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(54) Title: METHOD FOR ELEVATION ANGLE ESTIMATION BASED ON AN ULTRASOUND SENSOR

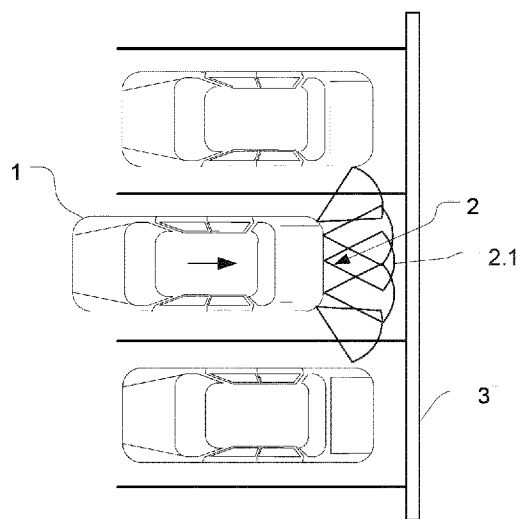


Fig. 1

(57) Abstract: The invention relates to a method for determining the elevation angle (a) and/or azimuth angle of a signal received by an ultrasound sensor (2), the method comprising the steps of: - providing an ultrasound sensor (2) with a frequency-dependent radiation pattern (2.1) (S10); - transmitting at least a first ultrasound wave at a first frequency (S11); - transmitting at least a second ultrasound wave at a second frequency different to the first frequency (S12); - receiving reflections of the first and second ultrasound wave, said reflections being caused by a certain object (S13); - determining the elevation angle (a) of the first and second reflected ultrasound wave based on the amplitudes of the reflections of the first and second ultrasound wave (S14); wherein determining the elevation angle (a) and/or azimuth angle is performed by calculating a ratio between the amplitudes of received reflections of first and second ultrasound wave and mapping the calculated ratio to an elevation angle (a) and/or azimuth angle, wherein said mapping is performed based on a predetermined ratio curve or ratio dataset which associates a certain amplitude ratio to an elevation angle and/or azimuth angle.

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Method for elevation angle estimation based on an ultrasound sensor

- 5 The present invention relates generally to the field of ultrasound sensors. More specifically, the invention relates to a method and a system for determining the elevation angle and/or azimuth angle of a signal received by an ultrasound sensor.
- 10 Height or elevation angle estimation using one-dimensional (1D) ultrasound sensors is fundamentally very difficult due to physical restrictions. Such ultrasound sensors are often used for distance measurements. Elevation angle may be determined based on geometric approaches, like rate-of-closing method. Said method is based on tracking
- 15 the rate of closing to an object, e.g. a curb and exploiting the distance difference travelled by an ultrasound wave to an reflecting object that is below the sensor compared to an reflecting object which is at sensor height.
- 20 Other sensing methodologies include a camera-assisted approach in which the elevation of the object is estimated in a 2D-image or a direction-of-arrival-method based on multiple sensors for estimating elevation angle based on triangulation.
- 25 The afore mentioned methodologies suffer from several drawbacks. One-dimensional rate-of-closing method relies on the correct association of reflections made over time to the same object. A wrong association means not only wrong height estimation but also a missed detection. Camera and multiple antenna based methods do not exploit the cost and mechanical
- 30 robustness advantages of 1D-ultrasound sensors.

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It is an objective of the embodiments of the invention to provide a method for determining the elevation angle of a signal received by an ultrasound sensor, specifically a 1D-ultrasound sensor, in a robust and cost-effective way. The objective is solved by the features of the independent claims.

- 5 Preferred embodiments are given in the dependent claims. If not explicitly indicated otherwise, embodiments of the invention can be freely combined with each other.

- According to an aspect, the invention refers to a method for determining
10 the elevation angle and/or azimuth angle of a signal received by an ultrasound sensor. The ultrasound sensor may be specifically a one-dimensional (1D) ultrasound sensor, i.e. a sensor which does not comprise physical sensor means for determining elevation angle (e.g. two sensor portions with different alignment for determining elevation). The
15 method comprises the following steps:

- First, an ultrasound sensor, specifically a 1D ultrasound sensor, with a frequency-dependent radiation pattern is provided. "Frequency-dependent radiation pattern" means that the gain or sensitivity of the sensor in a
20 certain direction defined by azimuth and elevation angle shows a frequency dependency, i.e. changes when varying ultrasound frequency.

- As a further step, at least a first ultrasound wave is transmitted at a first frequency. Said first frequency may be a fixed frequency of a transmission
25 pulse. Alternatively, said first frequency may be a frequency value of a chirped signal, i.e. a signal with changing frequency according to a ramp or in a stepped way.

- As a further step, a second ultrasound wave is transmitted at a second
30 frequency. Said second frequency may be a fixed frequency of a transmission pulse. Alternatively, said second frequency may be a

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frequency value of a chirped signal, i.e. a signal with changing frequency according to a ramp or in a stepped way. The second frequency has a frequency value different to first frequency.

- 5 After transmission of first and second ultrasound wave, reflections of the first and second ultrasound wave are received by said ultrasound sensor. Said reflections are caused by a certain object, specifically one and the same object, e.g. a curb, a car, a wall in the surrounding of the ultrasound sensor.

10

Finally, the elevation angle and/or azimuth angle of the first and second reflected ultrasound wave is determined based on amplitudes of the reflections of the first and second ultrasound wave. Said determination step may use information regarding the frequency dependency of the radiation pattern to determine or estimate the elevation angle and/or azimuth angle.

