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(54) SYSTEM AND METHOD FOR MEASURING A DISTANCE TRAVELLED BY A GUIDED VEHICLE

(57) System (1) and method for measuring a distance travelled by a guided vehicle (2) designed for being electrically connected to a power line (3). The system comprises:

- a sensor system (11) configured for being installed on-board the guided vehicle (2) and for measuring, for at least one field component of an electromagnetic field of said power line (3), values of said at least one field component; and
- a processing unit (12) connected to the sensor system (11), said processing unit (12) being configured for receiving, for each of the field components for which said values have been measured, the measured values;

wherein the processing unit (12) is configured for automatically calculating, for at least one of the field components for which said values have been measured, a travelled distance that has been travelled by the guided vehicle (2).

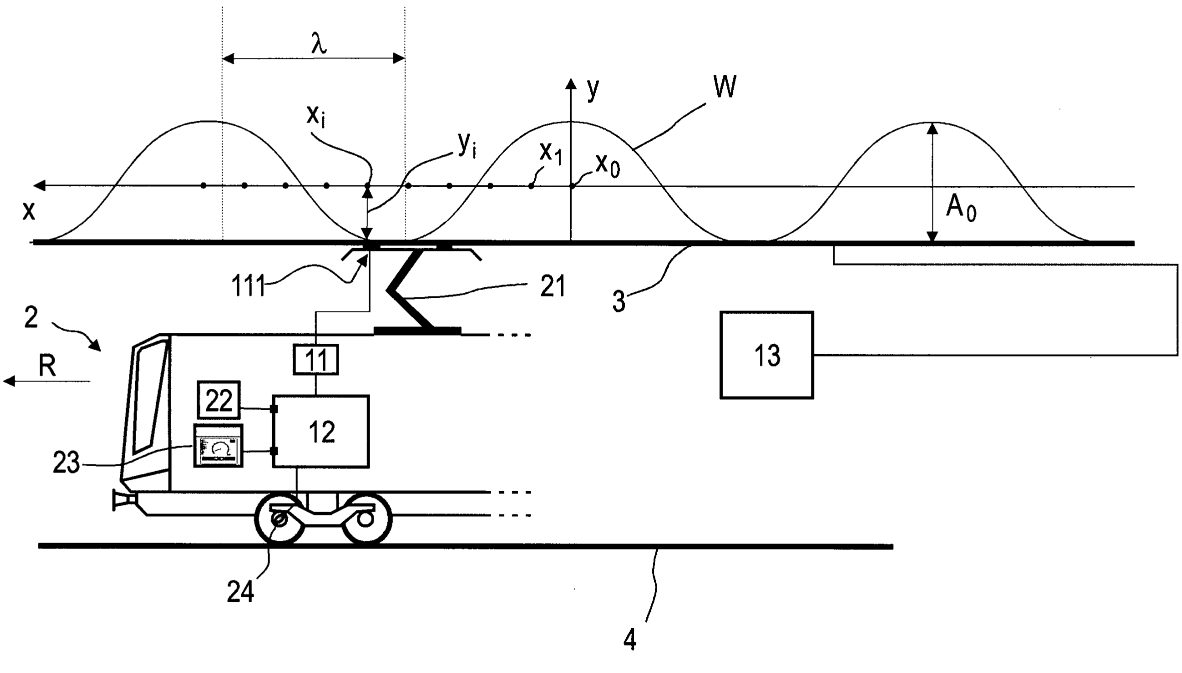

FIG 1

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Description

[0001] The present invention relates to odometry, i.e. techniques used for determining a change of the position of a moving object. More precisely, the present invention concerns guided vehicles, i.e. vehicles guided by at least one guiding means, like a rail, and configured for carrying or transporting goods and/or individuals. Such guided vehicles comprise notably public transport means such as buses, trolleybuses, streetcars, subways, trains or train units, etc., as well as load transporting means such as, for example, overhead traveling cranes or mining transportation means for which safety is a very important factor and which are guided along a route or railway by at least one guiding means configured for defining a trajectory for the guided vehicle, such guiding means being for instance a rail, or preferentially two rails.

[0002] A guided vehicle usually comprises automatic systems for controlling its speed in function of its position and/or of external inputs, which are for instance the neighboring presence of another guided vehicle, or the presence of a curve that requires a decrease of the guided vehicle speed. Examples of automatic systems are the Automatic train control (ATC) or the Automatic train protection (ATP) systems that commonly equip trains. Therefore, the change of the position of a guided vehicle is very important parameter which needs to be determined and which enables to locate a guided vehicle within a network, e.g. a railway network.

