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Apparatus and Method for Determining a Vehicle Feature

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(71) Applicant(s)
Kapsch TrafficCom AG

(72) Inventor(s)
NAGY, Oliver

(74) Agent / Attorney
HENRY HUGHES IP LTD, Level 33 Australia Square 264 George Street, Sydney, NSW, 2000, AU

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Abstract:

Apparatus and Method for Determining a Vehicle Feature

An apparatus (1) and method for determining a characteristic feature (M) of a vehicle (2) travelling on a roadway (5), comprising: a detector (8), which is directed towards the roadway (5) and which is configured to measure the movement vector (3) of the vehicle (2) at a current location (P_1) at a current time (t_1), a tracking unit (11), connected to the detector (8), for calculating a target location (P_2) of the vehicle (2) at a target time (t_2) on the basis of current location (P_1), current time (t_1) and movement vector (3), a first radar sensor (6), connected to the detector (8), for transmitting a first radar beam (7) directed towards the current location (P_1), receiving a first reflected radar beam (9) and determining a first frequency spectrum (F_1) thereof, a second radar sensor (12), connected to the tracking unit (11), for transmitting a second radar beam (13) directed towards the target location (P_2) at the target time (t_2), receiving a second reflected radar beam (14) and determining a second frequency spectrum (F_2) thereof, and an evaluation unit (19) for generating the characteristic feature (M) of the vehicle (2) from the determined frequency spectra (F_1, F_2), wherein the determined frequency spectra (F_1, F_2) constitute the characteristic feature (M) of the vehicle (2).

(Fig. 1)

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Apparatus and Method for Determining a Vehicle Feature

The present invention relates to an apparatus and a method for determining a characteristic feature of a vehicle travelling on a roadway. The invention further relates to a system comprising at least two such apparatuses.

The determination of characteristic features of vehicles is important for many tasks in the field of traffic control, traffic monitoring and traffic billing. Individual vehicles can thus be detected and for example counted or automatically tracked, assigned on the basis of their features to certain vehicles classes, for example passenger vehicles or lorries, and class-dependent tariff models or vehicle-class-dependent driving restrictions in road toll systems or parking fee systems can be created, checked and implemented on this basis.

Predominantly optical systems, such as light barriers, laser scanners or video cameras, are currently used to determine characteristic features. For example, a laser scanner operating on the basis of the light-section method is known for example from EP 2 306 429 B1. Such systems are reliant on good visibility and are therefore highly dependent on the weather; they often fail in rain, snow or spray. The optics of light barriers, laser scanners (e.g. US 2002/0140924 A1) and video cameras also require frequent cleaning in order to remain ready for use.

In sub-areas, such as traffic flow monitor systems, radar systems are also currently used, which, from a raised point, for example an antenna mast next to a motorway, detect the movements of the traffic by means of Doppler radar and can track said movements in a radar image. The measurement accuracy of such radar systems is limited however, and the evaluation of the speeds requires a high computing effort in order to create the traffic flow image. In document EP 0 636 900, radio waves are used for velocity and distance measurements to therefrom create a distance measurement point silhouette of the vehicle.

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The object of the invention is to create an apparatus and a method for determining a characteristic feature of a vehicle, said apparatus and method being less susceptible to failure and requiring less maintenance than the known optical systems and being simpler, more cost effective and more accurate than the known radar systems.

This object is achieved in a first aspect of the invention with an apparatus of the type mentioned in the introduction, comprising:

a detector, which is directed towards the roadway and which is configured to measure a movement vector of the vehicle at a current location at a current time,

a tracking unit connected to the detector for calculating a target location of the vehicle at a target time on the basis of the current location, current time and movement vector,

a first radar sensor, connected to the detector, for transmitting a first radar beam directed towards the current location, receiving a first reflected radar beam and determining a first frequency spectrum thereof,

a second radar sensor, connected to the tracking unit, for transmitting a second radar beam directed towards the target location at the target time, receiving a second reflected radar beam and determining a second frequency spectrum thereof, and

an evaluation unit for generating the characteristic feature of the vehicle from the determined frequency spectra, wherein the determined frequency spectra constitute the characteristic feature of the vehicle, and wherein the frequency spectra form the characteristic feature as a surface over a frequency/time plane.

The invention is based on the finding of the inventors that the determined frequency spectra reproduce characteristic vehicle features. The vehicle and specific surface structure thereof, such as transitions from body surfaces to glass surfaces, rear-view mirrors, antennas, windscreen wipers, exhaust parts or attached cooling apparatuses etc., each reflect specific spectral components of the transmitted radar beams and thus generate a specific profile of the frequency spectra as a characteristic feature of the vehicle. Changes therein from the first to the second determined frequency spectrum constitute an additional component of the characteristic feature of the vehicle. There is no need for interpretation of each frequency spectrum. This reduces the evaluation effort compared with the known prior art considerably. In comparison to optical sensors, radar sensors are also less susceptible to the visual impairments occurring in road traffic and are also less susceptible to soiling.