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Determining the elevation angle and/or azimuth angle is performed by calculating a ratio between the amplitudes of received reflections of first and second ultrasound wave and mapping the calculated ratio to an elevation angle and/or azimuth angle, wherein said mapping is performed based on a predetermined ratio curve or ratio dataset which associates a certain amplitude ratio to an elevation angle and/or azimuth angle. Said ratio curve or ratio dataset may be sensor-specific information indicative for the frequency dependency of the radiation pattern of the ultrasound sensor.

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Said method is advantageous because elevation information and/or azimuth information can be derived by using frequency dependency of the ultrasound sensor thereby maintaining cost and mechanical robustness advantages of ultrasound sensors. Furthermore, based on the amplitude

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ratio it is possible to determine the elevation angle and/or azimuth angle independent of the height of actual amplitude of ultrasound wave.

According to an embodiment, the radiation pattern of the ultrasound
5 sensor narrows with increasing frequency. In other words, angle of
aperture of radiation pattern at which the sensor sensitivity is decreased to
a certain sensitivity value is lower at higher frequencies. Also a vice versa
configuration may be possible, i.e. the radiation pattern of the ultrasound
sensor broadens with decreasing frequency. Thereby using at least two
10 ultrasound frequencies with a certain frequency gap leads to an amplitude
difference which is indicative for elevation angle and/or azimuth angle.

According to an embodiment, the step of determining the elevation angle
comprises removing ambiguities of the radiation pattern in vertical
15 direction. The radiation characteristics of the ultrasound sensor may be
symmetric to a horizontal or essentially horizontal plane. Said symmetry
may lead to ambiguities, i.e. a certain detection is not associated to a
single elevation angle but at least to a pair of elevation angles. By
removing the ambiguities an unambiguous association of a detection to an
20 elevation angle is possible.

According to an embodiment, ambiguities of the radiation pattern in
vertical direction are removed by using at least one ultrasound sensor
providing an asymmetric radiation pattern in vertical direction. Said
25 asymmetry may be a frequency-dependent asymmetry. Thereby, using
two or more ultrasound waves with different frequencies may lead to
unambiguous elevation information.

According to an embodiment, ambiguities of the radiation pattern in
30 vertical direction are removed by using received reflections of at least one
further ultrasound sensor. Said further ultrasound sensor may comprise a

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different alignment or may comprise an asymmetric radiation pattern in vertical direction.

According to an embodiment, ambiguities of the radiation pattern in
5 vertical direction are removed assuming that a detected object is arranged in the lower half-space. Said assumption exploits the fact that - in typical driving situations - objects are far more likely to be low and place on the ground, rather than high and hanging downwardly.

10 According to an embodiment, ambiguities of the radiation pattern in vertical direction are removed by using at least one further sensor using a technology different to ultrasound. Such sensor may be, for example, a camera, a radar sensor and/or a LIDAR sensor already installed at the vehicle for further driving assistance applications. Based on such further
15 sensor, the ambiguity can be resolved by evaluating information provided by said further sensor.

According to an embodiment, the azimuth angle of the object is determined based on at least one further ultrasound sensor located at a
20 different position. Typically multiple ultrasound sensors are arranged around the car, e.g. at different positions at the bumper. Information provided by one or more neighbored ultrasound sensors can be used to determine azimuth information.

25 According to an embodiment, transmitting first and second ultrasound wave is performed by providing a frequency-modulated transmit pulse to the ultrasound sensor. Thereby, the transmit pulse comprises at least two different frequencies based on which the elevation angle can be determined.

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According to an embodiment, said frequency-modulated transmit pulse comprises a linearly or non-linearly (e.g. exponentially) varied frequency over time. For example the frequency of the transmit pulse may be chirped from a start frequency to a stop frequency. Thereby, an ultrasound signal
5 comprising multiple frequencies is transmitted and the reflections of said signal can be evaluated for determining elevation angle.

According to an embodiment, said frequency-modulated transmit pulse comprises a frequency varying in steps over time. In other words, a
10 stepped frequency-modulated ultrasound signal is transmitted. Such stepped frequency-modulated ultrasound signal comprises multiple distinct frequencies which can be used for determining elevation angle.

Alternatively, multiple transmit pulses having different center frequencies
15 are provided to the ultrasound sensor. Said transmit pulses may be transmitted at different points of time in order to be able to evaluate the reflected signal between said pulses.

According to a further aspect, the invention relates to a driving assistance
20 system comprising at least one ultrasound sensor having a frequency-dependent radiation pattern and a control entity for controlling the provision of ultrasound signals to the ultrasound sensor. The control entity is configured to:

- initiate the transmission of at least a first ultrasound wave at a first
25 frequency;
- initiate the transmission of at least a second ultrasound wave at a second frequency different to the first frequency;
- receive information regarding reflections of the first and second ultrasound wave, said reflections being caused by a certain object;

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- determine the elevation angle and/or azimuth angle of the first and second reflected ultrasound wave based on the amplitudes of the reflections of the first and second ultrasound wave;
- determine the elevation angle and/or azimuth angle by calculating a ratio between the amplitudes of received reflections of first and second ultrasound wave and map the calculated ratio to an elevation angle and/or azimuth angle, wherein said mapping is performed based on a predetermined ratio curve or ratio dataset which associates a certain amplitude ratio to an elevation angle and/or azimuth angle.

According to yet a further aspect, the invention relates to a vehicle comprising a driving assistance system. The driving system is configured to perform a method according to anyone of the afore mentioned embodiments.

The term “vehicle” as used in the present disclosure may refer to a car, truck, bus, train or any other crafts.

The term “ultrasound sensor” may refer to a sensor configured to transmit and receive sound waves with frequencies above 20kHz.

