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(54) SYSTEM AND METHOD FOR MEASURING THE SPEED OF A GUIDED VEHICLE AND THE DISTANCE TRAVELLED BY THE LETTER

(57) The present invention concerns a system (1) and a method for determining the speed of a guided vehicle (2) and/or the distance travelled by said guided vehicle (2), the latter being guided along a route by at least one rail (3), the system (1) comprising:
- a laser beam emitter (11) configured for emitting a pulsed laser beam (111) aligned with a first direction (D1) configured for pointing to a first location on a rail surface (31);
- at least one IR detector (12, 13) configured for having a field of view (F21, F22) aligned with a second direction (D21, D22) in order to point to a second location on the rail surface (31) when the system (1) is installed onboard the guided vehicle (2) and the latter is guided by said rail (3) along said route, wherein the second location is separated from the first location by a predefined distance ΔX;
- a processing unit (14) configured for determining the distance travelled by the guided vehicle (2) and/or its speed from the predefined distance ΔX, a signal D (SD1, SD2) related to a detection by the IR detector (12, 13 respectively) of a warm spot at interaction area (I1, 12, 13) of the laser beam pulse with the rail surface (31) and control parameters related to the pulses emitted by the laser beam emitter (11).

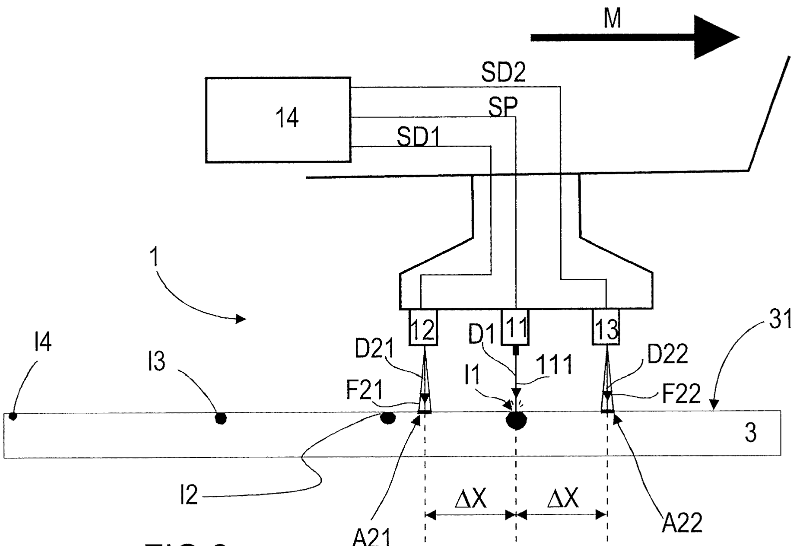

FIG 2

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Description

[0001] The present invention concerns a system and a method for measuring the speed of guided vehicle and/or the distance travelled by the latter.

[0002] The present invention is directed to odometry techniques for determining an actual speed and position for a guided vehicle moving along a route. "Guided vehicle" according to the present invention refers generally to a device for carrying or transporting substances, objects or individuals that is guided by at least one guiding means, such as a rail, and refers more particularly to 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 rail, in particular by two rails.

[0003] Guided vehicles usually comprise 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, for safety reason, the speed and position of a guided vehicle are important parameters that need to be precisely and reliably determined.

[0004] Up to now, different techniques have been used to determine the speed and/or position of a guided vehicle. They are for example techniques using balises, global navigation satellites, track circuits, tachometers, Doppler radar, etc. Unfortunately most of said techniques fail to detect wheel slip/slide events and/or near zero speed that may affect a speed/position measurement, and are often quite complex systems.

[0005] An objective of the present invention is therefore to propose a system and a method for determining the speed and/or position of a guided vehicle that is simple, precise and overcome the sleep/slide and near zero speed problems.

[0006] The aforementioned objective is achieved by a system and a method according to the independent claims. Further embodiments and other advantages of the present invention are proposed in the dependent claims.