[0003] Up to now, different techniques have been used to determine the change of the position of a guided vehicle. They are for example techniques using global navigation satellites (GPS), track circuits, tachometers, Doppler sensors, etc. Each of these techniques has some limitations. For instance, doppler sensors show errors in case of snow, GPS sensors are not able to determine a position within a tunnel, tachometers fail to detect wheel slip/slide events, etc. In order to improve the precision of system in charge of determining the position of a guided vehicle within a network, the above-mentioned techniques might be combined with each other.

[0004] An objective of the present invention is to propose a new technique for measuring a distance travelled by a guided vehicle, which is in particular not affected by slip/slide events or losing the position within a tunnel, and which can be combined or not to an already existing technique.

[0005] The aforementioned objective is achieved by a system and a method for measuring a distance travelled by a guided vehicle connected to a power line according to the independent claims. Further embodiments and other advantages of the present invention are proposed in the dependent claims.

[0006] The invention proposes in particular a system for measuring a distance travelled by a guided vehicle configured for being electrically connected to a power line (e.g. an overhead power line) configured for feeding the guided vehicle in energy in the form of alternating current, the system comprising:

- a sensor system configured for being installed on-board the guided vehicle and therefore for moving with the latter, said sensor system being configured for measuring, notably at different times t, for instance periodically, a value y of at least one component of an electromagnetic field of said power line (i.e. generated by said power line) . In the following, $y_i = y_{x\_i,t\_i}$ will represent a ith value of the variable y measured for the considered component at a time ti and position x_i. In case of periodical measurement, then the measurement period T_M is preferentially correlated to the period T_{PL} of the electromagnetic field of the power line, e.g. to alternating current provided/distributed by the power line, for instance $T_M = m \cdot T_{PL}$, with preferentially m = 1 or m being a fraction, e.g. m = 1/4. According to the present invention, the electromagnetic field is considered as having two components, namely an electric field component and a magnetic field component, wherein the electric field component might be measured or quantified through a voltage measurement, and wherein its magnetic field component might be measured or quantified through a magnetic field intensity measurement. The present invention proposes therefore in particular to measure the power line voltage and/or magnetic field intensity in function of the time and position of a first measurement point of the sensor system, said measurement point moving together with the guided vehicle when the latter travels on the network, said position being the unknown determined by the system according to the invention. The sensor system may comprise for instance a voltage sensor for measuring said voltage and/or a magnetometer for measuring the intensity of the magnetic field of the power line. Typically, the sensor system outputs thus voltage values and/or magnetic field intensity values. The voltage is measured as the difference in electric potential between said first point of measurement and a second point of measurement of the sensor system, said first measurement point being electrically connected to the power line so as to enable the measurement of said difference, and said second measurement point being a reference potential of the guided vehicle, for instance the ground, said sensor system measuring thus said difference in potential through its electrical connection to the first and second point of measurement. The voltage sensor is thus configured for measuring variations within the electric field of the power line when the guided vehicle is moving over the network, the displacement of the guided vehicle leading to the displacement of the first measurement point along the power line, wherein said variations depend thus on the time and position of the guided vehicle with respect to the stationary power line. The magnetic field intensity is also measured at said first point or at a position around said first point, in order to determine variations of the magnetic field of the powerline in function of the time and position of the guided vehicle. Preferentially, the intensity of the magnetic field is measured by the sensor system. In particular, if the sensor system is configured for measuring both the magnetic and electric field components, then the measurement of the voltage and the measurement of said magnetic field intensity preferentially take place at the same time, i.e. simultaneously. According to the present invention, the sensor system is thus configured for providing measurements of voltage and/or magnetic field intensity values y during the displacement of the guided vehicle from a start point (e.g. a first station) to an end point (e.g. an end station). The period T_{PL} of the alternating current of the power line might be stored as a parameter within the sensor system or might be measured by the sensor system, said period T_{PL} serving as reference for triggering successive periodical (according to period T_M) acquisitions of voltage and/or magnetic field intensity measurement values y by the sensor system for said power line;

