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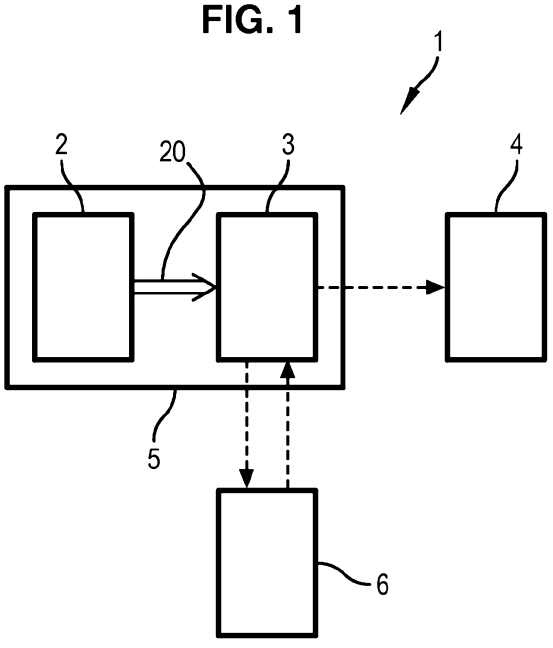
(54) Title : DEVICE AND METHOD FOR DETERMINING THE SPEED OF A WHEELED TERRESTRIAL VEHICLE FROM MEASUREMENTS OF A MAGNETIC FIELD

(54) Titre : DISPOSITIF ET PROCEDE POUR DETERMINER LA VITESSE D'UN VEHICULE TERRESTRE A ROUES A PARTIR DE MESURES D'UN CHAMP MAGNETIQUE

FIG. 1



(57) Abstract : A device for measuring the speed of movement of a wheeled terrestrial vehicle is characterized in that it comprises a magnetometer (2) intended to take measurements of a magnetic field and positioned so as to be sensitive to the magnetic field variations caused by the rotation of at least one at least partially metallic wheel, as such, of the vehicle and capable of delivering a corresponding signal (20), and means (3) for processing said signal that are capable of establishing a frequency spectrum thereof, of determining, from said frequency spectrum, a frequency of rotation of said wheel and of deducing therefrom, on the basis of information representative of the radius of the wheel, the speed of movement of the vehicle. Application in particular to tachometers for motor vehicles.

(57) Abrégé : Un dispositif de mesure de la vitesse de déplacement d'un véhicule terrestre à roues est caractérisé en ce qu'il comprend un magnétomètre (2) destiné à effectuer des mesures d'un champ magnétique et positionné de manière à être sensible aux variations de champ

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magnétique engendrées par la rotation d'au moins une roue au moins partiellement métallique du véhicule, telle quelle, et apte à délivrer un signal (20) correspondant, et des moyens de traitement (3) dudit signal aptes à établir un spectre de fréquences de celui-ci, à déterminer, à partir dudit spectre de fréquences, une fréquence de rotation de ladite roue, et à en déduire, à partir d'une information représentative du rayon de la roue, la vitesse de déplacement du véhicule. Application notamment aux tachymètres pour véhicules automobiles.

DEVICE AND METHOD FOR DETERMINING THE SPEED OF A WHEELED TERRESTRIAL VEHICLE USING MEASUREMENTS OF A MAGNETIC FIELD

The invention generally relates to the determination of the speed of movement of wheeled terrestrial vehicles by measuring the magnetic field. More particularly the invention relates to a device and a method for determining the speed of movement of wheeled terrestrial vehicles by determining a frequency of rotation of the wheels of the vehicle using a magnetometer.

A wheeled terrestrial vehicle comprises many parts with rotating or alternating movement in translation (for example for a car: wheels, pistons, crankshafts, etc.). It is known to use one or several magnetometers in order to determine a frequency of rotation of at least one of these parts and to deduce therefrom a speed of movement of the vehicle.

The most direct method consists in directly determining a frequency of rotation of a wheel, i.e. the number of revolutions per second of the wheel. It is then sufficient to multiply this frequency by the

perimeter of the wheel in consideration in order to obtain the speed of movement of the vehicle.

To do this, a known method of prior art consists in fixing a magnet on the wheel and to arrange a magnetometer in the vicinity of this wheel, for example on the bodywork of the car in the mouth of the wheel.