The term “essentially” or “approximately” as used in the invention means deviations from the exact value by +/- 10%, preferably by +/- 5% and/or deviations in the form of changes that are insignificant for the function and/or for the traffic laws.

The various aspects of the invention, including its particular features and advantages, will be readily understood from the following detailed description and the accompanying drawings, in which:

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Fig. 1 shows a schematic illustration of a parking situation in which a vehicle is parking into a parking space;

Fig. 2 schematically illustrates the radiation pattern of an ultrasound sensor included in a bumper in the parking situation of Fig. 1;

Fig. 3 illustrates the gain of an ultrasound sensor dependent on elevation angle for two different ultrasound frequencies;

Fig. 4 illustrates the ratio of gain of an ultrasound sensor dependent on elevation angle according to fig. 3;

Fig. 5 illustrates the 2D-radiation pattern of an ultrasound sensor dependent on azimuth and elevation angles for two different ultrasound frequencies;

Fig. 6 illustrates a linearly frequency-modulated first ultrasound signal and a stepped frequency-modulated second ultrasound signal; and

Fig. 7 shows a schematic block diagram illustrating the steps of a method for determining the elevation angle of a signal received by an ultrasound sensor.

The present invention will now be described more fully with reference to the accompanying drawings, in which example embodiments are shown. The embodiments in the figures may relate to preferred embodiments, while all elements and features described in connection with embodiments may be used, as far as appropriate, in combination with any other embodiment and feature as discussed herein, in particular related to any other embodiment discussed further above. However, this invention should not be construed as limited to the embodiments set forth herein.

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Throughout the following description similar reference numerals have been used to denote similar elements, parts, items or features, when applicable.

- 5 The features of the present invention disclosed in the specification, the claims, examples and/or the figures may both separately and in any combination thereof be material for realizing the invention in various forms thereof.
- 10 Fig. 1 shows a schematic top view on a parking situation in which a vehicle 1 is parking into a parking space being bordered by a curb 3. The vehicle 1 comprises a driving assistance system having multiple ultrasound sensors 2 being placed at different positions at the vehicle 1. The curb 3 may comprise a certain height and can be detected by said
- 15 driving assistance system, specifically by one or more ultrasound sensors 2 of the driving assistance system.

- Fig. 2 shows a side-view of the parking situation. On the left side, a bumper 1.1 of the vehicle 1 is shown which may comprise one or more
- 20 ultrasound sensors 2. The ultrasound sensor 2 may have a radiation pattern 2.1 comprising a lower radiation pattern portion which covers a lower half-space LHS and an upper radiation pattern portion which covers an upper half-space UHS. The dashed line indicates a horizontal plane dividing the radiation pattern 2.1 in said lower radiation pattern portion and
- 25 said upper radiation pattern portion. A curb 3 may be located in said lower half-space LHS.

- Fig. 3 shows the radiation pattern 2.1 of an ultrasound sensor 2 in vertical direction, i.e. the angle values refer to elevation angle, at different
- 30 frequency values. The solid line indicates the radiation pattern 2.1 at a first frequency and the dashed line indicates the radiation pattern 2.1 at a

second frequency, said first and second frequencies being different and said first frequency being higher than the second frequency. As shown, the radiation pattern 2.1 of the ultrasound sensor 2 narrows with increasing frequency.

5

Therefore, by providing ultrasound waves to the ultrasound sensor 2 at at least two different frequencies and evaluating the amplitudes of the reflected waves having different frequencies, the elevation angle α of a object (in the present example the curb 3) causing said reflections can be determined. More specifically, the elevation angle α can be determined by comparing the amplitudes of the reflected waves. Due to the frequency dependency of the radiation pattern leading to different shapes of radiation pattern and therefore an elevation dependency of the radiation pattern, the elevation angle α of the object can be determined.

15

The step of comparing the amplitudes of the reflected waves comprises calculating a ratio of the amplitudes of the reflected waves and mapping said ratio to an elevation value, wherein said mapping is performed based on a predetermined ratio curve or ratio dataset which associates a certain amplitude ratio to an elevation angle and/or azimuth angle.

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Fig. 4 shows a graph illustrating the quotient of amplitudes of reflected waves having different frequency and being received from different elevation angles. By means of said graph, a ratio value of a first reflected wave having a first frequency and a second reflected wave having a second frequency can be associated to an elevation angle.

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As shown in Fig. 3 to 5, the radiation pattern 2.1 may be symmetric or essentially symmetric with respect to a centre elevation angle. In the present example, the centre elevation angle may be, for example, 0° or essential 0° , i.e. the radiation pattern 2.1 may be symmetric with respect to

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a horizontal plane. According to other embodiments, the ultrasound sensors installed in vehicle may be pitched slightly upwards. Thus, for example, the centre elevation angle may be in the range between 1° to 10° , especially in the range between 1° to 4° . Said symmetry of radiation pattern 2.1 may lead to an ambiguity in determining elevation angle, i.e. a certain amplitude ratio of the reflected waves can be associated with at least two elevation angles. A first, positive elevation angle may be arranged in the upper half-space UHS and a second, negative elevation angle may be arranged in the lower half-space LHS.

10

Said ambiguity of elevation angle can be resolved in different ways:

According to a first embodiment, a further sensor, specifically an ultrasound sensor having a radiation pattern being non-symmetric with respect to the horizontal symmetry plane of the other sensors can be used. Based on a measured amplitude derived from said further sensor, the ambiguity can be remedied.

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According to another embodiment, the ambiguity can be remedied by assuming that the detected object is always arranged in the lower half-space LHS because in the vast majority of cases, said assumption leads to a correct detection result.