- a processing unit, comprising typically at least one processor and a memory, the processing unit being connected to the sensor system for receiving, for each component of the electromagnetic field that has been measured, and notably in real time, the value y that has been measured by the sensor system for the considered component. For instance it can receive a voltage value for each measured voltage and/or a magnetic field intensity value for each measured magnetic field intensity. The processing unit is further configured for automatically calculating a travelled distance Δx that has been travelled by the guided vehicle between (i.e. during the time separating) two measurements, e.g. two successive measurements, of the considered electromagnetic field component(s). For instance, it is configured for automatically determining the travelled distance Δx travelled between two successive measurements of the voltage and/or magnetic field intensity. The travelled distance Δx is calculated by the processing unit from received values yi and y_j received respectively for these two measurements, e.g. successive values yo and y_1, and by modeling the considered component of the electromagnetic field as a wave function W(x,t), with x representing the position and t the time, in order to determine from known characteristics of said wave function (i.e. of the power line electromagnetic field, e.g. its frequency f, its wavelength λ, and its amplitude A_0), the travelled distance $\Delta x = x_j - x_i$ travelled by the guided vehicle between said two measurements performed respectively at a time ti at position x_i for yi and at a time t_j at a position x_j for y_j. In other words, the processing unit is configured for determining from solving the equations $y_j = W(x_j,t_j)$ and $y_i = W(x_i,t_i)$ the travelled distance Δx. For instance, said wave function is a sinusoidal wave function $W(x,t) = A_0 \cdot \sin(2\pi/\lambda \cdot x - \omega t)$ (Eq. 1), wherein W(x,t) provides an estimation of the value $y_{x,t}$ measured for the considered electromagnetic component at a time t and a position x for the guided vehicle (in particular, said position x may correspond to the position of the first measurement point with respect to the power line), A_0 being the amplitude of the sinusoidal wave function for the considered component, wherein $\omega/2\pi = 1/T_{PL} = f$, f being the frequency of the sinusoidal wave function and λ its wavelength. In other words, each of the considered electromagnetic field components might be represented according to the present invention by a wave function, e.g. a standing wave according to Eq. 1, wherein the processing unit is configured for automatically determining the travelled distance Δx by solving for two different positions x (namely x_i and x_j) the equation y = W(x,t), y being measured at time t by the sensor system and x determined by the processing unit. In case of periodical measurement, one has for instance $t_j = t_i + \alpha \cdot T_M$ wherein α is a strictly positive integer, preferentially $t_j = t_i + m \cdot T_{PL}$. In Eq. 1 and for each of said components of the electromagnetic field, f, λ, and A_0 are known parameters characterizing said electromagnetic field.

[0007] The invention proposes also a method for measuring a distance travelled by a guided vehicle configured for being electrically connected to a power line feeding the guided vehicle in energy, wherein electric power is delivered by the power line in the form of alternating current, the method comprising:

- measuring, preferentially periodically measuring, by a sensor system installed on-board the guided vehicle at least one component of an electromagnetic field of the power line, e.g. measuring the electric and/or magnetic field of the power line;
- automatically determining, by a processing unit which is preferentially installed on-board the guided vehicle, a travelled distance $\Delta x = x_j - x_i$ travelled by the guided vehicle between two measurements of said at least one component, said two measurements being performed respectively at a time ti at position x_i and at a time t_j at position x_j, and giving rise respectively to the measured values $yi = y_{x\_i,t\_i}$ and $y_j = y_{x\_j,t\_j}$ for said at least one component, wherein $y_k = y_{x\_k,t\_k}$ represents the value measured at time t_k for the considered electromagnetic field component (e.g. the voltage or magnetic field intensity) at position x_k, wherein the position x_k is defined with respect to the power line (i.e. said power line serving as referential), the travelled distance Δx being determined by the processing unit by solving the equations $y_i = W(x_i,t_i)$ and $y_j = W(x_j,t_j)$ wherein W(x,t) is a wave function approximating/modelling variations of the considered component of the electromagnetic field in function of the time t and position x for the guided vehicle. In particular, said wave function W(x,t) further depends on known characteristics of the power line (e.g. frequency f, wavelength λ, and amplitude A_0).

[0008] The present invention proposes thus to measure the electric and/or the magnetic field(s) of the power line and to model each of the latter as a wave function W(x,t), e.g. as a sinusoidal standing plane wave function, in order to determine from measured values y of the magnetic and/or electric field(s) (e.g. magnetic field intensity and/or voltage) and known characteristics of the electric and/or magnetic field(s) (e.g. electric and/or magnetic frequency f, wavelength λ, and amplitude A_0) the distance travelled by the guided vehicle by solving y = W(x,t) for each of the considered component of the electromagnetic field.

[0009] Advantageously, having two different physical measurements, e.g. acquiring in parallel and/or simultaneously measurement values y_{i_Elec} for the electric field and measurement values y_{i_Magn} for the magnetic field, not only might prevent failures of the system, but might be used for increasing the precision of the system by calculating for instance a mean value for the travelled distance in function of the travelled distance $\Delta x_{\_Elec}$ obtained from the values measured for the electric field and the travelled distance $\Delta x_{\_Magn}$ obtained from the values measured for the magnetic field.

[0010] In particular, the system according to the invention is configured for automatically discarding a measurement value if a difference between the travelled distance calculated from measurement values obtained for the electric field (i.e. from the voltage) and measurement values obtained for the electromagnetic field is greater than a reliability constant, which might be defined in the system by a user. In particular, if said difference is smaller than said reliability constant, then the system is configured for calculating a mean travelled distance from the travelled distances $\Delta x_{\_Elec}$ and $\Delta x_{\_Magn}$ calculated by the system from respectively the electric field and the magnetic field.