It is favourable if the direction of the radar beam of the second radar sensor can be controlled. The second radar sensor can thus be easily adapted to different requirements, for example due to its mounting or with respect to the speed (possibly also the selected lane) of the vehicle; successive radar beams can also be transmitted in different directions.

The ability to control the direction of the second radar sensor can be achieved for example by at least two sequentially controllable radar antennas with different transmission direction; alternatively or in addition, a mechanically pivotable radar antenna could also be used. The second radar sensor particularly preferably has a radar antenna with controllable direction characteristic in the form of a phase-controlled antenna array. There is thus no need for any mechanical movable parts or for a switchover from one radar antenna to another radar antenna; the susceptibility to faults is further reduced in accordance with the invention, and the availability of the apparatus is increased.

It is advantageous if the tracking unit is configured to calculate at least one further target location/time pair, if the second radar sensor is, for this purpose, configured to determine at least one further frequency spectrum in the aforementioned manner, and if the evaluation unit is configured to generate the characteristic feature from all determined frequency spectra. Such further frequency spectra, which are determined with respect to a passing vehicle, make the character-

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istic feature of the vehicle even clearer, since modifications to the frequency spectra are incorporated in a number of steps.

In a preferred embodiment of the invention the first and second radar sensors are formed by a common radar sensor of which the direction can be controlled, whereby a radar sensor is spared. In a particularly simple embodiment of the invention the detector may also be formed by the first radar sensor, which measures the speed of the movement vector in the direction of travel of the roadway, preferably on the basis of a Doppler evaluation of the reflected radar beam. There is thus no need for any further sensors for detection of the current location and current time of the vehicle; in this embodiment, the recognition of a vehicle on the basis of an evaluation of the reflected first radar beam, for example in the frequency spectrum, is sufficient for detection. If no vehicle is detected, the first radar sensor can thus transmit a first radar beam directed towards the current location, for example at regular intervals, until a vehicle is detected.

It is particularly favourable if the direction of the movement vector is determined by the direction of travel of the roadway, since in this case the movement vector is already determined on the basis of a Doppler evaluation, determining the speed of the vehicle, of a reflected radar beam.

In a particularly advantageous embodiment of the invention the apparatus further comprises a database for receiving characteristic reference features of reference vehicles of known vehicle class, wherein the evaluation unit is further configured to compare the generated characteristic feature with the reference features and, in the case of a match, to output the vehicle class of the matching reference vehicle. A vehicle can thus be classified on the basis of the frequency spectra of reflected radar beams, which constitute a “fingerprint” of the vehicle so to speak. An assignment of individual peaks in the frequency spectra for example to attachment parts or to the entire (optical) appearance of the vehicle, as would be necessary

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in the case of optical image recognition, can be omitted; reference features can be generated by simply being "taught in", that is to say by recording the frequency spectra of identical or similar vehicles of known class.

In a second aspect the invention creates a system which comprises at least two of the aforementioned apparatuses, wherein the apparatuses are mounted at a distance from one another on a gantry spanning the roadway, and wherein at least two of the apparatuses are preferably directed towards different lanes of the roadway. A number of traffic lanes can thus be evaluated by one system. With a plurality of apparatuses directed towards a lane, the frequency spectra of the apparatus most clearly affected or an average of the frequency spectra of the apparatuses can be used, whereby the system is less susceptible to faults, for example due to indecisive lane selection of a vehicle.

In a third aspect the invention creates a method for determining a characteristic feature of a vehicle driving on a roadway, said method comprising:

transmitting a first radar beam, directed towards a current location, at a current time, receiving a first reflected radar beam, and determining a first frequency spectrum thereof, with simultaneous, prior or subsequent

measurement of a movement vector of the vehicle at the current location and calculation of a target location of the vehicle at a target time on the basis of the current location, current time and movement vector;

transmitting a second radar beam, directed towards the target location, at the target time, receiving a second reflected radar beam, and determining a second frequency spectrum thereof; and

generating the characteristic feature of the vehicle from the determined frequency spectra, wherein the determined frequency spectra constitute the characteristic feature of the vehicle, and wherein the frequency spectra form the characteristic feature as a surface over a frequency/time plane.

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In respect of the advantages of the method according to the invention, reference is made to the statements above concerning the apparatus.

In a preferred embodiment the frequency spectra form the characteristic feature as a surface over a frequency/time plane. The surface forms a “fingerprint” of the vehicle so to speak and can be easily stored, compared and even optically evaluated, without further interpretation of the spectral components of the frequency spectra.

It is particularly advantageous if at least one further target location/time pair is calculated and if at least one further frequency spectrum is determined in the aforementioned manner for this purpose, wherein the characteristic feature is generated from all determined frequency spectra. It is favourable here if, in order to calculate each further target location/time pair, a further movement spectra is measured in each case. Improved tracking of the vehicle is thus possible even with a change in speed and/or driving direction. If the tracking is to be as simple as possible, it is advantageous if the speed of the movement vector in the direction of travel of the roadway is measured on the basis of a Doppler evaluation of the reflected radar beam.

