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(54) Title: DETERMINING RELATIVE VELOCITY IN A VEHICLE RADAR SYSTEM

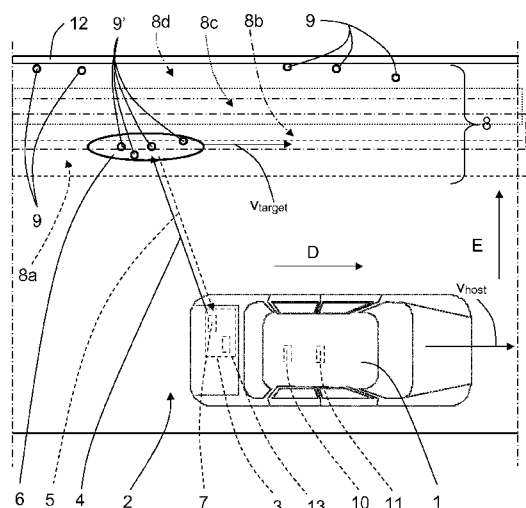


FIG. 1

(57) Abstract: The present disclosure relates to a vehicle radar system (3) arranged to be mounted in a host vehicle (1) arranged to run in a forward running direction (D). The vehicle radar system (3) comprises 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, 12). The radar system (3) is arranged to provide range (rn), azimuth angle (θ_n) and radial velocity (vm) for a plurality of measurement points (9, 9') at said objects (6, 12). The radar system (3) is furthermore arranged to divide a total detection volume (8) into at least two partial volumes (8a, 8b, 8c, 8d), and to perform a velocity estimation for each partial volume (8a, 8b, 8c, 8d) such that a total velocity distribution (14) is acquired along a side extension (E) that is perpendicular to an extension along the forward running direction (D).

TITLE

Determining relative velocity in a vehicle radar system

DESCRIPTION OF THE DISCLOSURE

- 5 The present disclosure relates to a vehicle radar system arranged to generate, transmit and receive reflected radar signals. The radar system is arranged to provide range, azimuth angle and radial velocity for a plurality of measurement points.
- 10 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 comprised in the radar system. The radar signals may for example be in the form of FMCW (Frequency Modulated Continuous Wave)
- 15 signals.

- A problem which frequently occurs in the steering of vehicles is the difficulty in noticing objects in proximity to the vehicle which are located in a position not easily seen by the driver.
- 20 A position such as this is conventionally known as the blind spot which for example typically is located in a direction of 90° to 170° from the direction of travel, both to the left and to the right of the motor vehicle. It is important for the driver of a vehicle to be alerted to the presence of objects in the
- 25 blind spot, particularly when turning or changing lanes in a multi-lane road or highway.

- For this purpose, vehicles have been equipped with radar systems that are arranged to detect the presence of an object in the
- 30 blind spot and automatically produce a signal which alerts the driver of the vehicle to the presence of the obstacle. In order to achieve this, a radar system must be able to determine the relative velocity between the vehicle into which it is fitted

and a potential obstacle in order to distinguish the obstacle from stationary objects.

5 The document US 7598904 describes how a relative velocity between two objects; a host vehicle comprising a radar system and a target vehicle, is determined. The radial velocity and the azimuth angle between the direction of observation and the direction of movement of the host vehicle are determined for a large number of measurement points, forming a cluster or cloud
10 of measurement points. The relative velocity is determined as an average of velocity components in a direction of driving.

However, in situations with small vehicles in front of a stationary object, such as for example a bicycle in front of a
15 wall, the cluster of measurement points which is used is a mixture of detections from the small vehicle and from the background. In this situation, the calculated relative velocity does not match the real relative velocity of the small vehicle resulting in that it is not detected as a moving object.

20 It is therefore desired to provide a vehicle radar system that is able to provide a more stable and reliable relative velocity difference between a host vehicle, comprising a radar system, and a target vehicle or other object.

25 The object of the present disclosure is thus to provide a vehicle radar system that is able to provide a more stable and reliable relative velocity difference between a host vehicle, comprising a radar system, and a target vehicle or other object.