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According to yet another embodiment, the ambiguity can be remedied by using a further information source, e.g. a further ultrasound sensor with an inclined radiation pattern (i.e. the beam maximum of radiation pattern is not arranged in the first sensor's horizontal plane). A further example may be a sensor using technology different to ultrasound, e.g. a camera, radar sensor, LIDAR sensor etc.

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Also information obtained by said one or more ultrasound sensors at different positions of the vehicle 1 can be used to remove ambiguities. In other words, multiple information gathered at different vehicle positions along the trajectory are exploited to remove ambiguities.

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As shown in Fig. 5, the radiation pattern of an ultrasound sensor may have a 2D-shape, i.e. a certain beam shape in view of azimuth and elevation. Therefore also ambiguity of detection results occurs in horizontal direction, i.e. in azimuth. In order to resolve azimuth ambiguity, information of a further sensor located at a different location (e.g. at a different position on the bumper) can be used. A preferred technique for remedying azimuth ambiguity may be trilateration.

10

As mentioned before, determination of elevation angle exploits the frequency dependency of radiation pattern of an ultrasound sensor 2, i.e. the 2D-shape of radiation beam is dependent on the frequency of ultrasound wave. Said ultrasound waves having at least two different frequencies can be generated as follows:

15

According to a first embodiment, two or more transmit pulses having different centre frequencies can be used.

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According to a second embodiment, a frequency-modulated transmit pulse can be used. Said frequency-modulated transmit pulse may be, for example, a linear frequency-modulated signal (also called "chirp signal").

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According to a third embodiment, a single frequency-modulated transmit pulse can be used where the frequency follows a step function.

Fig. 6 shows a linear frequency-modulated signal and a stepped frequency-modulated signal. The frequency of linear frequency-modulated

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signal changes linearly over time, whereas the frequency of stepped frequency-modulated signal changes stepwise over time.

Fig. 7 shows a block diagram illustrating method steps of a method for
5 determining the elevation angle α of a signal received by an ultrasound sensor 2.

First, an ultrasound sensor 2 with a frequency-dependent radiation pattern is provided (S10).

10

Said ultrasound sensor 2 transmits at least a first ultrasound wave at a first frequency (S11) and at least a second ultrasound wave at a second frequency different to the first frequency (S12).

15 After transmitting said ultrasound waves, reflections of the first and second ultrasound wave are received, said reflections being caused by a certain object (S13).

After receiving said reflections, the elevation angle α of the first and
20 second reflected ultrasound wave is determined based on the amplitudes of the reflections of the first and second ultrasound wave (S14), wherein determining the elevation angle α is performed by calculating a ratio between the amplitudes of received reflections of first and second ultrasound wave and mapping the calculated ratio to an elevation angle α ,
25 and wherein said mapping is performed based on a predetermined ratio curve or ratio dataset which associates a certain amplitude ratio to an elevation angle.

It should be noted that the description and drawings merely illustrate the
30 principles of the proposed invention. Those skilled in the art will be able to

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implement various arrangements that, although not explicitly described or shown herein, embody the principles of the invention.

List of reference numerals

5	1	vehicle
	1.1	bumper
	2	ultrasound sensor
	2.1	radiation pattern
	3	curb
10	LHS	lower half-space
	UHS	upper half-space

Claims

- 1) Method for determining the elevation angle (α) and/or azimuth angle of a signal received by an ultrasound sensor (2), the method comprising the steps of:
- providing an ultrasound sensor (2) with a frequency-dependent radiation pattern (2.1) (S10);
 - transmitting at least a first ultrasound wave at a first frequency (S11);
 - transmitting at least a second ultrasound wave at a second frequency different to the first frequency (S12);
 - receiving reflections of the first and second ultrasound wave, said reflections being caused by a certain object (S13);
 - determining the elevation angle (α) and/or azimuth angle of the first and second reflected ultrasound wave based on the amplitudes of the reflections of the first and second ultrasound wave (S14);
- wherein determining the elevation angle (α) and/or azimuth angle is performed by calculating a ratio between the amplitudes of received reflections of first and second ultrasound wave and mapping the calculated ratio to an elevation angle (α) and/or azimuth angle, wherein said mapping is performed based on a predetermined ratio curve or ratio dataset which associates a certain amplitude ratio to an elevation angle and/or azimuth angle.
- 2) Method according to claim 1, wherein radiation pattern (2.1) of the ultrasound sensor narrows with increasing frequency.
- 3) Method according to anyone of the preceding claims, wherein determining the elevation angle (α) comprises removing ambiguities of the radiation pattern (2.1) in vertical direction.

- 4) Method according to claim 3, wherein ambiguities of the radiation pattern in vertical direction are removed by using at least one ultrasound sensor (2) providing an asymmetric radiation pattern in vertical direction.
- 5) Method according to claim 3 or 4, wherein ambiguities of the radiation pattern (2.1) in vertical direction are removed by using received reflections of at least one further ultrasound sensor (2).
- 6) Method according to anyone of claims 3 to 5, wherein ambiguities of the radiation pattern (2.1) in vertical direction are removed assuming that a detected object is arranged in the lower half-space (LHS).
- 7) Method according to anyone of claims 3 to 6, wherein ambiguities of the radiation pattern (2.1) in vertical direction are removed by using at least one further sensor using a technology different to ultrasound.
- 8) Method according to anyone of the preceding claims, wherein the azimuth angle of the object is determined based on at least one further ultrasound sensor (2) located at a different position.
- 9) Method according to anyone of the preceding claims, wherein transmitting first and second ultrasound wave is performed by providing a frequency-modulated transmit pulse to the ultrasound sensor (2).
- 10) Method according to claim 9, wherein said frequency-modulated transmit pulse comprises a linearly or non-linearly varied frequency over time.