At each rotation, the magnetometer measures a strong increase in the magnetic field due to the proximity of the magnet. Such a signal is transmitted to a processing unit.

The processing unit compares the signal representative of the magnetic field to a reference value. It provides as output, for each magnetic field measurement, a 0 or a 1 according to whether or not the measurement is less than or greater than the reference threshold value.

As such, the processing unit provides a signal with successive slots of 0 and 1, with the time between two successive 1 slots representing the duration of one revolution of the wheel in consideration. As such, the frequency of rotation of the wheel is obtained at a given instant.

However, such an approach does not provide full satisfaction. In particular:

- The permanent magnet must be solidly fixed on the wheel which implies assembly constraints.

- The permanent magnet can induce undesirable imbalance.

- The magnetometer must be arranged very close to the permanent magnet in order to detect the magnetic field peaks. This implies additional assembly

constraints, and in addition the magnetometer must be protected from inclement weather and other moving parts.

The following discussion of the background to the invention is intended to facilitate an understanding of the invention. However, it should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was published, known or part of the common general knowledge as at the priority date of the application.

It is desirable therefore to provide an improved device for measuring a speed of movement of a wheeled terrestrial vehicle.

Viewed from one aspect of the present invention, there is provided a device for measuring speed of movement of a wheeled terrestrial vehicle, the device comprising a fixed magnetometer intended to carry out measurements of a magnetic field and positioned in such a way as to be sensitive to variations in the magnetic field caused by rotation of at least one partially metallic wheel of the vehicle, as it is, and able to deliver a corresponding signal, and means for processing said signal to establish a frequency spectrum of the latter, to determine, using said frequency spectrum, a frequency of rotation of said wheel, and to deduce therefrom, using information representative of the radius of the wheel, the speed of movement of the vehicle.

The invention is based on the surprising discovery that it is possible due to a developed signal processing technique to deduce the frequency of rotation of a wheel via a processing of the magnetic

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field variations induced by the metallic wheel as it is. This as such overcomes having to fix a magnet on the wheel, and there is greater flexibility as to the location of the magnetometer.

Note that this discovery is not limited to the determination of the speed of a vehicle and that it is possible, by a processing of the signal similar to that described hereinafter, to follow according to time the frequency of movement of any body that periodically disturbs the terrestrial magnetic field.

This is the case in particular with at least partially metallic bodies in rotating movement or in alternating translation, for example crankshafts or the pistons in a car engine.

More generally again, a determination can thus be made of the operating speed of robots with repetitive movements in an automated assembly line, the rotating speed of a turbine or other diverse applications.

Advantageously but optionally, embodiments of the device according to the invention may comprise at least one of the following characteristics:

- the means for processing are able to establish a frequency spectrum of the measurements of a magnetic field via a gliding-window fast Fourier transform;
- the magnetometer and the means for processing are arranged separately from one another, and the device further comprises a transmission channel between them;
- the magnetometer is able to measure a magnetic field according to one or more axes of measurement, and the magnetometer is arranged in such a way that the

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axis of rotation of the wheel is substantially parallel to one of said axes of measurement; and

- the magnetometer is able to measure a magnetic field according to one or more axes of measurement, and the magnetometer is arranged in such a way that the axis of rotation of the wheel is substantially perpendicular to one of said axes of measurement.

Viewed from another aspect of the present invention, there is provided a method for measuring speed of movement of a wheeled terrestrial vehicle, the method comprising the following steps:

- generating, by a fixed magnetometer, a signal representative of a variable magnetic field, of which certain variations are caused by rotation of at least one partially metallic wheel of the vehicle, as it is;

- establishing a frequency spectrum of said signal;

- determining, using said frequency spectrum, a frequency of rotation of said wheel; and

- deducing from the frequency and information representative of the radius of the wheel, the speed of movement of the vehicle.

Advantageously but optionally, embodiments of the method according to the invention may comprise at least one of the following characteristics:

- the establishment of the frequency spectrum is carried out via a gliding-window fast Fourier transform;

- the frequency of rotation of the wheel is carried out by selecting the main frequency of the frequency spectrum;

- the measurements of a magnetic field are carried out according to an axis that is substantially parallel

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to the axis of rotation of the wheel of the vehicle; and

- the measurements of a magnetic field are carried out according to an axis that is substantially perpendicular to the axis of rotation of the wheel of the vehicle.

