more occupants within the vehicle.

However it has been noted that predicting the noise, or the sound pressure level (SPL), at an ear of an occupant of the vehicle is troublesome. In order to be effective, audio output

means 141, 142 should be controlled to output audio to cancel the noise SPL at the ear of the occupant.

In embodiments of the invention the noise cancellation system 100 is arranged to selectively reduce noise arising from one or more predetermined sources. The one or more predetermined sources comprise at least one tyre horn associated with a wheel of the vehicle.

A tyre horn is a region associated with a vehicle tyre in which airborne noise is generated or emitted. Noise caused by movement of the tyre upon a road surface, particularly although not exclusively a porous road surface, may be amplified by a 'horn effect'. It has been noted by the present inventors that the vehicle tyre is associated with a plurality of tyre horns. Thus, in the present application the term 'tyre horn' is understood to mean a region associated with a vehicle tyre. The region may be understood to emanate from an area of a contact patch of the tyre with a road surface. Each tyre of the vehicle is associated with a plurality of tyre horns. In an illustrated example each tyre is shown as being associated with four tyre horns although it will be understood that each tyre may be associated with two or more tyre horns, such as four, six, eight or more.

Referring to Figure 2, a footprint of a vehicle tyre 200 on a road surface is illustrated. For example, the tyre 200 may be a rear right (RR) tyre of a vehicle, although it will be realised that this is only an example. The RR tyre 200 may be associated with right-rear-front (RRF) 210, right-rear-rear (RRR) 220, right-rear-inward (RRI) 230 and right-rear-outward (RRO) 240 tyre horns. It will be realised that, in other embodiments, each tyre 200 may be considered as being associated with more or less tyre horns, such as a right-rear-front-outward (RRFO) (not illustrated) tyre horn at an angle of between 0 and 90 degrees, such as 45 degrees to the tyre's direction of rotation. It will also be realised that other tyre horns may be associated with other tyres, such as left-rear (LR), right-front (RF), left-front (LF) tyres etc.

It has been observed that each tyre horn 210, 220, 230, 240 has an associated influence on noise experienced within the vehicle associated with the tyre. That is, each tyre horn 210, 220, 230, 240 differently influences the noise within the vehicle. Furthermore, each tyre horn 210, 220, 230, 240 may have an associated different influence on noise experienced at each of a plurality of positions within the vehicle. For example, a driver of the vehicle might observe different noise due to a particular tyre horn, such as RRI 230, than a passenger seated in a different position in the vehicle. Therefore, in embodiments of the invention, the noise cancellation controller 110 is arranged to generate a noise cancellation signal 145 for

in-vehicle noise cancellation by processing each respective noise signal according to one or more parameters associated with the respective noise source. In some embodiments each tyre horn 210, 220, 230, 240 is associated with respective one or more parameters for processing a noise signal associated with the respective tyre horn 210, 220, 230, 240.

In embodiments of the invention, at least some of the noise input means 131, 132 are each associated with a respective tyre horn 210, 220, 230, 240. At least some of the noise input means 131, 132 may be microphones arranged to detect noise arising from an associated tyre horn. The microphones may be directional microphones arranged to generally pickup only the noise of the respective tyre horn 210, 220, 230, 240. In other words, each microphone is arranged to selectively receive the noise associated with one of the tyre horns 210, 220, 230, 240. For example, first noise input means 131 is, in one embodiment, a microphone 215 arranged to detect noise arising from the tyre horn RRF 210 and second noise input means 132 is a microphone 225 arranged to detect noise arising from the tyre horn RRR 220. Therefore each microphone 215, 225 isolates and receives noise from any predetermined tyre horns. It will be realised that the microphones may be associated with other, or further, tyre horns. In some embodiments at least some of the microphones may be omnidirectional microphones arranged in a location to receive noise associated with a predetermined tyre horn. The microphone may be arranged at a distance from a location at which an associated tyre contacts the ground. Furthermore the noise cancellation controller 110 may be arranged to receive noise signals from additional noise input means 130 not associated with respective tyre horns, such as an accelerometer associated with a suspension of the vehicle.