30 This object is achieved by means of a vehicle radar system arranged to be mounted in a host vehicle arranged to run in a forward running direction. The vehicle radar system comprises at least one transceiver arrangement arranged 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 system is arranged to provide range, azimuth angle and radial velocity for a plurality of measurement
5 points at said objects. The radar system is furthermore arranged to divide a total detection volume into at least two partial volumes, and to perform a velocity estimation for each partial volume, such that a total velocity distribution is acquired along a side extension that is perpendicular to an extension along the
10 forward running direction.

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

- Generating and transmitting radar signals.
- 15 - Receiving reflected radar signals, where the transmitted radar signals have been reflected by one or more objects.
- Providing azimuth angle and radial velocity for a plurality of measurement points at said objects.
- Dividing a total detection volume into at least two partial
20 volumes.
- Performing a velocity estimation for each partial volume such that a total velocity distribution is acquired along a side extension that is perpendicular to an extension along a forward running direction.

25 According to an example, the radar system is arranged to check whether the magnitude of the total velocity distribution changes from one partial volume to another partial volume such that said change exceeds a certain threshold, and if that is the case, to
30 group measurement points corresponding to a certain partial velocity distribution.

According to another example, the radar system is arranged to form said partial volumes as mutually parallel slices.

According to another example, the radar system is arranged to only take an x-component of the radial velocity into account when the radial velocity is determined.

5

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 that is
10 able to provide a more stable and reliable relative velocity difference between a host vehicle, comprising a radar system, and a target vehicle or other object. In particular, smaller target vehicles are distinguished from background objects to a higher degree than before.

15

BRIEF DESCRIPTION OF THE DRAWINGS

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

20 Figure 1 shows a schematic top view of a vehicle and target object;

Figure 2 shows radial velocity and azimuth angle for a certain measurement point;

25

Figure 3 shows an estimation $\Delta V'$ of the actual relative velocity as a function of the side extension E for all measurement points; and

30 Figure 4 shows a flowchart for methods according to the present disclosure.

DETAILED DESCRIPTION

Figure 1 schematically shows a top view of a vehicle 1 arranged to run on a road 2 in a forward running direction D, where the vehicle 1 comprises a vehicle radar system 3 which is arranged to distinguish and/or 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 range, azimuth angle and radial velocity of possible target objects 6, here in the form of a target vehicle 6, by simultaneously sampling and analyzing phase and amplitude of the received signals 5 by means of Doppler signal processing in a previously known manner by one or more control units 13. This will be discussed more in detail later with reference to Figure 2. The distance to said target objects 6 is according to some aspect also acquired.

According to some aspects, the radar signals may be in the form of FMCW (Frequency Modulated Continuous Wave) Doppler signals operating at 77 GHz.

The vehicle 1 in question, the host vehicle 1, is running at a host velocity v_{host} alongside the target vehicle 6, in this example in the form of a schematically indicated bicycle, which is running at a target velocity v_{target} . Behind the target vehicle 6 there is a stationary object; in this example a wall 12. By means of the vehicle radar system 3, the radial velocity and the azimuth angle between the direction of observation and the direction of movement of the host vehicle 1 are acquired for a large number of measurement points 9, 9' (only a few shown for reasons of clarity) where there is a total number N of measurements points.

With reference also to Figure 2, a range r_n , a radial velocity v_{rn} and an azimuth angle θ_n between the direction of observation and the direction of movement of a certain measurement point 9_n , being an n :th measurement point, $n = 1 \dots N$.

5

In the following, said certain n :th measurement point 9_n , $n = 1 \dots N$, among all the measurement points 9 , $9'$ will be discussed.

10

The radial velocity v_{rn} has an x-component v_{xn} and a y-component v_{yn} , where the x-component v_{xn} runs parallel to the direction D and the y-component v_{yn} runs perpendicular to the x-component v_{xn} .

15

The radial velocity v_{rn} is determined, for example, from the Doppler frequency and the Doppler phase shift. Information on the range may also be included for said measurement point 9_n .