It is favourable if the current location/time pair is determined by detection of the current time of part of the vehicle at a predefined current location, wherein the vehicle part is detected by comparing the frequency spectrum of the first reflected radar beam with a reference frequency spectrum determined with an empty roadway. This constitutes a very simple decision criterion for a vehicle detection.

In accordance with an advantageous embodiment of the invention the method is further used to classify a vehicle, wherein the generated characteristic feature is compared with reference features of reference vehicles of known vehicle class, and, in the case of a match, the vehicle class of the matching reference vehicle is output.

The invention will be explained in greater detail hereinafter on the basis of an exemplary embodiment illustrated in the accompanying drawings, in which:

Fig. 1 shows a schematic side view, transverse to the direction of travel of a roadway, of an apparatus according to the invention for determining a characteristic feature of a vehicle;

Fig. 2 shows a block diagram of an example of the apparatus according to Fig. 1;

Fig. 3 shows an example for a frequency/time graph of frequency spectra which have been determined with an apparatus according to Fig. 1 or 2; and

Fig. 4a and 4b show a system comprising a plurality of apparatuses according to Fig. 1 or 2 in a plan view (Fig. 4a) and a view in the longitudinal direction of the roadway (Fig. 4b).

Fig. 1 and 2 show an apparatus 1 for determining a characteristic feature M of a vehicle 2, which travels at a speed v along a movement vector 3 in the direction of travel 4 of a roadway 5. A first radar sensor 6 of the apparatus 1 transmits a first radar beam 7, which is directed towards a current location P_1 at which the vehicle 2 is detected by a detector 8. The first radar beam 7 is reflected at least in part by the vehicle 2. The first radar sensor 6 then receives a first radar beam 9 reflected on the vehicle 2 and determines a first frequency spectrum F_1 thereof in a manner known to a person skilled in the art, for example by means of fast Fourier transformation (FFT).

The detector 8 detects not only a vehicle 2 at a current location P_1 at a current time t_1, but also measures the movement vector 3 of the vehicle 2, more specifically before, simultaneously with, or after the transmission of the first radar beam 7. To this end, the detector 8, for example at a current location P_1, may have light barriers (not illustrated) running at a suitable height transversely over the roadway 5 or may be formed as a laser sensor or separate radar sensor. The detector

8 may be directed fixedly towards the current location P_1 and may detect the appearance of a vehicle 2 at this location, may measure the current time t_1 of the appearance and may ascertain the current location/time pair P_1, t_1; alternatively, the detector 8 may also be formed for example as a roadway laser scanner and may record the detection location of a vehicle 2 together with the detection moment as a current location/time pair P_1, t_1.

In the example of Fig. 1 the detector 8 is formed by the first radar sensor 6 itself, which determines the current location/time pair P_1, t_1 by detecting the current time t_1 of part of the vehicle 2 at a predefined current location P_1, towards which the first radar sensor 6 is fixedly directed. The vehicle part (here a vertically protruding exhaust part 10) is detected in this example by comparing the frequency spectrum F_1 of the first reflected radar beam 7 with a reference frequency spectrum determined with an empty roadway 5.

In order to detect characteristic features M of a vehicle 2, a suitable frequency selection of the radar system is helpful, wherein a broadband radar is very advantageous, for example UWB (ultra wide band) radar. Characteristic features in the form of specific vehicle objects (for example superstructures, body parts, etc.) here provide a reference point for the suitable selection of the frequency range, of which the mechanical dimensions correspond with the wavelength (or multiple thereof) of the radar beam.

The apparatus 1 measures the movement vector 3 according to Fig. 1 for example on the basis of a Doppler evaluation of the first reflected radar beam 9, and more specifically measures the speed v thereof under the assumption of the direction of travel 4 of the roadway 5 as the direction of movement of the vehicle 2. Alternatively, the apparatus 1 could determine the movement vector 3 in a different way, for example from the measurement of at least two successive vehicle positions and moments in time.

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A tracking unit 11 connected to the detector 8 calculates, on the basis of the current location P_1, current time t_1 and movement vector 3 of the vehicle 2, a target location P_2, at which the vehicle 2 should be located at a target time t_2 which has likewise been calculated. The apparatus 1 may have range limits for this calculation, within which the target location P_2 and/or the associated target time t_2 are to be located with this calculation.

A second radar sensor 12, connected to the tracking unit 11, then transmits a second radar beam 13, directed towards the target location P_2, at the target time t_2, receives a second radar beam 14 reflected by the vehicle 2, and determines a second frequency spectrum F_2 thereof. If desired, the tracking unit 11 can calculate further target location/time pairs P_i, t_i ($i = 3, 4, 5, \ldots$), wherein, for the calculation of each further target location/time pair P_i, t_i, a further movement vector 3 of the vehicle 2 may optionally be measured in each case in order to increase the accuracy; the second radar sensor 12, as shown in Fig. 1, then also transmits further second radar beams 13' or receives further reflected second radar beams 14' and determines further frequency spectra F_i ($i = 3, 4, 5, \ldots$) thereof.