[0007] The invention proposes in particular an on-board system for determining the speed of a guided vehicle and/or the distance travelled by said guided vehicle, the latter being guided along a route by at least one rail, the system according to the invention being configured for being installed on-board the guided vehicle, for instance on a bogie of the guided vehicle, the system comprising:

- a laser beam emitter configured for emitting a pulsed laser beam aligned with a first direction configured for pointing to a rail surface, for instance a top head surface of the rail, when the system is installed on-board the guided vehicle and the latter is guided by said rail along said route. In particular, a laser beam pulse P_i emitted by the laser beam emitter at time T_i is able to interact with the rail surface at an interaction area A_i by generating a warm spot, also called hereafter "foot-print" F_i, the laser beam emitter being in particular further configured for being controlled by a signal SP generated by a processing unit, said signal P determining the time T_i at which the pulse P_i has to be emitted. Preferentially, the first direction is a fixed direction;

- at least one infrared radiation (IR) detector configured for having a field of view (or field of detection) aligned with a second direction pointing to said rail surface and defining a detection area on the rail surface when the system is installed on-board the guided vehicle and the latter is guided by said rail along said route, wherein said second direction is different from said first direction in order to have the detection area separated from the interaction area by a predefined distance ΔX, the IR detector being in particular further configured for outputting a signal D related to the detection of footprints F_i in function of the time T'_i. In other words, according to the present invention, the first direction with which the laser beam is aligned with is configured for pointing to a first location on the rail surface, while the second direction with which the field of view is aligned with is configured for pointing to a second location on the rail surface, wherein the first location and the second location are separated by said predefined distance ΔX on the rail surface, and correspond respectively to the location of the interaction area and the location of the detection area, the predefined distance ΔX remaining constant with the time, and thus with the displacement of the guided vehicle along said route;
- a processing unit configured for controlling the laser beam emitter according to control parameters and for determining the distance travelled by the guided vehicle and/or its speed from the predefined distance ΔX, the signal D and the control parameters, which are preferentially determined by the processing unit for controlling the laser beam emitter, said control parameters being in particular used by the processing unit for controlling the time T_i and for generating the signal SP configured for controlling the laser beam emitter. In particular, a footprint F_i resulting from a pulse P_i emitted at time T_i is detected at a time T'_i, wherein the time $\Delta T_i = T_i' - T_i$ is the time needed by the guided vehicle for travelling the predefined distance ΔX, the travel of the guided vehicle along said route "bringing" the footprint F_i created on the rail surface in the detection area of the IR detector. In particular, the travelled distance being

then directly obtained by addition of the predefined distance ΔX, and the guided vehicle speed being given by $\Delta X/\Delta T_i$. Preferentially, the processing unit is configured for outputting said signal SP configured for controlling laser beam emitter, said signal SP controlling for example the time T_i at which the pulse P_i has to be emitted, and optionally its intensity. The control parameters are for instance the time T_i at which the pulse P_i has to be emitted (i.e. the frequency of the pulse), optionally the intensity or energy of the pulse, optionally its duration, and are determined and/or adapted by the processing unit, for instance in function of a previously determined speed of the guided vehicle.

[0008] The present invention further proposes in particular a method for determining the speed of a guided vehicle and/or the distance travelled by the guided vehicle, the latter being guided along a route by at least one rail, the method according to the invention comprising:

- preferentially while the guided vehicle is moving, emitting, preferentially continuously emitting, a pulsed laser beam from the guided vehicle, for instance by means of a laser beam emitter installed on-board the guided vehicle and controlled by a processing unit via a signal SP, wherein said pulsed laser beam is directed to a first location on a rail surface of the rail and each pulse P_i is configured for interacting with the rail surface at an interaction area A_i by temporarily generating a warm spot or footprint F_i;
- preferentially while the guided vehicle is moving, detecting, preferentially continuously detecting, the footprints F_i in function of the time, by using for instance an IR detector, wherein a detection area of each footprint is separated from the interaction area by a predefined distance ΔX so that a footprint F_i enters the detection area once the guided vehicle moved from said predefined distance ΔX;
- determining the speed and/or distance travelled by the guided vehicle from the predefined distance ΔX, the detection of the footprints F_i and control parameters determined by the processing unit for controlling the emission of the pulse P_i.

[0009] 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 first preferred embodiment of a system according to the invention mounted on board a guided vehicle.

Figure 2 detailed view of the first preferred embodiment of figure 1.