[0011] Finally, the system is preferentially configured for automatically discarding a measurement value which does not satisfy a physical rule. In particular, the system comprises a database configured for storing at least one physical rule, for instance a set of physical rules. Thanks to the physical rule, calculations of travelled distances which would give rise to erroneous results are prevented. Preferentially, the system comprises at least one physical rule configured for preventing the processing unit to calculate a travelled distance if a measurement value implies a guided vehicle speed greater than the maximum speed of the guided vehicle, and/or an acceleration value greater than the maximum acceleration of the guided vehicle. For instance, before calculating the travelled distance, the processing unit automatically applies at least one physical rule to the measured value for the electric field and only computes the travelled distance if said physical rule is verified for said measured value, the latter being otherwise discarded. The same applies mutatis mutandis to measured values of the magnetic field.

[0012] Further aspects of the present invention will be better understood through the following drawings, wherein like numerals are used for like and corresponding parts:

Figure 1 schematic representation of a system according to the invention.

Figure 2 flowchart of a preferred method according to the invention.

[0013] Figure 1 shows the basic concept of the invention. A guided vehicle 2 is moving on track 4, comprising for instance at least one rail, and is powered in energy through electrical power transmitted by a power line 3, e.g. an electrical wire. Typically, said power line 3 distributes electrical energy as alternating current. The power line 3 is for instance an overhead catenary configured for being in electrical contact with a pantograph 21 of the guided vehicle 2. Due to the presence of electrical charges within the power line 3, the latter generates an electromagnetic field which is a combination of an electric field and a magnetic field, called, in the present application, the components of the electromagnetic field. The present invention proposes to measure a distance travelled by the guided vehicle 2 based on measurement of the electric and/or magnetic field of the power line 3. The proposed system might be installed integrally on-board the guided vehicle.

[0014] According to the present invention, the claimed system comprises a sensor system 11 configured for measuring said magnetic field and/or electric field. The sensor system 11 may comprise one or several sensors configured for instance for measuring a voltage and/or a magnetic field intensity of the power line 3. Preferentially, a voltage sensor may measure the difference in electric potential between a first point of measurement 111 and a second point of measurement of the sensor system 11. The first point of measurement 111 may be electrically connected to a pantograph slide plate or a contact shoe of the pantograph, or in other words a part of the pantograph configured for being in electrical contact with the power line 3. For instance, said first point of measurement might be only connected to the power line when the pantograph is in contact with the latter, while the electrical connection is automatically cut off when the pantograph lose the contact with the power line. The second point of measurement might be connected to a reference tension, e.g. to the ground. The first point of measurement 111 moves together with the guided vehicle 2 enabling therefore measurements of voltage values yi at different positions x_i along the power line 3. The same applies to a sensor configured for measuring the magnetic field intensity. Said sensor might measure the magnetic field intensity at said first measurement point 111 or at another measurement point close enough to the power line 3 for enabling magnetic field intensity measurements, wherein the measurement point for the magnetic field intensity moves together with the guided vehicle, enabling therefore measurements of magnetic field intensity values y_i at different positions x_i along the power line 3. The concept being the same for the magnetic field and electric field measurements, there will be in the following no distinction between the measured values of the magnetic field and electric field, both being represented by the variable yi. The skilled person will understand that in some cases, it represents magnetic field intensity values, and in other cases voltage values depending on the measurement that is performed.

[0015] The variations of the electric field, as well as the variations of the magnetic field, in function of the position x along the length of the power line 3 (see the horizontal x-axis extending along the power line 3) might be represented by a wave function W which is substantially stationary. It is typically a sinusoidal wave function as shown in Fig. 1 with an amplitude A_0 and a wavelength λ. In case of measurements of the electric field by the sensor system 11 at different positions x, e.g. x_0, x_1, ..., x_i along the power line 3, different voltage values y, e.g. y_0, y_1, ..., y_i are measured at different times t, e.g. t_0, t_1, ..., ti during the displacement of the guided vehicle 2 along the direction R. By modeling the electric field as a wave function y = W(x,t) as schematically represented in the graph of Figure 1 wherein the horizontal axis represents the position x and the vertical axis the measured value y, any measured voltage value yi at a time t_i might be used for determining a position x_i along the power line 3, and thus a travelled distance. Indeed, by performing two measurements of the voltage at two different times ti and t_j, a processing unit 12 might determine the travelled distance Δx travelled between the period of time $\Delta t = t_j - t_i$ separating the two measurements. The same technique applies mutatis mutandis to measurements of magnetic field intensity values in order to determine from the latter said travelled distance. Therefore, by measuring magnetic field intensity values and voltage values, the processing unit 12 might determine a first travelled distance $\Delta x_{\_Elec}$ obtained from the voltage values and a second travelled distance $\Delta x_{\_Magn}$ obtained from the magnetic field intensity values, wherein said first and second travelled distance are preferentially combined for improving the precision of the determination of the distance travelled by the guided vehicle 2 during said period of time. For instance, the magnetic field intensity and voltage measurements are performed simultaneously and the processing unit 12 is configured for calculating the mean value of $\Delta x_{\_Magn}$ and $\Delta x_{\_Elec}$. Optionally, the processing unit 12 might combine the travelled distance obtained according to the previously described technique to other techniques for determining the position of the guided vehicle 2, for instance with data coming from an odometer 24 or from GPS data coming from a GPS system 22. The travelled distance might be then outputting by the processing unit 12 and sent to a control system 23 of the guided vehicle 2.

