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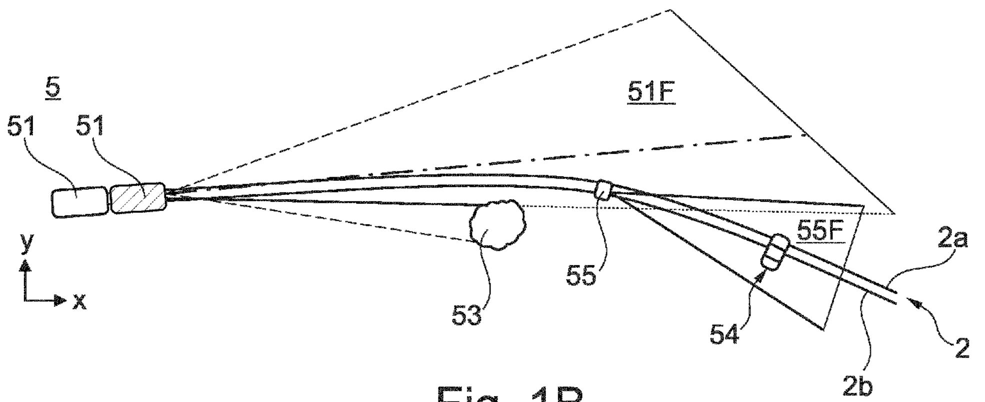

Fig. 1B

(57) Abstract: An ultra-lightweight railway drone vehicle (100 -500) includes a vehicle body (110-510) at least two track wheels (151, 152, 251, 252) for running on rails (2a, 2b) of a railway track (2). The at least two track wheels are rotatably connected with the vehicle body. At least one first sensor (S1-S3) for detecting obstacles (54, 741, 742, 840) on the railway track (2) is mounted on and connected with the vehicle body. A propulsion system is connected with the vehicle body for operating the railway drone vehicle at a speed of at least 50 km/h and/or beyond a maximum speed limit of a given type of the rails (2a, 2b), the railway track (2) and/or a segment of the railway track (2).

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Description

RAILWAY DRONE VEHICLE AND RAILWAY VEHICLE SYSTEM

Technical field

[0001] The present invention relates to improving the safety of rail transport. More particularly, the present invention relates to a railway drone vehicle sensing for dangerous situations such as damages of the railway track, obstacles and/or persons on the rail track while travelling ahead a railway vehicle, to a railway vehicle system including the railway vehicle and the railway drone vehicle and to related methods.

Background

[0002] For example, fallen trees, a landslide and vehicles such as a car, a bus or a truck stalled or left on the rails an animal or a person may form an obstacle obstructing the rail track ahead of a train. A collision between the moving train and the obstacle may result severe damages and even in a loss of life. Likewise, damages of the railway track may cause damaging the train (e.g. derailment of the train).

[0003] With increasing speed of the train both the collision risk and the energy released during or after a collision with the obstacle and/or a derailment may increase. In particular, the braking distance to safely bring the train to a complete stop in front of a hazard increases with the train speed. Note that the breaking or stopping distance may be long.

[0004] Therefore, an early warning system for such potentially dangerous situations on the rail track is particularly desirable for trains travelling at high speeds, for example at a speed of at least 100 km/h or even at least 160 km/h.

[0005] Further, curves of the railway track and/or lateral fix object next to the railway track may make it impossible for the driver or any LOS (line of sight) sensors fitted on the train to detect obstacle timely enough.

[0006] The publication WO 2004036529 A1 describes a system for preventing trains from derailing and colliding with hazards on railways is disclosed. The system includes a safety vehicle (i.e., 'trolley') that travels along a railway ahead of a train. The train and trolley each include GPS receivers which constantly provide GPS location information to a computer in the train. The computer calculates the distance between the trolley and the train, speed at which the train is traveling, and the distance required for the train to stop. The computer transmits acceleration and deceleration commands to the trolley and/or train to maintain a safe distance between the trolley and the train. The computer thereby keeps the safety vehicle far enough ahead of the train to allow the train to stop prior to reaching the safety vehicle should the safety vehicle impact an object, derail or detonate an explosive device on the railway ahead of the train, yet close enough to the train to maintain communication between the safety vehicle and the train. This approach may avoid serious damage to the train and possibly derailment of the train. However, the trolley may collide with foreign objects or even people on the rail without using the brakes.

[0007] The publication WO 2003068577 A1 describes a train having a guiding dummy molded to fit the front of the train, attached with two parallel hydraulic pistons. The dummy extends along the track in front of the train relative to its speed. At top speed the dummy is fully extended, while is right up against the drivers carriage when stationery. The dummy is well below the driver's line of sight. The hydraulic pistons alternatively 'push' and 'pull' the dummy away from or towards the drivers carriage depending on the speed that it is travelling. Laser sensors in front of the dummy help to alert the driver to any obstacles on the track. The dummy may derail the obstacle prior to the train reaching it or alternatively allow more time for braking prior to the train itself colliding with the obstacle. Collision with an obstacle would also apply automatic braking to the train. As the guiding dummy is permanently attached to the train using the hydraulic pistons, the distance between train and the guiding dummy is limited. Accordingly, obstacles ahead of the train may be detected too late to prevent severe damages.

[0008] The publication WO 2008017821 A2 describes an apparatus including a platform means for moving along a path; a guide means for directing the movement of said platform means; and a sensor means for detecting a threat to security, in particular a bomb; said sensor means being mounted on said platform means. The guide means may be a rail, a pair of rails, a conductor, which may be buried, a passageway, or a radio signal. The platform may be implemented as a "robot" with a number of sensors that traverses railroad tracks in front of a train. But even if the platform is implemented as a so called Hi-Rail-equipped truck, achievable speeds and/or operating ranges may be too low. The apparatus may also utilize an unmanned aerial vehicle (UAV) operating away from the platform. UAVs may achieve comparatively high speeds. However, the operating ranges of UAVs may be low. In particular, the operating range and or the speed of UAVs of reasonable cost may be too low. Further, UAVs may not be operable in tunnels, between masts, near overhead line, in zones with dense population or intense railway operation and/or under bad weather conditions. Even further, UAVs would have to comply with flight regulations in addition to railways safety regulation for this purpose.

[0009] The publication US 5 786 750 A describes a self-propelled remotely controlled pilot vehicle adapted for use on rail tracks to monitor hazardous conditions and obstacles on the railroad tracks. The pilot vehicle precedes a train along the railroad tracks at a distance which will allow the train to come to a complete stop in the event the pilot vehicle encounters a hazardous condition on the track. The pilot vehicle is equipped with a sensor array which measures a variety of different parameters such as the presence of noxious gases, moisture in the atmosphere, breakage in one or both rails of the track and orientation with respect to the force of gravity as well as the yaw, pitch and roll attitude of the tracks upon which the pilot vehicle is riding. The pilot vehicle is also equipped with a television camera which provides a visual image of the railroad track ahead of the pilot vehicle to the engineer of the train. An infrared camera which is mounted on the front of the pilot vehicle generates an infrared image of the tracks. Information gathered by the pilot vehicle's sensor array is supplied to a computer on board the pilot vehicle and is also transmitted to the train to enable the engineer to be apprised of conditions existing on the tracks ahead of the train in order to have time to react to dangerous situations on the railroad tracks. However, the remotely controlled pilot vehicle has comparatively high purchase costs and/or operating costs.

[0010] This applies also to the robotic vehicle described in the publication US 5 429 329 A and having conventional train flanged wheels riding upon common railroad tracks. The body of the vehicle encloses a conventional diesel electric power unit with speed characteristics comparable to the train it precedes. The power unit is controlled by a computer program, but has remote control override provisions in the software as directed by the engineer in the locomotive cab following the robotic vehicle (RV). The RV has a television camera viewing the track ahead and a transmitter for sending the video signal to the locomotive cab's TV monitor/video cassette recorder. The range and power of the electromagnetic wave exchange directly between the RV and cab will be low power broadcasts and signal frequencies as assigned by the FCC. The RV has safety sensors as described in the detailed description which display warnings in the locomotive cab for the engineer to apply the train's brakes in time, thus preventing an accident, since the distance between the train and the RV is approximately 1 to 2 miles.

[0011] The publication WO 2012 040794 A1 describes an inspection vehicle implemented as a drone that is remotely controlled by a central command center, and independently of a train. The unmanned railway track inspection vehicle includes a controller for determining that the vehicle encounters a hazard. The controller is configured to automatically (i.e. without human intervention) reduce the speed of the inspection vehicle responsive to determining that the inspection vehicle encounters the hazard. The speed of the inspection vehicle is automatically reduced when encountering the hazard so that the vehicle does not encounter the hazard at an unreasonably high speed. However, the operating range of the inspection vehicle may be too low for operating it as pilot vehicle preceding a high speed train.

[0012] The publication EP 1 037 788 A1 describes self-propelled trolley remotely controlled from a train locomotive, able to proceed in front of the same train, at a suitable distance, or frontally coupled to the same train, when the train is stopped, or during the crossing of critic switching platforms, and provided with sensor means to reveal anomalies, obstacles, etc. along the railroad; an integration system between the train and the trolley, to pilot the trolley from the train and transfer from the trolley to the train any information revealed; and a trolley self-elimination system, with forced ejection from the railroad. Said trolley has an extra-flat profile, made up of ultra-light material and provided with ballast, in order to simulate the train effect, said ballast being particularly comprised of a removable plastic container, filled with water, lead spheres or any other substance which, once released, does not hamper the coming train. Accordingly, the operating range of the self-propelled trolley may be too low for operating it as pilot vehicle preceding a high speed train.

[0013] Furthermore, the operating range of the above described railway vehicles is typically limited by railways safety regulation to a released operation block or segment of the railway track. Accordingly, the time for safely stopping a following train may be too low, in particular when the vehicle is reaching the end of the operation block.

<u>Problem to be solved</u>

[0014] It is a task of the invention to provide methods, systems and devices allowing for safe early warning with improved performance and/or lower costs even for trains capable of travelling at high speeds and/over longer distances.

<u>Solution according to the invention</u>

[0015] Said task is solved by the subject matter of the dependent claims.

[0016] According to an embodiment of an ultra-lightweight railway drone vehicle for (autonomously) operating ahead of a railway vehicle, in particular a locomotive and/or a train, the railway drone vehicle includes a vehicle body, at least two track wheels for running on rails of a railway track, at least one first sensor for detecting obstacles on the railway track, and a propulsion system connected with the vehicle body for operating the railway drone vehicle at a speed of at least 50 km/h and/or beyond a maximum speed limit of a given type of the rails, the railway track and/or a segment of the railway track. The at least one first sensor is mounted on and/or connected with the vehicle body. Each of the at least two track wheels is rotatably connected with the vehicle body.

[0017] The term "ultra-lightweight railway drone vehicle" as used in this specification intends to describe that the railway drone vehicle is at least mainly, more typically as far as possible made up of light or even ultra-light materials, light or even ultra-light structures and/or light or even ultra-light components to achieve low, more typical minimal overall weight. In particular, construction principles, design rules as well as technologies from the aerospace industries and UAVs may be used. At least some of the components may be miniaturized; in particular components referring to energy storage, traction and breaking as well as any electronic equipment like sensors, control components and transmission components.

[0018] In the following, the railway drone vehicle is also referred to as drone vehicle. Further, the railway track is in the following also referred to a rail track.

[0019] A weight of the railway drone vehicle is typically at most 150 kg, more typically at most 100 kg, even more typically at most 70 kg, for example in a range between 20 kg to 60 kg. Due to the ultra-lightweight set-up, a comparatively high operation range on the railway track can be achieved. Note that a much higher operation range can be achieved at lower costs compared to UAVs of similar weight and/or size. Further, the comparatively low mass allows a comparatively low braking distance of the railway drone vehicle of for example less than about 100 m, even when running at a speed of 160 km/h. Even further, (even manually) lifting the railway drone vehicle and/or docking to railway vehicle may be facilitated. For example, the railway drone vehicle may be lift /displaced by four or even two persons only.

[0020] Furthermore due to the comparatively low weight of said drone vehicle, the railway drone vehicle may not be detectable by weight sensors of an existing wayside traffic regulation system, often also referred to as railway signalling and traffic management systems, monitoring the railway track and the railway vehicles on the railway track, and assigning, depending on the conditions, cleared operation blocks (released operation blocks) to the railway vehicles for running.

[0021] Accordingly, the railway drone vehicle may enter / operate in an operation block ahead of the cleared operation block for the railway vehicle, in particular a not yet cleared operation block for the way the vehicle. Thus, a large enough distance for stopping the railway vehicle can be ensured in case the railway drone vehicle detects a hazard, animals or person at risk on or next to the railway track.