Figure 3 schematic representations of the signal SP and the signal D used for determining the speed and/or travelled distance of the guided vehicle.

[0010] Figure 1 shows a system 1 according to the invention mounted on-board a guided vehicle 2 which is configured to follow a route defined by one or two rails 3, the guided vehicle 2 moving for instance according to the direction M illustrated by the corresponding arrow. The system 1 according to the invention is preferentially installed on a bogie of the guided vehicle 2.

[0011] Figure 2 is an enlargement of detail A of figure 1. The system 1 according to the invention comprises a laser beam emitter 11 configured for being controlled by a signal SP, an IR detector 12 configured for outputting a signal SD1, optionally another IR detector 13 configured for outputting a signal SD2, and a processing unit 14 for generating the signal SP according to control parameters determined by the processing unit and optionally stored in said processing unit 14, analyzing the signal SD1 and optionally the signal SD2 in order to determine the speed and/or distance travelled by the guided vehicle 2, wherein the processing unit 14 is in particular configured for using the signal SD1 for the determination of the speed and/or travelled distance when the guided vehicle 2 is moving according to the direction M, and the signal SD2 when the guided vehicle is moving in a direction opposed to the direction M.

[0012] The laser beam emitter 11 is configured for emitting a pulsed laser beam 111, wherein the frequency of the pulses is either maintained constant as shown in graphic A of Fig. 3 or dynamically tuned by the processing unit 14. Indeed, according to the present invention, the processing unit 14 is preferentially able to dynamically adapt and control the frequency of the pulses and/or the energy of the laser beam in function of the guided vehicle speed by calculating new control parameters and/or updating previously determined control parameters. For instance, when the guided vehicle starts moving according to an increasing speed comprised within a first speed interval SI1 = [0, V1], then the pulse frequency is controlled by the processing unit 14 which is configured for increasing said frequency with an increase of the guided vehicle speed 2, and when the guided vehicle is moving according to a speed comprised within a second speed interval SI2 =]V1, V2], then the pulse frequency is maintained constant by the processing unit 14. According to the present invention, the time interval ΔT between the time T_i at which a pulse is emitted and the time T_{i+1} at which the next pulse is emitted might be thus either constant or may vary, depending notably on the guided vehicle speed that has been previously determined by the system 1. Preferentially, said frequency is maintained constant by the signal SP of the processing unit 14 when the guided vehicle is moving at a speed greater than the speed V1, and is dynamically tuned by the processing unit 14 controlling the laser beam emitter 11 when the guided vehicle speed V is comprised between 0 and V1:

$0 \leq V \leq V1$.

[0013] Preferentially, the system 1 according to the invention comprises a feedback loop designed for controlling the pulse frequency of the laser beam emitter by means of the processing unit 14. Said feedback loop is in particular used for the detection of the first pulse emitted by the laser beam emitter 11 when the guided vehicle starts moving. By means of said feedback loop, the processing unit 14 is able to control the laser beam emitter 11 and to force the latter to

a) either maintain the duration of the first laser pulse,
b) or increase the pulse frequency so that the resulting consecutive warm spots on the rails surface 31 intersect with each other mimicking a single warm spot on said rail surface 31 and thus said first laser pulse whose duration has been maintained,

until the IR detector 12,13 detects a first warm spot, i.e. until it detects the beginning of the first interaction area resulting from the interaction of the first pulse with the rail surface 31 (case (a)) or from the interaction of the series of pulses whose frequency is choses for creating a series of warm spots intersecting with each other (case (b)), so that when the guided vehicle starts moving, the first warm spot has preferentially a length that is equal to or greater than ΔX. By this way, the processing unit 14 is able to associate the detection of the first warm spot to the first pulse or to the series of pulses according to case (b) when the guided vehicle starts moving, the first pulse or the last pulse of said series of pulses being then preferentially separated from the next pulse by a time interval predefined in a memory of the processing unit 14 and used by the latter for dynamically tuning the frequency of the laser beam pulses. In particular, the detection of the first warm spot automatically launches within the processing unit 14 a counting of the pulses and of the detected warm spots, which advantageously ensures the correct correlation between the pulse emitted at the time T_i and the corresponding detection of the resulting warm spot detected at time T'_i, since the n^{th} detected warm spot simply corresponds to the n^{th} pulse, once the first pulse and first warm spot have been correlated according to the previous explanation.