As is known from the prior art, the radar sensors 6, 12 transmit their radar beams 7, 13, 13' via radar antennas 15, 16 each with a lobe-shaped direction characteristic 17, wherein the central axes of the primary transmitting lobes 17 are considered to be the primary transmitting directions 18 directed towards the current or target locations P_j ($j = 1, 2, 3, \ldots$), see Fig. 1. The opening or bundling angle of a transmitting lobe 17 depends on the directivity of the respective antenna 15, 16, which is also defined by what is known as the “antenna gain”. The stronger the directivity of the radar antennas 15, 16, the more radar energy lies in the primary transmitting direction 18 and the more pronounced is the emergence of individual vehicle parts, contacted by the transmitted radar beams 7, 13, 13', in the frequency spectra F_j (j = 1, 2, 3, …). By contrast, the lower the directivity of the transmitting lobe 17, that is to say the lower the antenna gain, the greater is the expected diversity of amplitude peaks occurring in the frequency spectra F_j.

A greater beam opening width transverse to the roadway 5 and a smaller beam opening width along the roadway 5 are advantageous with the selection of the antenna directivity.

To direct the second radar beam 13 to different target locations P_2, the direction of the second radar beam 13 of the second radar sensor 12 can be controlled, in particular if further target location/time pairs P_i, t_i are to be calculated and for this purpose further frequency spectra F_i are to be determined. To this end, the second radar sensor 12 may have a plurality of sequentially controlled and differently oriented radar antennas 16, or a second radar antenna 16 may be mechanically adjustable.

In the present exemplary embodiment the second radar antenna 16 has a controllable direction characteristic, which is formed by a phase-controlled antenna array. Of course, it may also be possible to control the direction of the first radar beam 7 of the first radar sensor 6. Furthermore, if desired, the first and the second radar sensor 6, 12 can be formed by a common radar sensor 12 (not illustrated), of which the direction can be controlled.

With reference again to Fig. 2, an evaluation unit 19 generates the characteristic feature M of the vehicle 2 from the first and the second frequency spectrum F_1, F_2 and the possible further frequency spectra F_i, that is to say from all frequency spectra F_j.

Here, frequency spectra F_j of the entire vehicle 2 or parts of the surface structure thereof, for example one or more characteristic attachment parts of the vehicle 2, such as the aforementioned exhaust part 10, a cooling apparatus 20, rear-view mirror 21, bumper 22, headlight 23, wind deflector 24 or

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radiator grill 25 of the vehicle, can be used here as a characteristic feature M of the vehicle 2. The determined frequency spectra F_j quite generally constitute the characteristic feature M of the vehicle 2 either directly or in further processed form. In principle, the polarisation of the radar beams 7, 9, 13, 14, 14' can also be used, besides the frequency, to determine the characteristic feature M.

In the example of Fig. 3, the determined frequency spectra F_j are plotted as a surface 26 over the frequency/time plane f/t. The surface 26 on the whole thus forms the characteristic feature M of the vehicle 2 and therefore a characteristic “fingerprint” of the vehicle 2 so to speak. It can be seen in the illustration of Fig. 3 that, as a result of the tracking of the vehicle 2 and as a result of the imaging and plotting of a plurality of frequency spectra F_j, the characteristic feature M of the vehicle 2 is co-determined by the temporal change of the frequency spectra F_j. Different vehicles 2 which have similar frequency spectra F_j in individual perspectives can still be distinguished on the basis of the temporal profile, and errors when determining the characteristic feature M of a vehicle 2 can be avoided. The temporal profile of the frequency spectra F_j constitutes a spatial radar signature from various aspect angles of a characteristic feature M.

The surface 26 illustrated in Fig. 3 is determined and spanned by the amplitudes A of the frequency spectra F_j; alternatively or in addition, the phases of the frequency spectra F_j can also be taken into consideration and plotted however. As indicated in Fig. 3, the frequency spectra F_j and the surface 26 could also be formed according to an angle of reflection α, measured with respect to the primary transmitting direction 18 of the first radar beam 7, or the current and target locations P_j instead of the time t, for example if significantly variable speeds v of a vehicle 2 would lead to a non-uniform resolution or a distortion of the surface 26.

If desired, frequency spectra F_j, for example in the form of surfaces 26, can be stored in an optional database 27 of the apparatus 1 as characteristic reference features M_{Ref} of reference vehicles. If these reference vehicles are assigned to specific vehicle classes C, the evaluation unit 19 can thus compare the generated characteristic feature M of a vehicle 2 with the reference features M_{Ref} from the database 27 in a classification stage 28, and, in the case of a match, can output the vehicle class C of the matching reference vehicle for the vehicle 2, that is to say can classify the vehicle 2.