[0016] Optionally, in order to improve the precision of the measurement of the travelled distance, the system according to the invention may comprise a modulator 13 configured for modulating at least one of the field components of the electromagnetic field with a reference signal, wherein said reference signal is characterized by a frequency that is greater than the frequency of the considered field component and an amplitude which is smaller than the amplitude of the considered field component. The wavelength of the reference signal is preferentially a fraction of the wavelength of the electric field. The processing unit 12 may use then a lock-in amplifier technique, or may comprise a lock-in amplifier, for retrieving said reference signal in the measurement values transmitted by the sensor system. According to this technique, the wave function W which is used for power transmission is an AC carrier signal which is modulated by the reference signal of higher frequency. Said modulator 13 might be installed on-board or off-board and is connected to the power line for adding to the AC carrier signal said modulation. The reference signal is preferentially a sinusoidal signal (e.g. a voltage varying sinusoidally in function of the time), i.e. represented by a wave function M, wherein preferentially the value m=M(x,t) of said wave function M at position x and time t is zero when the value y (e.g. the measured voltage) of the electric field (represented by the wave function W(x,t)) is zero. By using a lock-in amplifier technique based on the reference signal and measuring preferentially continuously the electric field, the processing unit 12 becomes able to increase the precision of the determination of the position of the guided vehicle 2. Preferentially, several reference signals might be added to the AC carrier signal for increasing the precision of the determination of the position of the guided vehicle 2.

[0017] Figure 2 presents a flowchart of a preferred embodiment of a method according to the invention:

At step 201, the sensor system 11 installed on-board the guided vehicle 2 measures at least one field component of the electromagnetic field of the power line 3. It can be the electric field, or the magnetic field, or both the electric and magnetic field. Known techniques in the art are used for performing said measurement. Said measurement may take place continuously (notably in the case of the use of the lock-in amplifier technique by the processing unit 12) or periodically. In case of periodical measurements, the sensor system 11 is preferentially configured for measuring said electric field, respectively magnetic field, according to a period of time that is equal to the oscillation period T_{PL} of said electromagnetic field. In such a case, the values periodically measured by the sensor system 11 when the guided vehicle is at standstill will remain the same. Said values will change as soon as the guided vehicle starts moving. Using periodical measurements characterized by a period of measurement $T_M = T_{PL}$ simplifies the processing of data by the processing unit 12.

[0018] At step 202, the sensor system 11 transmits, for instance in real time, the measured values to the processing unit 12.

[0019] At step 203, the processing unit 12 automatically determines whether a received measured value has to be discarded or not for the calculation of the travelled distance. For this purpose, the processing unit 12 comprises a database for storing at least one predefined physical rule. Said predefined rule is configured for being applied to a measured value received by the processing unit 12 in order to determine whether it is satisfied or not by said received measured value. Said rule may trigger the determination of a guided vehicle speed and/or acceleration from the received measured value and any other previously received value, and automatically determine whether the calculated acceleration and/or speed exceed(s) a predefined value. The processing unit 12 is therefore configured for applying the predefined physical rule to each measured value it receives and for discarding for the calculation of the travelled distance any measured value that does not satisfy the applied predefined physical rule. In particular, only non-discarded values are then kept for the calculation of the travelled distance according to step 204.

[0020] At step 204, the processing unit 12 automatically determines the travelled distance $\Delta x = x_j - x_i$ travelled by the guided vehicle 2 between two measurements of said at least one field component, said two measurements being performed respectively at a time ti at position x_i and at a time t_j at position x_j, and giving rise respectively to the values yi and y_j measured by the sensor system 11 for the considered field component. The sensor system 11 may therefore send to the processing unit 12 a first set of data comprising voltage values and/or a second set of data comprising magnetic field intensity values, the processing unit 12 calculating for each of said sets of data a travelled distance. Said travelled distance $\Delta x = x_j - x_i$ is calculated by the processing unit 12 by solving, for each of the field component for which it received measured values, the following equations:

$$y_j = W(x_j, t_j) \;;$$

and

$$y_i = W(x_i, t_i)$$

wherein $W(x_k, t_k)$, with k = i or j, is the wave function configured for modelling the values y_k measured (y_k being the k^{th} measured value) for the considered field component in function of the position x_k and time t_k, wherein the positions x_k are defined along the power line 3. We have for instance, t_j > ti, the position $x_j \geq x_i$ with respect to a reference point xo and a direction of travel R according to x positive as well as a wave direction according to x positive, the travelled distance being therefore also positive. Other conventions for the direction of displacement, wave function, signed of the travelled distance, etc. might be taken as known in the art and based on the present concept. Optionally, the processing unit 12 might be configured for automatically determining a change of a direction of travel of the guided vehicle from successive voltage or respectively magnetic field measurements realized between two extrema of the wave function modeling the considered field. Indeed, the processing unit 12 might be configured for comparing any newly measured voltage value (resp. magnetic field intensity value) to a reference voltage value (resp. reference magnetic field intensity value) in order to determine an increase or a decrease of the measured value, and from said increase or decrease, whether a change of direction occurred: between two extrema of the wave function, the measured values (electric or magnetic field) should continuously increase or decrease as long as the guided vehicle is moving. If a newly measured value expected to be greater, resp. lower, than a previously measured value is lower, resp. greater, than the latter, then the processing unit 12 is configured for indicating a change of direction.

[0021] Optionally or alternately, the travelled distance Δx can be obtained by the processing unit 12 from continuous measurement of the electric and/or magnetic field and by measuring the time $\Delta t = t_j - t_i$ for which $y_j = W(x_j, t_j) = y_i = W(x_i, t_i)$. In such a case, the processing unit 12 is configured for:

- indicating that the guided vehicle is at standstill if $\Delta t = T_{PL}$, i.e. the period of the electromagnetic field;
- if $\Delta t < T_{PL}$, then the guided vehicle is moving towards the electromagnetic wave source and the travelled distance is determined by the processing unit 12 from: $\Delta x = \Delta t \cdot s = \Delta t \cdot S(T_{PL}/\Delta t - 1)$, with s being the speed of the guided vehicle and S being the electromagnetic wave propagation speed in the power line; and
- if $\Delta t > T_{PL}$, then the guided vehicle is moving in the same direction of propagation as the electromagnetic wave and the travelled distance is determined by the processing unit 12 from: $\Delta x = \Delta t \cdot s = \Delta t \cdot S\ (1 - T_{PL}/\Delta t)$.

[0022] At step 205, the processing unit 12 automatically outputs the calculated travelled distance, sending for instance the latter to a control system 23 of the guided vehicle 2.

[0023] Finally, the present invention proposes a new system and method for easily measuring a distance travelled by a guided vehicle, based on measurements of the electric and/or magnetic field of a power line feeding electric power to a guided vehicle. Advantageously, the proposed technique for measuring the travelled distance is not affected by slip/slide events of guided vehicle wheels, can measure near-zero speed, and enables to measure the distance travelled by the guided vehicle 2 also in tunnels.

Claims

1. System (1) for measuring a distance travelled by a guided vehicle (2) designed for being electrically connected to a power line (3), the system (1) comprising:

   - a sensor system (11) configured for being installed on-board the guided vehicle (2) and for measuring, for at least one field component of an electromagnetic field of said power line (3), values of said at least one field component;
   - a processing unit (12) connected to the sensor system (11), said processing unit (12) being configured for receiving, for each of the field components for which said values have been measured, the measured values;

   characterized in that the processing unit (12) is configured for automatically calculating, for at least one of the field components for which said values have been measured, a travelled distance $\Delta x = x_j - x_i$ that has been travelled by the guided vehicle (2) by solving, for the considered field component, the following equations:

$$y_j = W(x_j, t_j) \; ;$$

   and

$$y_i = W(x_i, t_i)$$

   wherein

   y_j is the value measured by the sensor system (11) for said considered field component at position x_j and time t_j;
   yi is the value measured by the sensor system (11) for said considered field component at position x_i and time t_i;
   $W(x_k,t_k)$ is a wave function configured for modelling the values y_k measured for the considered field component in function of the position x_k and time t_k, wherein the positions x_k are defined along the power line (3);
   the travelled distance $\Delta x = x_j - x_i$ being the distance travelled by the guided vehicle (2) between two measurements of the considered field component performed respectively at time ti at position x_i and at time t_j at position x_j and resulting in measured values yi and y_j respectively.

2. System (1) according to claim 1, wherein the electromagnetic field is represented as a combination of its field components, namely the combination of an electric field component and a magnetic field component, the sensor system (11) being configured for measuring a voltage value of the electric field component and/or an intensity value of the magnetic field component.

3. System (1) according to claim 2, wherein the sensor system (11) is configured for measuring both voltage values and magnetic field intensity values for the electromagnetic field of the power line, and the processing unit (12) is configured for calculating said travelled distance Δx for each of the field components, wherein $\Delta x_{\_Elec}$ is the travelled distance calculated from measured voltage values and $\Delta x_{\_Magn}$ is the travelled distance calculated from measured intensity values.