[0014] According to another preferred embodiment, the processing unit is configured for evaluating if the time $\Delta T_i = T_i' - T_i$ is going to be greater than a first predefined value, and if this is true, then the processing unit 14 dynamically controls the pulse frequency and/or beam energy of the laser beam emitter, wherein the dynamic control comprises triggering a next pulse only if the warm spot of a previous pulse has been detected by one of the IR detectors. By this way, if the guided vehicle starts moving and the wheels slip, a single pulse will be emitted by the laser beam emitter until the warm spot resulting from said single pulse is detected by one of the IR detectors, said detection triggering the emission of the next pulse, until the time ΔT_i is smaller or equal to the first predefined value, after what the pulse frequency becomes for instance constant.

[0015] Optionally and advantageously, the processing unit 14 is configured for determining or evaluating if the time interval separating the time T_i at which a pulse P_i is emitted and the time T'_i at which the corresponding warm spot is detected by the IR detector is going to exceed a second predefined value, and if this is true, then the processing unit 14 restarts counting the pulses. Indeed, as the thermal spot dissipates with increasing time, there is always a maximum possible time of reliable detection above which the thermal footprint will be too weak for a proper detection. This maximum possible time of reliable detection is said second predefined value, which is in particular managed and calculated by the processing unit 14 in function of internal parameters such as output laser energy or intensity, and/or external parameters such as ambient temperature. The second predefined value might be stored in a memory of the processing unit and frequently recalculated. Preferentially, once the second predefined value is exceeded, the processing unit 14 triggers a new laser pulse and restarts the counting of the pulses and the calculation of the guided vehicle speed and/or distance.

[0016] According to the present invention, the pulsed laser beam is aligned with a first direction D1 configured for pointing to a first location on the rail surface 31 when the system 1 is installed on-board the guided vehicle 2 and the latter is guided by said rail 3 along said route. Preferentially, said rail surface 31 is a part of the rail that is located the farthest from a contact of a guided vehicle wheel with the rail, in order to avoid any drawback from a braking of the guided vehicle that may heat up the rail. Said rail surface 31 might be for instance the top surface of a rail head, or a side of said rail, e.g. at least one of the lateral faces of a rail web. Therefore, when the guided vehicle is moving, the laser beam will interact discontinuously (i.e. only each time a pulse is emitted and during the duration of said pulse) with the rail surface at different interaction areas I_i, creating a series of successive warm spots or thermal footprints F_i (see I1-I4 on Fig. 2), which will be successively detected by the IR detector 12 or the other IR detector 13 depending on the direction of displacement of the guided vehicle 2. As the guided vehicle speed increases, the distance between consecutive thermal footprints will also increase in the particular case the processing unit 14 maintains the pulse frequency of the laser beam constant.

[0017] The signal SP is provided by the processing unit 14 as input for the laser beam emitter and allows a determination and a control of the time T_i at which a pulse P_i will be emitted. A signal SP is schematically represented in graphic A of figure 3 in function of the time for a moving guided vehicle. In particular, when the guided vehicle starts moving, the signal SP may comprise information about the start and the end of the first pulse if the latter is a pulse that lasts until the IR detector 12 detects said first warm spot, or information about the time T1_1 of the emission of the first pulse of the series of pulses according to case (b) and the time T1_n of the emission of the last pulse of said series of pulses. According to the present invention, the time T_i is the time at which a pulse is emitted, being further preferentially supposed that, apart from case (a) wherein the duration of the pulse is intentionally increased, each pulse is short, so that the time corresponding to the end of the pulse emission is close to T_i, the pulse being instantaneous or quasi-instantaneous.

[0018] The system 1 according to the invention comprises said IR detector 12, and preferentially another IR detector 13, each being configured for having a field of view F21, F22 respectively aligned with a second direction D21 and a third direction D22 pointing respectively to a second location and a third location on said rail surface 31 and each designed for defining a detection area A21, A22 on the rail surface 31 when the system 1 is installed on-board the guided vehicle 2 and the latter is guided by said rail 3 along said route. The second direction D21 is different from said first direction (D1) in order to have the detection area A21 separated from the interaction area I1 of the pulsed laser beam 111 with the rail surface 31 by a predefined distance ΔX. Optionally, if the system 1 comprises two detectors, the third direction D22 is further different from the first and second direction in order to have the corresponding detection area A22 separated from the interaction area I1 by another predefined distance which might be preferentially equal to ΔX.