In accordance with the examples in Fig. 4a and 4b, a plurality of the apparatuses 1 - here 1a, 1b, 1c, 1d – can be combined to form a system 29. In this example, the apparatuses 1a, 1b, 1c, 1d are mounted at a distance from one another to a gantry 30 spanning the roadway 5, wherein two apparatuses 1a, 1b are directed towards a traffic lane 31a and the two other apparatuses 1c and 1d are directed towards the adjacent traffic lane 31b.

As shown in Fig. 4a, the primary transmitting directions 18 may have different and, if desired, even variable angles β in a plane transverse to the direction of travel 4 with respect to a normal 32 to the roadway 5. Further, the apparatuses 1a, 1b, 1c, 1d can be interconnected via a data connection 33 and can be connected to a computing unit 34. The computing unit 34 could record the characteristic features M of the vehicles 2 or optional classification results C and/or could forward these to a central unit (not illustrated), for example of a road toll system. Further, individual tasks of the detector 8 of the tracking unit 11 and of the radar sensors 6, 12 and of the evaluation 19 can be outsourced to the computing unit 34 if desired, said computing unit in this case also being able to carry out these tasks, for example the tracking or a spectral analysis, centrally for all apparatuses 1a, 1b, 1c, 1d.

Of course, the roadway 5 from Fig. 4a and 4b may also have more than two lanes and/or the lanes 31a, 31b may have differ-

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ent directions of travel 4. One apparatus or more than two apparatuses 1 may also be used for each lane 31a, 31b and can be arranged, if desired, also to the side of the roadway 5 or before or after a bend, even in line with the roadway 5, provided radar beams 7, 13, 13' can be transmitted towards a passing vehicle 2.

The invention is not limited to the presented embodiments, but includes all variants, modifications and combinations of the presented measures which fall within the scope of the accompanying claims.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated feature but not to preclude the presence or addition of further features in various embodiments of the invention.

It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

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Patent claims:

1. An apparatus for determining a characteristic feature of a vehicle travelling on a roadway, comprising:

a detector, which is directed towards the roadway and which is configured to measure a movement vector of the vehicle at a current location at a current time,

a tracking unit, connected to the detector, for calculating a target location of the vehicle at a target time on the basis of current location, current time and movement vector,

a first radar sensor, connected to the detector, for transmitting a first radar beam directed towards the current location, receiving a first reflected radar beam and determining a first frequency spectrum thereof,

a second radar sensor, connected to the tracking unit, for transmitting a second radar beam, directed towards the target location, at the target time, receiving a second reflected radar beam and determining a second frequency spectrum thereof, and

an evaluation unit for generating the characteristic feature of the vehicle from the determined frequency spectra, wherein the determined frequency spectra constitute the characteristic feature of the vehicle, and wherein the frequency spectra form the characteristic feature as a surface over a frequency/time plane.

2. The apparatus according to Claim 1, characterised in that the direction of the radar beam of the second radar sensor can be controlled.

3. The apparatus according to Claim 2, characterised in that the second radar sensor has a radar antenna with controllable direction characteristic in the form of a phase-controlled antenna array.

4. The apparatus according to Claim 2 or 3, characterised in that the tracking unit is configured to calculate at least one further target location/time pair, in that the second radar

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sensor is configured to determine at least one further frequency spectrum, and in that the evaluation unit is configured to generate the characteristic feature from all determined frequency spectra.

5. The apparatus according to any one of Claims 2 to 4, characterised in that the first and second radar sensors are formed by a common radar sensor, of which the direction can be controlled.

6. The apparatus according to any one of Claims 1 to 5, characterised in that the detector is formed by the first radar sensor, which measures the speed of the movement vector in a direction of travel of the roadway.

7. The apparatus according to claim 6, characterised in that the detector uses a Doppler evaluation of the first reflected radar beam for measuring the speed of the movement vector.

8. The apparatus according to any one of Claims 1 to 7, further comprising:

a database for receiving characteristic reference features of reference vehicles of known vehicle class, wherein the evaluation unit is further configured to compare the generated characteristic feature with the reference features, and, in the case of a match, to output the vehicle class of the matching reference vehicle.

9. A system comprising at least two apparatuses according to any one of Claims 1 to 8, characterised in that the apparatuses are mounted at a distance from one another on a gantry spanning the roadway.

10. A system according to claim 9, wherein at least two of the apparatuses are directed towards different lanes of the roadway.

11. A method for determining a characteristic feature of a vehicle travelling on a roadway, said method comprising:

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transmitting a first radar beam, directed towards a current location, at a current time, receiving a first reflected radar beam and determining a first frequency spectrum thereof, with simultaneous, prior or subsequent measurement of a movement vector of the vehicle at the current location and calculation of a target location of the vehicle at a target time on the basis of the current location, current time and movement vector;

transmitting a second radar beam, directed towards the target location, at the target time, receiving a second reflected radar beam and determining a second frequency spectrum thereof; and

generating the characteristic feature of the vehicle from the determined frequency spectra, wherein the determined frequency spectra constitute the characteristic feature of the vehicle, and wherein the frequency spectra form the characteristic feature as a surface over a frequency/time plane.