In some embodiments, the noise cancellation controller 110 is arranged to reduce noise within one or more noise cancellations zones within the vehicle. In one embodiment, substantially the entire interior of the vehicle is determined as the noise cancellation zone i.e. there is only one noise cancellation zone. In some embodiments, the vehicle comprises a plurality of noise cancellation zones within the interior of the vehicle. In some embodiments each of one or more noise cancellation zones are arranged proximal to an expected location of an occupant of the vehicle. For example, a first noise cancellation zone may be arranged proximal to an intended location of a driver of the vehicle. The intended location may correspond to a head location of the occupant. A second, and possibly further, noise cancellation zone(s) may be respectively arranged in relation to each potential further occupant within the vehicle and, in some embodiments, corresponding to an expected head location of each occupant.

Figure 3 illustrates a vehicle 300 according to an embodiment of the invention. The vehicle 300 comprises a noise cancellation system 100 according to an embodiment of the invention. A first microphone 310, representing a first noise input means, is arranged to output a first noise signal indicative of noise associated with a predetermined first tyre horn. As illustrated in Figure 3 the first tyre horn is a left-front-forward (LFF) tyre horn, although it will be realised that the first tyre horn may be another tyre horn and may be associated with another tyre of the vehicle. A second microphone 320 is arranged to output a second noise signal indicative of noise associated with a predetermined second tyre horn. As illustrated in Figure 3 the second tyre horn is a left-front-read (LFR) tyre horn, although it will be realised that the second tyre horn may be another tyre horn. Each microphone 310, 320 is arranged to receive noise generated external to the vehicle 300 proximal to a region of the respective tyre horn. In particular, each microphone 310, 320 may be a directional microphone directed toward the respective tyre horn. In some embodiments, each microphone is directed downward toward a location at which the tyre contacts the road beneath the vehicle. Although the microphones 310, 320 are shown as externally mounted upon the vehicle 300 in Figure 3 the microphones 310, 320 may be concealed such as mounted within a wheel-arch of the vehicle 300 or other trim or body-panel but arranged to have a sensitive area or pickup area of the microphone 310, 320 directed toward the respective tyre horn. The microphones 31, 320 may be arranged behind a wheel-arch liner of the vehicle in some embodiments. The first and second noise signals output by the microphones 310, 320 are provided to the noise cancellation controller 210.

Figure 4 illustrates an embodiment of the noise cancellation system 400 arranged in use within a vehicle, such as the vehicle 300 illustrated in Figure 3. The noise cancellation system 400 comprises a noise cancellation controller 410 communicably connected to a first noise input means 420 and a first audio output means 430. It will be realised, however, that this is not limiting and that the system 400 may be connected to more than one input 420 and output 430 means, respectively. Furthermore it is not necessary for the number of input means 420 to equal the number of output means 430. The first noise input means 420 is a first directional microphone such as microphone 310 illustrated in Figure 3. The first audio output means 430 is a speaker arranged within the vehicle 300.

The noise cancellation controller 410 is arranged to receive a first noise signal 425 indicative of noise associated with a predetermined first tyre horn. The first noise signal 425 is output by the microphone 420 indicative of noise detected by the microphone 420 which, in use, corresponds to the first tyre horn.

The noise cancellation system 400 is arranged to output a noise cancellation signal 435 to the audio output means 430, wherein the audio output means 430 outputs an audible signal corresponding thereto. The audio output means 430 is, in one embodiment, an audio output device such as a speaker arranged within an occupant compartment of the vehicle i.e. within an interior of the vehicle. The speaker 430 may be arranged within, for example, a dashboard, interior body panel or door panel of the vehicle, although it will be realised that these embodiments are not exhaustive. In one embodiment the speaker 430 is arranged within a headrest of the vehicle proximal to an occupant's expected head position. The speaker 430 may be located within a noise cancellation zone 450 indicated with dotted line in Figure 4. The noise cancellation zone 450 may be a volume within the vehicle 300 within which the system 400 is intended, in use, to reduce noise.