[0019] Each IR detector 12, 13 according to the invention is further configured for outputting a signal D, respectively SD1 for the IR detector and SD2 for said other IR detector, said signal D being designed for enabling a determination of the time T'_i at which the warm spot corresponding generated at the interaction area I1 has been detected by the IR detector. Graphic B of figure 3 schematically presents a signal SD1 according to the invention, wherein a warm spot resulting from a pulse emitted at time T_i is detected at time T_i'.

[0020] The processing unit 14 is configured for determining the distance travelled by the guided vehicle (2) and/or its speed from the signal SP, the predefined distance ΔX, the signal SD1, and optionally from said another predefined distance and the signal SD2. Preferentially, the speed V of the guided vehicle moving in the direction M is given by:

$$V = \frac{\Delta X}{T'_i - T_i}$$

wherein the signal SP provides the time T_i at which a pulse P_i is emitted and interacts with the rail surface 31 at an interaction area I_i, and the signal SD1 provides the time T'_i at which the warm spot located at the interaction area I_i is detected by the IR detector 12. The same concept applies mutatis mutandis when the guided vehicles is moving according to a direction opposite to M, wherein the speed is determined from the signal SD2 provided by said another IR detector 13, said another predefined distance, and the signal SP.

Claims

1. System (1) for determining the speed of a guided vehicle (2) and/or the distance travelled by said guided vehicle (2), the latter being guided along a route by at least one rail (3), the system (1) comprising:

    - a laser beam emitter (11) configured for emitting a pulsed laser beam (111) aligned with a first direction (D1) configured for pointing to a first location on a rail surface (31) when the system (1) is installed on-board the guided vehicle (2) and the latter is guided by said rail (3) along said route;
    - at least one IR detector (12, 13) configured for having a field of view (F21, F22) aligned with a second direction (D21, D22) in order to point to a second location on the rail surface (31) when the system (1) is installed on-board the guided vehicle (2) and the latter is guided by said rail (3) along said route, wherein the second location is separated from the first location by a predefined distance ΔX;
    - a processing unit (14) configured for controlling the laser beam emitter (11) according to control parameters and for determining the distance travelled by the guided vehicle (2) and/or its speed from the predefined distance ΔX, a signal D (SD1, SD2) related to a detection by the IR detector (12) of a warm spot at interaction area (I1, I2, I3) of the laser beam pulse with the rail surface (31) and said control parameters of the laser beam emitter (11).

2. System (1) according to claim 1, wherein the processing unit (14) is configured for outputting a signal SP (SP), wherein said signal SP (SP) is designed for controlling the time T_i at which a pulse P_i has to be emitted according to said control parameters.

3. System (1) according to claim 1 or 2, wherein the field of view (F21, F22) and said second location are configured for defining a detection area (A21, A22) on the rail surface (31) through which interaction areas (I1, I2, I3) are detected at said second location.

4. System (1) according to claims 1-3, wherein the IR detector (12, 13) is further configured for outputting the signal D (SD1, SD2) that is designed for enabling a determination of the time T'i at which the interaction area (I1) has been detected.

5. System (1) according to one of the claims 1-4, wherein the first direction (D1) and the second direction (D21, D22) are in a same plane.

6. System (1) according to one of the claim 1-5, wherein the first direction (D1) and/or the second direction (D21, D22) are perpendicular to the rail surface (31) when the system (1) is installed on-board the guided vehicle and the latter moving along said route guided by said rail (3).

7. System (1) according to one of the claims 1-6, wherein the rail (3) comprises a foot to be directly or indirectly installed on a ground, a web supported by said foot and to which is attached a head, and wherein the rail surface (31) according to the invention is the top surface of the rail head or at least one of the two lateral surfaces of the rail web.