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11) Method according to claim 9, wherein said frequency-modulated transmit pulse comprises a frequency varying in steps over time.

12) Method according to anyone of claims 1 to 8, wherein multiple transmit pulses having different center frequencies are provided to the ultrasound sensor (2).

13) Driving assistance system comprising at least one ultrasound sensor (2) having a frequency-dependent radiation pattern and a control entity for controlling the provision of ultrasound signals to the ultrasound sensor, the control entity being configured to:

- initiate the transmission of at least a first ultrasound wave at a first frequency;
- initiate the transmission of at least a second ultrasound wave at a second frequency different to the first frequency;
- receive information regarding reflections of the first and second ultrasound wave, said reflections being caused by a certain object;
- determine the elevation angle (α) and/or azimuth angle of the first and second reflected ultrasound wave based on the amplitudes of the reflections of the first and second ultrasound wave;
- determine the elevation angle (α) and/or azimuth angle by calculating a ratio between the amplitudes of received reflections of first and second ultrasound wave and map the calculated ratio to an elevation angle (α) and/or azimuth angle, wherein said mapping is performed based on a predetermined ratio curve or ratio dataset which associates a certain amplitude ratio to an elevation angle and/or azimuth angle.

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- 14) Vehicle comprising a driving assistance system, the driving assistance system configured to perform a method according to anyone of claims 1 to 12.