As illustrated, in the noise cancellation system 400, first noise input means 420 and first audio output means 430 form an open-loop system. That is, the noise cancellation controller 410 receives the noise signal 425 and outputs the noise cancellation signal 435 based thereon according to a predetermined algorithm.

In some embodiments a closed-loop system is formed by the inclusion of one or more feedback means 440. The feedback means 440 provides at least one feedback signal 445 to the noise cancellation system 400. The feedback signal 445 is indicative of noise within the noise cancellation zone 450. Therefore the feedback signal 445 may be an error signal indicative of remaining noise present within the noise cancellation zone 450. The error signal may correspond to a sum of the noise within the noise cancellation zone 450, the audible signal corresponding to the noise cancellation signal 435 and, in some circumstances, an intended audio signal within the noise cancellation zone such as audio output by an entertainment system of the vehicle such as music. It will be appreciated that the noise cancellation signal 435 may have a minus sign intended to cancel the noise within the noise cancellation zone 450. As the noise cancellation signal is intended to cancel the noise, it may be considered as a negative signal, or having a negative sign, thus being subtracted from the noise within the noise cancellation zone 450. Therefore the feedback signal 445 may be equal to *[measured noise]-[intended noise].*

The feedback means 440 is a feedback device such as a vibroacoustic device for deleting noise. The feedback device may be at least one microphone arranged within the noise cancellation zone 450. For example, in one embodiment, the feedback means 440 may be a microphone arranged within the occupant compartment of the vehicle. The microphone 440

may be arranged within a headrest of the vehicle. In another embodiment the feedback device may be an accelerometer.

In one embodiment the noise cancellation controller 410 comprises a data store 460 such as a memory formed by one or more memory devices. The data store 460 may store one or more parameters associated with one or more further tyre horns such as second tyre horn, third tyre horn etc. The data store 460 may store one or more parameters associated with the first tyre horn and the noise cancellation zone 450 and the first tyre horn and a second noise cancellation zone, respectively. The one or more parameters associated with each noise cancellation zone for the same tyre horn 210, 220, 230, 240 may be different.

The one or more parameters for each tyre horn 210, 220, 230, 240 and, in some embodiments, noise cancellation zone 450, may form a table of noise cancellation data, although it will be realised that embodiments of the invention are not limited in this respect. In one embodiment, the data store 460 stores a plurality of sets of one or more coefficients each associated with a transfer function of the noise cancellation controller 410. Each transfer function defines a relationship between the received noise signal 425 and the noise cancellation signal 435. In some embodiment the transfer function includes at least one component corresponding to feedback signal 445. The noise cancellation controller 410 comprises a processing means such as one or more processors 470 which are arranged to process the noise signal 425 to generate and output the noise cancellation signal 435 according to the transfer function.

In one embodiment, the data store 460 of the noise cancellation controller 410 stores one or more parameters associated with at least one of a reference transfer function (RTF) and a speaker transfer function (STF).

The RTF represents a transfer function from one or more acoustic sensing devices such as the microphone 420. The transfer function may be from the microphone 420 to the one or more associated noise cancellation zones 450. As noted above, a respective RTF may be provided for each tyre horn 210, 220, 230, 240 and, in some embodiments, for each combination of tyre horn 210, 220, 230, 240 and cancellation zone 450. The RTF may comprise a plurality of coefficients. The RTF may represent be used to configure at least one filter. The RTF represents how noise within the vehicle 300 is caused by acoustic signals at the acoustic sensing device 420. For example, the RTF may place emphasis on acoustic signals in one or more frequency ranges resulting in noise within the noise cancellation zone 450.

The STF represents a transfer function from the one or more audio output devices 141, 142, such as the speaker 430. The STF may represent a transfer function from an audio output device i.e. the speaker 430 to a particular noise cancellation zone, such as zone 450. A respective STF may be provided for each cancellation zone 200. The STF may comprise a plurality of coefficients. For example, the STF may place emphasis on acoustic signals in one or more frequency ranges resulting in noise within the noise cancellation zone 200.