[0022] After entering and not yet cleared operation block; the drone vehicle typically also searches for trains or other railway vehicles running ahead of the drone vehicle. For this purpose drone vehicle may use the at least one sensor.

[0023] In particular, the vehicle body, typically at least a chassis, a frame and/or a streamlined fairing of the vehicle body may be at least mainly made of dielectric composite(s) such as a fiber-reinforced plastic, for example fibreglass (GFK) and/or another stable and light-weight material, in particular a light-weight non-magnetic material such as aluminum or magnesium.

[0024] Using fiber-reinforced plastics for the vehicle body and preferably also for the track wheels (to the extent reasonable / possible) may reduce the radar cross-section (RCS) and thus facilitate hiding the railway vehicle from a radar detection system of the wayside traffic regulation system.

[0025] Alternatively and/or in addition, stealth technology (also known as low observable technology, LO technology) such as appropriate vehicle shaping and applying or spraying radar-absorbent materials may be used to reduce radar detectability (radar signature) of the railway drone vehicle. Alternatively or in addition, a visual detectability (visual signature) of the railway drone vehicle, an infrared detectability (infrared signature) of the railway drone vehicle and/or a sonar detectability (sonar signature) of the railway drone vehicle may be reduced using a respective stealth technology. In particular, a multi-spectral camouflage technique may be used.

[0026] For example, the radar signature and/or the sonar signature of the railway drone vehicle may be comparable to or even lower than respective signatures of a larger bird such as a common buzzard flying low over the railway track.

[0027] Likewise, using non-magnetic material for the vehicle body and preferably also for the track wheels may facilitate hiding the railway drone vehicle from a magnetic and/ or an electro-magnetic detection system of the wayside traffic regulation system.

[0028] Unless the railway vehicle, the railway drone vehicle is typically not detectable by a railway signaling system and/or traffic management system, e.g. an ATO/ETCS/signaling system. The railway vehicle and the railway drone vehicle may be handled (supervised) by the railway signaling system and/or traffic management system as a single entity (with a unique footprint).

[0029] Further, the track wheels and/or a respective axis holding the track wheels may have a high Ohmic resistance of e.g. at least 100 k Ohm or even at least 500 k Ohm. For example, the track wheels may be partly or completely made of a high-Ohmic material such as fiber-reinforced plastic. Accordingly, the railway drone vehicle may not be detectable by an electric sensor of the wayside traffic regulation system.

[0030] In particular, an electric resistance between the running surfaces of two of the track wheels configured to run in parallel on two parallel tracks of the railway track may be at least 200 k Ohm or even at least 1 M Ohm.

[0031] Note that the railway drone vehicle is typically configured for traveling on two parallel rails of the railway track, and therefore typically has two pairs of track wheels. The track wheels of each pair may be connected with each other and/or the vehicle body via a respect axis.

[0032] Only one of the pairs of track wheels may be driven by a motor, in particular an electric motor electrically connected with an electrical energy storage typically forming the propulsion system. In the following, the railway drone vehicle is also referred to as self-propelled railway drone vehicle.

[0033] Alternatively or in addition, electric motor may be supplied from overhead lines or power rails.

[0034] The track wheels of the other pair may be auxiliary track wheels. The auxiliary track wheels may be smaller than the track wheels drivable by the motor.

[0035] Alternatively or in addition, the propulsion system may include one or more propellers driven by the motor or an additional motor, in particular an additional electric motor.

[0036] In other words, the propulsion system may include and/or be implemented as an electric propulsion connected to the vehicle body and an electrical energy storage electrically connected with the electric propulsion and allowing movements within the range of the electrical energy storage.

[0037] The propulsion system, in particular the (electric motor) is typically connected with and controlled by a traction control unit of the drone vehicle.

[0038] The electrical energy storage may include and/or be implemented as a battery or a super capacitor.

[0039] Furthermore, the electrical energy storage may have a capacity allowing operating the drone vehicle at up to about 160 km/h for at least one or two hours, typically up to a few hours.

[0040] Even further, brake energy recuperation may be used to prolong the operating time without external recharging the electrical energy storage.

[0041] For example, the electric motor may be operable to work as a generator in a braking mode of the railway drone vehicle.

[0042] The total power consumption of the drone vehicle may be in a range from 1 kW to 2 kW at a speed of 80km/h.

[0043] The capacity of the electrical energy storage may be in a range from about 1 kWh to about 10 kWh.

[0044] Further, a charging time of the electrical energy storage may be low, for example less than 10% of a driving time of the drone vehicle. The driving time of the drone vehicle may be in a range from one hour to several hours.

[0045] Alternatively or in addition, the drone vehicle may have a (powerful) mechanical brake(s) such as a disc brake to facilitate breaking, in particular emergency braking after detecting an obstacle or another hazard source on or close to the railway track.

[0046] For example, the drone vehicle may brake with a deceleration up to 1 g or even up to 2 g.

[0047] Note that the drone vehicle may have, in addition to a docking connector for mechanically docking to the railway vehicle, an electric connector for charging the electrical energy storage in a docking mode of the drone vehicle using an internal power supply of the railway vehicle.

[0048] Typically, the drone vehicle has four track wheels. Note that the drone vehicle is lightweight and comparatively small. Therefore, more than four wheels would result in a higher rolling drag without significantly improving other relevant parameters like running smoothness of the drone vehicle.

[0049] The comparatively low weight of the railway drone vehicle also facilitate lifting the railway drone vehicle and docking the railway drone vehicle to the railway vehicle, in particular to the front side or front face of the railway vehicle. For this purpose, the railway vehicle may have a respective docking mechanism for the railway drone vehicle. The docking mechanism may be arranged on the front face of the railway vehicle.

[0050] For similar reasons, the size of the railway drone vehicle is typically comparatively low. For example, a height of the vehicle body or even the drone vehicle, a width of the vehicle body or even the drone vehicle, and/or a length of the vehicle body or even the drone vehicle may be less than or equal to 3 m or even less than or equal to 2.5 m.

[0051] Furthermore, the length of the vehicle body is typically larger than its width and height.

[0052] Accordingly, the field of view of a driver of the railway vehicle may not be impacted by the railway drone vehicle even when docked to the front side of the railway vehicle.

[0053] Further, the vehicle body, in particular a frame of the vehicle body may be foldable. Accordingly, the size of the drone vehicle may be lower when docked to the front side of the railway vehicle. This may reduce restrictions of the docking place on the front side of the railway vehicle. In addition, the (additional) aerodynamic drag of the railway vehicle carrying the drone vehicle may be reduced in this way.

[0054] Furthermore, the vehicle body may be at least substantially hull-shaped and/or shell-shaped when seen in a front view.

[0055] Accordingly, a (aerodynamic) drag coefficient c_w of the railway drone vehicle may be comparatively low when running on the rail track. Thus, the operating distance of the railway drone vehicle may be increased. For example, drag coefficient c_w may be at most 0.1 or even at most 0.05.

[0056] Alternatively and/or in addition, the vehicle body may be shaped and/or provided with appropriate aerodynamic elements like flaps known from aerospace industries to enable usage of aerodynamic forces for functions like driving stability (down-lift loads and/or yaw steering at high speed) and braking, in particular air brakes.

[0057] For example, an activatable air brake may be attached to the vehicle body and frame, respectively, typically to an upper portion of the vehicle body and frame, respectively.

[0058] Typically, an outer diameter of the vehicle body is larger than an inner diameter of the vehicle body by a factor of at most 1.5, more typically at most 1.2 when seen in front view and/or in a cross-section view.

[0059] Likewise, an area of the vehicle body between an outer boundary line of the vehicle body and an inner boundary line of the vehicle body may correspond to at most 20%, more typically at most 10% of an area defined by the inner boundary line when seen in front view and/or in a cross-section view.

[0060] The drone vehicle may include an airbag mounted to a front side of the drone vehicle. The airbag may be activated after detecting the hazard or person(s) at risk.

[0061] Accordingly, the person at risk as well the as drone vehicle may be protected against severe damages during a collision and/or the shock at least partly absorbed.

Furthermore, the inflated airbag may facilitate pushing a small obstacle out of the way in a soft manner.

[0062] Alternatively or in addition the drone vehicle may include a warning display for displaying a warning notice (alert).

[0063] Alternatively or in addition the drone vehicle may include a flashlight, a speaker and/ or a siren for emitting respective warning signals.

[0064] Accordingly, person(s) or animal(s) at risk may be warned while the typically breaking drone vehicle is approaching.

[0065] In one embodiment the warning display is formed on the front side of the airbrake that can be fold out.

[0066] The railway drone vehicle typically includes a wireless data transmission unit for communicating with the railway vehicle typically also having a respective wireless data transmission unit.

[0067] When the railway drone vehicle detects a hazard such as an obstacle or a person at risk, a respective warning signal may be transmitted to a main control unit of the railway vehicle via a wireless data link established between the wireless data transmission units of the railway drone vehicle and the railway vehicle. After receiving the warning message, the main control unit of the railway vehicle may decide to initiate braking.

[0068] Further, the railway drone vehicle may include a positioning system for determining a position of the railway drone vehicle. For example, the positioning system may be provided by and/or include a Global Positioning System (GPS) unit configured to (continuously) receive GPS location information associated with the drone vehicle from GPS satellites.

[0069] Likewise, the railway vehicle may also include a positioning system for determining a position of the railway vehicle and may also be be provided by and/or include a GPS unit which is configured to (continuously) receive GPS location information associated with the railway vehicle from the GPS satellites.

[0070] The positioning system of the railway drone vehicle and/or the positioning system of the railway vehicle may alternatively or in addition be provided by and/or include a respective inertial reference unit (e.g. based on one or more, typically multiple gyrometers and/or one or more accelerometers) and/or a respective visual odometry unit (e.g. based on a camera) and/or a respective or mechanical odometry unit (e.g. based on wheel turn counter) and/or use a pre-stored or an on-line cartography database.

[0071] The determined positions of the railway drone vehicle and the railway vehicle may be exchanged via a data link established between the wireless data transmission units of the railway drone vehicle and the railway vehicle and/or used for controlling a distance between the railway drone vehicle and the railway vehicle. Controlling the distance is typically performed by a main drone control unit of the the railway drone vehicle. Accordingly, the railway drone vehicle may cruise ahead the railway vehicle at a desired distance or in a desired distance range ensuring emergency braking to full stop of the railway vehicle prior to reaching a hazard area on or at the railway track.

[0072] As the desired distance and the desired distance range, respectively, typically depends on the speed of the railway vehicle, the speed of the railway vehicle is typically also transmitted via the wireless data link to the railway drone vehicle and the main drone control unit, respectively.

[0073] Likewise, the speed of the drone vehicle maybe transmitted via the wireless data link to the railway vehicle and its main control unit, respectively.

[0074] The main drone control unit is typically connected (via respective wireless or wired links) with the at least one first sensor, the traction control unit, the positioning system, the wireless data transmission unit, the airbag, the air brake, the warning display, the flashlight, the speaker and/or the siren.

[0075] Furthermore, the main drone control unit is typically configured to detect the hazard such as an obstacle using data received from the at least one first sensor, to classify the hazard, e.g. the obstacle, and to determine at least one of a position of the hazard (e.g. the obstacle), a speed of the obstacle, an acceleration of the obstacle, a path of the obstacle, a collision probability of the drone vehicle and/or the railway vehicle with the obstacle, and/or an estimated respective time of a collision with the obstacle.

[0076] One, more or even all these information may be used by the main drone control unit to determine if a warning message is to be sent to the the railway vehicle, if the drone vehicle is to be slowed down, to be prepared for a collision, and/or if the airbag, the air brake, the warning display, the flashlight, the speaker and/or the siren is to be activated.

[0077] Alternatively or in addition, one, more or even all these information may be transmitted via the wireless data link to the railway vehicle and its main control unit, respectively, where the final decision on braking the railway vehicle may be made by the main control unit the railway vehicle or a driver.

[0078] The at least one first sensor is typically mounted to an upper portion of the vehicle body. Accordingly, a surveillance area of the at least one first sensor, in particular the area that can be monitored by the at least one first sensor may be as large as possible.

[0079] The surveillance area of the at least one first sensor is typically at least substantially centered with respect to a driving direction of the railway drone vehicle and/or covers an area to be monitored in front of the railway drone vehicle.

[0080] In addition, the railway drone vehicle may have at least one second sensor for detecting obstacles on the railway track and having a surveillance area covering an area to be monitored behind the railway drone vehicle.