4. System (1) according to claim 3, wherein the processing unit (12) is configured for automatically discarding a calculated travelled distance if a difference between $\Delta x_{\_Elec}$ and $\Delta x_{\_Magn}$ is greater than a reliability constant, and otherwise for calculating a mean value of $\Delta x_{\_Elec}$ and $\Delta x_{\_Magn}$ for determining a mean distance travelled by the guided vehicle (2).

5. System (1) according to one of the claims 1 to 4,
   wherein the wave function W is periodical and the sensor system (11) is configured for periodically measuring the value of said at least one field component, wherein the period of measurement equals the period of the wave function W.

6. System (1) according to claim 1 to 5, wherein the wave function W is a sinusoidal wave function given by:

$$W(x_k, t_k) = A_0 \cdot \sin(2\pi/\lambda \cdot x_k - \omega t_k),$$

wherein A_0 is the amplitude of the wave function W for the considered field component, $\omega/2\pi = 1/T_{PL} = f$, f being the frequency of the wave function for the considered field component, T_{PL} its period, and λ its wavelength.

7. System (1) according to claims 1-6, wherein the processing unit (12) comprises a database for storing at least one predefined physical rule, wherein the processing unit (12) is configured for applying said predefined physical rule to each measured value and for discarding for the calculation of the travelled distance any measured value that does not satisfy the applied predefined physical rule.

8. System (1) according to claims 1-7, comprising a modulator (13) configured for modulating at least one of the field components of the electromagnetic field with a reference signal whose frequency is greater than the considered field component frequency while its amplitude smaller, the processing unit (12) being configured for using a lock-in amplifier technique based on said reference signal for determining said travelled distance.

9. Method for measuring a distance travelled by a guided vehicle (2) configured for being electrically connected to a power line (3), the method comprising:

- measuring (201) by a sensor system (11) installed on-board the guided vehicle (2) at least one field component of an electromagnetic field of the power line (3);
- automatically determining (204), by a processing unit (12) and for at least one of the field components for which values have been measured, a travelled distance $\Delta x = x_j - x_i$ travelled by the guided vehicle (2) between two measurements of the considered field component, said two measurements being performed respectively at a time ti at position x_i and at a time t_j at position x_j, and giving rise respectively to the measured values yi and y_j for the considered field component, wherein the travelled distance Δx is calculated by the processing unit (12) by solving for the considered field component the following equations:

$$y_j = W(x_j, t_j) \;;$$

and

$$y_i = W(x_i, t_i)$$

wherein $W(x_k, t_k)$ is a wave function configured for modelling the values y_k measured for the considered field component in function of the position x_k and time t_k, wherein the positions x_k are defined along the power line (3).

10. Method according to claim 9, wherein the electromagnetic field is represented as a combination of an electric field component and a magnetic field component, the method comprising measuring a voltage value of the electric field component and/or an intensity value of the magnetic field component.

11. Method according to claim 10, comprising measuring both voltage values and magnetic field intensity values for the electromagnetic field of the power line (3), and calculating said travelled distance Δx for each of its field components, wherein $\Delta x_{\_Elec}$ is the travelled distance calculated from measured voltage values and $\Delta x_{\_Magn}$ is the travelled distance calculated from measured intensity values.

12. Method according to one of the claims 9-11, wherein the wave function W is periodical, and the method comprises periodically measuring the value of said at least one field component, wherein the period of measurement equals the period of the wave function W.

13. Method according to one of the claims 9-12, wherein the wave function W is a sinusoidal wave function given by:

$$W(x_k, t_k) = A_0 \cdot \sin(2\pi/\lambda \cdot x_k - \omega t_k),$$

wherein A_0 is the amplitude of the wave function W for the considered field component, $\omega/2\pi = 1/T_{PL} = f$, f being the frequency of the wave function for the considered field component, T_{PL} its period, and λ its wavelength.

14. Method according to one of the claims 9-13, comprising storing in a database at least one predefined physical rule, the method further comprising applying said predefined physical rule to each measured value of said at least one field component for discarding any measured value that does not satisfy the applied predefined physical rule for the calculation of the travelled distance.

15. Method according to one of the claims 9-14, comprising modulating at least one of the field components of the electromagnetic field with a reference signal whose frequency is greater than the frequency of the considered field component while its amplitude smaller, and using a lock-in amplifier technique based on said reference signal for determining said travelled distance.