12. The method according to Claim 11, characterised in that at least one further target location/time pair is calculated, at least one further frequency spectrum is determined, and the characteristic feature is generated from all determined frequency spectra.

13. The method according to Claim 12, characterised in that, for the calculation of the further target location/time pair, a further movement vector is measured.

14. The method according to any one of Claims 11 to 13, characterised in that the speed of the movement vector in the direction of travel of the roadway is measured on the basis of a Doppler evaluation of the reflected radar beam.

15. The method according to any one of Claims 11 to 14, characterised in that the current location/time pair is determined by detecting the current time of a part of the vehicle at a predefined current location, wherein the vehicle part is detected by comparing the frequency spectrum of the first

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reflected radar beam with a reference frequency spectrum determined with an empty roadway.

16. The method according to any one of Claims 11 to 15, further comprising classifying the vehicle, wherein the generated characteristic feature is compared with reference features of reference vehicles of known vehicle class, and, in the case of a match, the vehicle class of the matching reference vehicle is output.

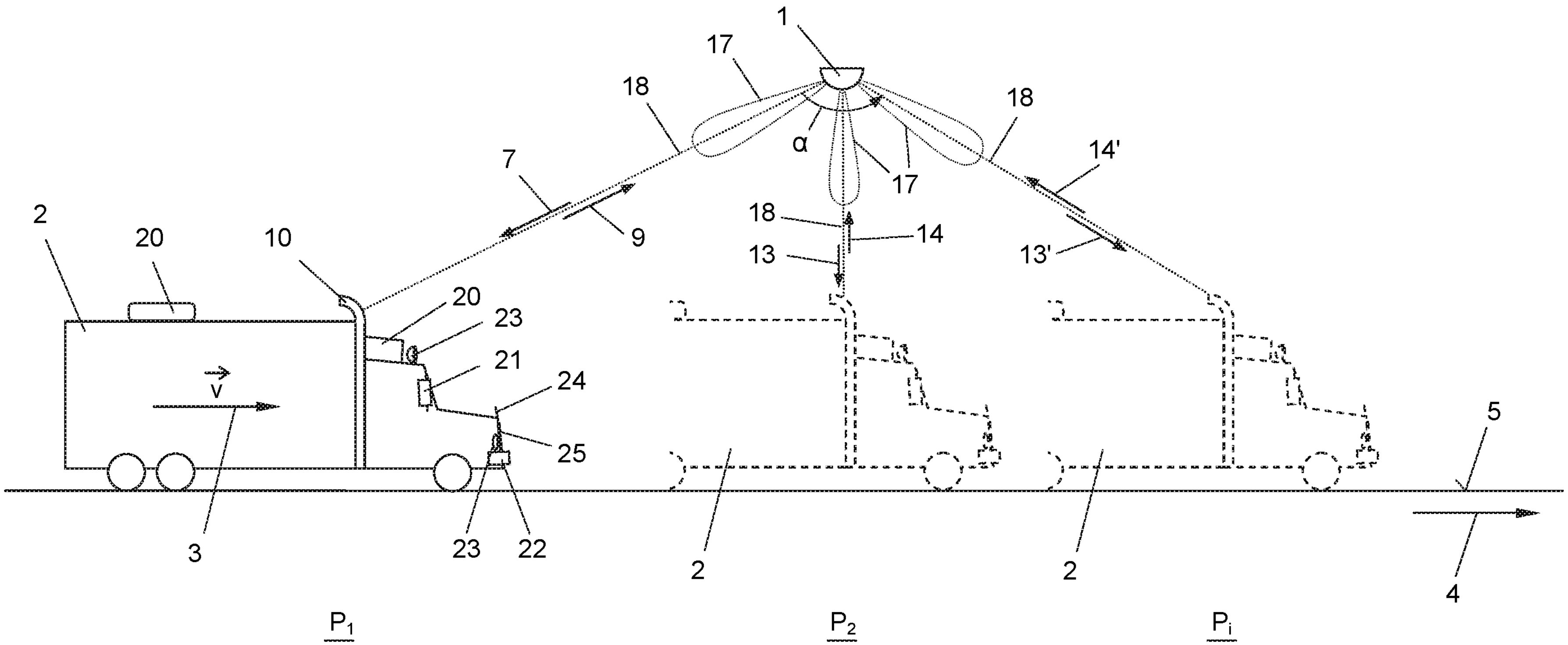
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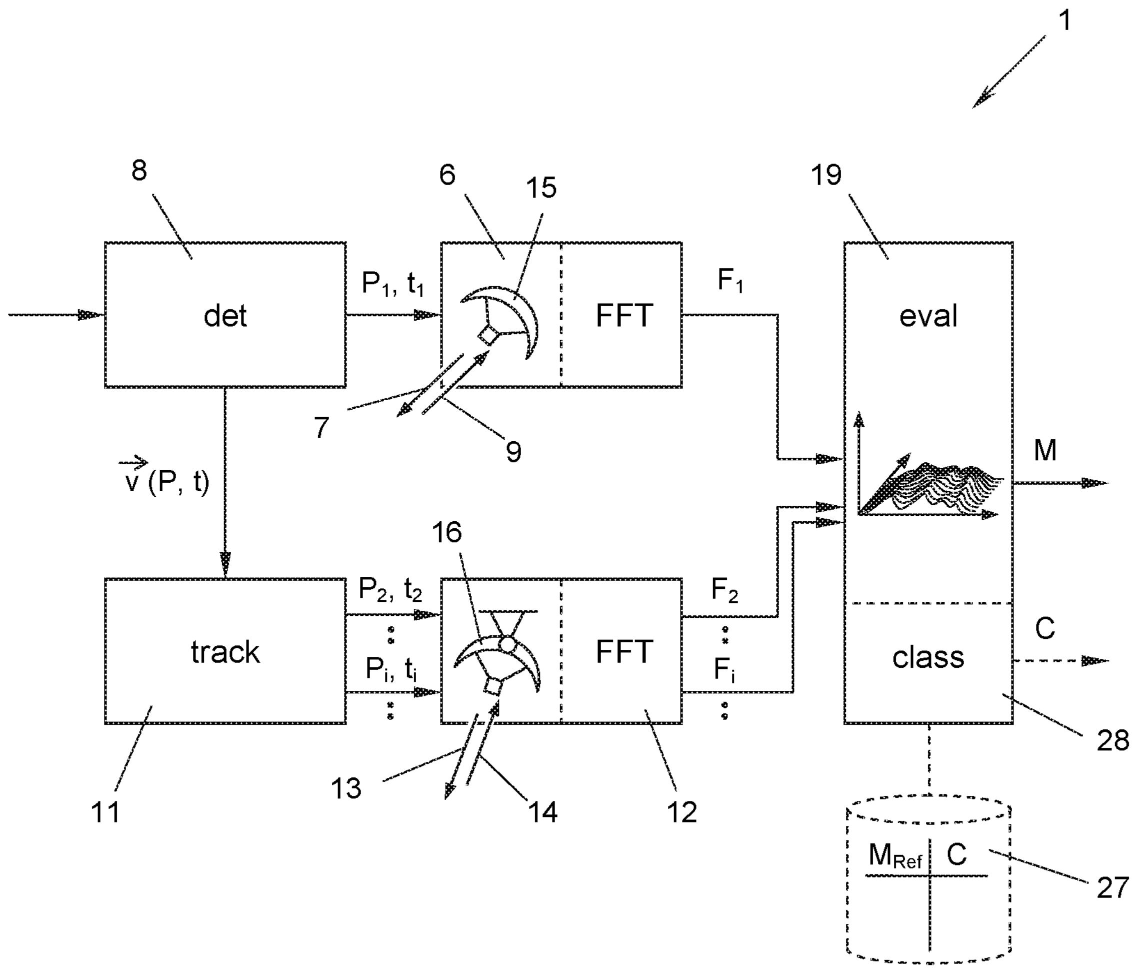
Fig. 1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6
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F_1
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track
P_2, t_2
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F_2
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13
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12
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M_{Ref}
C
27