[0081] Accordingly, the railway drone vehicle may cruise further ahead the railway vehicle even if the railway track is curved. Thus, the reaction time and/or the available braking distance of the railway vehicle may be increased and the deceleration of the railway vehicle decreased, respectively.

[0082] The at least one second sensor is typically also mounted to the upper portion of the railway drone vehicle body.

[0083] Further, the surveillance area of the at least one second sensor may be at least substantially centered with respect to the driving direction and/or along an (longitudinal) axis of the railway drone vehicle.

[0084] Typically, the drone vehicle has two, three or even more first sensors and/or two, three or even more second sensor of the same and/or different sensor types.

[0085] Accordingly, the detection reliability and detection accuracy can be significantly improved.

[0086] Likewise, the railway vehicle may have at least one third sensor for detecting obstacles on the railway track and in front of the railway vehicle. Accordingly, the railway drone vehicle may safely cruise further ahead the railway vehicle.

[0087] The at least one third sensor may be connected with the main control unit of the railway vehicle.

[0088] Further, the surveillance area of the at least one third sensor may be at least substantially centered with respect to the driving direction of the railway drone vehicle.

[0089] Even further, the railway vehicle may have two, three or even more third sensors of the same and/or different sensor types.

[0090] The at least one first sensor, the at least one second sensor and/or the at least one third sensor may be selected from a group consisting of a radar, a LIDAR, an ultra-sonic sensor, in particular a sonar, a camera (optical, IR, time-of-flight), an infrared range finder and a laser.

[0091] The railway vehicle and the drone vehicle may form a (communicating) system, which is in the following also referred to as railway vehicle system. The system may be treated as one unit by a wayside traffic regulation system.

[0092] The railway vehicle may have an onboard ATO (Automatic Train Operation) system configured to control the railway drone vehicle and the main drone control unit, respectively.

[0093] The main control unit of the railway vehicle may be part of and/or be provided by the ATO system. In the following, the main control unit of the railway vehicle is also referred to as main vehicle control unit.

[0094] The ATO system of the railway vehicle may control the railway drone operation. The operating decision from the ATO system is typically taken automatically, more typically by a specific logic programmed inside the ATO on-board controller(s). However, an ATO human operator may take-over control. The enables the ATO human operator, typically located in a remote control center, to take control decision using pictures or obstacle detection alarms sent by the railway drone to the railway vehicle and further transmitted to the remote control center. The driver of the railway vehicle may also take over the control of the drone vehicle. This enables the train driver to controls the drone vehicle operation. For example, the decision of the driver to take over the control may be based on / triggered by pictures sent by the drone vehicle to the railway vehicle.

[0095] If no new control order is received from the railway vehicle or the driver, the railway drone typically operates autonomously, using the last orders received either from the ATO or the driver, and its own information provided by its sensors.

[0096] As will be explained in more detail below, the railway drone vehicle is typically operable in three (autonomous) modes: a cruising mode, in which the drone vehicle drives ahead from the railway vehicle, a controlled collision mode and a docking / undocking mode. The docking / undocking mode has typically two sub- modes, namely a docking mode for attaching to the railway vehicle and an undocking mode for releasing from the railway vehicle.

[0097] The 3 way of control enables the entity in charge of the control of the drone vehicle operation (either the ATO system, the driver or the drone vehicle itself) to decide which of the 3 modes (cruising mode, controlled collision mode and docking / undocking mode) is to be activated. The cruising mode (nominal mode) is typically set to avoid a collision with obstacles or persons. In the controlled collision mode the rolling drone is in some conditions allowed to collide with the obstacle. In the docking / undocking mode the drone vehicle may contact smoothly the rail vehicle front face and get locked on it / unlocked from it. In any of the 3 drone operation modes (cruising mode, docking/undocking mode and controlled collision mode), the drone vehicle typically operates permanently within the cleared operation block(s) of the railway vehicle. Accordingly, the drone vehicle operates always within the same operation block(s) as the rail vehicle independent of the train control process is (fixed or moving operation blocks. The drone may only enter into a next operation block after having received a “clearance for the next block“ - order from the railway vehicle it is slaved with or from the driver or an ATO remote human operator. The linear along the railway track between the railway vehicle and the end of its cleared operation blocks is in the following also referred to as remaining authorized distance.

[0098] According to an embodiment of a railway vehicle system, the railway vehicle system includes a railway vehicle including a main vehicle control unit and a self-propelled railway drone vehicle. The (self-propelled railway) drone vehicle includes at least one first sensor for detecting obstacles on a rail track and in front of the railway drone vehicle, and a main drone control unit connected with the at least one first sensor, and is configured to operate the railway drone vehicle on the rail track, ahead the railway vehicle and within one or more cleared operation blocks for the railway vehicle, to search autonomously for obstacles on the rail track using the at least one first sensor, and to send via a data connection with the main vehicle control unit a warning message to the railway vehicle after detecting an obstacle arranged on and/or at the rail track or approaching the rail track.

[0099] The data connection may be implemented as a wireless data link.

[00100] The main vehicle control unit is typically configured to control a speed of the railway vehicle and/or to decelerate the railway vehicle after receiving the warning message.

[00101] Further, the main vehicle control unit is typically operable as a master controller (primary controller) and the main drone control unit is typically operable as a slave controller (secondary controller) of the railway vehicle system.

[00102] The main drone control unit is typically configured to receive an instruction from the main vehicle control unit via the data connection requesting to operate the railway drone vehicle in a cruising mode to search autonomously for obstacles on the rail track while driving ahead the railway vehicle and within one or more cleared operation blocks.

[00103] In the cruising mode, the main drone control unit is typically configured to operate the railway drone vehicle ahead of a cruising zone of the railway vehicle.

[00104] Furthermore, the main drone control unit may be configured to operate autonomously in the absence of incoming instructions from the main vehicle control unit.

[00105] The main drone control unit may even be configured to autonomously decide enter a not yet cleared operation block.

[00106] After detecting a train or another railway vehicle running ahead in the not yet cleared operation block, the main drone control unit may operate the drone vehicle so that a predefined safety distance to the railway vehicle running ahead is not reached. The drone vehicle may also be slowed down or even stopped. Note that the railway vehicle running ahead may be detected using the at least one first sensor.

[00107] After detecting the obstacle or another hazard, the main drone control unit may decelerate the railway drone vehicle, and send a warning signal to the obstacle. Further, the railway drone vehicle may activate an airbag, a warning display, a flashlight, a speaker and/or a siren of the railway drone vehicle.

[00108] If a collision with the obstacle is unavoidable, the main vehicle control unit may switch from the cruising mode into a controlled collision mode, typically with reduced speed and/or activated airbag(s).

[00109] Further, the railway drone vehicle may be configured to approach the railway vehicle in a docking mode.

[00110] For example, the main drone control unit may be configured to operate the railway drone vehicle in the docking mode when the railway vehicle stops and/or when an energy stock level of the railway drone vehicle falls below a given threshold and/or a threshold that does not ensure reaching the next regular stop of the railway vehicle.

[00111] During approaching the railway vehicle, the railway drone vehicle typically drives at a lower speed, typically at a (very) low relative speed compared to the railway vehicle or even at a low absolute speed. For example, the railway drone vehicle speed may be lower than railway vehicle speed by 1 to 3 km/h. Furthermore, the speed of both the railway drone vehicle and the railway vehicle may be fairly low, typically 25 km/h or less. Accordingly, the sensitivity and/or the complexity of controlling during approaching may be reduced.

[00112] The railway vehicle is typically configured to lift the railway drone vehicle, to carry the railway drone vehicle and/or to place the railway drone vehicle to a front side or face of the railway vehicle.

[00113] According to an embodiment of a method for improving the safety of a railway vehicle when driving on a rail, the method includes instructing a self-propelled railway drone vehicle, which comprises at least one sensor, to drive on the rail, ahead the railway vehicle and within one or more cleared operation blocks of the railway vehicle, and to search autonomously for obstacles on the rail track during driving on the rail track using the at least one sensor.

[00114] After detecting am obstacle, a type of the detected obstacle, a position of the obstacle, a speed of the obstacle, an acceleration of the obstacle, a path of the obstacle, and/or a collision probability between the detected obstacle and at least one of the railway drone vehicle and the railway vehicle may be determined and/or estimated.

[00115] After detecting the obstacle, a warning message may be transmitted from the railway drone vehicle to the railway vehicle, in particular a collision risk alarm and/or a braking order / braking recommendation may be transmitted to the railway vehicle.

[00116] Further, the railway drone vehicle may decelerate after detecting the obstacle.

[00117] Even further, the railway drone vehicle may display a warning note and/or send (emit) warning signal(s) towards the detected obstacle and/or people at risk after detecting the obstacle. For example, visual and/or audio instructions such as “leave track immediately“ or other (pre-recorded) emergency instructions may be displayed and broadcast, respectively.

[00118] After transmitting the warning message to the railway vehicle, the railway vehicle may decelerate.

[00119] After detecting the obstacle, an airbag of the railway drone vehicle may be activated.

[00120] In particular in the cruising mode, position(s) and/or speed(s) of the railway vehicle may be transmitted from the railway vehicle to the railway drone vehicle.

[00121] Likewise, position(s) and/or speed(s) of the drone vehicle may be transmitted from the drone vehicle to the railway vehicle, in particular in the cruising mode.

[00122] Further, a new cleared operation block(s) for the railway vehicle may be transmitted to the railway vehicle from a control center for railway vehicles on the rail track.

[00123] Thereafter, the new cleared operation block(s) may be transmitted from the railway vehicle to the drone vehicle.

[00124] Further, the one or more cleared operation blocks may be updated (at the railway vehicle and/or the drone vehicle).

[00125] In addition, the drone vehicle may enter a not yet cleared operation block for the railway vehicle. However, the railway drone vehicle may only enter a not yet cleared operation block under certain circumstances, in particular in non-nominal ATO operating conditions like degraded modes, partial or total failure tests, and/or commissioning of the network infrastructure and/or signalling systems, but not during normal operation of the

vehicle system. In such an event, the drone vehicle typically searches autonomously for obstacles on the rail track and railway vehicles running ahead on the rail track.

[00126] Prior to driving on the rail track ahead the railway vehicle, the railway drone vehicle may undock from the railway vehicle.

[00127] When an energy stock level of the railway drone vehicle falls below a given threshold and/or when the railway vehicle stops, the railway drone vehicle may dock to the railway vehicle.

[00128] Thereafter, an electrical energy storage of the railway drone vehicle may be recharged in the docking mode using an internal power supply of the railway vehicle.

[00129] The above-described embodiments can be combined with each other in any way if not specified otherwise. Those skilled in the art will recognize additional features and advantages upon reading the following detailed description, and upon viewing the accompanying drawings.

Brief description of the figures

[00130] The attached drawings illustrate embodiments and together with the description serve to explain the principles of the invention. The elements of the drawings are shown relative to each other and are not necessarily to scale.

[00131] The same reference numbers denote similar or even equal components.

[00132] For better orientation, the drawings in FIG.1A to FIG. 9 are supplemented with a respective exemplary Cartesian coordinate system with x, y referring to orthogonal horizontal directions and z referring to the vertical direction. Typically, the (positive) x-direction refers to the normal driving direction of the railway drone vehicle and the railway vehicle, respectively, on the railway track. The only exception is FIG. 7A where the normal driving direction of the railway drone vehicle on the curved railway track depends on the time t and the position s(t) of the railway drone vehicle on the railway track, respectively.

[00133] FIG. 1A shows a schematic top view of a train running on railway track and obstacle on the railway track.

[00134] FIG. 1B shows a schematic top view of railway vehicle system with a railway vehicle running on a railway track and a railway drone vehicle running ahead the railway vehicle on the railway track, searching for an obstacle on the railway track and forming a railway vehicle system with the railway vehicle according to an embodiment.

[00135] FIG. 2A shows a schematic side view of railway drone vehicle according to an embodiment.

[00136] FIG. 2B shows a schematic top view of the railway drone vehicle illustrated in FIG. 2A according to an embodiment.

[00137] FIG. 2C shows a schematic front view of the railway drone vehicle illustrated in FIG. 2A according to an embodiment.

[00138] FIG. 2D shows a schematic side view and a schematic top view of a track body of the railway drone vehicle illustrated in FIG. 2A according to an embodiment.

[00139] FIG. 3A shows a schematic side view of the railway drone vehicle illustrated in FIG. 2A and a railway vehicle shortly after releasing the railway drone vehicle from a docked position at the railway vehicle according to an embodiment.