8. System (1) according to one of the claims 1-7, wherein the IR detector is installed in a forward and/or backward position compared to the position of the laser beam emitter, so that the second location is located forward and/or backward compared to the first location when considering a direction (M) of displacement of the guided vehicle (2).

9. System (1) according to claims 8, wherein the IR detector (12) is installed in a backward position compared to the position of the laser beam emitter in order to have said second location located backward the first location when considering a direction of displacement (M) of the guided vehicle, and wherein the system (1) comprises another IR detector (13) installed in a forward position compared to the position of the laser beam emitter in order to define a third location for detecting interaction areas, wherein said third location is situated forward the first location.

10. System (1) according to one of the claims 1-9, wherein the processing unit (14) is configured for correlating each emitted pulse with a warm spot once the guided vehicle is moving.

11. System (1) according to one of the claims 1-10, wherein the processing unit is configured for determining the speed V of the guided vehicle from the equation:

$$V = \frac{\Delta X}{T'_i - T_i}$$

wherein the processing unit (14) is configured for determining the time T_i at which a pulse P_i has to be emitted for interacting with the rail surface (31) at an interaction area I_i, and the signal D (SD1, SD2) is configured for providing the time T'_i at which the warm spot located at the interaction area I_i has been detected by the IR detector (12, 13).

12. System (1) according to one of the claims 1-11, wherein the processing unit (14) is configured for dynamically adapting a resolution of the travelled distance and/or speed measurement to an actual guided vehicle speed by changing the pulse frequency and/or the pulsed laser beam energy.

13. Method determining the speed of a guided vehicle (2) and/or the distance travelled by the guided vehicle (2), the latter being guided along a route by at least one rail (3), the method comprising the following steps:

- emitting a pulsed laser beam (111) from a laser beam emitter (11) of the guided vehicle (2) controlled by control parameters of a processing unit (14), wherein said pulsed laser beam (111) is directed to a first location on a rail surface (31) of the rail (3) and is configured for interacting with the rail surface (31) by temporarily creating a warm spot at an interaction area (I1) with said rail surface (31);
- detecting the warm spot by means of a IR detector (12), wherein a detection area (A21, A22) of the IR detector is located at a second location on said rail surface (31) that is separated from the first location by a predefined distance ΔX;
- determining the speed and/or distance travelled by the guided vehicle (2) from the predefined distance ΔX, a signal D (SD1, SD2) related to the detection of said warm spots and the control parameters configured for controlling the emission of the laser beam pulses.

14. Method according to claim 13, wherein the speed of the guided vehicle (2) is determined from the equation:

$$V = \frac{\Delta X}{T'_i - T_i}$$

wherein V is the guided vehicle speed, the signal SP (SP) the time T_i is determined by the processing unit (14) and controls the time at which a pulse P_i is emitted for interacting with the rail surface (31) at an interaction area I_i, and the signal D (SD1, SD2) provides the time T'_i at which the warm spot located at the interaction area I_i is detected by the IR detector (12, 13).

15. Method according to claim 13 or 14, comprising dynamically adapting the pulse frequency and/or the pulsed laser beam energy in function of an actual guided vehicle speed.