The one or more parameters associated with each tyre horn 210, 220, 230, 240 may configure one or both of the at least one RTF or STF. In one embodiment a plurality of RTFs and/or STFs are stored within the data store 460 of the noise cancellation controller 410. In some embodiments, one RTF and STF may receive inputs associated with a plurality of tyre horns 210, 220, 230, 240 having one or more respective parameters.

In some embodiments the noise cancellation controller 410 is operative based on a plurality of filter coefficients to determine the noise cancellation signal 435. Each acoustic device 141, 142 may be associated with one or more filter coefficients. In particular, each acoustic device may be associated with a plurality of filter coefficients where each filter coefficient corresponds to a respective reference acoustic pattern. The filter coefficients may be represented as $w_{km}[i]$ which denotes a filter coefficient to drive an acoustic device *m* based on a *k*-th reference acoustic pattern.

It will be appreciated that embodiments of the invention are useful for operatively reducing noise within a vehicle. Embodiments of the invention operate on noise associated with at least one predetermined tyre horn of the vehicle to output at least one noise cancellation signal according to an algorithm having one or more parameters associated with the respective tyre horn. In this way, the noise cancellation signal is generated based upon the characteristics of the tyre horn and its influence on noise within the vehicle. In some embodiments, the one or more parameters are also associated with a particular noise cancellation zone within the vehicle.

It will be appreciated that embodiments of the present invention can be realised in the form of hardware, software or a combination of hardware and software. Any such software may be stored in the form of volatile or non-volatile storage such as, for example, a storage device like a ROM, whether erasable or rewritable or not, or in the form of memory such as, for example, RAM, memory chips, device or integrated circuits or on an optically or magnetically readable medium such as, for example, a CD, DVD, magnetic disk or magnetic

tape. It will be appreciated that the storage devices and storage media are embodiments of machine-readable storage that are suitable for storing a program or programs that, when executed, implement embodiments of the present invention. Accordingly, embodiments provide a program comprising code for implementing a system or method as claimed in any preceding claim and a machine readable storage storing such a program. Still further, embodiments of the present invention may be conveyed electronically via any medium such as a communication signal carried over a wired or wireless connection and embodiments suitably encompass the same.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed. The claims should not be construed to cover merely the foregoing embodiments, but also any embodiments which fall within the scope of the claims.

## CLAIMS

1. A noise cancellation controller, comprising:

noise cancellation means arranged to receive a first noise signal indicative of noise associated with a predetermined first tyre horn;

wherein the noise cancellation means is arranged to generate a first noise cancellation signal for in-vehicle noise cancellation by processing the first noise signal with an algorithm having one or more parameters associated with the first tyre horn.

2. The noise cancellation controller of claim 1, wherein the noise cancellation means is arranged to receive a second noise signal indicative of noise associated with a predetermined second tyre horn and to generate a second noise cancellation signal for in-vehicle noise cancellation by processing the second noise signal with an algorithm having one or more parameters associated with the second tyre horn.

3. The noise cancellation controller of claim 1 or claim 2, wherein the one or more parameters associated with the first tyre horn define a first noise transfer function associated with the first tyre horn.

4. The noise cancellation controller of claim 2 or claim 3 when dependent from claim 2, wherein the one or more parameters associated with the second tyre horn define a second noise transfer function associated with the second tyre horn.

5. The noise cancellation controller of any preceding claim, wherein the one or more parameters are associated with a filter applied to the noise signal; optionally the one or more parameters are filter coefficients.

6. The noise cancellation controller of claim 3 or claim 4, wherein each noise transfer function defines one or both of a reference transfer function (RTF) or a speaker transfer function (STF).

7. The noise cancellation controller of any preceding claim, wherein the first noise cancellation signal is associated with a first noise cancellation zone and the noise cancellation means is arranged to generate a second noise cancellation signal associated with a second noise cancellation zone by processing the first noise signal with an algorithm having one or more second parameters associated with the first tyre horn.

8. The noise cancellation controller of any preceding claim, wherein the first noise signal is received from a first noise input means directed to the first tyre horn.