[00140] FIG. 3B shows a schematic top view of the railway drone vehicle and the railway vehicle illustrated in FIG. 3A according to an embodiment.

[00141] FIG. 3C shows a schematic side view of the railway drone vehicle and the railway vehicle illustrated in FIG. 3A with the railway drone vehicle docked to the front side the railway vehicle according to an embodiment.

[00142] FIG. 3D shows a schematic front view of the railway drone vehicle and the railway vehicle illustrated in FIG. 3C according to an embodiment.

[00143] FIG. 4A shows a schematic side view of the railway drone vehicle and a railway vehicle with the railway drone vehicle approaching the railway vehicle for docking according to an embodiment.

[00144] FIG. 4B shows front views of the railway drone vehicle and a railway vehicle with illustrated in FIG. 4A according to an embodiment.

[00145] FIG. 4C shows an early stage of docking the railway drone vehicle to the railway vehicle illustrated in FIG. 4A in a schematic side view according to an embodiment.

[00146] FIG. 4D shows a schematic front view of the railway drone vehicle and the railway vehicle illustrated in FIG. 4C according to an embodiment.

[00147] FIG. 5A to FIG. 5F illustrate the railway drone vehicle to the railway vehicle illustrated in FIG. 4A during further docking processes in respective schematic side views according to an embodiments.

[00148] FIG. 6A shows a schematic side view of railway drone vehicle with inflated airbags according to an embodiment.

[00149] FIG. 6B shows a schematic top view of the railway drone vehicle illustrated in FIG. 6A according to an embodiment.

[00150] FIG. 6C shows a schematic front view of the railway drone vehicle illustrated in FIG. 6A according to an embodiment.

[00151] FIG. 6D shows a schematic top view of a railway vehicle system including a railway vehicle and a railway drone vehicle according to an embodiment.

[00152] FIG. 7A shows a schematic side view of railway drone vehicle according to an embodiment.

[00153] FIG. 7B shows a schematic top view of a railway vehicle system including a railway vehicle and the railway drone vehicle illustrated in FIG. 7A during searching for obstacle on the railway track in front an behind the railway drone vehicle according to an embodiment.

[00154] FIG. 8A shows a schematic side view of railway drone vehicle according to an embodiment.

[00155] FIG. 8B shows a schematic front view of the railway drone vehicle illustrated in FIG. 8A according to an embodiment.

[00156] FIG. 8C shows a schematic top view of the railway drone vehicle illustrated in FIG. 8A and an obstacle according to an embodiment.

[00157] FIG. 9 shows a schematic top view of a railway vehicle system including a railway vehicle and the railway drone vehicle during searching for an obstacle on the railway track according to an embodiment.

[00158] FIG. 10A shows a schematic top view of a railway vehicle system including a railway vehicle and the railway drone vehicle according to an embodiment.

[00159] FIG. 10B and FIG. 10C illustrate processes of methods for operating the railway vehicle system illustrated in FIG. 10A.

Detailed description

[00160] FIG. 1A shows a schematic top view of a train 5 running on a curved railway track 2 with two rails 2a, 2b. The train 5 has one locomotive 51 and several wagons 52 four of which are shown figure 1A.

[00161] As illustrated in figure 1A, a line of sight (LOS) detection system of the locomotive 51 may not always be effective in detecting obstacles such as the exemplary car 54 on the railway track 2. In the exemplary situation, a tree 53 close to a curved section of the railway track 2 forms a viewing obstacle for the approaching locomotive 51. Accordingly, obstacles 54 on or close to the railway track 2 in the hatched zone 2z cannot be detected by the LOS detection system of the locomotive 51 prior to entering the curved section of the railway track 2. Thus, the obstacle 54 may be detected too late to avoid a collision.

[00162] Note that the stopping distance (braking distance) of the train 5 may be large, in particular for cargo trains typically having a huge mass (up to thousands of tons) and/or trains running at high speed (80 to 160 km/h or even above). In these cases, the stopping distance may exceed 500 m or even 700 m. The stopping distance may even exceed one km or even a few km for a mining train in a descending railway track section.

[00163] In the situation illustrated in figure 1A, even a larger field of view (FOV) 51F of the locomotive's 51 LOS detection system may not help to avoid the collision between the train 5 and the obstacle 54 as the obstacle 54 may even then be completely hidden behind the illustrated single tree 53. This is typically also the case when more or larger viewing obstacles than the single tree 53 are present and/or for a curved railway track section running through a narrow deep valley. In some situations, a larger field of view (FOV) 51F of the locomotive's 51 LOS detection system may help to avoid the collision between the train 5 and the obstacle 54. However, such an LOS detection system would be more complex and expensive.

[00164] Alternatively, a fixed way side obstacle detection system may be used. However, such an obstacle detection system is expensive and/or may be laborious to maintain.

[00165] FIG. 1B shows a slightly enlarged schematic top view of the train 5 close to the curved section of the railway track 2. However, an ultra-lightweight railway drone vehicle 55 is running ahead the train 5 on the railway track 2 and operates as detection device for obstacles on or close to the railway track 2. After detecting the obstacle 54 in its FOV 55F, the drone vehicle 55 may send a warning message to the train 5. After receiving the warning message, the train may safely stop prior to reaching the obstacle 54 (and the drone vehicle 55). This is due to timely detecting the obstacle 54 on the drive path of the train 5.

[00166] Likewise, the rolling drone vehicle 55 typically having a much shorter braking distance than the train 5 may break and come to full stop after detecting the obstacle 54 prior to reaching the obstacle 54. For example, the braking distance of the drone vehicle 55 may be lower than a factor of five or even 10 than the braking distance of the train 5.

[00167] As will be explained below in more detail, the drone vehicle 55 may even warn person(s) on the railway track 2. This applies both to pedestrians as well as people in cars, buses or trucks on, close to and/or approaching the railway track 2. The drone vehicle 55 may command the person(s) to keep away and/or to leave the drive path (of the train 5) the railway track 2. Thus, manned obstacles may even be caused to leave and/or to keep outside the hazard zone. Accordingly, an impending collision may be avoided completely.

[00168] The train 5 (or any other rail vehicle) and the (self-propelled) drone vehicle 55 thus form a railway vehicle system with improved safety characteristics.

[00169] Typically, the train 5 operates as a master instructing the drone vehicle 55 to drive ahead and to search autonomously during driving on the rail track 2 for obstacles on the rail track 2, obstacles to close to the rail track 2 and/or obstacles approaching the rail track 2 in a dangerous way.

[00170] Depending on speed of the train 5, the drone vehicle 55 may run between a few ten meters up to few hundred meters ahead the train 5.

[00171] Typically, the higher the train speed is, the bigger the distance between train 5 and the drone vehicle 55 is chosen.

[00172] FIG. 2A shows a schematic side view of railway drone vehicle 100 on a railway track 2. Only three railway sleepers 1 and the left rail 2a in normal travel direction x of the drone vehicle 100 are visible in the section of figure 2A.

[00173] In the exemplary embodiment, the drone vehicle 100 runs on four track wheels 151, 152 on the railway track 2 two which are shown in figure 2A, namely two main track wheels 151 connected with a respective electric motor (not shown in figure 2A) and to non-driven (auxiliary) track wheels 152. In FIG 2B showing a schematic top view of the railway drone vehicle 100 all four track wheels 151, 152 are visible.

[00174] As depicted in the lower drawing of figure 2D, each of the two main track wheels 151 may be implemented as a rim wheel including an electric motor. The electric motors may also be operable as generators during braking. Further, (at least) each of the two main wheels 151 may have an integrated disc brake unit.

[00175] In the exemplary embodiment, the drone vehicle 100 has a chassis or frame 110, 120 and two typically identically shaped bodies 150 which are mechanically connected via the frame 110, 120. In the following the bodies 150 are also referred to as track bodies and side bodies, respectively. The track bodies 150 may even be identical. The frame 110, 120 and the track bodies 150 typically form a rigid vehicle body of the drone vehicle 100.

[00176] Between the track bodies 150 a docking conus 160 may be attached to a lower portion 120 of the frame 110, 120. Typically, the docking conus 160 is arranged symmetrically with respect to a central longitudinal axis (normal travel direction x, coaxially with the longitudinal axis in top view) of the drone vehicle 100 and the two track bodies 150, respectively. The conus 160 may be used for docking to / undocking from a locomotive or another railway vehicle. The functions of the conus 160 are explained in detail below with regard to figure 3A to figure 3D.

[00177] In the exemplary embodiment, the drone vehicle 100 further has an air brake 180 attached to an upper end of the frame 110, 120.

[00178] As illustrated in figures 2A to 2D, the track bodies 150 are typically suitably shaped to minimize aerodynamic drag during driving in forward direction x.

[00179] Further and as illustrated in figure 2C illustrating a schematic front view of the drone vehicle 100, the frame 110, 120 is typically substantially hull-shaped or shell-shaped to

reduced aerodynamic drag during driving. For the same reason, the vehicle body may have a typically large central air channel or passage.

[00180] When seen in front view, an area of the vehicle body including the conus 160 between an outer boundary line of the vehicle body and an inner boundary line of the vehicle body including the conus 160 corresponds to at most 20% , more typically at most 10% of an area defined by the inner boundary line.

[00181] For example, the upper frame portion 110 may be comparatively thin, e.g. may have shell thickness (do-di)/2 of at most 20 cm or even at most 10 cm, where do denotes a maximum outer horizontal extension of the upper frame portion 110 and the drone vehicle 100, respectively. The maximum outer horizontal extension do is typically a bit larger than a track gauge of the railway track 2 of e.g. 1435 mm.

[00182] For reasons of low weight, the frame 110, 120, the shell of the track bodies 150 as well as the conus 160 is typically at least substantially made of one or more stable lightweight materials such as GFK or aluminium. Further, even the track wheels 151, 152 may be at least partly or even at least substantially made of one or more stable lightweight materials.

[00183] As illustrated in figure 2C, the drone vehicle 100 may have several first sensors S1, S2, S3 for detecting obstacles on the railway track 2 in front of the drone vehicle 100.

[00184] The first sensors S1, S2, S3 may form a sensor unit 140 for detecting obstacles.

[00185] Typically, the first sensors S1, S2, S3 are attached to an upper or even an upper most part (e.g. a head portion) of the frame 110, for example an upper most cross strut.

[00186] As illustrated in figure 2C, one or even both track bodies 150 may host a traction control unit 156 electrically connected with the electric motor (s).

[00187] Note that both track bodies 150 may be substantially or even completely identical (identically equipped). Accordingly, a higher redundancy can be achieved.

[00188] Alternatively, one, two or even all illustrated components 155 to 157 are only present once, i.e. in one but not necessarily in the same of the two track bodies 150. Accordingly, the drone vehicle 100 may be even lighter.

[00189] Due to its typical comparatively high weight, the electrical energy storage 155 may, for stability reasons, be arranged in a comparatively low vertical position within the respective track body 150, arranged in both track bodies 150, typically equally sharing the weight, and/or between the main track wheel 151 and the auxiliary wheel 152 when seen from above and/or in side view.

[00190] Further, a traction control unit 156 electrically connected with the electric motor(s) and the electrical energy storage 155 may be arranged within the respective track body 150.

[00191] Even further, a main drone control unit 157 electrically connected with the first sensor S1-S3, the traction control unit 156 and further components like the air brake 180 may be arranged within the track body (bodies) 150.

[00192] FIG. 3A and FIG. 3B show a schematic side view and a corresponding schematic top view, respectively, of the railway drone vehicle 100 and a railway vehicle 700 shortly after releasing the railway drone vehicle 100 from a docked position at a locomotive (railway vehicle) 700. For reasons of clarity, only parts of the locomotive 700 which are most relevant for docking /undocking the drone vehicle 100 are illustrated in figure 3A to 3D.

[00193] The docked position is illustrated in figures 3C and 3D, wherein figure 3C shows a schematic top view and FIG. 3D shows a corresponding schematic front view.

[00194] In the exemplary embodiment, a spring loaded docking piston 750 operable as an automatic docking/undocking device for the drone vehicle 100 is attached via a supporting element 755 to a lower part 710 of the front side of the locomotive 700. The supporting element 755 may e.g. be substantially Y-shaped, substantially shaped as a snow plug or substantially shaped as a cow pusher. Further, the supporting element 755 may be fixed with respect to the lower part 710. Alternatively, the supporting element 755 may be implemented as or include a pivotable arm.

[00195] For docking the drone vehicle 100, the docking piston 750 may fulfill at least one, typically all of the following functions: damping the motion, centering within the conus 160 acting as a receptacle for the head of the docking piston, and thereafter locking the drone vehicle 100.