Viewed from another aspect of the present invention, there is provided a wheeled terrestrial vehicle comprising at least one partially metallic wheel, wherein the vehicle comprises a device for determining speed of movement according to the invention as described herein.

Advantageously but optionally, embodiments of the vehicle according to the invention may comprise at least one of the following characteristics:

- the magnetometer is fixed to the bodywork of the vehicle;

- the vehicle comprises an instrument panel, and the magnetometer is arranged in the vicinity of the instrument panel; and

- the vehicle comprises a trunk and the magnetometer is arranged in the trunk.

Where the terms "comprise", "comprises", "comprised" or "comprising" are used in this specification (including the claims) they are to be interpreted as specifying the presence of the stated features, integers, steps or components, but not precluding the presence of one or more other features, integers, steps or components, or group thereto.

Other characteristics, purposes and advantages of this invention shall appear when reading the following detailed description, with regards to the annexed drawings, provided by way of non-restricted examples and wherein:

- figure 1 diagrammatically shows a device for determining the speed of movement of a wheeled terrestrial vehicle by determining a frequency of rotation of the wheels of the vehicle using a magnetometer according to a possible embodiment of the invention;

- figures 2a to 2c each show a wheeled terrestrial vehicle provided with a device for determining speed according to a possible embodiment of the invention; and

- figure 3 is a graph showing the speed curve of a vehicle according to the time obtained by a device according to the invention and a speed curve

reconstituted using measurements from an inertial unit mounted on the vehicle

In reference to figure 1, a device 1 for determining the speed of movement of a wheeled terrestrial vehicle according to a possible embodiment of the invention comprises a magnetometer 2 and a data processing unit 3.

The magnetometer 2 is able to capture an ambient magnetic field and transmit a signal 20 representing the change in the magnetic field to a data processing unit 3.

The processing unit 3 establishes a frequency spectrum of the signal 20. For example a method of the "detecting the maximum autocorrelation of the signal with its delayed version" type can be used. In this method, described in one of the works of the mathematician Stéphane Mallat, if u(t) is the signal, the windowed integral of u(t)*u(t-T) is plotted and the first value of T that maximises this integral is taken. Preferably, the method used is the sliding-window fast Fourrier transform (commonly called FFT), an algorithm known for its execution speed. Any other method of signal frequency analysis known to those skilled in the art can however be used.

The processing unit 3 then determines, among the frequencies identified, the frequency of rotation of at least one metallic wheel of the vehicle. This frequency is then multiplied at the perimeter of the wheel in question in order to obtain the speed of movement of the vehicle.

It is important to note here that the wheel of the vehicle is a wheel as it is, i.e. devoid of any magnet or other magnetic part specifically intended to interact with the magnetometer.

In addition, "partially metallic wheel" means a wheel of which at least one of the constituents is at least partially made of metallic material. It can be the rim, the brake disc, a trim, or any other component rotating at the same speed as the wheel. As such, the at least partially metallic constituent causes a periodical disturbance in the magnetic field and the frequency of this perturbation is the same as that of the rotation of the wheel.

The metallic material can be constituted of steel, an aluminium alloy or any metal alloy, in particular those generally used in the construction of the constituents of a wheel.

The invention is founded on the fact that first of all the terrestrial magnetic field (of a magnitude of 0.5 gauss) is disturbed by the elements of the vehicle in periodic movement. As such, in a car with a combustion engine for example, the movement of the wheels but also of the pistons, of the crankshaft, of the transmission members, etc., cause as many periodic disturbances of which the frequencies are within the spectrum of the signal 20 transmitted by the magnetometer 2.

The invention is further founded on the fact that an appropriate treatment within the processing unit 3 is able to identify, in the frequency spectrum, the frequency of rotation of a wheel of the vehicle.

Preferably, but not in a limited manner, the identification of the frequency of rotation of a wheel is carried out by selecting the main frequency in the frequency spectrum of the signal 20, i.e. that of the highest amplitude.

Note that the magnetic field is also disturbed by the environment of the vehicle, in particular by high- and medium-frequency transmissions (starting the engine, telephone, radio).