20

The desired differential velocity between the host vehicle 1 and the target vehicle 8 is:

$$\Delta V = V_{\text{target}} - V_{\text{host}} \quad (1)$$

For said measurement point 9_n , a radial velocity, V_{rn} is calculated according to:

25

$$V_{rn} = \Delta V \cdot \cos(\theta_n) \quad (2)$$

30

If it is assumed that the host vehicle 1 and the target vehicle 8 run substantially parallel to one another, the radial velocity V_{rn} will not have a y-component v_{yn} for said measurement point 9_n , and the relative velocity for said measurement point 9_n corresponds respectively to the x-component V_{xn} .

The x-component V_{xn} of the radial velocity V_{rn} for said measurement point 9_n is calculated according to:

$$V_{xn} = \frac{V_{rn}}{\cos(\theta_n)} \quad (3)$$

5

An estimation $\Delta V'$ of the actual relative velocity ΔV can now be obtained by determining the average of the quotients according to equation (3). This can be written as:

$$\Delta V' = \frac{\overline{V_m}}{\cos(\theta_n)} \quad (4),$$

10

where $\overline{V_m}$ is the average of the radial velocity of all measurement points $9, 9'$ calculated according to equation (2).

15 According to the present disclosure, in order to facilitate the possibility to distinguish between measurement points 9 at the wall 12 and measurement points $9'$ at the target vehicle 6 , a total detection volume 8 is divided into at least two overlapping partial volumes, here in the form of four slices; a first partial
20 volume $8a$, a second partial volume $8b$, a third partial volume $8c$ and a fourth volume partial $8d$. The target vehicle 6 is positioned in the first partial volume $8a$ and the second partial volume $8b$.

25 Said control unit 13 is arranged to perform a velocity estimation for each partial volume $8a, 8b, 8c, 8d, 8e$ such that a total velocity distribution 14 is acquired along a side extension E that is perpendicular to the extension of the direction D , as illustrated in Figure 3 that shows the estimation $\Delta V'$ of the
30 actual relative velocity, according to Equation 4, as a function of the side extension E for all the measurement points $9, 9'$.

Said control unit 13 is further arranged to check whether the magnitude of the total velocity distribution 14 changes from one partial volume to another partial volume such that said change exceeds a certain threshold. If that is the case, those measurement points 9' corresponding to a certain partial velocity distribution 22 are determined to belong to a certain group 23 of measurement points 9'.

In this way, one or more groups of measurement points 9, 9' are formed, where each group of measurement points 9, 9' corresponds to one or more partial volumes and to a certain partial velocity distribution 22. Adjacent groups of measurement points 9, 9' have a difference of velocity distribution magnitude that exceeds a certain threshold. In this manner target objects with different velocities can be separated from each other.

Here, one partial velocity distribution 22 determined to belong to a certain group 23 of measurement points 9' is shown, corresponding to the target vehicle. Another partial velocity distribution can be determined to belong to a certain group of measurement points 9 corresponding to the wall 12.

It is for example conceivable that there are several moving target objects in Figure 1, such as for example two bicycles moving with different velocities and a slower pedestrian. By means of the present disclosure, these can be separated from each other.

As schematically indicated in Figure 1, the vehicle 1 comprises a safety control unit 10 and safety means 11, for example an emergency braking system and/or an alarm signal device. The safety control unit 10 is arranged to control the safety means 11 in dependence of input from the radar system 3.

With reference to Figure 4, the present disclosure also relates to a method for a vehicle radar system, where the method comprises:

15: Generating and transmitting radar signals 4.

5 16: Receiving reflected radar signals 5, where the transmitted radar signals 4 have been reflected by one or more objects 6, 12.

17: Providing range r_n , azimuth angle θ_n and radial velocity v_{rn} for each one of a plurality of measurement points
10 9, 9' at said objects 6, 12.

18: Dividing a total detection volume 8 into at least two partial volumes 8a, 8b, 8c, 8d.

19: Performing a velocity estimation for each partial volume 8a, 8b, 8c, 8d such that a total velocity distribution 14
15 is acquired along a side extension E that is perpendicular to an extension along a forward running direction D.

According to an example, the method also comprises:

20: Checking whether the magnitude of the total
20 velocity distribution 14 changes from one partial volume to another partial volume such that said change exceeds a certain threshold, and, if that is the case,

21: grouping measurement points 9' corresponding to a certain partial velocity distribution 22.