[00196] For undocking the drone vehicle 100, the docking piston 750 may fulfill at least one, typically both of the following functions: unlocking and thereafter accelerating (helping to accelerate) the drone vehicle 100 (acting as a catapult element).

[00197] Actuation power for accelerating the drone vehicle 100 may be either electro-mechanical (as illustrated by the spring 751) and/or pneumatical, e.g. using the typical available low pressured air from the locomotive 700.

[00198] The docking / undocking device 750, 755 typically allows a certain freedom of translation and angular displacement between the drone vehicle 100 and the locomotive 700 (more typical in three axes).

[00199] Accordingly, dynamic effects during drive, in particular in curves where the three dashed dotted center lines (in figure 3B) of the rails 2a, 2b, the drone vehicle 100 and the locomotive's 700 front side are typically neither aligned nor superimposed.

[00200] As further illustrated in figures 3C and 3D, the upper portion 110 of the frame may be attached to front buffers 715 of the locomotive 700. Accordingly, a stable connection between the drone vehicle 100 and the locomotive 700 may be achieved in the docked state of the drone vehicle 100.

[00201] Further, the drone vehicle 100 is typically designed such that a Berner zone BZ is kept free in the docked state of the drone vehicle 100. The Berner zone is the area to be kept free for personnel in charge of coupling and uncoupling (shunting) the locomotive and the drone vehicle, respectively, from each other or other rail vehicles such as wagons or other locomotives.

[00202] In the docked state, the electrical energy storage, e.g. the battery pack(s) of the drone vehicle 100 may be recharged.

[00203] This may be achieved via an electrical connection (not shown in figures 3C and 3D) between the locomotive 700 and the drone vehicle 100. For this purpose, an electric connector may be integrated into the docking piston 750. Alternatively, the electrical connection for charging / recharging the electrical energy storage may be implemented using a separated electric side connector.

[00204] This electrical connection for recharging may be made either via metallic contacts and/or via induction devices. Preferably, the electrical connection has a nominal

loading power of at least 100 kW up to several hundred kW, for example up to 500 kW. Further, the electrical connection may provide a charging voltage of several hundred Volts, for example up to 900 V.

[00205] Accordingly, a low (re)charging time of the electrical energy storage may be achieved.

[00206] Alternatively or in addition, the electric motor(s) of the drone vehicle 100 may be operated in a generator mode when driven by the track wheels (151) during motion of the locomotive 700.

[00207] When the electrical energy storage(s) of the drone vehicle 100 are recharged using both the electrical connection with the locomotive 700 and the generated current of the electric motor(s) of the drone vehicle, a particularly low (re)charging time of the electrical energy storage may be achieved.

[00208] FIG. 4A shows a schematic side view of a railway drone vehicle 200 and a railway vehicle 800. The railway drone vehicle 200 is typically similar to the railway drone vehicle 100 explained above with regard to figure 2A to figure 3D. Likewise, the railway vehicle and locomotive 800 of the railway vehicle, respectively, is typically similar to the locomotive 700 (of a train) explained above with regard to figure 2A to figure 3D.

[00209] However, the drone vehicle 200 has only one (central) track body 250. The track body 250 is connected to two main track wheels 251 (a left and a right one) and two smaller auxiliary wheels 252 (a left and a right one). Further, the frame 210, 220 of the drone vehicle 200 which is connected to the track body 250 is foldable along pivot points 270. Furthermore, the lower frame part(s) 220 is foldable with respect to the track body 250 along the axes / axis of the main track wheels 251.

[00210] The locomotive 800 has a corresponding docking device 860 which is arranged and the front side of the locomotive 800 and capable to lift the drone vehicle 200.

[00211] In the exemplary embodiment, the docking device 860 has two lever arms 861 each of which is connected to a respective pivot device (drive) 862 attached the front side of the locomotive 800.

[00212] While figure 4A shows a schematic side view, figure 4B shows schematic front views of the locomotive 800 and the approaching railway drone vehicle 200 prior to docking.

[00213] As illustrated in figures 4C, 4D referring to an early stage of docking the railway drone vehicle 200 to the locomotive 800, the arms 861 of the locomotive may lowered and attached to handles to 260 of the drone vehicle to 200 after the drone vehicle 200 has reached the front side of the locomotive 800.

[00214] Thereafter, the locomotive 800 may lift the drone vehicle 200 with the arms 861.

[00215] During lifting, the drone vehicle 200 is typically folded as illustrated in the side views of figures 5A to 5F. Note that figures 4C, 4D correspond to a state between states shown in figures 5A and 5B.

[00216] The folding of the drone vehicle 200 may be manually assisted by train staff or other railway staff, but may also be carried out completely automatically.

[00217] Figures 6A, 6B, 6C show a schematic side view, a schematic top view and a schematic front view, respectively, of a railway drone vehicle 300. The railway drone vehicle 300 is typically similar to the drone vehicle 100 explained above with regard to figure 2A to 3D. However, the drone vehicle 300 has at its front side for airbags 371 to 373 which are illustrated in inflated states.

[00218] In the exemplary embodiment, the drone vehicle 300 has a lower airbag 371, two side airbags (left and right) 372, 374 and a top airbag 373 which are attached to respective portions of the frame 310.

[00219] Note that the drone vehicle 200 explained above with regard to figure 4A to 5F may also have at least one airbag at its front side.

[00220] FIG. 6D shows a schematic top view of a railway vehicle system formed by a railway drone vehicle 55 and a railway vehicle 5 as explained herein. For example, the railway drone vehicle 55 may be one of the drone vehicles 100 to 500, and the railway vehicle 5 may be the locomotive 700 or 800, or a train formed by the locomotive 700 or 800 and attached wagons.

[00221] In the exemplary embodiment, the railway vehicle 5 has a main vehicle control unit 57 configured to communicate with a main drone control 7 unit via a wireless data connection DL. The drone vehicle 55 drives ahead the railway vehicle 5 and has a first sensor(s) S1 for detecting obstacles 54 on the rail track 2 in front of the railway drone vehicle 55. The first sensor S1 is electronically connected with the main drone control unit 7 which is configured to operate the drone vehicle 55 on the rail track 2, ahead the railway vehicle 5 and within a cleared operation blocks CB of the railway vehicle 5, to search autonomously for obstacles 54 on the rail track 2 using the first sensor S1, and to send via the data connection DL a warning message to the railway vehicle 5 after detecting an obstacle 54 arranged on the rail track 2, to close to the rail track 2 or approaching the rail track 2.

[00222] Furthermore, the railway vehicle system may be complemented by a control center 70, for example an ATO-center, configured to communicate with the main vehicle control unit 57 unit via a further (wireless) data connection.

[00223] Further, the drone vehicle 55 may have a second sensor(s) T1 electronically connected with the main drone control unit 7 for detecting obstacles on the rail track 2 and behind the railway drone vehicle 55 (in front of the railway vehicle 5).

[00224] FIG. 7A shows a schematic side view of railway drone vehicle 400. The drone vehicle 400 is typically similar to the drone vehicles 100, 300 explained above with regard to figures 2A to 3D and 6A to 6C, respectively. However, the drone vehicle 400 has in addition to the first sensor(s) 411 a second sensor(s) 442 typically mounted on an upper most portion of the frame 410 for detecting obstacles on the railway track 2 which are behind of the railway drone vehicle 400.

[00225] As illustrated in figure 7B showing a schematic top view of a railway vehicle system formed by the railway vehicle 5 and the railway drone vehicle 400, this allows detecting obstacles 742 in front of the drone vehicle 400 (field of view 400F of the first sensor 441 and front side field of view, respectively) as well as obstacles 741 behind the drone vehicle 400 (field of 300F view of the first sensor 442 and back side field of view, respectively) which are not yet in the FOV 51F of locomotive 51 of the train 5.

[00226] Accordingly, even an obstacle likes the illustrated car 741 that approaches and/or comes to still stand on the railway track 2 between the railway vehicle 5 and the railway drone 400 may be detected in good time for braking train 5 by the drone vehicle 400 communicating the detection of the obstacle to the locomotive 51 in a respective warning message.

[00227] Figures 8A and 8B shows a schematic side view and a schematic front view, respectively, of a railway drone vehicle 500. The drone vehicle 500 is typically similar to the drone vehicles 100, 300, 400 explained above with regard to figures 2A to 3D, 6A to 6C, and

7A, respectively. However, flashlights 511, 512 and speakers 513, 514 (or a speaker 513 and a siren 514 are mounted to the front side of the frame 510 of the drone vehicle 500.

[00228] Further, two warning display 581, 582 of the unfolded air brake 580 may display a warning instructions such as “leave track immediately“.

[00229] Accordingly, persons such as pedestrian(s) that may cross the track or professional railway workers as well as person(s) in obstacle likes the illustrated car 840 of figure 8C may be both warned and instructed to remove the obstacle / leave the railway track 2 after being detected by the drone vehicle 500 in its field of view 500F.

[00230] Figure 9 shows a schematic top view of a railway vehicle 5 with one locomotive 51 pulling two exemplary wagons 52 and a railway drone vehicle 55 driving ahead the locomotive 51 in a cleared operation block Bl1. The drone vehicle 55 may be similar to even or equal to any of the drone vehicles 100 - 500 explained above with regard to figures 2A to 3D, 6A to 6C, 7A, and 8A to 8C, respectively. Likewise, the locomotive 51 may be similar to or even equal to the locomotive 700 or locomotive 800 explained above with regard to figures 3A to 5F.

[00231] Both the locomotive 51 and the drone vehicle 55 may search for obstacles 54 in their respective field of view 51F, 55F on and/or close to the railway track 2.

[00232] As illustrated in figure 9, the drone vehicle 55 typically drives in the cruising mode semi-autonomously, i.e. autonomously in the absence of further instructions from locomotive 51, ahead of a cruising zone CZ of the locomotive 51, typically slightly ahead the cruising zone CZ, for example at a distance in a range from 105% to 150%, more typically from 110% to 125% of a cruising distance Dcd defined by a deceleration distance (braking distance) Ds of the train 5 plus a typically comparatively short decision distance Dd to initiate emergency braking of the train 5 after receiving the warning message of the drone vehicle 55.

[00233] Between docking sequences with the locomotive 51, the drone vehicle 55 may accelerate, cruise, and/or decelerate ahead of the cruising zone (and still within the cleared operation block(s) authorized by the locomotive 51) at a controlled preferred or even optimum distance or distance range (within a few percent) from the locomotive 51 with respect to safety, until the obstacle 54 is detected in the field of view 55F from the drone vehicle 55.

[00234] The size of the cruising zone CZ defines the desired minimum distance between the railway drone vehicle 55 and the locomotive 51 and typically depends on the speed of train 5, the weight of train 5, adherence condition, and/or the geometry of the rail track 2, in particular, curvature and inclination of the rail track 2.

[00235] Therefore, the drone vehicle 55 typically feedback - controls its position on the track 2 and the distance to the locomotive 51, respectively, using velocity and position information of the locomotive 51.

[00236] When the drone vehicle 55 reaches the end of cleared block(s), it typically decelerates. This is illustrated in figures 10A to 10C. FIG. 10A shows a schematic top view of the railway vehicle 5 and the railway drone vehicle 55 cruising on a railway track 2 having at point B a track switch where the railway track 2 bifurcates.

[00237] In the exemplary embodiment, the train 5 and the drone vehicle 55 drive at an initial speed v1 of 80 km/h. Initially, the drone vehicle 55 drives at substantially the same speed (v1) ahead the locomotive 51 of the train 5. In figures 10A and 10C, the distance between the locomotive 51 and the drone vehicle 55 is denoted as Dspd (slaved pair distance). Figure 10B illustrates the velocity of locomotive 51 as function of its position s on the railway track 2 for two scenarios.

[00238] In a first scenario, blocks Bl2 and/or Bl3 are cleared. However, the allowed speed in blocks Bl2 and Bl3 is reduced to v3 (25 km/h in the exemplary embodiment). Therefore, the train 5 reduces its speed stepwise till point B (upper curve in figure 10B). Due to the reduced train speed, the cruising distance Dcd of train 5 is reduced stepwise in parallel. Thus, the distance between locomotive 51 and drone vehicle 55 Dspd may also be reduced stepwise in parallel as shown in figure 10C illustrating Dcd and Dspd as function of the train position s on the railway track 2.

[00239] As illustrated in figure 10C, the railway drone 55 may drive ahead locomotive 51 substantially at the cruising distance (Dspd~Dcd, 200 m in the exemplary embodiment) at lower speeds (in blocks Bl2, Bl3).

