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(54) Title: A VEHICLE RADAR SYSTEM ARRANGED FOR DETERMINING AN UNOCCUPIED DOMAIN

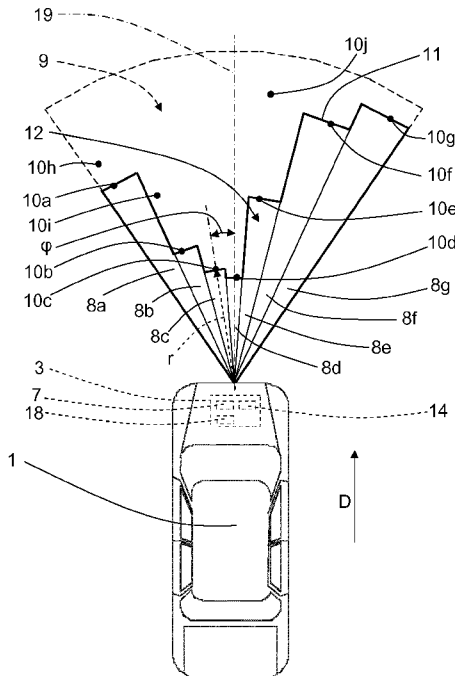
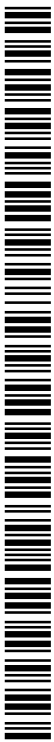


FIG. 3

(57) Abstract: The present disclosure relates to vehicle radar system (3) comprising at least one transceiver arrangement (7) arranged to generate and transmit radar signals (4), and to receive reflected radar signals (5). The radar signals form a plurality of sensing sectors, sensing bins (8a, 8b, 8c, 8d, 8e, 8f, 8g), that together form a transceiver coverage (9). For each sensing bin (8a, 8b, 8c, 8d, 8e, 8f, 8g) the radar system (3) is arranged to obtain a target angle (φ) and a target range (r) to possible target objects (10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g, 10h, 10i, 10j). The radar system (3) is further arranged to determine an unoccupied domain border (11) and a corresponding unoccupied domain (12) for the radar transceiver coverage (9). The present disclosure also relates to a corresponding method.



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TITLE

A vehicle radar system arranged for determining an unoccupied domain

5 DESCRIPTION OF THE DISCLOSURE

The present disclosure relates to a vehicle radar system comprising at least one transceiver arrangement arranged to generate, transmit and receive reflected radar signals. The radar signals form a plurality of sensing sectors, sensing bins,
10 that together form a transceiver coverage area.

Many vehicle radar systems comprise radar transceivers that are arranged for generating radar signals that are transmitted, reflected and received by means of appropriate antennas
15 comprised in the radar system. The radar signals may for example be in the form of FMCW (Frequency Modulated Continuous Wave) signals.

For a collision avoidance system in a vehicle, it is desired to
20 obtain a sufficiently reliable representation of at least a part of the environment surrounding the vehicle and may be formed as a free space representation. Such a representation should comprise both stationary and moving objects.

25 US 7227474 describes an object detection system where a plurality of sensor fields form a transceiver coverage area, and are overlaid on a desired detection zone. A range gate is a distance from the sensor where a sensing field and a desired detection zone overlap, and if an object has a range less than the range
30 gate, the object will be determined as within the desired detection zone.

It is however desired to obtain a more flexible vehicle radar system for determining a free space representation of at least
35 a part of the environment surrounding the vehicle.

The object of the present disclosure is thus to provide a vehicle radar system for determining a free space representation of at least a part of the environment surrounding the vehicle that is
5 more flexible than prior art systems.

This object is achieved by means of a vehicle radar system comprising a vehicle radar system comprising at least one transceiver arrangement. The transceiver arrangement is arranged
10 to generate and transmit radar signals, and to receive reflected radar signals, where the transmitted radar signals have been reflected by one or more objects. The radar signals form a plurality of sensing sectors, sensing bins, that together form a transceiver coverage. For each sensing bin the radar system is
15 arranged to obtain a target angle and a target range to possible target objects. The radar system is further arranged to determine an unoccupied domain border and a corresponding unoccupied domain for the radar transceiver coverage.

20 This object is also achieved by means of a method for a vehicle radar system, where the method comprises:

- Generating and transmitting radar signals.
- Receiving reflected radar signals, where the transmitted radar signals have been reflected by one or more objects,
25 where the radar signals form a plurality of sensing sectors, sensing bins that together form a transceiver coverage.
- Obtaining a target angle and a target range to possible target objects for each sensing bin.
- Determining an unoccupied domain border and a corresponding
30 unoccupied area for the radar transceiver coverage.

According to an example, the sensing bins have a non-uniform angular size.

According to another example, the vehicle radar system is arranged to independently pre-classify detections into moving or stationary detections.

5 According to another example, the radar system is arranged to be installed in a vehicle, and is arranged to perform said pre-classification by performing an analysis of the Doppler velocity and the angle of each detected target object with respect to motion and yaw rate of said vehicle.

10

According to another example, the vehicle radar system comprises a detection memory that is arranged to store detections observed in a certain number of radar cycles.

15 According to another example, the radar system is arranged to calculate the unoccupied domain border in each sensing bin by choosing the closest stationary target objects in each sensing bin within the set of all stored detections in the detection memory.