25 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
30 aircraft.

The radar transceiver 7 is adapted for any suitable type of Doppler radar in a Doppler radar system. 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 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.

5

Radar signal processing is performed by one or more control units 13 comprised in any kind of suitable processor arrangement comprised in the vehicle radar system 3, such as a DSP (Digital Signal Processor) or an RCU (Radar Control Unit) which according to some aspects comprises a DSP.

10

The direction of the relative velocity ΔV that is desired has been shown to coincide with the running direction of the vehicles 1, 8. However, the direction of the relative velocity ΔV that is desired may have any suitable direction. According to an aspect, the target vehicle is constituted by any suitable object 6.

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Applications like LDW (Lane Departure Warning) or LCA (Lane Change Assist) that are following objects that are on the next lane can benefit from the present disclosure to estimate the correct object velocity for adjacent objects.

20

The number N of measurements points can vary, but should be more than three.

25

In this example, the partial volumes 8a, 8b, 8c, 8d are overlapping, but this is not necessary.

Generally, the present disclosure relates to a vehicle radar system 3 arranged to be mounted in a host vehicle 1 arranged to run in a forward running direction D , the 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

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reflected by one or more objects 6, 12, where the radar system 3 is arranged to provide range r_n , azimuth angle θ_n and radial velocity v_{rn} for a plurality of measurement points 9, 9' at said objects 6, 12. The radar system 3 is arranged to divide a total detection volume 8 into at least two partial volumes 8a, 8b, 8c, 8d, and to perform a velocity estimation for each partial volume 8a, 8b, 8c, 8d such that a total velocity distribution 14 is acquired along a side extension E that is perpendicular to an extension along the forward running direction D.

10

According to an example, the radar system 3 is arranged to check whether the magnitude of the total velocity distribution 14 changes from one partial volume to another partial volume such that said change exceeds a certain threshold, and if that is the case, to group measurement points 9' corresponding to a certain partial velocity distribution 22.

15

According to an example, the radar system 3 is arranged to form said partial volumes 8a, 8b, 8c, 8d as mutually parallel slices.

20

According to an example, the radar system 3 is arranged to only take an x-component V_{xn} of the radial velocity V_{rn} into account when the radial velocity V_{rn} is determined.

25 According to an example, the partial volumes 8a, 8b, 8c, 8d are overlapping.

Generally, the present disclosure also relates to a method for a vehicle radar system 3, where the method comprises:

- 30 15: generating and transmitting radar signals 4;
 16: receiving reflected radar signals 5, where the transmitted radar signals 4 have been reflected by one or more objects 6, 12;

17: providing range r_n , azimuth angle θ_n and radial velocity v_{rn} for a plurality of measurement points 9, 9' at said objects 6, 12;

18: dividing a total detection volume 8 into at least
5 two partial volumes 8a, 8b, 8c, 8d; and

19: performing a velocity estimation for each partial volume 8a, 8b, 8c, 8d such that a total velocity distribution 14 is acquired along a side extension E that is perpendicular to an extension along a forward running direction D.

10

According to an example, the method comprises:

20: checking whether the magnitude of the total velocity distribution 14 changes from one partial volume to another partial volume such that said change exceeds a certain
15 threshold, and, if that is the case,

21: grouping measurement points 9' corresponding to a certain partial velocity distribution 22.

According to an example, the method comprises forming said
20 partial volumes 8a, 8b, 8c, 8d as mutually parallel slices.

According to an example, the method comprises only taking an x-component V_{xn} of the radial velocity V_{rn} into account when the radial velocity V_{rn} is determined.

25

According to an example, the partial volumes 8a, 8b, 8c, 8d are overlapping.