[00240] In the second scenario, blocks Bl2 and Bl3 are not (yet) cleared. In this scenario, the train 5 typically stops at point A' prior to reaching point B (lower curve in figure 10B).

[00241] Likewise, the speed of the drone vehicle 55 may be reduced in the second scenario, but typically to a large extent. Accordingly, the drone vehicle 55 may be approached by the locomotive 51 at or close to point A' and docked to the locomotive 51.

[00242] In the docked state (docking mode *DM*), the electrical energy storage of drone vehicle 55 may be recharged until blocks Bl1, Bl3 are cleared.

[00243] Thereafter, drone vehicle 55 may undock and set back to cruising mode CM.

[00244] As already explained above, the detection range of trains for obstacles can be doubled if the drone vehicle is equipped with a forward looking obstacle detection system (first sensor(s)) identical to the one fitted on the railway vehicle. The detection range can even be tripled if the drone vehicle is equipped with two typically identical obstacle detection systems, one forward looking and another one rearward looking (second sensor(s)). The detection range can be extended even much further (up to over several kilometers) by enabling operation of the drone vehicle up to the end of the cleared operation block attributed to the train and possibly beyond.

[00245] When fitted on the drone vehicle able to move very close to the obstacle, even simple, cheap and service-proven short range sensor(s) and/or data processes can used for detecting and/or identifying obstacles. Still much better obstacle detection performance may be obtained compared to the much more complex, expensive and even to be qualified sophisticated long range detection solutions that would be required for sensors only fitted on the train.

[00246] When a collision between the train and the obstacle could not be avoided, a first collision between the drone vehicle and the obstacle may be controlled. Thus the shock energy may be extremely reduced as the drone vehicle can brake much harder and its mass is extremely low compared to the mass of the railway vehicle. This controlled collision of the drone vehicle with the obstacle may be even used for trying to clear the railway track before the train arrives, typically with deployed front airbag(s).

[00247] Alternatively or in addition to operating together with a railway vehicle as a rail vehicle system, the railway drone vehicle may be used (independently) for rail condition monitoring, overhead line condition monitoring, track side condition monitoring, testing of track side signaling, testing of a Train Control System such as the European Train Control

System (ETCS), ETCS/ATO deployment and/or even a complete infrastructure check for network under construction (before railway vehicle are allowed to drive).

[00248] Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

List of reference numbers

1	railway sleeper
2	railway track
2a, 2b	rails
5, 700, 800	train / railway vehicle/ locomotive
51	locomotive / railcar / railway vehicle
51F	surveillance area / FOV (field of view) of a railway vehicle
52	wagon of a railway vehicle / train
53	view obstacle
54, 741, 742, 840	mechanical obstacle on rail
55, 100, 200, 300, 400, 500	railway drone vehicle / (rolling) drone
55F	surveillance area / FOV of 55
57	control unit(s) / main control unit, sensor control unit, data transmission unit of the railway vehicle
70	control system
300F, 400F	FOV of 400
500F	FOV of 500
110, 120, 310, 410, 510	parts of chassis, frame, coachwork, support mast
101, 301	front side
140, 440, 441	sensor unit
150, 350, 450	track body
151, 251,..551	main wheel / rim wheel / electrically powered wheel typically including a disc brake unit
152, 252,...552	secondary wheel, none-powered wheel, passive/auxiliary wheel
155	electrical energy storage, e.g. battery packs
156	traction controller
157, 7	control unit(s) / main control unit, sensor control unit, data transmission unit of the railway drone vehicle
160, 360, 460	docking conus
180, 380, 580	airbrakes
260	handle
270	pivot point
280	upper portion / head portion for sensors
371 - 374	airbags
511, 512	flash lights

513, 514	speaker, siren
581, 582	warning display
710	lower part of 700
715, 815	front buffer
750	docking piston 750
751	spring
755	supporting element
860	docking device
861	lever arm
862	pivot device 862
BZ	Berner Zone
CB	cleared operation block
CM	cruising mode
CZ	cruising zone
Da	remaining authorized distance
Dcd	cruising distance
Dd	decision distance
DL	(wireless) data link between railway vehicle and railway drone vehicle
DM	docking mode
Ds	deceleration distance
Dspd	slaved pair distance
S1 – S3	first sensors
T1	second sensor
R1	third sensor
V	velocity / speed
s	distance on railway track
x, y, z	Cartesian coordinates

Claims

1. Ultra-lightweight railway drone vehicle (100 -500) for operating ahead of a railway vehicle (5), comprising:
   - a vehicle body (110-510);
   - at least two track wheels (151, 152, 251, 252) for running on rails (2a, 2b) of a railway track (2), the at least two track wheels being rotatably connected with the vehicle body;
   - at least one first sensor (S1-S3) for detecting obstacles (54, 741, 742, 840) on the railway track (2), the at least one first sensor (S1-S3) being mounted on and connected with the vehicle body; and
   - a propulsion system connected with the vehicle body for operating the railway drone vehicle at a speed of at least 50 km/h and/or beyond a maximum speed limit of a given type of the rails (2a, 2b), the railway track (2) and/or a segment of the railway track (2).

2. The railway drone vehicle (55, 100 -500) of claim 1, wherein the vehicle body (110-510) comprises at least one of a chassis (110, 120, 210, 220), a frame (110, 120, 210, 220), a streamlined fairing, and a track body (150, 250), and/or wherein a weight of the railway drone vehicle is at most 150 kg, more typically at most 100 kg.

3. The railway drone vehicle (55, 100 -500) of claim 1 or 2, wherein at least one of a height of the vehicle body, a width of the vehicle body and a length of the vehicle body is less than 3 m, more typical less than 2.5 m, wherein the vehicle body is substantially hull-shaped and/or shell-shaped when seen in a front view, wherein an outer diameter (do) of the vehicle body is larger than an inner diameter (d1) of the vehicle body by a factor of at most 1.5, more typically at most 1.2 when seen in front view and/or in a cross-section view, wherein, in a cross-section and/or when seen in front view, an area of the vehicle body between an outer boundary line of the vehicle body and an inner boundary line of the vehicle body corresponds to at most 20% , more typically at most 10% of an area defined by the inner boundary line, and/or wherein the vehicle body is foldable.

4. The railway drone vehicle (55, 100 -500) of any preceding claim, wherein a visual detectability of the railway drone vehicle (55, 100 -500), a radar detectability of the railway drone vehicle (55, 100 -500), an infrared detectability of the railway drone vehicle (55, 100 -500), and/or a sonar detectability of the railway drone vehicle (55, 100 -500) is reduced using a respective stealth technology, and/or wherein the vehicle body (110-510) comprises and/or is at least mainly made of a fiber-reinforced plastic and/or a non-magnetic material such as aluminum or magnesium.

5. The railway drone vehicle (55, 100 -500) of any preceding claim, wherein the at least two track wheels (151, 152) and/or an axis connecting two of the at least two track wheels (151, 152) comprises and/or is at least mainly made of a fiber-reinforced plastic, a non-magnetic material, and/or a high-Ohmic material, wherein the railway drone vehicle (55, 100 -500) is configured for running on two parallel rails (2a, 2b) of the railway track (2), wherein an electric resistance between running surfaces of two of the at least two track wheels configured to run in parallel on the two parallel tracks is at least 200 k Ohm, and/or wherein the railway drone vehicle (55, 100 -500) comprises at most four track wheels.

6. The railway drone vehicle (55, 100 -500) of any preceding claim, wherein the propulsion system comprises an electric propulsion connected to the vehicle body and an electrical energy storage (155) electrically connected with the electric propulsion.

7. The railway drone vehicle (55, 100 -500) of any preceding claim, wherein the propulsion system comprises an electric motor mechanically connected with at least one of the at least two track wheels (151, 152), and an electrical energy storage (155) electrically connected with the electric motor.

8. The railway drone vehicle (55, 100 -500) of any preceding claim, wherein the railway drone vehicle further comprises an air brake (180, 580), a mechanical brake for braking at least one of the at least two track wheels (151, 152, 251, 252), and/or wherein the electric motor is operable to work as a generator in a braking mode of the railway drone vehicle.

9. The railway drone vehicle (55, 100 -500) of any preceding claim, further comprising at least one of a docking connector (160-560) for docking to the railway vehicle (700, 800), in particular to a front face of the railway vehicle (700, 800), and/or an electric connector for charging the electrical energy storage (155) in a docking mode of the railway drone vehicle.

10. The railway drone vehicle (55, 100 -500) of any preceding claim, further comprising an airbag (371-374), a warning display (581, 582), a flashlight (511, 512), a speaker (513, 514) and/ or a siren.

11. The railway drone vehicle (55, 100 -500) of any preceding claim, further comprising at least one of:

 - a traction control unit (156) connected with the electric motor;
 - a positioning system for determining a position of the railway drone vehicle (55, 100 -500);
 - a wireless data transmission unit; and
 - a main drone control unit (157) connected with the at least one first sensor and at least one of the traction control unit, the positioning system, the wireless data transmission unit, the airbag, the air brake, the mechanical brake, the warning display, the flashlight, the speaker and the siren, and/or configured to detect the obstacle using data received from the at least one first sensor, to classify the obstacle and/or to determine at least one of a position of the obstacle, a speed of the obstacle, an acceleration of the obstacle, a path of the obstacle, a collision probability with the obstacle, and a time of collision with the obstacle.

12. The railway drone vehicle (55, 100 -500) of claim 11, wherein the main drone control unit (157) is, in a cruising mode, configured to follow instructions of a following railway vehicle (5), to process positioning and/or speed data received from the following railway vehicle (5), to keep the railway drone vehicle (55, 100 -500) ahead of a cruising zone (CZ) of the railway vehicle (5) and/or within a cleared operation

block of the railway vehicle (5), and/or to initiate sending a warning message to the railway vehicle (5) after detecting the obstacle.

13. The railway drone vehicle (55, 100 -500) of any preceding claim, wherein the at least one first sensor (S1-S3) is mounted on an upper portion (280) of the vehicle body (110-510), wherein a surveillance area (55F, 400F, 500F) of the at least one first sensor (S1-S3) is at least substantially centered with respect to a driving direction of the railway drone vehicle and/or covers an area in front of the railway drone vehicle, wherein the railway drone vehicle comprises at least one second sensor (T1, 442) for detecting obstacles on the railway track (2), wherein the at least one second sensor is mounted on the upper portion (280) of the railway drone vehicle body (110-510), wherein a surveillance area (300F) of the at least one second sensor (T1, 442) is at least substantially centered with respect to the driving direction of the railway drone vehicle and covers an area behind the railway drone vehicle, and/or wherein the at least one first sensor and/or the at least one second sensor are selected from a group consisting of a radar, a LIDAR, an ultra-sonic sensor, a sonar, a camera, an infrared range finder and a laser.

14. A system comprising a railway vehicle (5, 700, 800) and the railway drone vehicle (55, 100 -500) of any preceding claim.

15. The system of claim 14, wherein the railway vehicle (51) comprises a docking mechanism for the railway drone vehicle (55, 100 -500), the docking mechanism typically being arranged on a front face of the railway vehicle (5, 700, 800) and/or at least one third sensor (R1) for detecting obstacles (54, 741, 742, 840) on the railway track (2) and in front of the railway vehicle.

16. The system of claim 14 or 15, wherein the railway vehicle comprises an onboard ATO system, wherein the railway vehicle and/or the onboard ATO system is configured to control the railway drone vehicle (55, 100 -500) and/or the main drone control unit (157), and/or wherein the railway vehicle is configured to decelerate after receiving the warning message from the railway drone vehicle (55, 100 -500).