Advantageously, the processing unit 3 is also able to filter, upstream of the frequency processing, the signal delivered by the magnetometer. Preferably, the filtering is a low-pass filtering in order to filter the high-frequency noise contained in the signal and coming from the environment of the vehicle.

Advantageously, but not in a limited manner, the magnetometer 2 has the following characteristics:

- a measurement range of a magnitude of +/- 2 gauss at least,
- a precision of at least 1 milligauss,
- a sampling frequency of the magnetic field of at least 100 Hz, and more preferably of at least 150 Hz,
- in the case of a digital magnetometer, the data is provided over at least 12 bits.

Preferably, but not in a limited manner, the magnetometer 2 is a digital three-axis magnetometer of reference HMR2300 of the Honeywell® brand, directly delivering a digital signal sampling the current value of the field according to the three axes over 16 bits.

The processing unit comprises a specification containing a piece of data representative of the radius R of the wheel or of its perimeter 2*π*R.

As such, the frequency of rotation of the wheel is multiplied by the value 2*π*R in order to obtain the speed of movement of the vehicle as explained hereinabove.

Advantageously, the device 1 comprises a visualisation unit 4 in order to display in real time the value of the speed determined by the device 1.

Advantageously, the device 1 further comprises a case 5 containing the magnetometer 2 and the processing unit 3.

Preferably, but not in a limited manner, the processing unit 3 is a DSP (Digital Signal Processor). The device 1 then has the form of a case 5 of which the dimensions are from a few centimetres to a decimetre according to the three axes.

More generally, the processing unit can contain any means of calculation.

According to another possible embodiment of the invention, the magnetometer 2 and the processing unit 3 are arranged at different locations on the vehicle. The signal 20 then follows a wired transmission or a wireless transmission, for example of the Wi-fi or Bluetooth type.

Further advantageously, the data processing unit 3 and the display device 4 are combined into the same unit, or even incorporated into the instrument panel of the vehicle.

According to a possible embodiment of the invention, the device 1 is coupled to a position-determining device 6, for example of the GPS (Global Positioning System) type.

As such, when the position-determining device 6 is no longer receiving any satellite data (for example when the vehicle is passing through a tunnel), the device 1 takes the relay and provides data representative of the speed of movement of the vehicle to the position-determining device 6 which can then determine the position of the vehicle in the tunnel.

Each of the figures 2a to 2c show a wheeled terrestrial vehicle 7 provided with a device 1 in order to determining its seed according to the invention.

The vehicle 7 has at least one wheel at least partially metallic 70, for example the front left wheel for a car with four wheels.

In reference to figure 2a and according to a possible embodiment of the invention, the magnetometer 2 of the device 1 is placed in the vicinity of the wheel 70, by being fixed to the bodywork of the vehicle 7. As such, the rotation of the wheel 70 significantly disturbs the magnetic field in the region of the magnetometer, which facilitates the determination of the frequency of rotation of the wheel in the frequency spectrum of the signal 20.

In this example, the processing unit 3 is arranged at another location on the vehicle 7. Preferably, but not in a limited manner, the vehicle 7 comprises an instrument panel 71 wherein is located the processing unit 3. Advantageously, the processing unit 3 then

receives the signal 20 of the magnetometer 2 via wireless communication.

Preferably, but not in a limited manner, one of the axes of measurement of the magnetometer 2 is substantially parallel (respectively perpendicular) to the axis of rotation of the wheel 70, i.e. the two axes are parallel (or respectively perpendicular) or there is an angular separation of a magnitude of 30° at most between the axis of measurement in question and the axis of rotation of the wheel (respectively the perpendicular to the axis of rotation of the wheel).

In reference to figure 2b, the vehicle 7 comprises advantageously a baggage trunk 72 wherein the magnetometer 2 is arranged.

As such, the magnetometer is separated from the elements of the engine that disturb the magnetic field such as the pistons, the crankshaft, etc. These disturbances will therefore be less substantial in the signal 20.

According to another embodiment of the invention, the vehicle shown in figure 2c comprises an instrument panel 71 wherein is arranged the device 1 in its entirety, i.e. including the magnetometer 2. Preferably, the signal 20 is then transmitted by wired communication.

This embodiment is particularly suitable in association with the device 1 with a position-determining device 6 as described hereinabove.

Tests were carried out in order to validate the reliability of the device according to the invention.