30

CLAIMS

1. A vehicle radar system (3) arranged to be mounted in a host vehicle (1) arranged to run in a forward running direction (D), the 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, 12), where the radar system (3) is arranged to provide range (r_n), azimuth angle (θ_n) and radial velocity (v_{rn}) for a plurality of measurement points (9, 9') at said objects (6, 12), **characterized in** that the radar system (3) is arranged to divide a total detection volume (8) into at least two partial volumes (8a, 8b, 8c, 8d), and to perform a velocity estimation for each partial volume (8a, 8b, 8c, 8d) such that a total velocity distribution (14) is acquired along a side extension (E) that is perpendicular to an extension along the forward running direction (D).
2. The vehicle radar system (3) according to claim 1, **characterized in** that the radar system (3) is arranged to check whether the magnitude of the total velocity distribution (14) changes from one partial volume to another partial volume such that said change exceeds a certain threshold, and if that is the case, to group measurement points (9') corresponding to a certain partial velocity distribution (22).
3. The vehicle radar system (3) according to any one of the claims 1 or 2, **characterized in** that the radar system (3) is arranged to form said partial volumes (8a, 8b, 8c, 8d) as mutually parallel slices.
4. The vehicle radar system (3) according to any one of the previous claims, **characterized in** that the radar system (3)

is arranged to only take an x-component (V_{xn}) of the radial velocity (V_{rn}) into account when the radial velocity (V_{rn}) is determined.

5 5. The vehicle radar system (3) according to any one of the previous claims, **characterized in** that the partial volumes (8a, 8b, 8c, 8d) are overlapping.

10 6. A method for a vehicle radar system (3), where the method comprises:

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

 (16) receiving reflected radar signals (5), where the transmitted radar signals (4) have been reflected by one or more objects (6, 12); and

15 (17) providing range (r_n), azimuth angle (θ_n) and radial velocity (v_{rn}) for a plurality of measurement points (9, 9') at said objects (6, 12); **characterized in** that the method further comprises:

20 (18) dividing a total detection volume (8) into at least two partial volumes (8a, 8b, 8c, 8d); and

 (19) performing a velocity estimation for each partial volume (8a, 8b, 8c, 8d) such that a total velocity distribution (14) is acquired along a side extension (E) that is perpendicular to an extension along a forward running direction (D).

25 7. The method according to claim 6, **characterized in** that the method comprises:

30 (20) checking whether the magnitude of the total velocity distribution (14) changes from one partial volume to another partial volume such that said change exceeds a certain threshold, and, if that is the case,

 (21) grouping measurement points (9') corresponding to a certain partial velocity distribution (22).

8. The method according to any one of the claims 6 or 7, **characterized in** that the method comprises forming said partial volumes (8a, 8b, 8c, 8d) as mutually parallel slices.

5 9. The method according to any one of the claims 6-8, **characterized in** that the method comprises only taking an x-component (V_{xn}) of the radial velocity (V_{rn}) into account when the radial velocity (V_{rn}) is determined.

10 10. The method according to any one of the claims 6-9, **characterized in** that the partial volumes (8a, 8b, 8c, 8d) are overlapping.