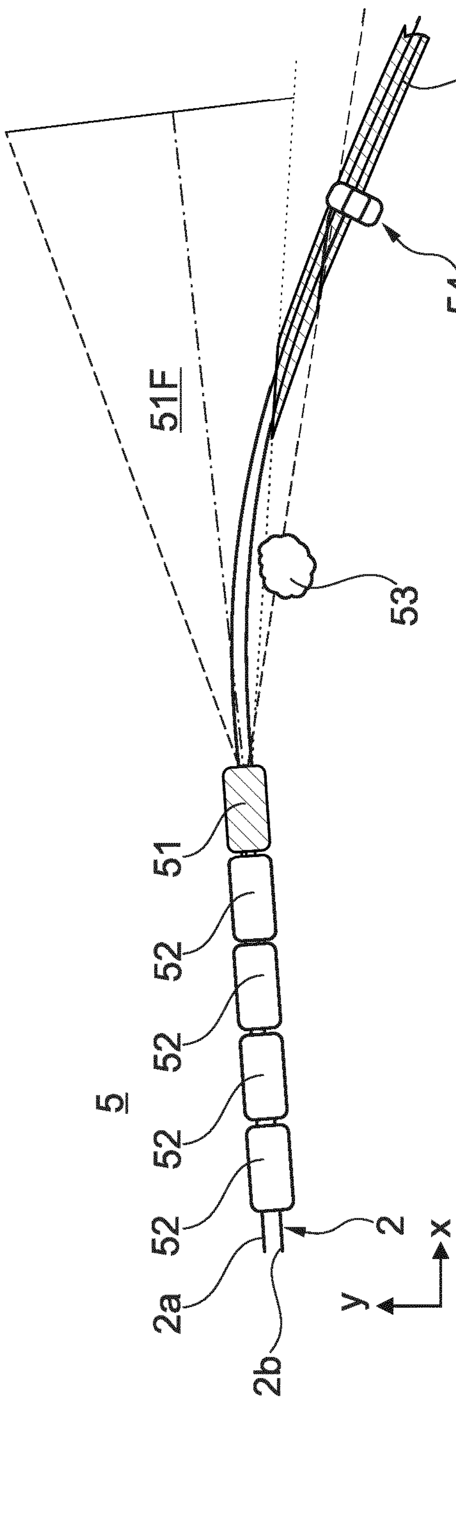
5
51
52
52
52
52
2
2a
2b
x
y
51F
53
54
2z