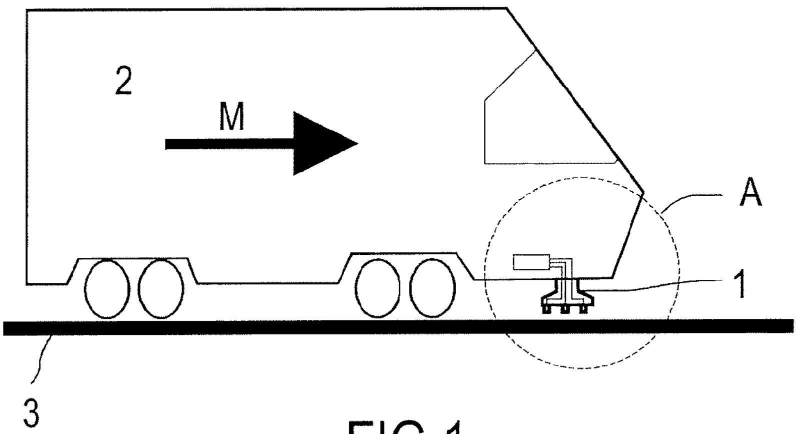
2
M
A
1
3

FIG 1

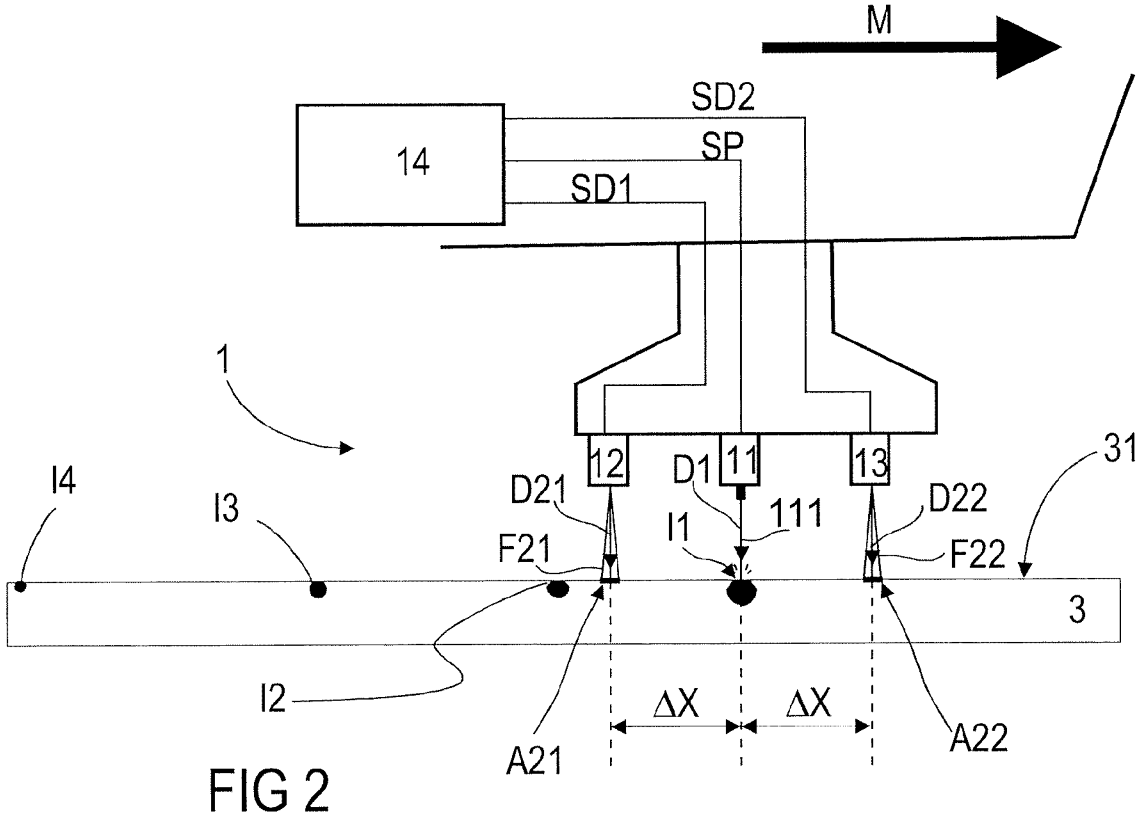
M
SD2
14
SP
SD1
1
12
11
13
31
I4
I3
D21
D1
111
D22
I1
F21
F22
3
I2
ΔX
ΔX
A21
A22