Fig. 2

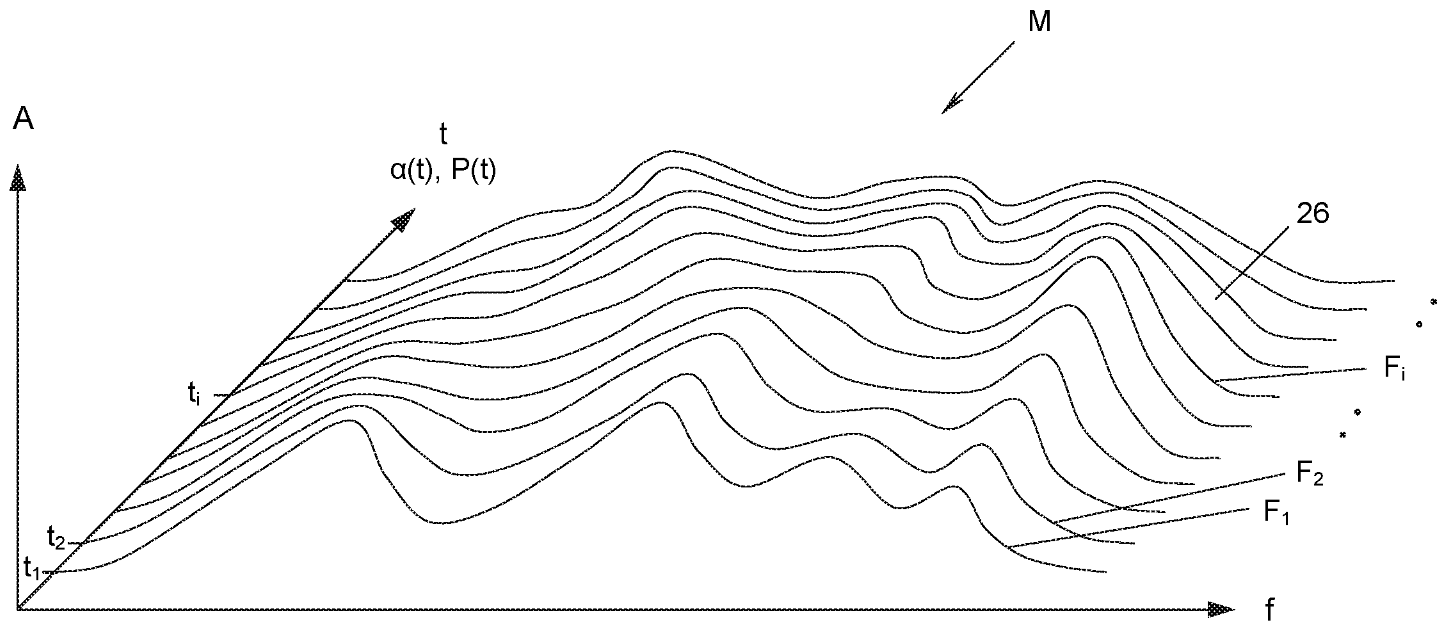

Fig. 3

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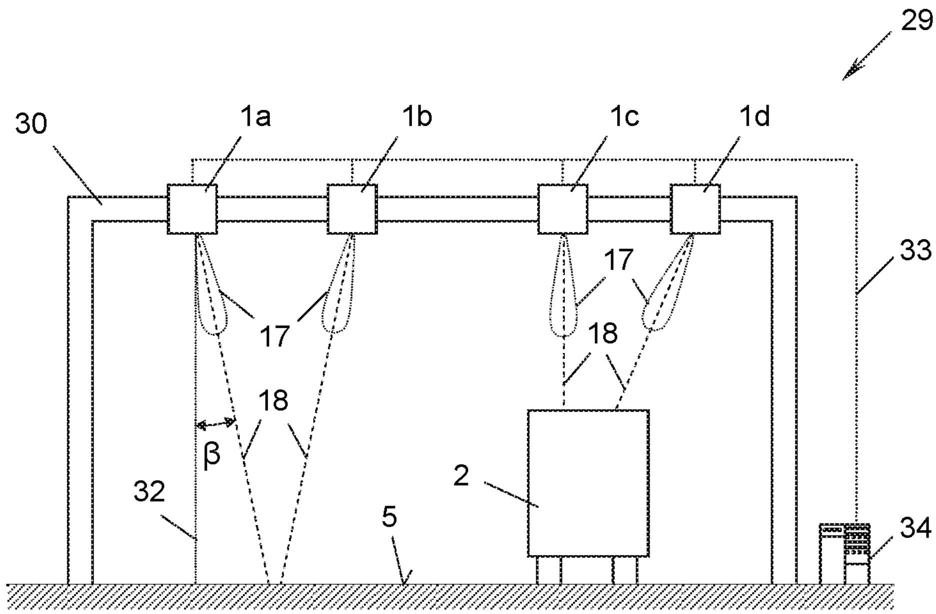

Fig. 4a

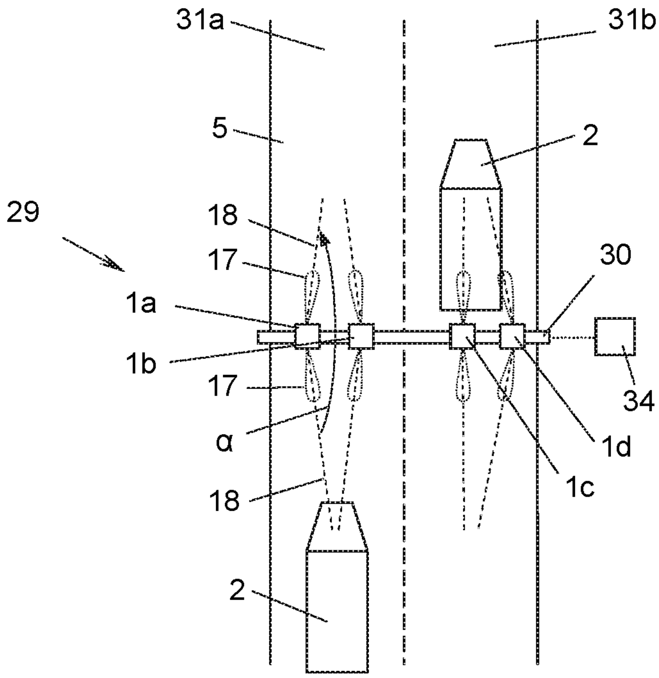

Fig. 4b