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As such, a device 1 was mounted on a vehicle equipped with a position-determining device of the GPS type. Here, the vehicle is a car on the Volkswagen® make, model Golf III TDI®.

In this example, the magnetometer 2 carried out measurements at a frequency of 154 Hz.

Figure 3 shows a diagram of the speed of the vehicle, in km/h, according to time, in seconds.

The curve 9 shows the change in the value of the speed of the vehicle reconstituted using satellite data received by the GPS.

The curve 8 shows the change in the value of the speed determined by the device 1 according to the invention according to time. This curve is remarkably close to that obtained using the GPS.

Key to the figures

Figure 3

vitesse (km/h)	speed (km/h)
temps	time

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The claims defining the invention are as follows:

1. Device for measuring speed of movement of a wheeled terrestrial vehicle, the device comprising a fixed magnetometer intended to carry out measurements of a magnetic field and positioned in such a way as to be sensitive to variations in the magnetic field caused by rotation of at least one partially metallic wheel of the vehicle, as it is, and able to deliver a corresponding signal, and means for processing said signal to establish a frequency spectrum of the latter, to determine, using said frequency spectrum, a frequency of rotation of said wheel, and to deduce therefrom, using information representative of the radius of the wheel, the speed of movement of the vehicle.

2. Device according to claim 1, wherein said means for processing are able to establish a frequency spectrum of said signal via a gliding-window fast Fourier transform.

3. Device according to claim 1 or claim 2, wherein the magnetometer and the means for processing are arranged separately from one another, and further comprising a transmission channel between them.

4. Device according to any one of claims 1 to 3, wherein the magnetometer is able to deliver a signal representative of the magnetic field according to several axes of measurement, and wherein the magnetometer is arranged in such a way that the axis of

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rotation of the wheel is substantially parallel to one of said axes of measurement.

5. Device according to any one of claims 1 to 3, wherein the magnetometer is able to deliver a signal representative of the magnetic field according to several axes of measurement, and wherein the magnetometer is arranged in such a way that the axis of rotation of the wheel is substantially perpendicular to one of said axes of measurement.

6. Method for measuring speed of movement of a wheeled terrestrial vehicle, the method comprising the following steps:

- generating, by a fixed magnetometer, a signal representative of a variable magnetic field, of which certain variations are caused by rotation of at least one partially metallic wheel of the vehicle, as it is; and
- establishing a frequency spectrum of said signal,
- determining, using said frequency spectrum, a frequency of rotation of said wheel; and
- deducing from the frequency and information representative of the radius of the wheel, the speed of movement of the vehicle.

7. Method according to claim 6, wherein the step of establishing said frequency spectrum is implemented via gliding-window fast Fourier transform.

8. Method according to claim 6 or claim 7, wherein the step of determining the frequency of rotation of

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the wheel is implemented by selecting a main frequency of the frequency spectrum.

9. Method according to any one of claims 6 to 8, wherein said signal is representative of the magnetic field according to an axis that is substantially parallel to the axis of rotation of the wheel of the vehicle.

10. Method according to any one of claims 6 to 8 wherein said signal is representative of the magnetic field according to an axis that is substantially perpendicular to the axis of rotation of the wheel of the vehicle.

11. Wheeled terrestrial vehicle comprising at least one partially metallic wheel, wherein the vehicle comprises a device according to any one of claims 1 to 5.

12. Vehicle according to claim 11, wherein the magnetometer is fixed to bodywork of the vehicle.

13. Vehicle according to claim 11, comprising an instrument panel, and wherein the magnetometer is arranged in the vicinity of said instrument panel.

14. Vehicle according to claim 11, comprising a trunk, and wherein the magnetometer is arranged in said trunk.

15. Device for measuring speed of movement of a wheeled terrestrial vehicle, the device substantially as hereinbefore described with reference to any one of

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the embodiments as illustrated in the accompanying drawings.

16. Method for measuring speed of movement of a wheeled terrestrial vehicle, the method substantially as hereinbefore described with reference to any one of the embodiments as illustrated in the accompanying drawings.

17. Wheeled terrestrial vehicle substantially as hereinbefore described with reference to any one of the embodiments as illustrated in the accompanying drawings.