20 Other examples are disclosed in the dependent claims.

A number of advantages are obtained by means of the present disclosure. Mainly, a vehicle radar system is provided for determining a free space representation of at least a part of
25 the environment surrounding the vehicle in a more flexible manner than prior art systems.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure will now be described more in detail with
30 reference to the appended drawings, where:

Figure 1 shows a schematic top view of a vehicle;

Figure 2 shows a schematic top view of a vehicle with sensing
35 bins;

Figure 3 shows a schematic top view of a vehicle with sensing bins according to an example;

5 Figure 4 shows a schematic top view of a vehicle with sensing bins according to another example;

Figure 5 shows a schematic top view of a vehicle with sensing bins according to another example;

10 Figure 6 shows a schematic top view of a vehicle with sensing bins according to another example; and

Figure 7 shows a flowchart for a method according to the present disclosure.

15

DETAILED DESCRIPTION

Figure 1 schematically shows a top view of a vehicle 1 arranged to run on a road 2 in a direction D, where the vehicle 1 comprises a vehicle radar system 3 which is arranged to distinguish and/or
20 resolve single targets from the surroundings by transmitting signals 4 and receiving reflected signals 5 and using a Doppler effect in a previously well-known manner. The vehicle radar system 3 thus comprises a radar transceiver arrangement 7 and is arranged to provide azimuth angles of possible target objects 6
25 by simultaneously sampling and analyzing phase and amplitude of the received signals 5. The radar signals may for example be in the form of FMCW (Frequency Modulated Continuous Wave) signals operating at 77 GHz. The vehicle radar system 3 also comprises a radar control unit (RCU) 18.

30

As shown in Figure 2, the radar signals form a plurality of sensing sectors or sensing bins 8a, 8b, 8c, 8d, 8e, 8f, 8g that together form a transceiver coverage area 9, where an angle

normal line 19 extends in a forward running direction of the vehicle.

According to the present disclosure, as shown in an example with
5 reference to Figure 3, for each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g, a target angle ϕ and a target range r to possible target objects 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g, 10h, 10i, 10j are obtained, such that the RCU 18 is enabled to determine an unoccupied area border 11 and a corresponding
10 unoccupied area 12 for the radar transceiver coverage area 9 by means of polar coordinates. In the rest of the description, only a unoccupied area 12 will be discussed, although a corresponding unoccupied volume is conceivable. For reasons of clarity, the target angle ϕ and the target range r are only indicated for one
15 target object 10c in Figure 3, where the target angle ϕ is determined with respect to the angle normal line 19.

The unoccupied area 12 is within the solid line indicating the unoccupied area border 11. In this example, for each sensing bin
20 8a, 8b, 8c, 8d, 8e, 8f, 8g, there is a closest detected target object 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g that defines the position of the unoccupied area border 11 at each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g. Target objects outside the determined unoccupied area border 11 are not considered in
25 this example, but may be considered as will be discussed in a further example.

More in detail, the free space is represented as multiple range values, one for each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g in
30 an angle-quantized grid. Thus, the number of range values is identical to the number of sensing bins, where the number of sensing bins depends on the visible angle of the field of view of the radar transceiver and the size of each quantized angle bin.

This means that for each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g, a floating point value describing the free space, range of unoccupied space, for that particular sensing bin is acquired. It is to be noted that a floating point value is not necessary; according to some aspects the value describing the free space is a fixed point or a scaled integer value.

In order to obtain this, for each radar detection cycle, a detection list comprising radar signal data is used for obtaining range, azimuth angle and Doppler velocity.

According to an example, with reference to Figure 4, a non-uniform angular size of the sensing bins 8a', 8b', 8c', 8d', 8e', 8f', 8g' is used which for example is advantageous in certain driving scenarios; for example for country road and highway driving scenarios where free space mainly extends at the front of the transceiver arrangement 7. In these cases, a higher resolution in the driving direction D and a lower resolution to the side can be used. Any suitable type of non-uniform angular size of the sensing bins is of course conceivable; according to some aspects the sensing bins may have a smaller angular size in front of the vehicle and an increasing angular size towards the sides of the transceiver coverage area 9.

According to an example, the vehicle radar system 3 comprises a detection memory 14 that is used to increase robustness by storing detections observed in a certain number N of previous radar cycles. Such previous radar cycle detections are considered when determining the present unoccupied area border for the sensing bins.

According to an example, detections are independently pre-classified into moving or stationary detections. By analyzing

the Doppler velocity and the angle of each detection with respect to the host-motion and the yaw rate, each detection can be pre-classified as either moving or stationary. Taking yaw rate into consideration benefits in curved drives, such as for example roundabouts.

Detections are further, according to some aspects, fully classified into either the class of stationary objects, or individual motion classes for each moving object. This is achieved by incorporating output from a suitable general object tracking algorithm. Pre-classified detections can thus robustly be classified as moving or stationary.

Detections from previous cycles which are stored in the detection memory 14 are corrected by their combined motion or group motion. For the relevant group of stationary detections, this means compensating the position, x and y coordinates, by the change in the vehicle position and rotation as obtained through processing of vehicle velocity and yaw rate. Other detections, for example belonging to objects moving in the observable area, the transceiver coverage area 9, are corrected by the same mechanism and are in addition propagated by their group motion vector.

According to some aspects, to calculate the free space border in each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g, the RCU is arranged to choose the closest stationary target objects in each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g within the set of all stored detections in the detection memory 14. The range of the free space border is then given by the range of these closest target objects.

To increase robustness against outliers and spurious detections within the free space, a set of closest target objects in a given

bin can be considered. Most of all, not the closest stationary target objects n , but the second, third,..., n -th closest target objects with a given sensing bin can be chosen.