9. The noise cancellation controller of claim 8, wherein the first noise input means is an audio input means for audibly detecting the first tyre horn and outputting the first noise signal based thereon.

10. The noise cancellation controller of any one of claims 7 to 9, wherein the first noise input means is a microphone directed to the first tyre horn; optionally the microphone is a directional microphone.

11. A noise cancellation system for a vehicle, comprising:

noise cancellation means communicably coupled to first and second noise input means;

wherein the first noise input means is arranged for receiving a first noise signal indicative of noise associated with a predetermined first tyre horn and the second noise input means is arranged for receiving a second noise signal indicative of noise associated with a predetermined second tyre horn; and

the noise cancellation means is arranged to generate a first noise cancellation signal for in-vehicle noise cancellation by processing the first noise signal with an algorithm having one or more parameters associated with the first tyre horn and to generate a second noise cancellation signal by processing the second noise signal with an algorithm having one or more parameters associated with the second tyre horn.

12. A method of in-vehicle noise cancellation, comprising:

receiving a first noise signal indicative of noise associated with a predetermined first tyre horn; and

generating a first noise cancellation signal for in-vehicle noise cancellation by processing the first noise signal with an algorithm having one or more parameters associated with the first tyre horn.

13. The method of claim 12, comprising:

receiving a second noise signal indicative of noise associated with a predetermined second tyre horn; and

generating a second noise cancellation signal for in-vehicle noise cancellation by processing the second noise signal with an algorithm having one or more parameters associated with the second tyre horn.

14. The method of claim 12 or claim 13, wherein the one or more parameters associated with the first tyre horn define a first noise transfer function associated with the first tyre horn.

15. The method of claim 13 or claim 14 when dependent from claim 13, wherein the one or more parameters associated with the second tyre horn define a second noise transfer function associated with the second tyre horn.

16. The method of any of claims 12 to 15, wherein the one or more parameters are associated with a filter applied to the noise signal; optionally the one or more parameters are filter coefficients.

17. The method of claim 14 or claim 15, wherein each noise transfer function defines one or both of a reference transfer function (RTF) or a speaker transfer function (STF).

18. The method of any one of claims 12 to 17, wherein the first noise cancellation signal is associated with a first noise cancellation zone and the method comprises generating a second noise cancellation signal associated with a second noise cancellation zone by processing the first noise signal with an algorithm having one or more second parameters associated with the first tyre horn.

19. The method of any of claims 12 to 18, wherein the first noise signal is received from a first noise input means directed to the first tyre horn.

20. The method of claim 19, wherein the first noise input means is an audio input means for audibly detecting the first tyre horn and outputting the first noise signal based thereon.

21. The method of claim 19 or claim 20, wherein the first noise input means is a microphone directed to the first tyre horn; optionally the microphone is a directional microphone.

22. A vehicle comprising a noise cancellation controller of any of claims 1 to 10 or a noise cancellation system of claim 11.

23. The vehicle of claim 22, wherein the first noise input means is a first microphone directed to the first tyre horn.

24. The vehicle of claim 23, wherein the first microphone is a microphone configured to have a directivity pattern directed toward the associated tyre horn.

25. The vehicle of claim 23 or claim 24, wherein the first microphone is arranged proximal to a first wheel of the vehicle.

26. The vehicle of claim 23, 24 or 25, comprising a second microphone directed to a second tyre horn, wherein the first and second microphones are arranged in non-parallel axes; optionally the axes are at least 45 degrees.

27. Computer software which, when executed by a processor, configures the processor to perform a method according to any of claims 12 to 21.