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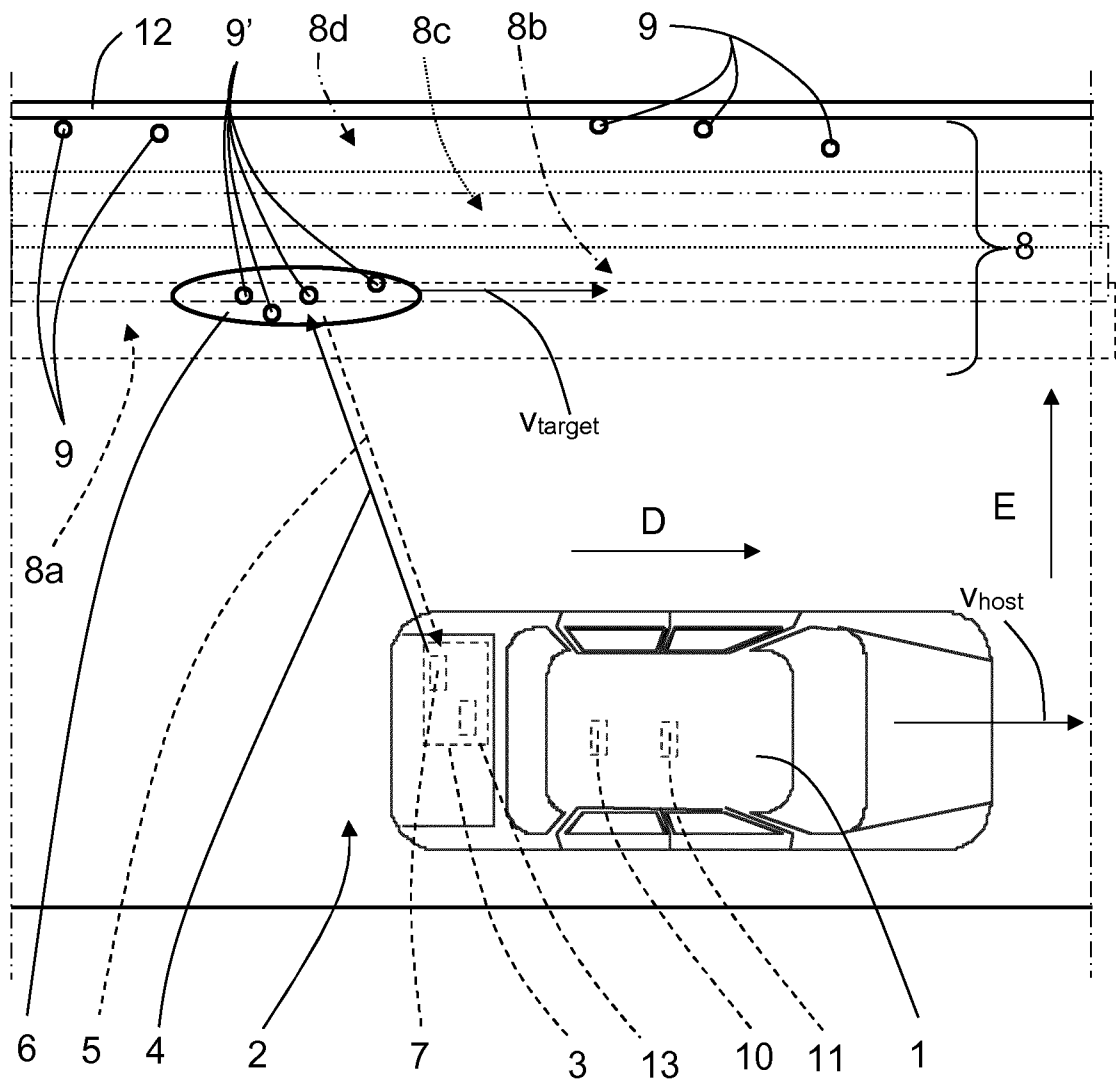