5 Especially for a coarse angular grid (i.e. low number of bins), the representation of the free space border can appear uneven and discontinuous, since the information in each bin is reduced to one range value. With reference to Figure 5, showing another example, in addition to the range value for each sensing bin
10 $8a''$, $8b''$, $8c''$, $8d''$, $8e''$, $8f''$, $8g''$, an angle value can be stored for each sensing bin $8a''$, $8b''$, $8c''$, $8d''$, $8e''$, $8f''$, $8g''$ representing the precise position, given by range and angle, of the closest detection $10a''$, $10b''$, $10c''$, $10d''$, $10e''$, $10f''$, $10g''$, $10e''$, $10f''$, $10''g$ in each sensing bin $8a''$, $8b''$,
15 $8c''$, $8d''$, $8e''$, $8f''$, $8g''$.

The fact that each bin has an individual angle in this example is indicated in Figure 5 for a sixth detection that has a target angle φ'' with respect to the angle normal line 19 and a range
20 r'' . This increases the memory requirements, but it gives a more detailed free space representation and allows for a more precise and natural road boundary visualization. This provides a slightly different unoccupied area representation $12''$, since the unoccupied area border $11''$ runs between the detections
25 $10a''$, $10b''$, $10c''$, $10d''$, $10e''$, $10f''$, $10g''$, $10e''$, $10f''$, $10''g$.

This gives a smoother unoccupied area border representation and provides a more precise localization of the detected object
30 $10a''$, $10b''$, $10c''$, $10d''$, $10e''$, $10f''$, $10g''$, $10e''$, $10f''$, $10''g$ in each sensing bin $8a''$, $8b''$, $8c''$, $8d''$, $8e''$, $8f''$, $8g''$.

If no detection is available within a certain sensing bin, the corresponding free space boundary is set to the default maximum range value. This can be undesirable, if adjacent bins have a well observable range boundary. Angular smoothing can be added
5 to overcome this problem. This is done by adding a filter such as for example a sliding window minimum filter of the range boundary values over adjacent sensing bins.

In addition to the angular smoothing, with reference to Figure
10 6, a further smoothing procedure significantly improves performance. For this, the Cartesian coordinates of each sensing bin $8a'''$, $8b'''$, $8c'''$, $8d'''$, $8e'''$, $8f'''$, $8g'''$ defined by the angle of the bin center and the range value of that sensing bin, are considered. If the Euclidean distance between the
15 Cartesian coordinates of any two sensing bins i , j is less than a desired minimum value, the range value of any intermediate sensing bin k is smoothed.

This smoothing is done by interpolating between the Cartesian
20 coordinates of bin i and j and ensuring that the range of the intermediate bins k does not exceed a smoothing threshold value in the form of an interpolated range value. If the interpolated range value is exceeded, the intermediate bins are smoothed from their original appearance. This means that in this example a
25 third sensing bin $8c'''$ and a fourth sensing bin $8d'''$ are smoothed from their original appearance, as indicated with a dashed line, to a reduced form that is limited by an interpolation line border line 15 running between the Cartesian coordinates 16, 17 (symbolically indicated with circles) of an
30 adjacent second sensing bin $8b'''$ and fifth sensing bin $8e'''$.

The representation in angular sensing bins, constituting a polar representation, is natural, efficient, robust and generic.

A polar representation is natural because the input data is generated in polar coordinates, contrary to the current state of the art in free space modeling that use a uniformly spaced Cartesian grid. The representation is efficient, because a full
5 field of view can be represented in a relatively low number of range values and allows for efficient transmission of the determined free space to other processing units. The representation is robust, since a robust filtering of noise is enabled. The representation is generic because it allows a
10 representation of free space in all driving scenarios. No prior assumptions regarding surroundings have to be made, working likewise on a highway, a country road, at city driving, or at narrow parking lots.

15 As indicated in Figure 1, the vehicle 1 comprises a safety control unit 35 and safety means 36, for example an emergency braking system and/or an alarm signal device. The safety control unit 35 is arranged to control the safety means 36 in dependence of input from the radar system 3.

20

With reference to Figure 7, the present disclosure relates to a method for a vehicle radar system, where the method comprises:

20: generating and transmitting radar signals 4;

21: receiving reflected radar signals 5, where the transmitted
25 radar signals 4 have been reflected by one or more objects 6, where the radar signals form a plurality of sensing sectors, sensing bins 8a, 8b, 8c, 8d, 8e, 8f, 8g, that together form a transceiver coverage 9,

22: obtaining a target angle φ and a target range r to possible
30 target objects 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g, 10h, 10i, 10j for each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g;
and

23: determining an unoccupied domain border 11 and a corresponding unoccupied domain 12 for the radar transceiver coverage 9.

5 The present disclosure is not limited to the examples above, but may vary freely within the scope of the appended claims. For example, the radar system may be implemented in any type of vehicle such as cars, trucks and buses as well as boats and aircraft.

10

The radar transceiver 7 is adapted for any suitable type of Doppler radar. There may be any number of radar transceivers 7 in the vehicle radar system 3, and they may be arranged for transmission and signals in any suitable direction. The
15 plurality of sensing sectors or sensing bins may thus be directed in other desirable directions, such as rearwards or at the sides of the vehicle 1.

20

In this context, a radar cycle is one observation phase in which the radar acquires data, processes the data on several signal processing levels and sends out available results. This can be a fixed time interval (i.e. 40 to 60 milliseconds), or it can be a dynamic time interval depending on environment conditions and processing load.

25

Since an unoccupied volume also is conceivable for the present disclosure, the unoccupied area 12 is generally constituted by an unoccupied domain 12 and the unoccupied area border 11 is generally constituted by an unoccupied domain border 12.