FIG. 1

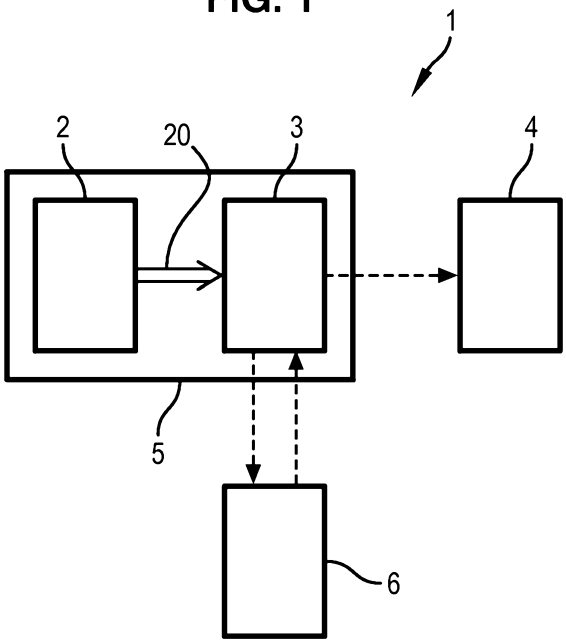


FIG. 2a

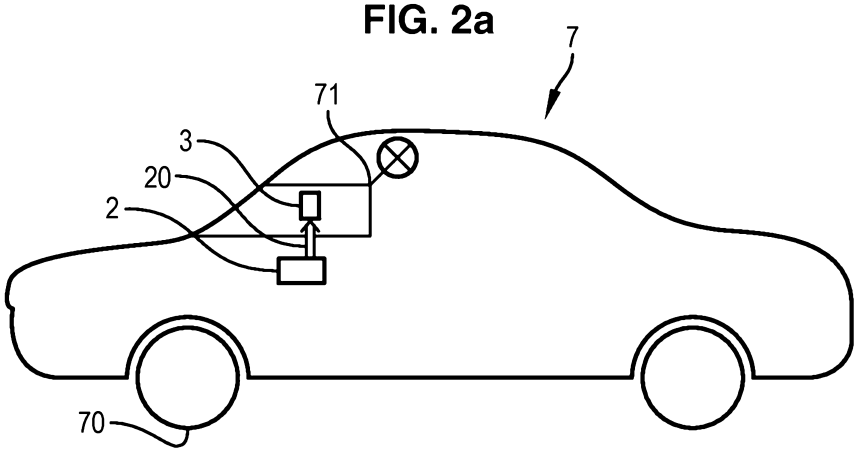


FIG. 2b

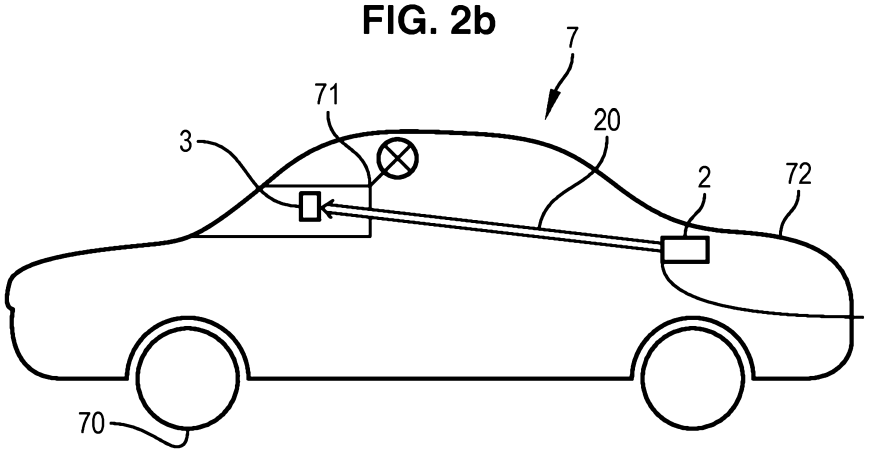


FIG. 2c