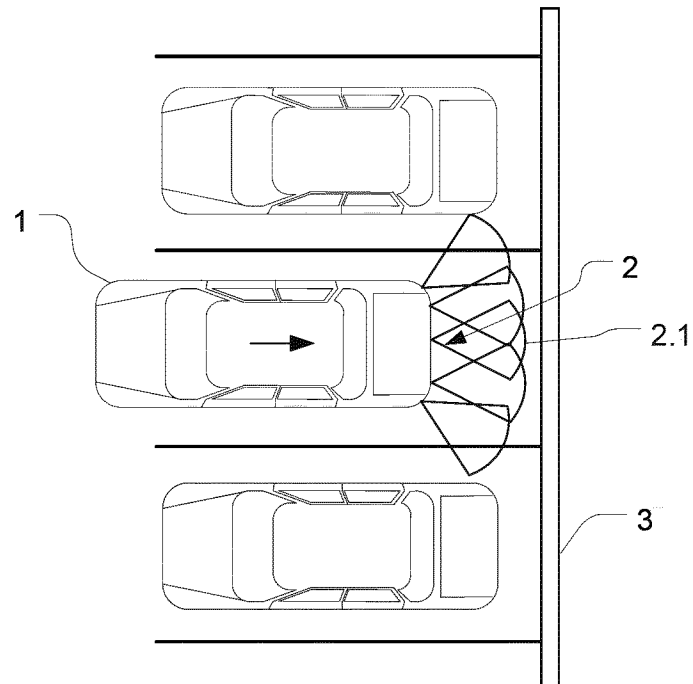


Fig. 1

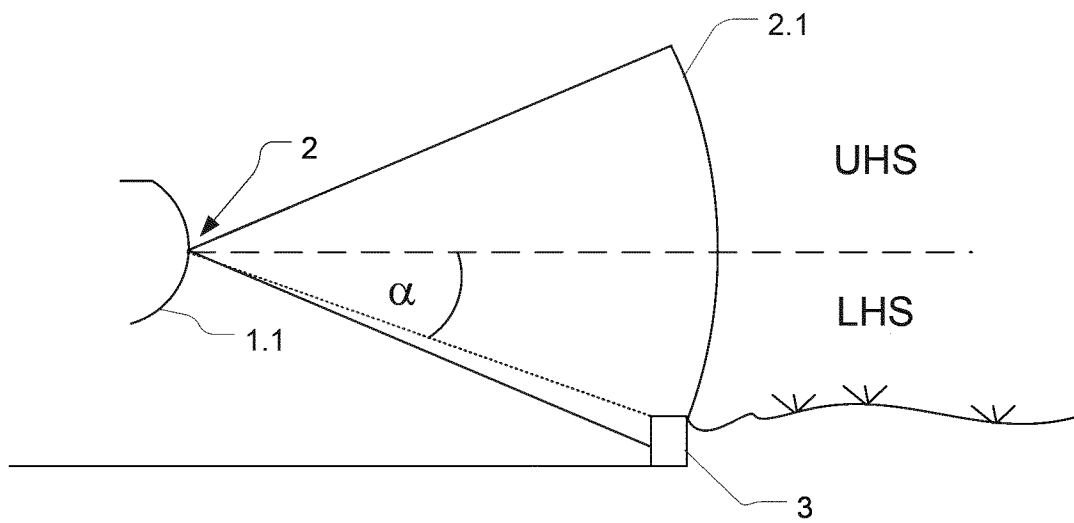


Fig. 2

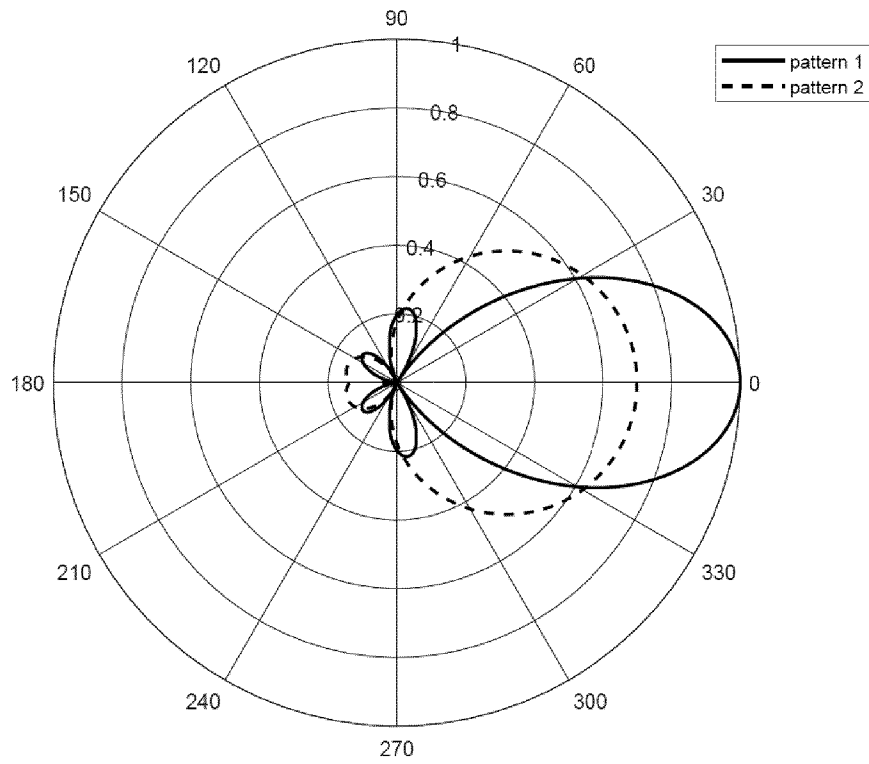


Fig. 3

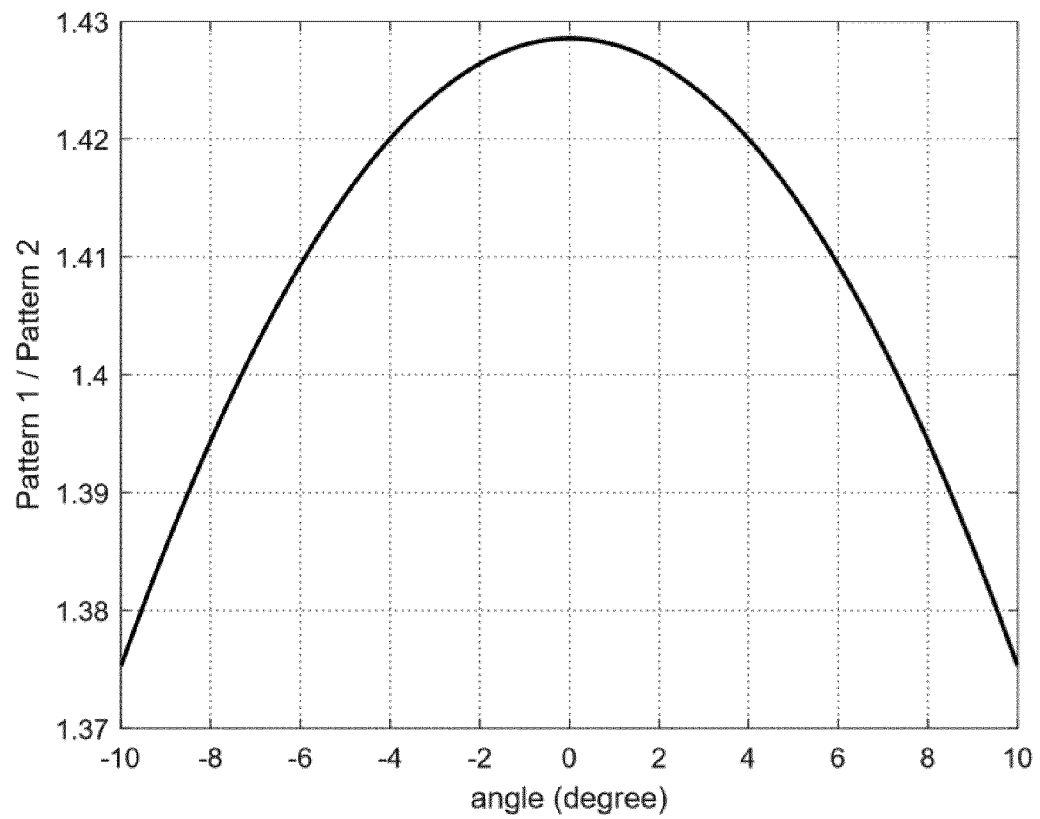


Fig. 4

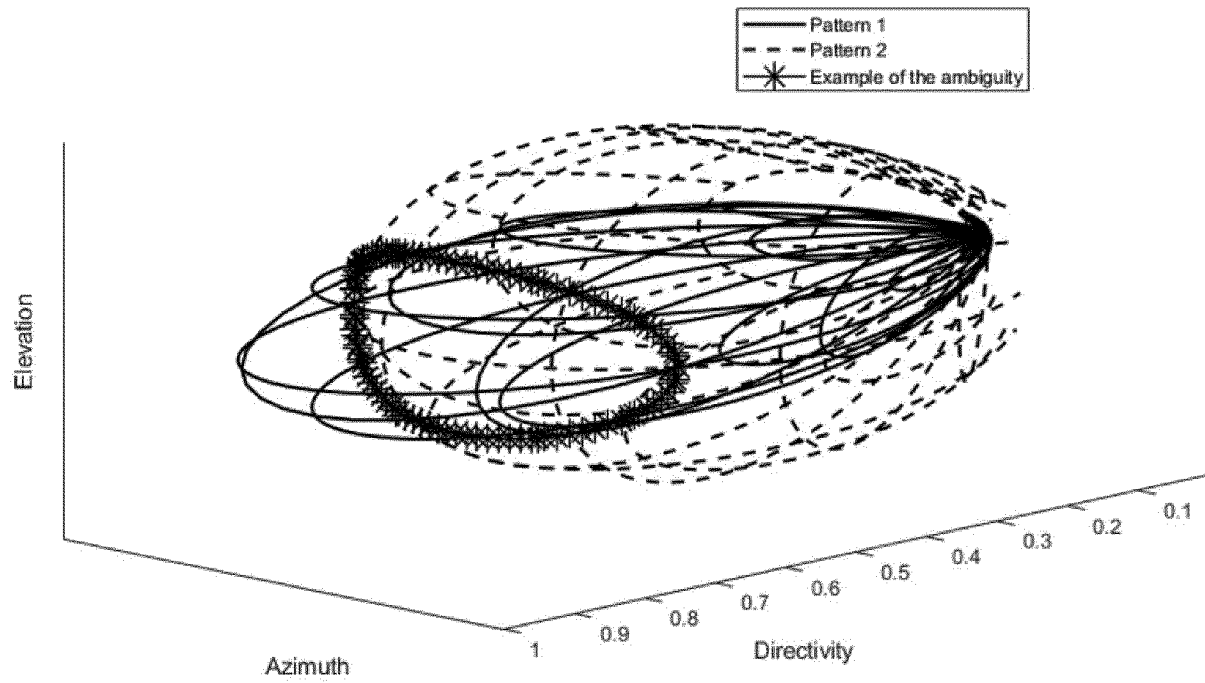


Fig. 5

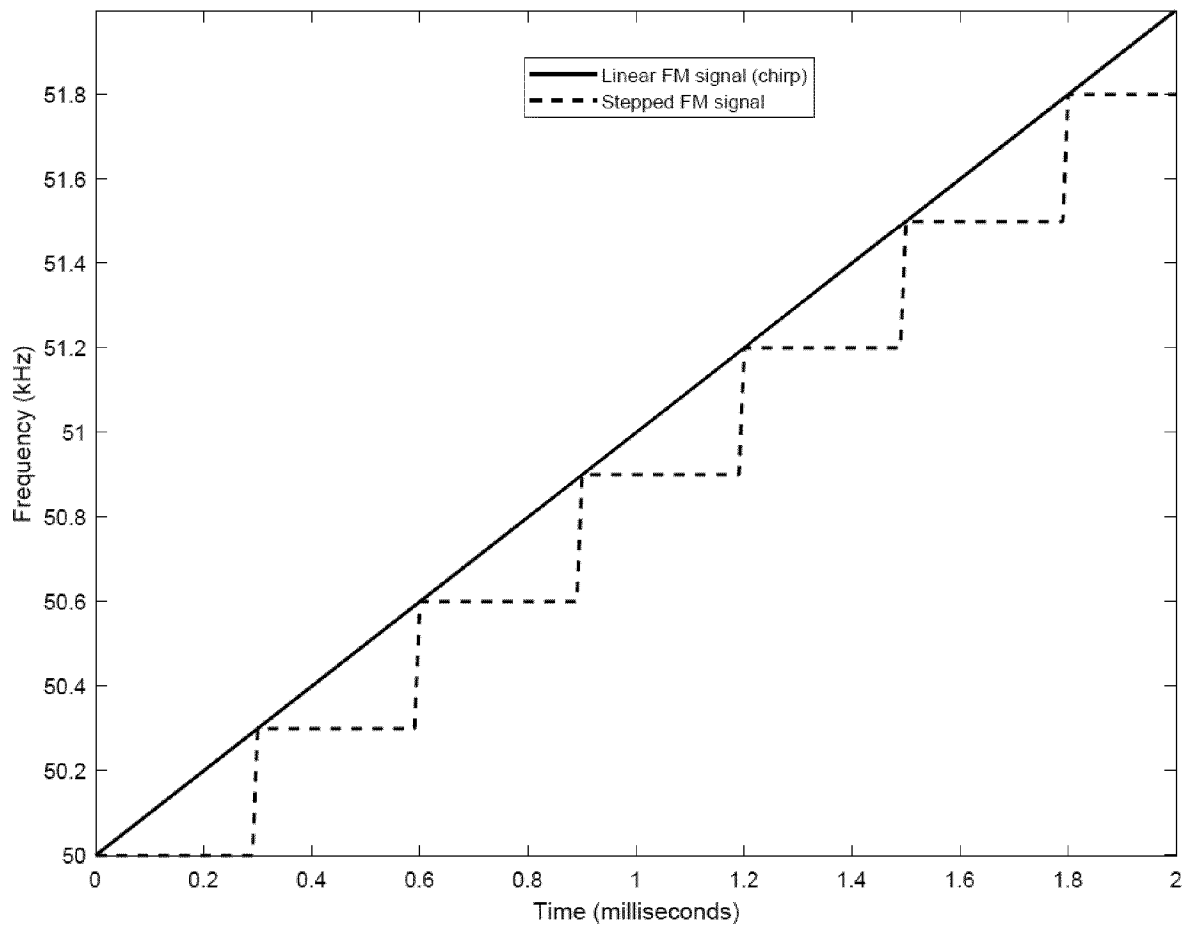


Fig. 6

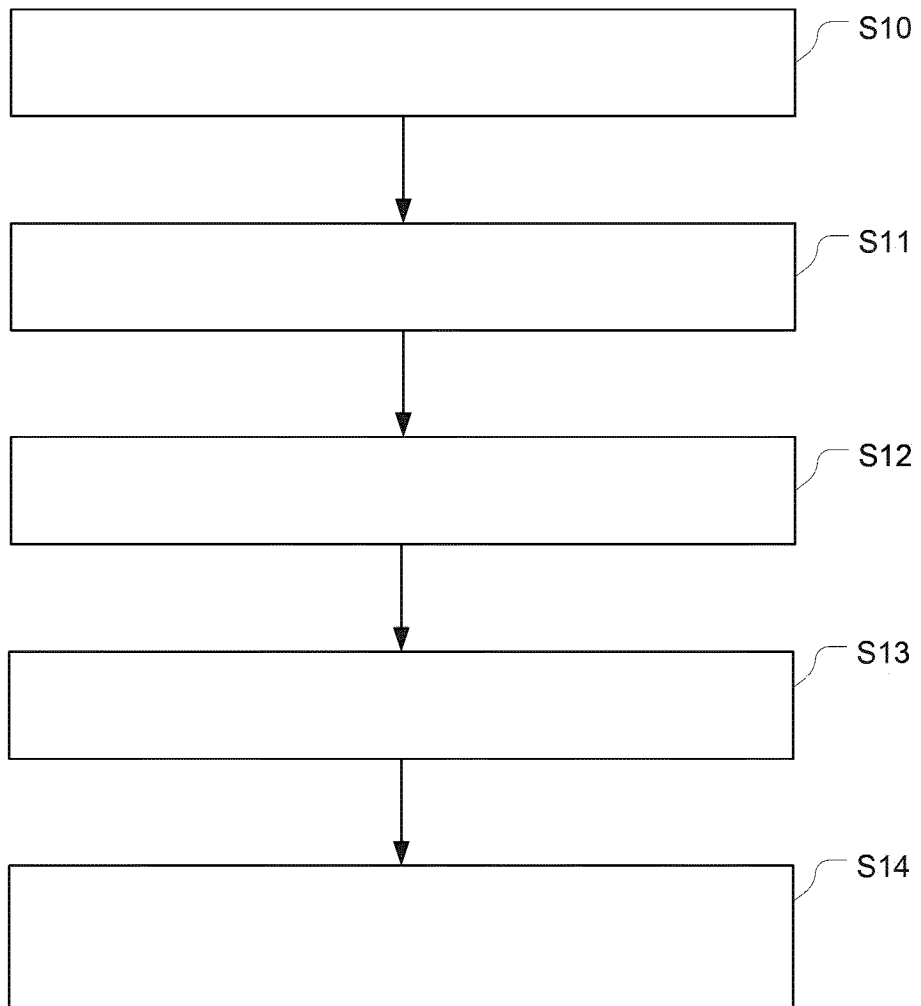


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/074176

A. CLASSIFICATION OF SUBJECT MATTER		
INV. G01S7/524	G01S15/10	G01S15/34
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		G01S15/42
		G01S15/87
		G01S15/931
		G01S15/46
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) G01S		
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.
X	DE 10 2018 103490 A1 (VALEO SCHALTER & SENSOREN GMBH [DE]) 22 August 2019 (2019-08-22)	1,2, 9-11,13, 14
Y	paragraphs [0001] - [0003], [0006] - [0023], [0030] - [0037]; figures 1-6 -----	3-5,7,8
X	DE 10 2018 101324 A1 (VALEO SCHALTER & SENSOREN GMBH [DE]) 25 July 2019 (2019-07-25)	1,2,9, 11-14
Y	paragraphs [0001], [0002], [0012] - [0014], [0017], [0020] - [0022], [0030] - [0035], [0037] - [0038]; figures 1-3,5 -----	3-5,7,8