30

Correspondingly, the transceiver coverage area 9 is generally constituted by a transceiver coverage.

All detections correspond to detected target objects.

According to an aspect, other coordinates than polar coordinates are used, for example Cartesian coordinates.

Generally, the present disclosure relates to vehicle radar system 3 comprising at least one transceiver arrangement 7 arranged to generate and transmit radar signals 4, and to receive reflected radar signals 5, where the transmitted radar signals 4 have been reflected by one or more objects 6, where the radar signals form a plurality of sensing sectors, sensing bins 8a, 8b, 8c, 8d, 8e, 8f, 8g, that together form a transceiver coverage 9. For each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g the radar system 3 is arranged to obtain a target angle ϕ and a target range r to possible target objects 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g, 10h, 10i, 10j, where the radar system 3 further is arranged to determine an unoccupied domain border 11 and a corresponding unoccupied domain 12 for the radar transceiver coverage 9.

According to an example, the sensing bins 8a', 8b', 8c', 8d', 8e', 8f', 8g' have a non-uniform angular size.

According to an example, the vehicle radar system 3 is arranged to independently pre-classify detections into moving or stationary detections.

According to an example, the radar system 3 is arranged to be installed in a vehicle 1, and where the radar system 3 further is arranged to perform said pre-classification by performing an analysis of the Doppler velocity and the angle ϕ of each detected target object 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g, 10h, 10i, 10j with respect to motion and yaw rate of said vehicle 1.

According to an example, the vehicle radar system 3 comprises a detection memory 14 that is arranged to store detections observed in a certain number N of radar cycles.

5 According to an example, the radar system 3 is arranged to calculate the unoccupied domain border 11 in each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g by choosing the closest stationary target objects 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g in each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g within the set of
10 all stored detections in the detection memory 14.

According to an example, the unoccupied area border 11'' runs between the detections 10a'', 10b'', 10c'', 10d'', 10e'', 10f'', 10g'', 10e'', 10f'', 10''g.

15

According to an example, the vehicle radar system 3 is arranged to perform a smoothing procedure that is arranged to:
interpolate between the Cartesian coordinates of two sensing bins 8b''', 8e''';

20 check whether the range of intermediate bins 8c''', 8d''' exceed a smoothing threshold value; and,
if the smoothing threshold value is exceeded, to smooth the intermediate bins 8c''', 8d''' from their original values.

25 Generally, the present disclosure also relates to a method for a vehicle radar system, where the method comprises:

20: generating and transmitting radar signals 4;

21: receiving reflected radar signals 5, where the transmitted radar signals 4 have been reflected by one or more
30 objects 6, where the radar signals form a plurality of sensing sectors, sensing bins 8a, 8b, 8c, 8d, 8e, 8f, 8g, that together form a transceiver coverage 9,

22: obtaining a target angle ϕ and a target range r to possible target objects 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e,

10f, 10g, 10h, 10i, 10j for each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g; and

23: determining an unoccupied domain border 11 and a corresponding unoccupied area 12 for the radar transceiver
5 coverage 9.

According to an example, the sensing bins 8a', 8b', 8c', 8d', 8e', 8f', 8g' have a non-uniform angular size.

10 According to an example, the method comprises independently pre-classifying detections into moving or stationary detections.

According to an example, said pre-classification is performed by analyzing the Doppler velocity and the angle ϕ of each detected
15 target object 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g, 10h, 10i, 10j with respect to motion and yaw rate of a vehicle 1.

According to an example, the method comprises storing detections
20 observed in a certain number N of radar cycles.

According to an example, the method comprises calculating the unoccupied domain border 11 in each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g by choosing the closest stationary target objects
25 10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g in each sensing bin 8a, 8b, 8c, 8d, 8e, 8f, 8g within the set of all stored detections.

According to an example, the unoccupied area border 11'' runs
30 between the detections 10a'', 10b'', 10c'', 10d'', 10e'', 10f'', 10g'', 10e'', 10f'', 10''g.

According to an example, the method comprises a smoothing procedure which in turn comprises:

interpolating between the Cartesian coordinates of two sensing bins $8b'''$, $8e'''$;

checking whether the range of intermediate bins $8c'''$, $8d'''$ exceed a smoothing threshold value; and

5 if the smoothing threshold value is exceeded, smoothing the intermediate bins $8c'''$, $8d'''$ from their original values.

CLAIMS

1. A vehicle radar system (3) comprising at least one transceiver arrangement (7) arranged to generate and transmit radar signals (4), and to receive reflected radar signals (5), where the transmitted radar signals (4) have been reflected by one or more objects (6), where the radar signals form a plurality of sensing sectors, sensing bins (8a, 8b, 8c, 8d, 8e, 8f, 8g), that together form a transceiver coverage (9), **characterized in** that for each sensing bin (8a, 8b, 8c, 8d, 8e, 8f, 8g) the radar system (3) is arranged to obtain a target angle (ϕ) and a target range (r) to possible target objects (10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g, 10h, 10i, 10j), where the radar system (3) further is arranged to determine an unoccupied domain border (11) and a corresponding unoccupied domain (12) for the radar transceiver coverage (9).

2. The vehicle radar system (3) according to claim 1, **characterized in** that the sensing bins (8a', 8b', 8c', 8d', 8e', 8f', 8g') have a non-uniform angular size.

3. The vehicle radar system (3) according to any one of the previous claims, **characterized in** that the vehicle radar system (3) is arranged to independently pre-classify detections into moving or stationary detections.