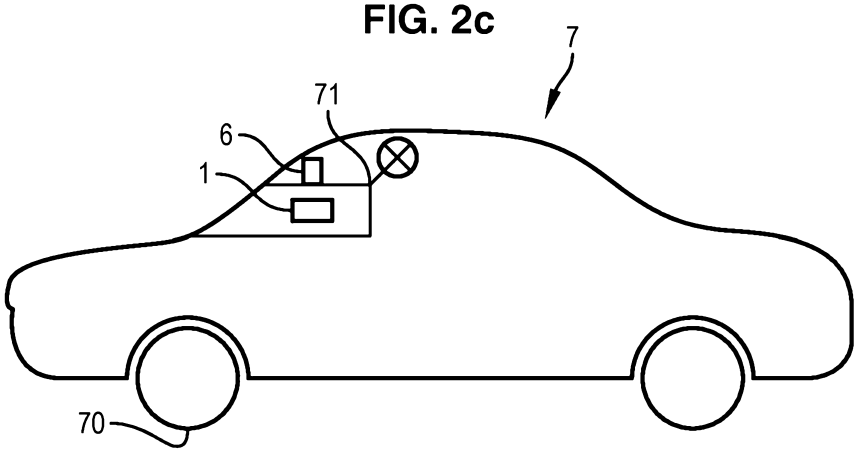
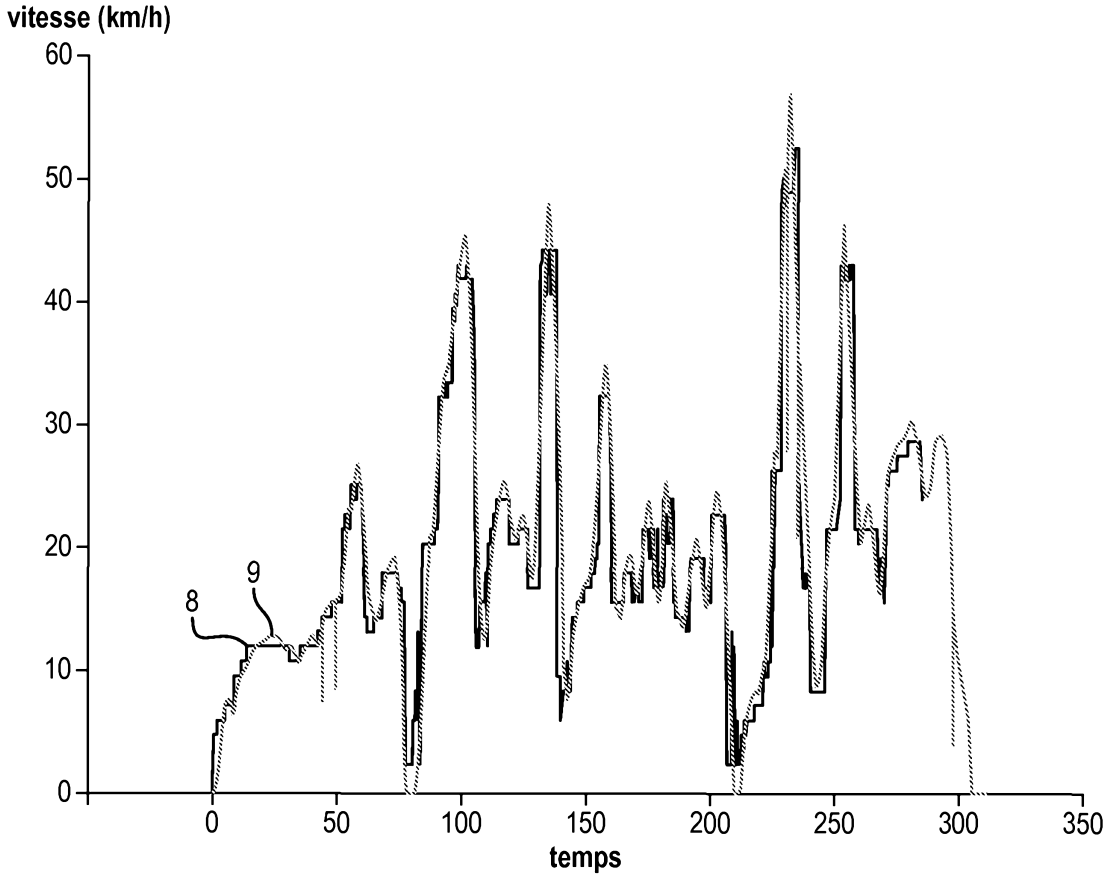


FIG. 3


vitesse (km/h)
60
50
40
30
20
10
0
8
9
0
50
100
150
200
250
300
350
temps