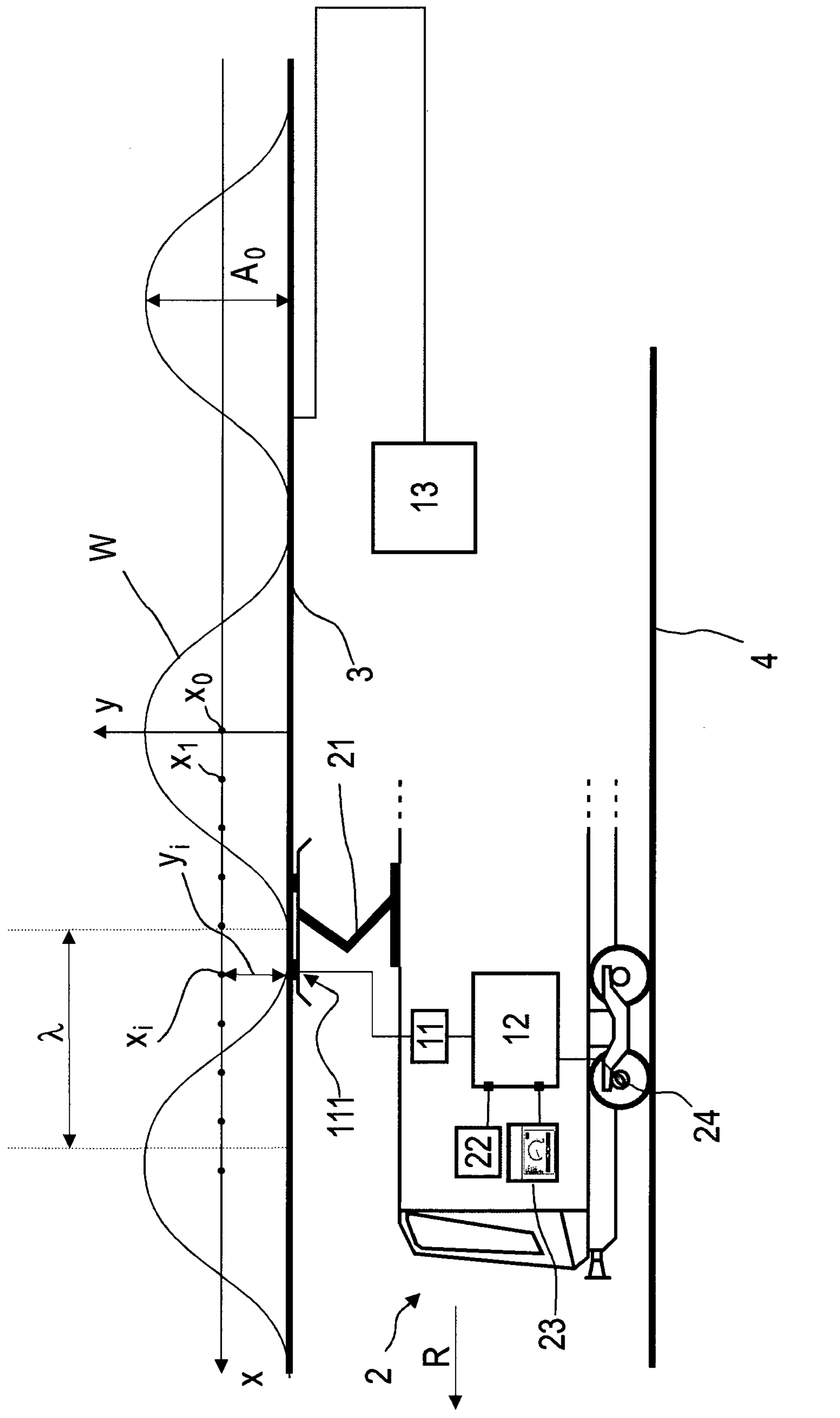

FIG 1

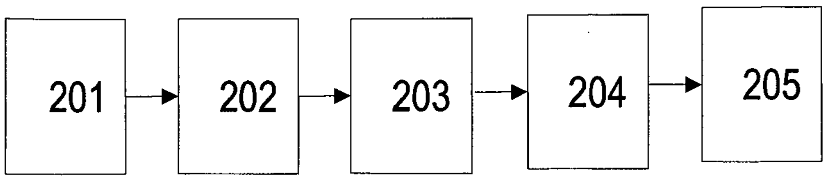

FIG 2

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EUROPEAN SEARCH REPORT

Application Number
EP 20 38 0022

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	MARC HEDDEBAUT ET AL: "Wideband analysis of railway catenary line radiation and new applications of its unintentional emitted signals", MEASUREMENT SCIENCE AND TECHNOLOGY, IOP, BRISTOL, GB, vol. 29, no. 6, 17 April 2018 (2018-04-17), page 65101, XP020327267, ISSN: 0957-0233, DOI: 10.1088/1361-6501/AAB07F [retrieved on 2018-04-17] * Section 3.3; figure 10 * * Section 4.1; figure 11 *	1,9	TECHNICAL FIELDS SEARCHED (IPC): B61L

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	26 May 2021	Martínez Martínez, J

CATEGORY OF CITED DOCUMENTS

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26-05-2021

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