4. The vehicle radar system (3) according to claim 3, **characterized in** that the radar system (3) is arranged to be installed in a vehicle (1), and where the radar system (3) further is arranged to perform said pre-classification by performing an analysis of the Doppler velocity and the angle (ϕ) of each detected target object (10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g, 10h, 10i, 10j) with respect to motion and yaw rate of said vehicle (1).

5. The vehicle radar system (3) according to any one of the previous claims, **characterized in** that the vehicle radar system (3) comprises a detection memory (14) that is arranged to
5 store detections observed in a certain number (N) of radar cycles.

6. The vehicle radar system (3) according to claim 5, **characterized in** that the radar system (3) is arranged to
10 calculate the unoccupied domain border (11) in each sensing bin (8a, 8b, 8c, 8d, 8e, 8f, 8g) by choosing the closest stationary target objects (10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g) in each sensing bin (8a, 8b, 8c, 8d, 8e, 8f, 8g) within the set of all stored detections in the detection memory (14).

15

7. The vehicle radar system (3) according to claim 6, **characterized in** that the unoccupied area border (11'') runs between the detections (10a'', 10b'', 10c'', 10d'', 10e'', 10f'', 10g'', 10e'', 10f'', 10''g).

20

8. The vehicle radar system (3) according to any one of the previous claims, **characterized in** that the vehicle radar system (3) is arranged to perform a smoothing procedure that is arranged to:

25 interpolate between the Cartesian coordinates of two sensing bins (8b''', 8e''');

check whether the range of intermediate bins (8c''', 8d''') exceed a smoothing threshold value; and,

30 if the smoothing threshold value is exceeded, to smooth the intermediate bins (8c''', 8d''') from their original values.

9. A method for a vehicle radar system, where the method comprises:

(20) generating and transmitting radar signals (4); and

(21) receiving reflected radar signals (5), where the transmitted radar signals (4) have been reflected by one or more objects (6), where the radar signals form a plurality of sensing sectors, sensing bins (8a, 8b, 8c, 8d, 8e, 8f, 8g), that together
5 form a transceiver coverage (9),

characterized in that the method further comprises:

(22) obtaining a target angle (φ) and a target range (r) to possible target objects (10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g, 10h, 10i, 10j) for each sensing bin (8a, 8b,
10 8c, 8d, 8e, 8f, 8g); and

(23) determining an unoccupied domain border (11) and a corresponding unoccupied area (12) for the radar transceiver coverage (9).

15 10. The method according to claim 9, **characterized in** that the sensing bins (8a', 8b', 8c', 8d', 8e', 8f', 8g') have a non-uniform angular size.

11. The method according to any one of the claims 9 or 10,
20 **characterized in** that the method comprises independently pre-classifying detections into moving or stationary detections.

12. The method according to claim 11, **characterized in** that said pre-classification is performed by analyzing the Doppler
25 velocity and the angle (φ) of each detected target object (10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g, 10h, 10i, 10j) with respect to motion and yaw rate of a vehicle (1).

13. The method according to any one of the claims 9-12,
30 **characterized in** that the method comprises storing detections observed in a certain number (N) of radar cycles.

14. The method according to claim 13, **characterized in** that the method comprises calculating the unoccupied domain border

(11) in each sensing bin (8a, 8b, 8c, 8d, 8e, 8f, 8g) by choosing the closest stationary target objects (10a, 10b, 10c, 10d, 10e, 10f, 10g, 10e, 10f, 10g) in each sensing bin (8a, 8b, 8c, 8d, 8e, 8f, 8g) within the set of all stored detections.

5

15. The method according to claim 14, **characterized in** that the unoccupied area border (11'') runs between the detections (10a'', 10b'', 10c'', 10d'', 10e'', 10f'', 10g'', 10e'', 10f'', 10''g).

10

16. The method according to any one of the claims 9-15, **characterized in** that the method comprises a smoothing procedure which in turn comprises:

interpolating between the Cartesian coordinates of two
15 sensing bins (8b''', 8e''');

checking whether the range of intermediate bins (8c''', 8d''') exceed a smoothing threshold value; and

if the smoothing threshold value is exceeded, smoothing the intermediate bins (8c''', 8d''') from their original values.