FIG. 1

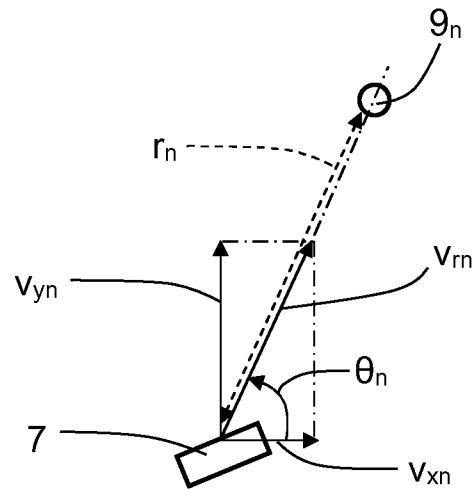


FIG. 2

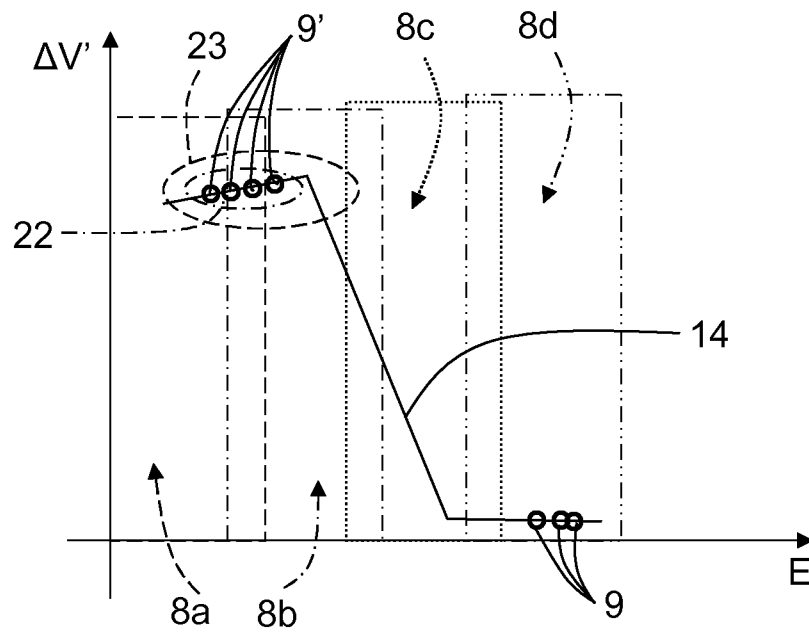


FIG. 3

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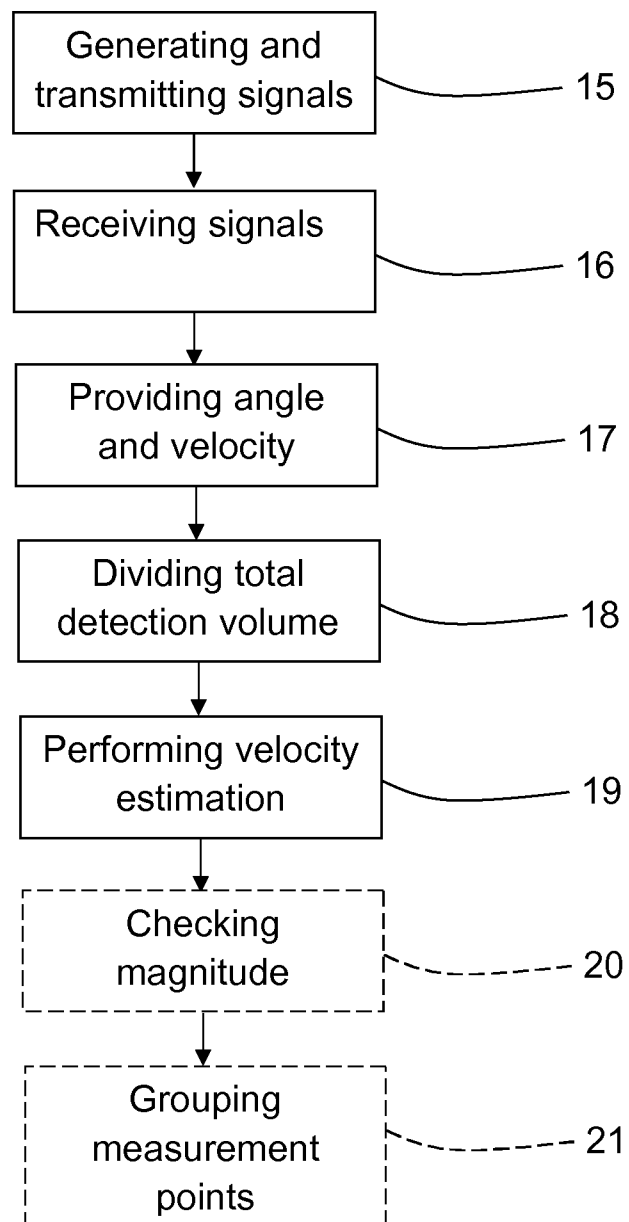


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/072606

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01S13/93 G01S7/41 G01S13/536 G01S13/72
ADD. G01S13/42

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

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	US 5 929 803 A (UEHARA NAOHISA [JP] ET AL) 27 July 1999 (1999-07-27) column 5, line 34 - column 6, line 11; figure 1 column 7, line 43 - column 11, line 56; figures 7-19 -----	1-10
X	WO 2014/150908 A1 (AUTOLIV ASP INC [US]) 25 September 2014 (2014-09-25) page 5, line 13 - page 8, line 21; figures 1-5 ----- -/--	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

30 November 2017

Date of mailing of the international search report

08/12/2017

Name and mailing address of the ISA/

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Schmelz, Christian

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/072606

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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