FIG 2

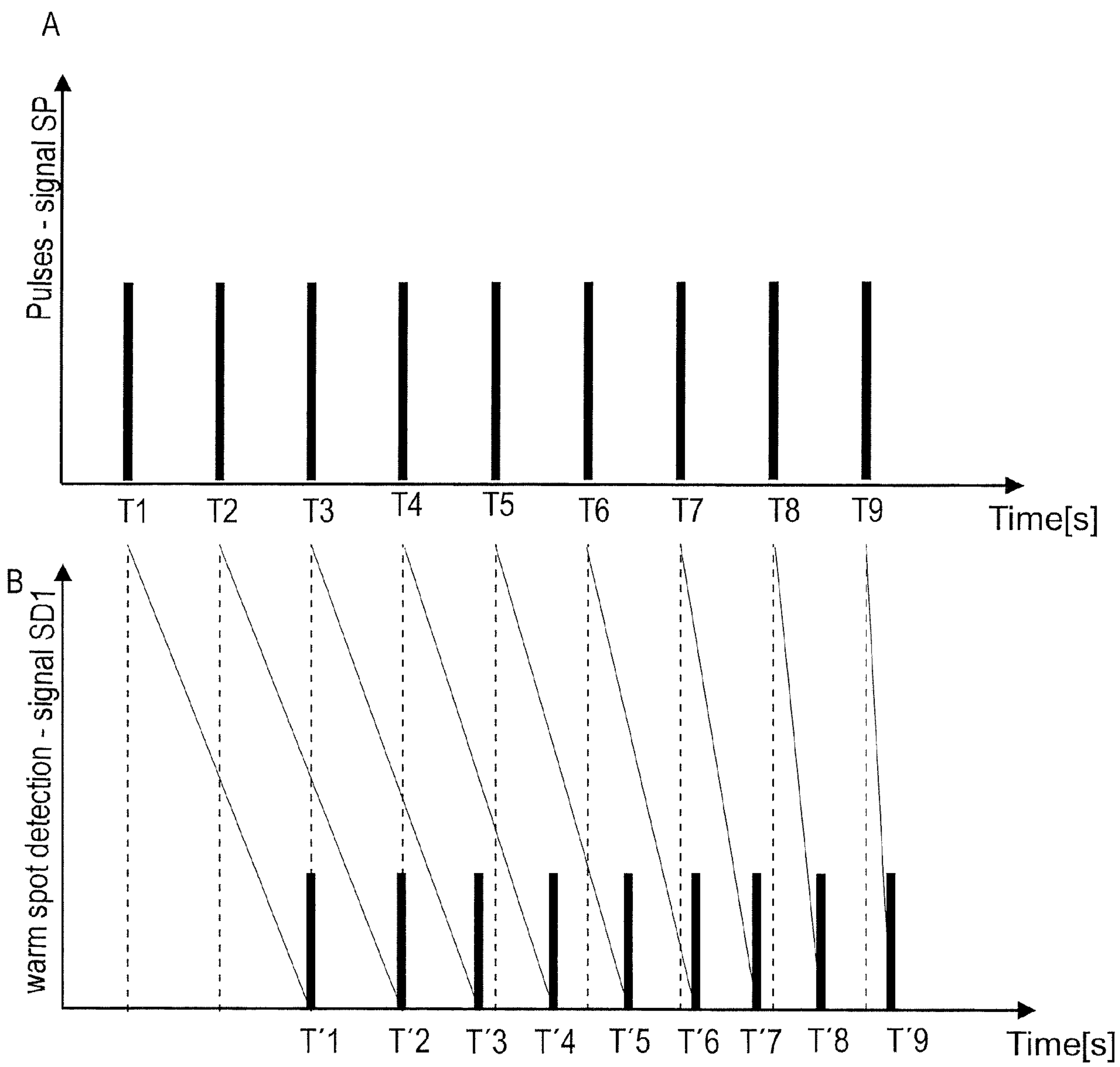
A
Pulses - signal SP
T1
T2
T3
T4
T5
T6
T7
T8
T9
Time[s]
B
warm spot detection - signal SD1
T'1
T'2
T'3
T'4
T'5
T'6
T'7
T'8
T'9
Time[s]

FIG 3

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EUROPEAN SEARCH REPORT

Application Number
EP 16 38 0014

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 22 39 896 A1 (SIEMENS AG) 28 February 1974 (1974-02-28) * page 2 - page 7; claim 4; figures 1,2 * -----	1-15	INV. B61L25/02
X	WO 2009/030519 A1 (SIEMENS SCHWEIZ AG [CH]; REICHLIN ANTON [CH]; MUELLER XAVER [CH]) 12 March 2009 (2009-03-12) * claim 1; figure 1 * -----	1-15	
A	DE 195 22 265 C1 (ABB RESEARCH LTD [CH]) 14 August 1996 (1996-08-14) * abstract; figures 1,2 * -----	1-15	

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 September 2016	Plützer, Stefan

CATEGORY OF CITED DOCUMENTS

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