20

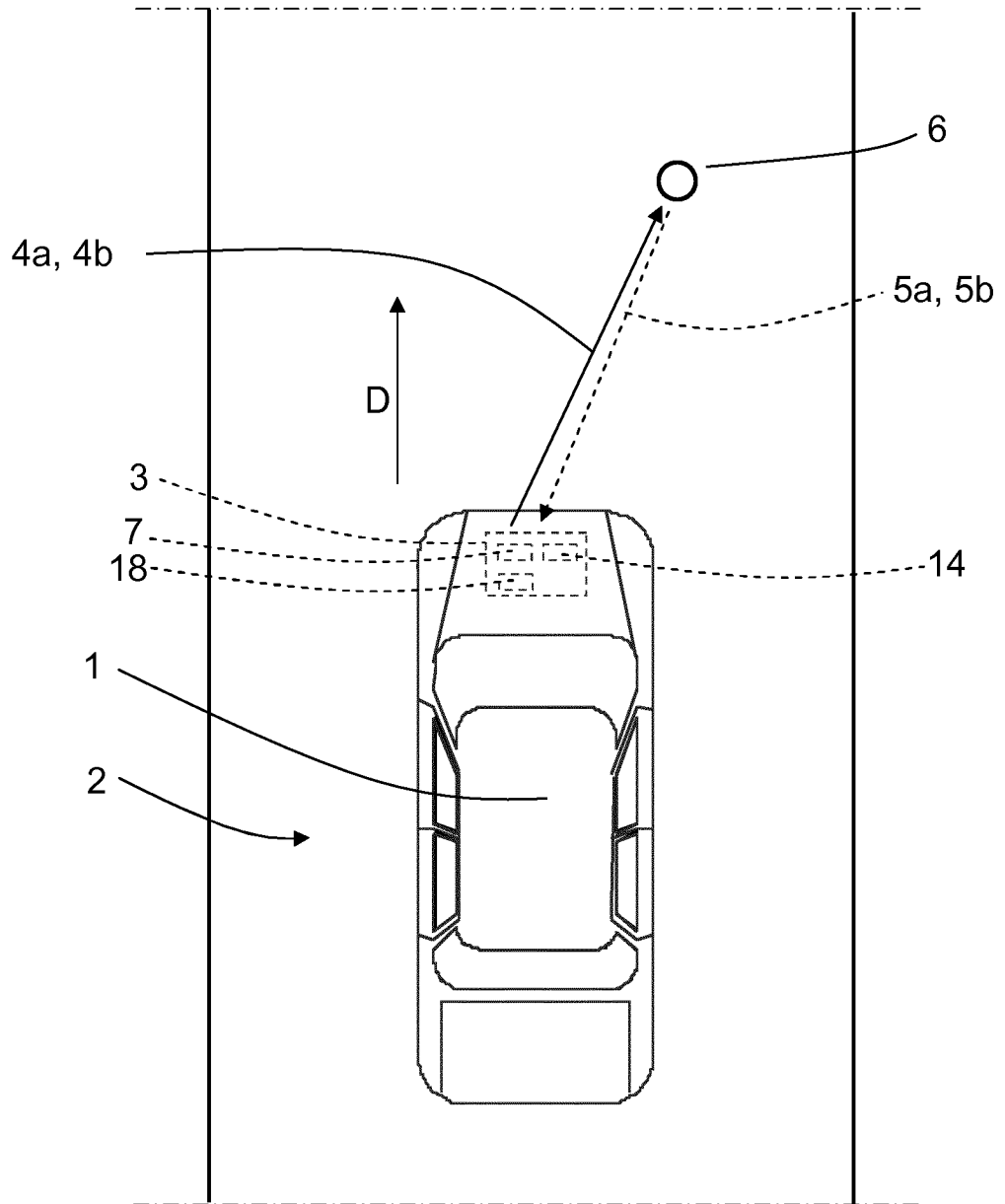


FIG. 1

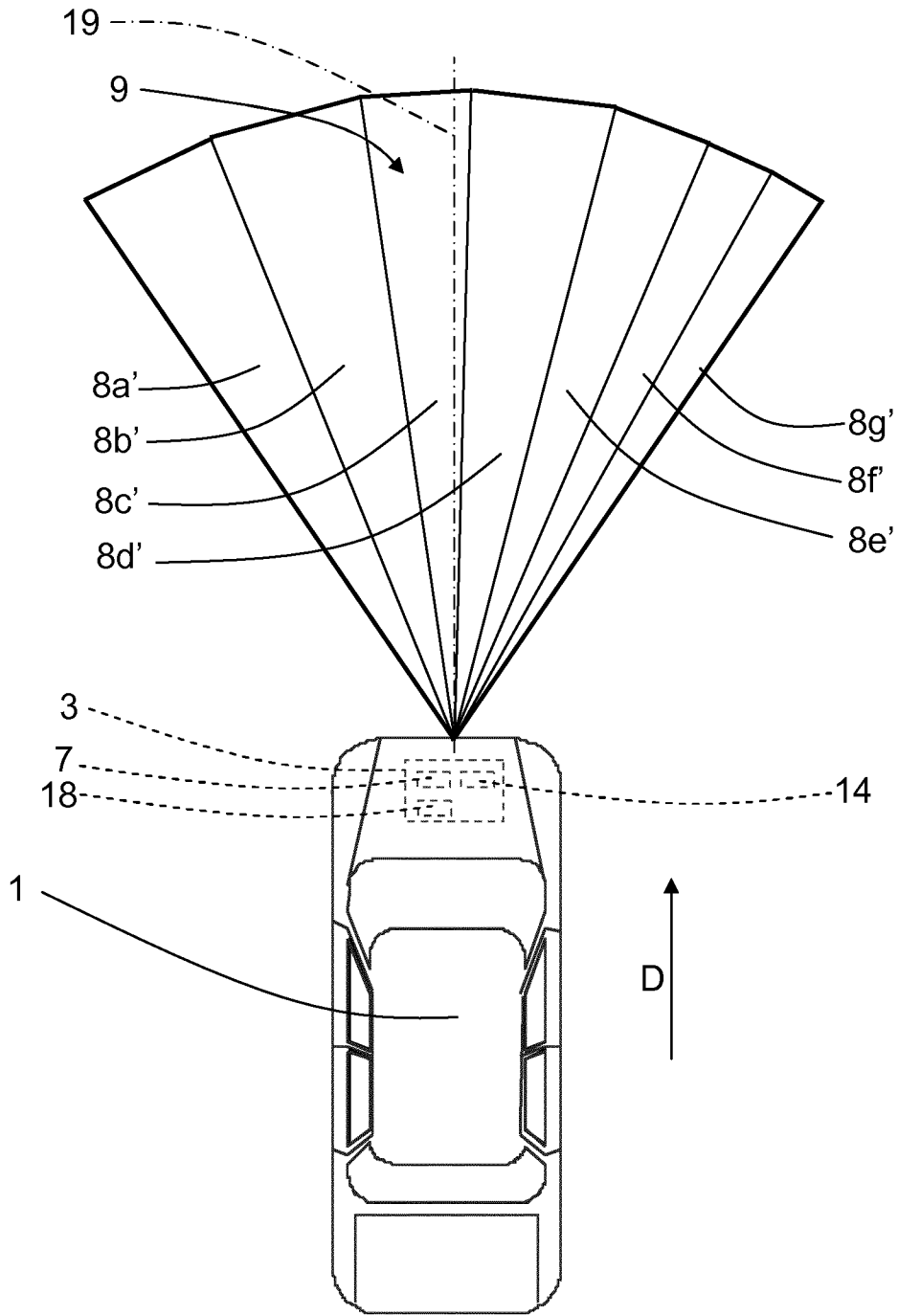


FIG. 4

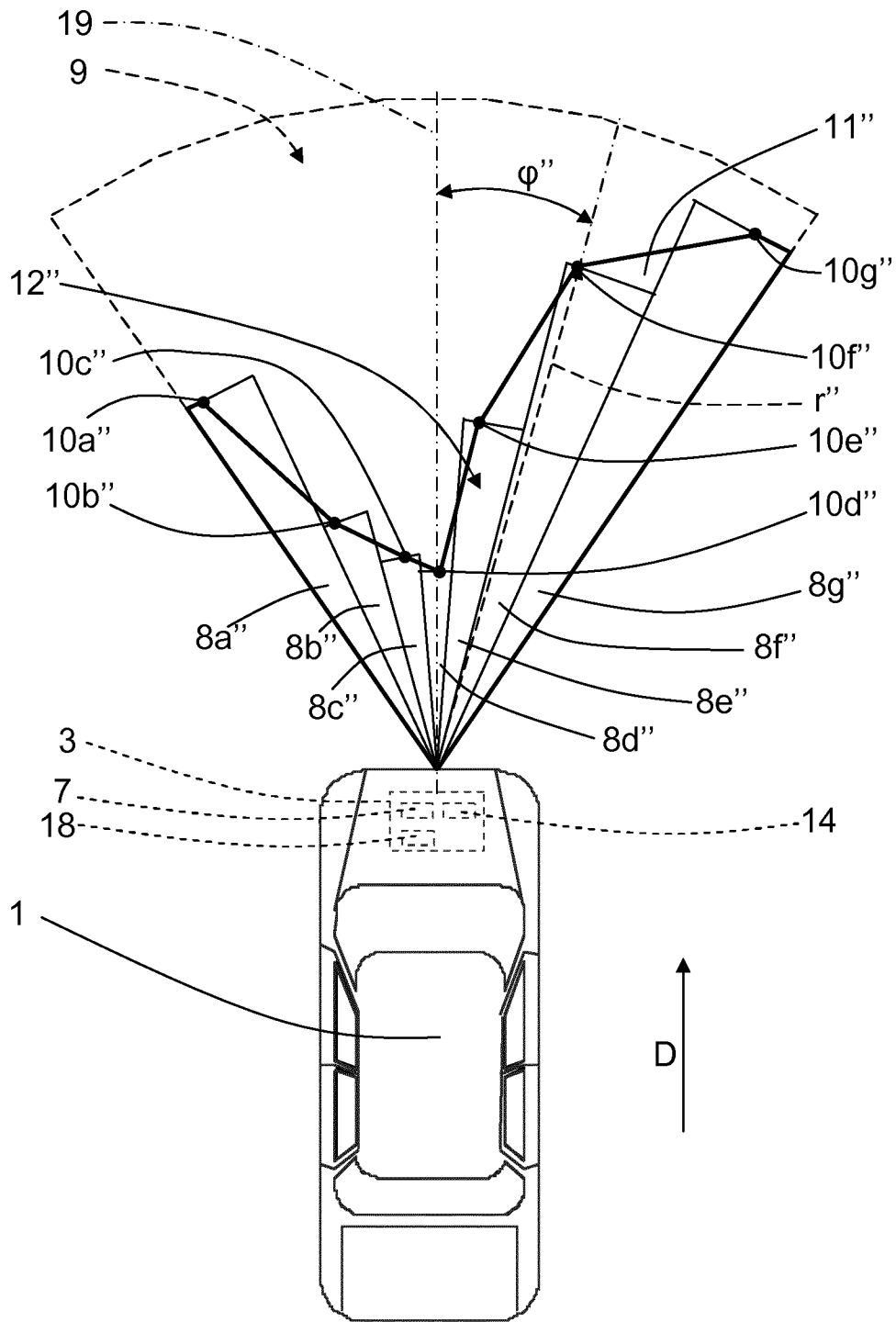


FIG. 5

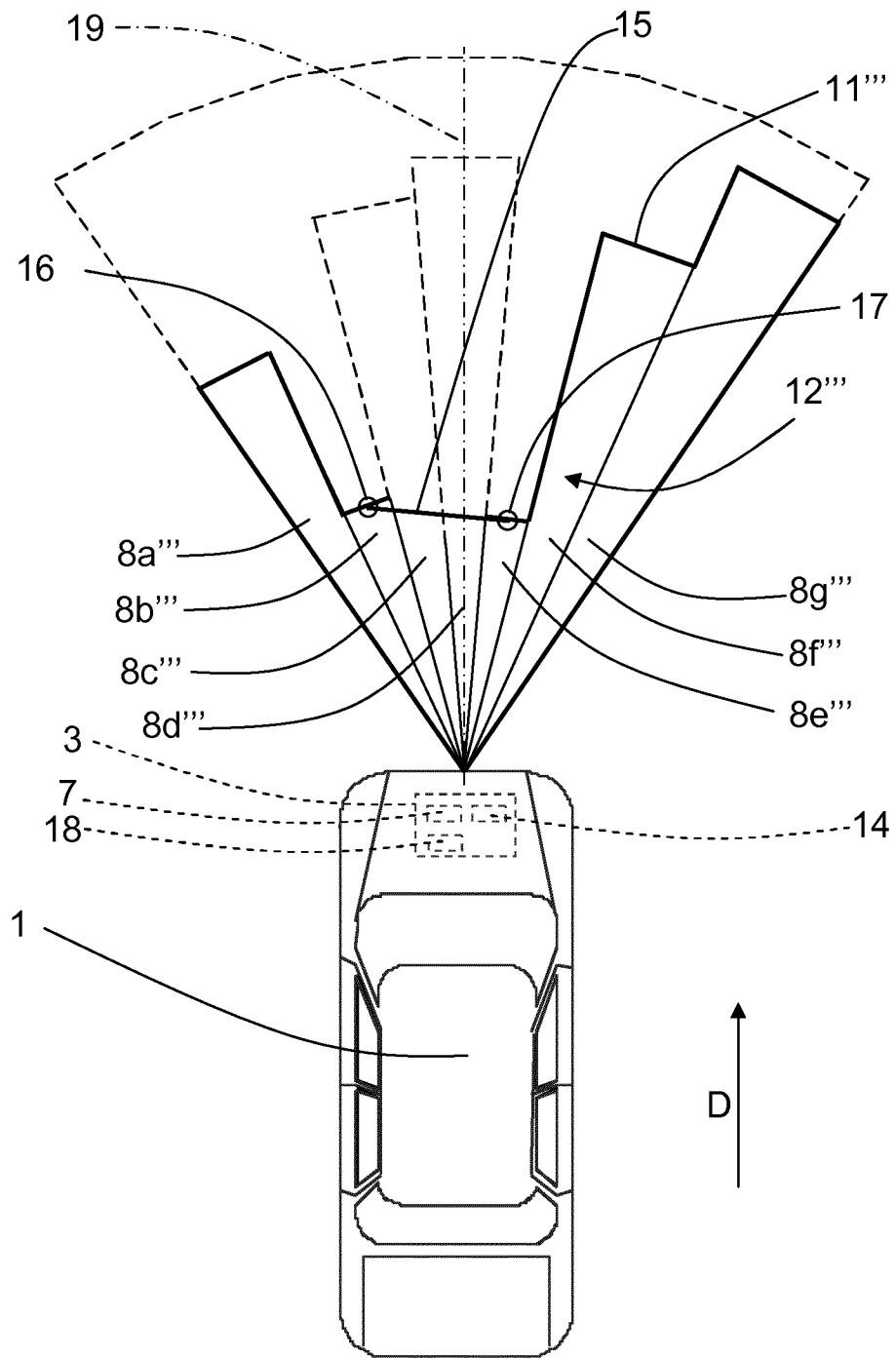


FIG. 6

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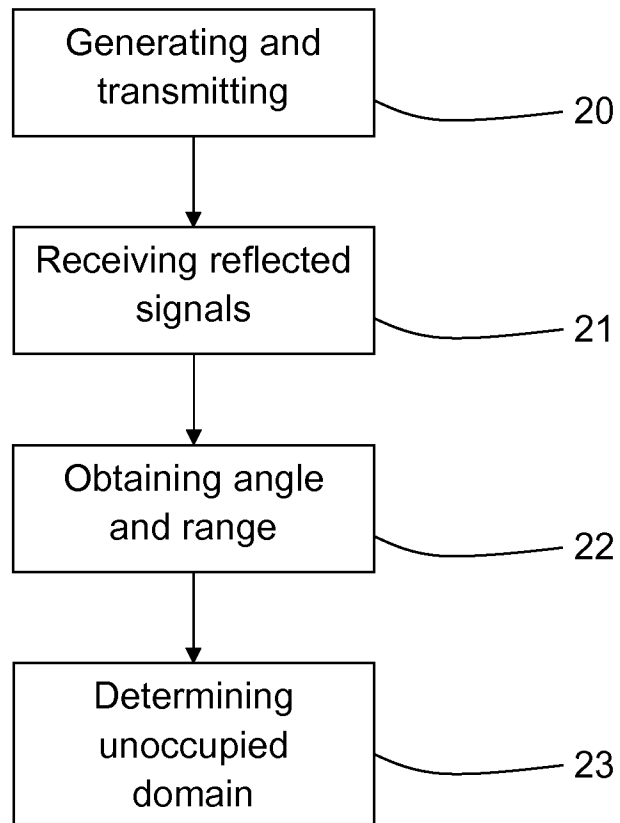


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/081459

A. CLASSIFICATION OF SUBJECT MATTER
 INV. G01S13/42 G01S13/536 G01S13/93
 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)
 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, INSPEC, 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	US 5 758 298 A (GULDNER JURGEN [DE]) 26 May 1998 (1998-05-26)	1,3,4, 6-16
Y	fig. 1,3 and 4, col. 1, lines 61-63, col. 9, lines 47-59, col. 10, lines 12-34 and 56-63 and col. 11, lines 8-15 and line 65 - col. 12, line 22	2,5
Y	----- US 6 163 252 A (NISHIWAKI TAKESHI [JP]) 19 December 2000 (2000-12-19)	2,5
A	figure 1 and 5, col. 5, lines 20-24 -----	1,3,4, 6-16

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	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 7 March 2017	Date of mailing of the international search report 15/03/2017
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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 Metz, Carsten
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/081459

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