X	DE 10 2010 028829 A1 (BOSCH GMBH ROBERT [DE]) 17 November 2011 (2011-11-17)	1-6,8-14
Y	paragraphs [0007] - [0012], [0021] - [0036], [0038]; figures 1-4 -----	1-11
	-/--	
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 9 December 2020		Date of mailing of the international search report 17/12/2020
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Schmelz, Christian

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/074176

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 10 2013 207823 A1 (BOSCH GMBH ROBERT [DE]) 30 October 2014 (2014-10-30) paragraphs [0027], [0029], [0031], [0037], [0039]; figures 3,4 -----	1-11
Y	US 2018/106885 A1 (BLAYVAS ILYA [IL]) 19 April 2018 (2018-04-19) paragraphs [0061], [0066]; figure 2 -----	7
Y	DE 10 2012 004320 A1 (VOLKSWAGEN AG [DE]) 5 September 2013 (2013-09-05) paragraphs [0021], [0034] - [0036], [0039] - [0042]; figures 2a-d, 4 -----	3-7
Y	WO 2017/157483 A1 (VALEO SCHALTER & SENSOREN GMBH [DE]) 21 September 2017 (2017-09-21) paragraphs [0010], [0011], [0019], [0059], [0063], [0069]; figures 3-5 -----	8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2020/074176

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
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.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1, 2, 9-14

Determination of elevation/azimuth with single ultrasound sensor applying the amplitude monopulse principle via FM-pulses.

Problem solved: direction determination with single sensor.

1.1. claim: 12

Multiple transmit pulses with different center frequency.

Problem solved: distinction of pulses, e.g. for interference mitigation.

2. claims: 3-7

Removal of ambiguity via asymmetric radiation pattern, additional sensor (of same / different technology) or half-space assumption.

Problem solved: ambiguity removal.

3. claim: 8

Determination of azimuth with further ultrasound sensor.
Problem solved: improved/redundant azimuth determination (e.g. for safety-relevant situations like determining the direction of oncoming moving objects in pre-crash situations).

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/074176

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