28. A computer readable storage medium comprising the computer software of claim 27 stored thereon.

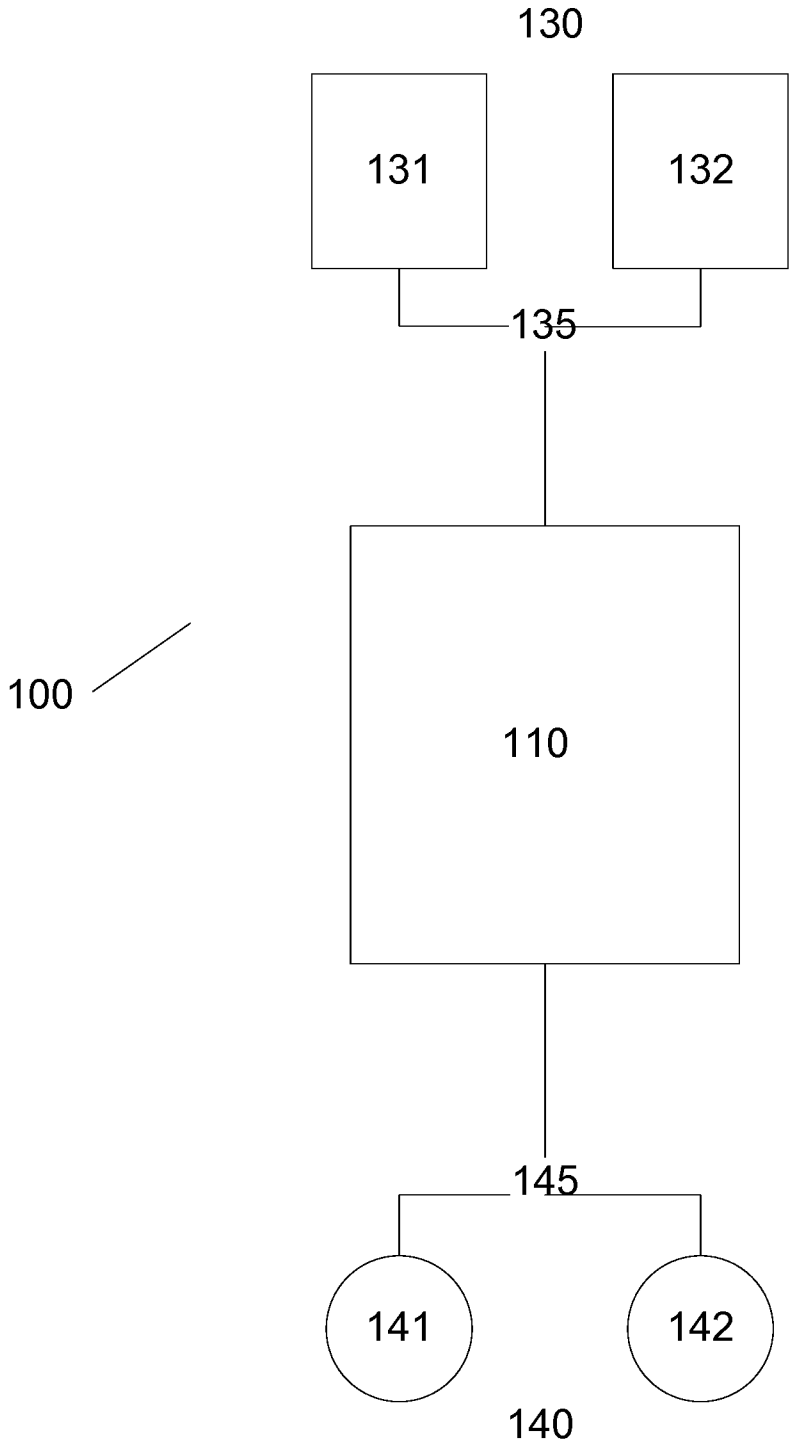


Fig 1

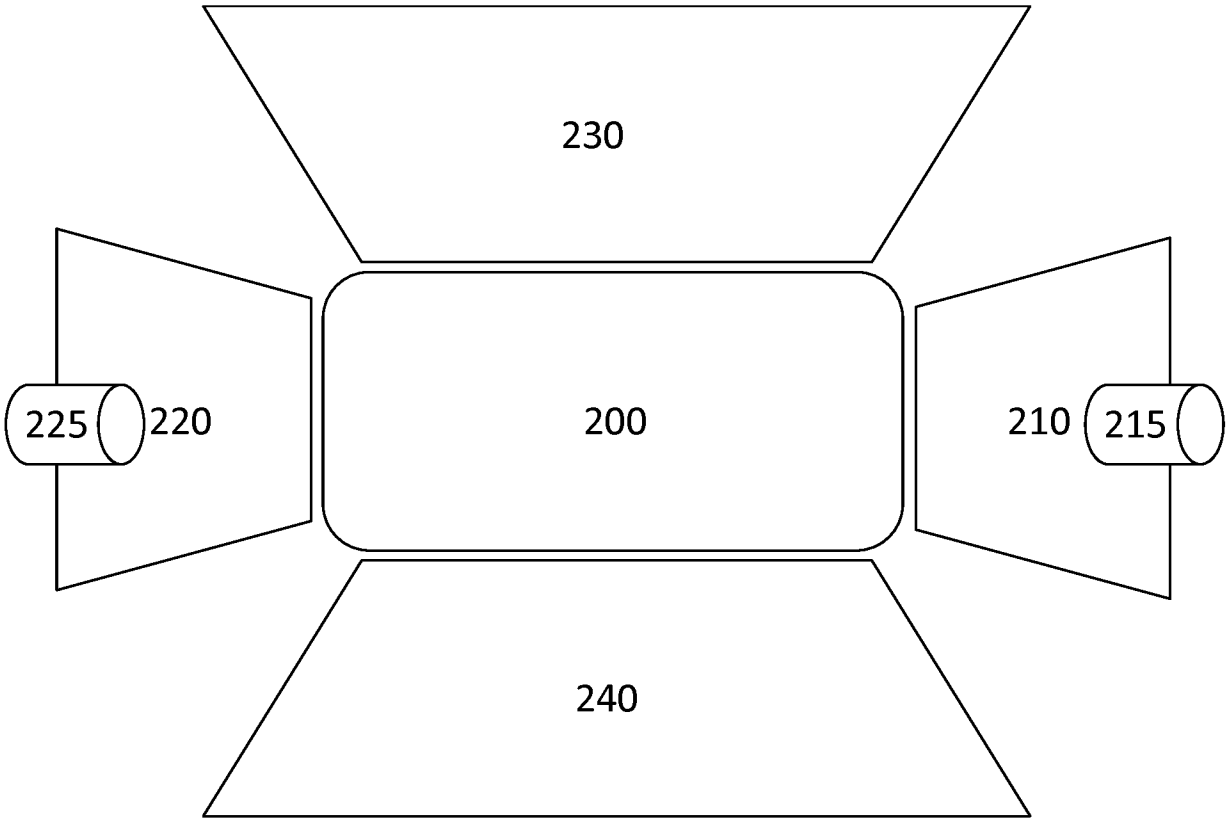


Fig 2

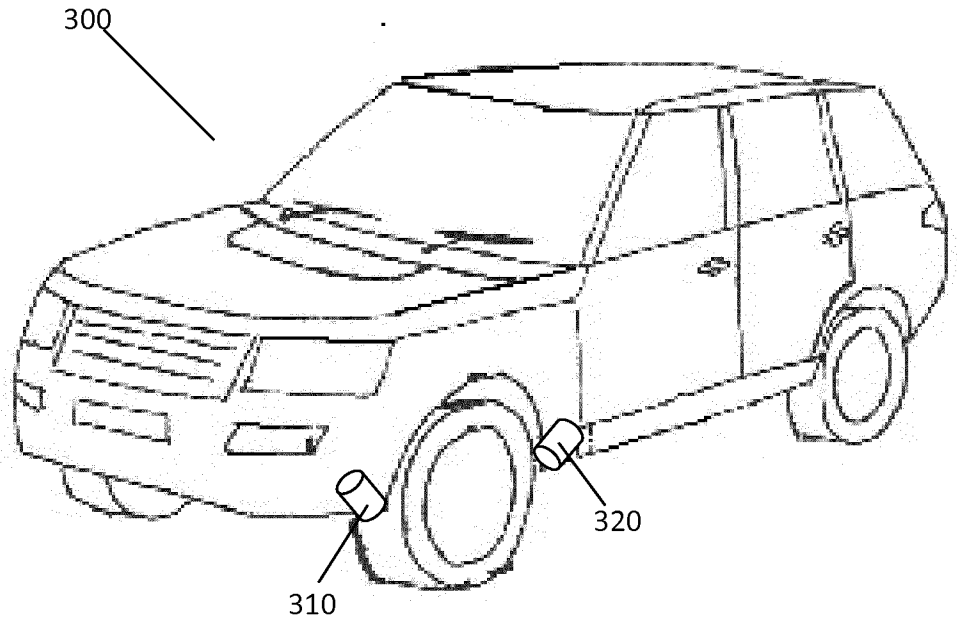


Fig 3

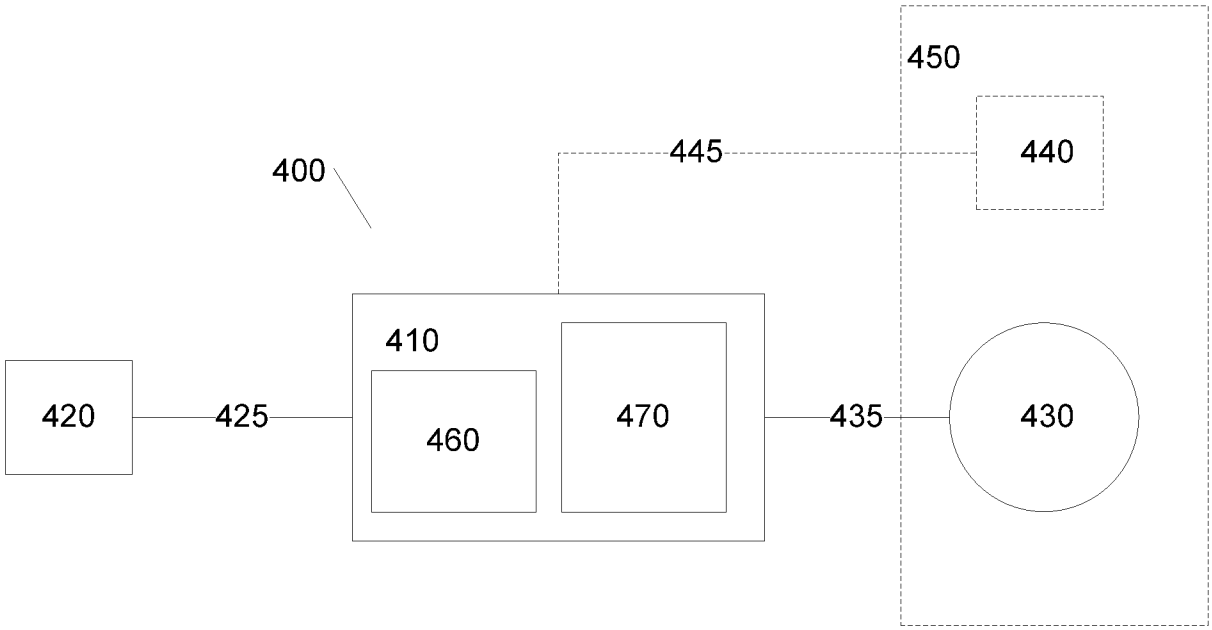


Fig 4

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/053124

A. CLASSIFICATION OF SUBJECT MATTER
INV. G10K11/178
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)
G10K

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

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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| X | WO 2015/023707 A1 (ANALOG DEVICES INC [US]; MORTENSEN MIKAEL [US]; NGUYEN KHIEM QUANG [US) 19 February 2015 (2015-02-19) paragraphs [0003], [0033], [0034], [0038], [0039]; figures 1A,1C,2 | 1-28 |
| X | EP 0 590 350 A2 (MATSUSHITA ELECTRIC IND CO LTD [JP]) 6 April 1994 (1994-04-06) columns 1,7-9; figures 2,3,4 | 1-25,27, 28 |
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 10 April 2017 | 20/04/2017 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Bream, Philip |

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# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/053124

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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