Fig. 1A

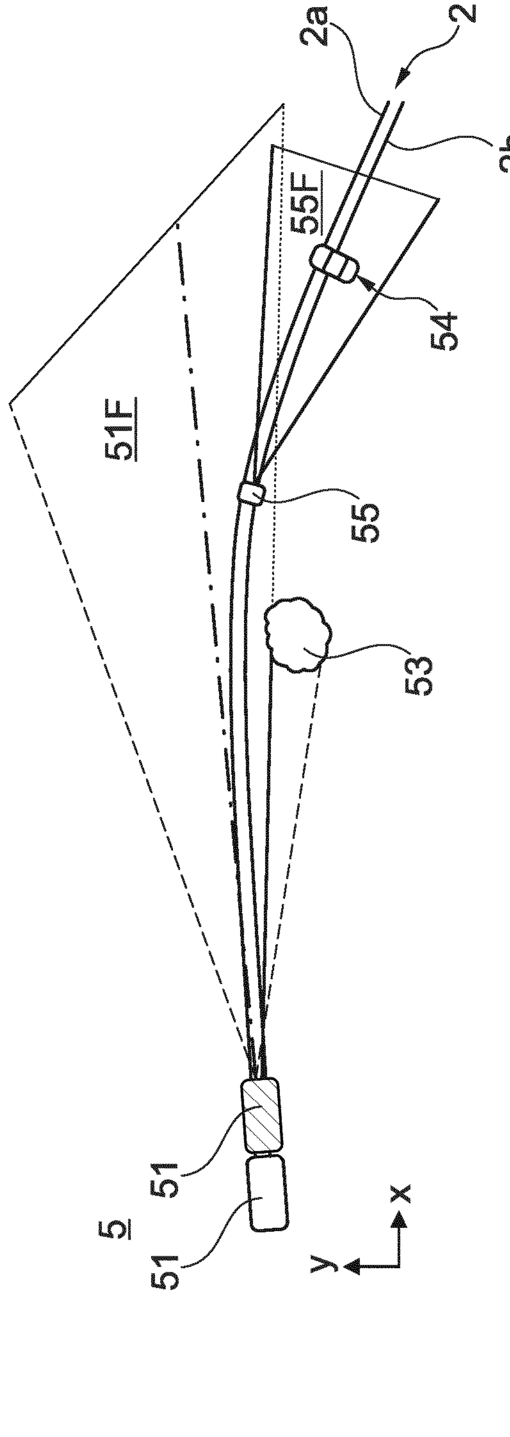
2
2a
2b
55F
54
51F
55
53
51
51
5
x
y

Fig. 1B

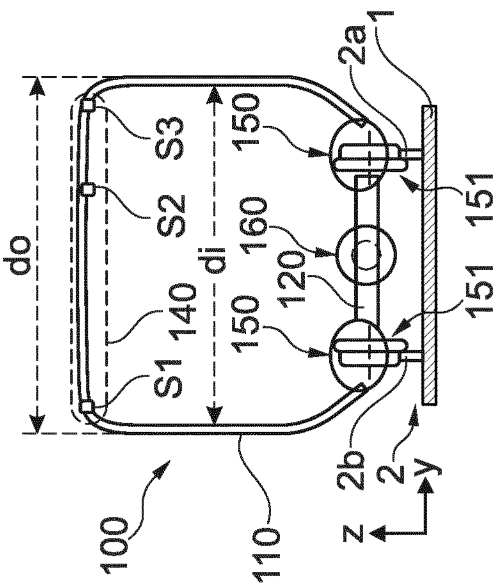

Fig. 2C

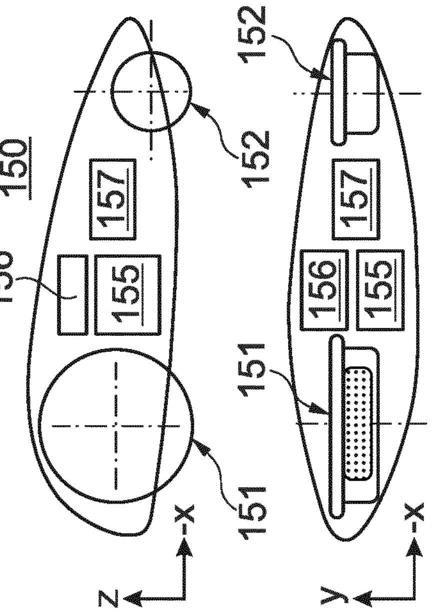

Fig. 2D

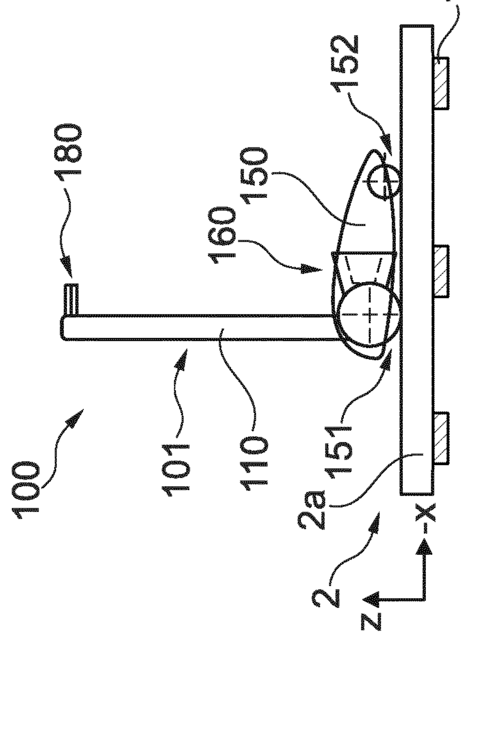

Fig. 2A

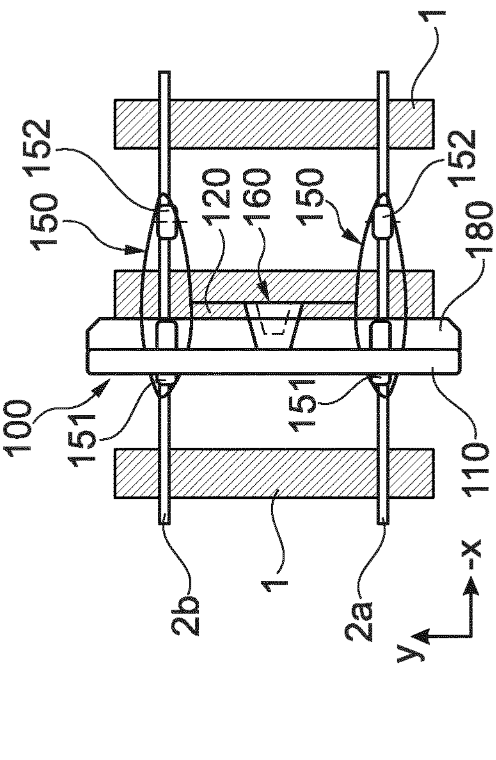

Fig. 2B

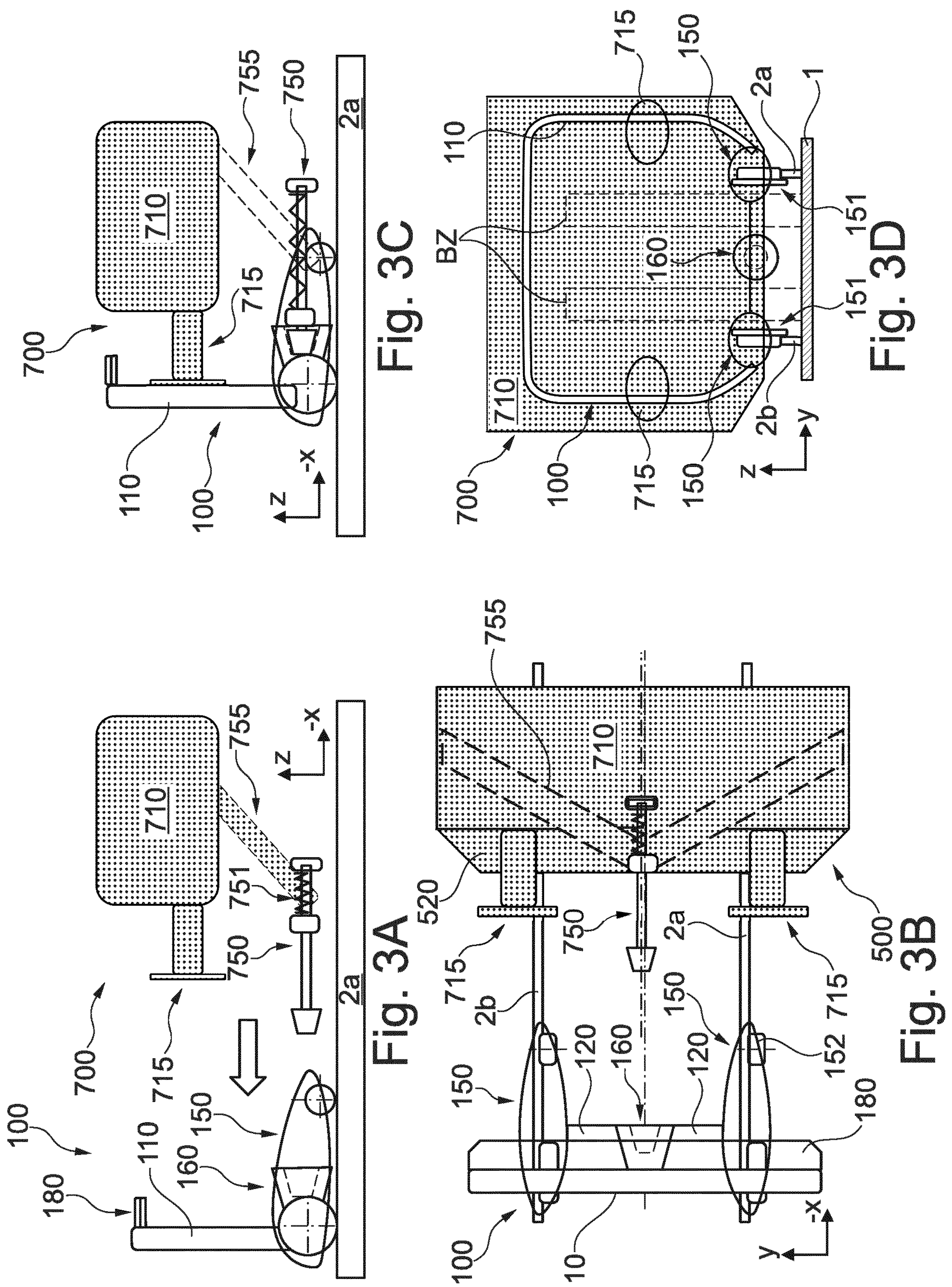

Fig. 3A
Fig. 3B
Fig. 3C
Fig. 3D

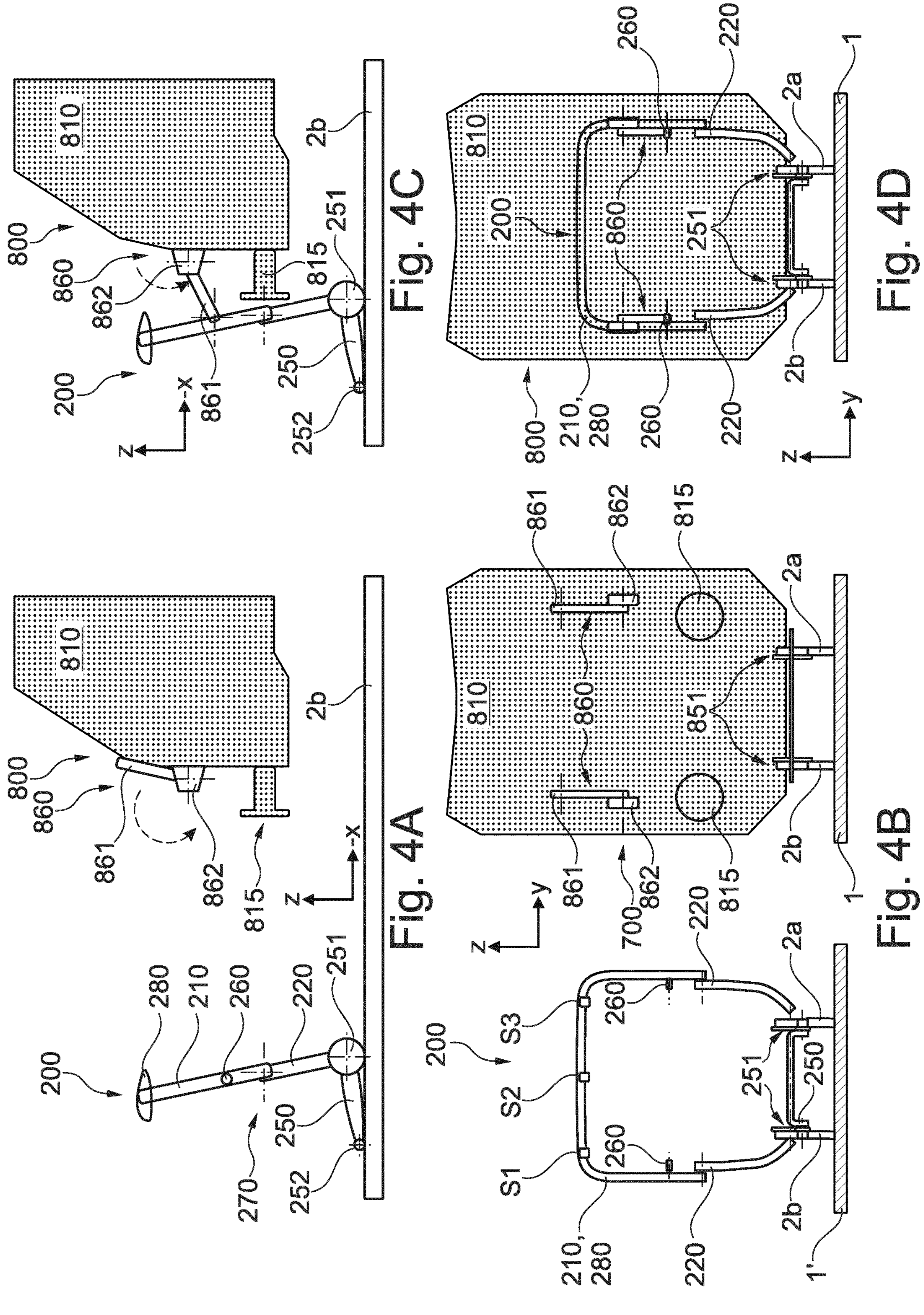

Fig. 4A

Fig. 4B

Fig. 4C

Fig. 4D

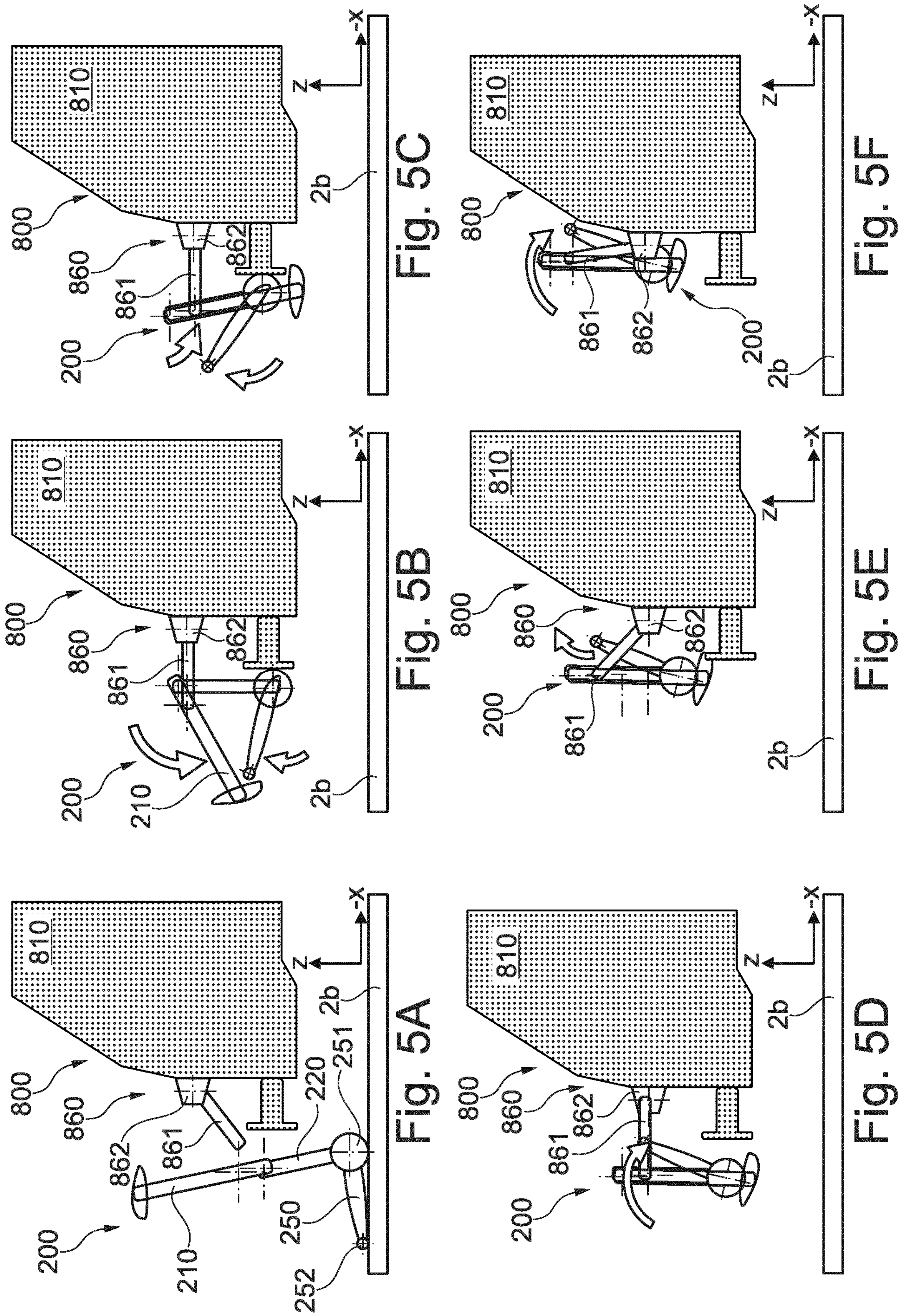

Fig. 5A Fig. 5B Fig. 5C Fig. 5D Fig. 5E Fig. 5F

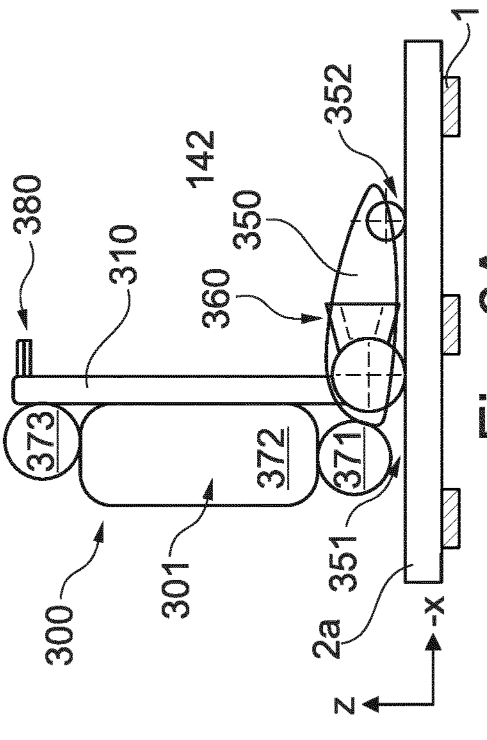

Fig. 6A

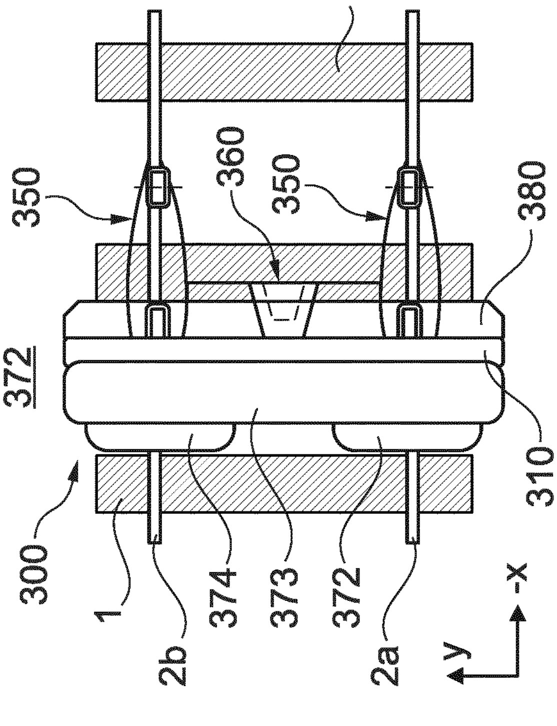

Fig. 6B

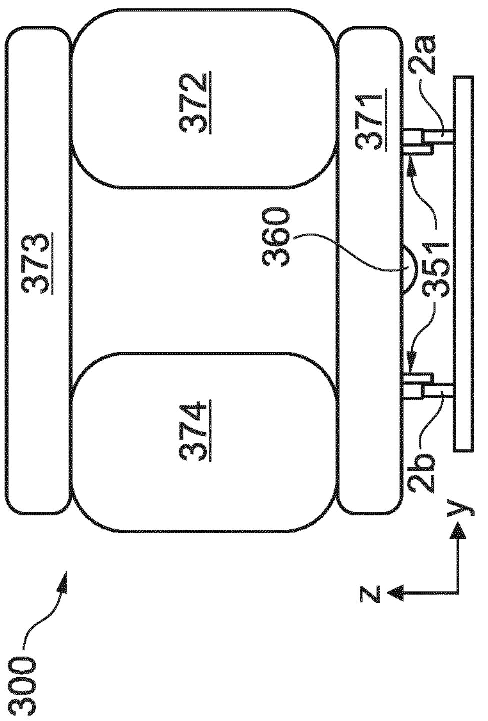

Fig. 6C

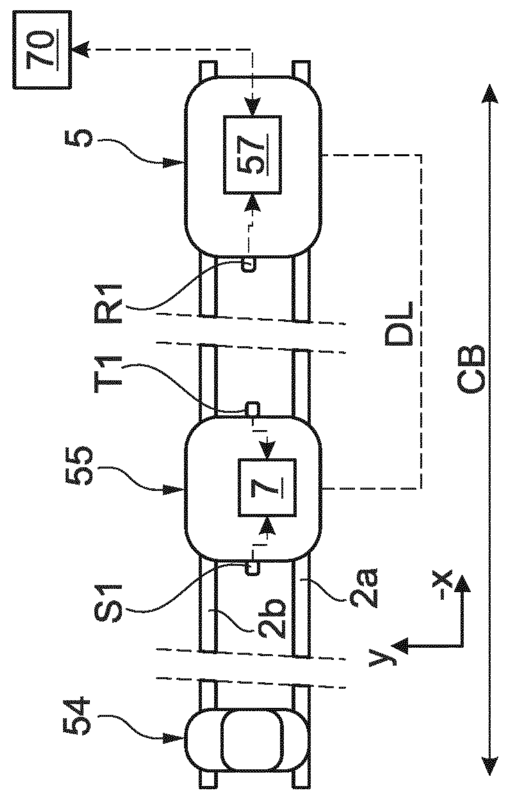

Fig. 6D

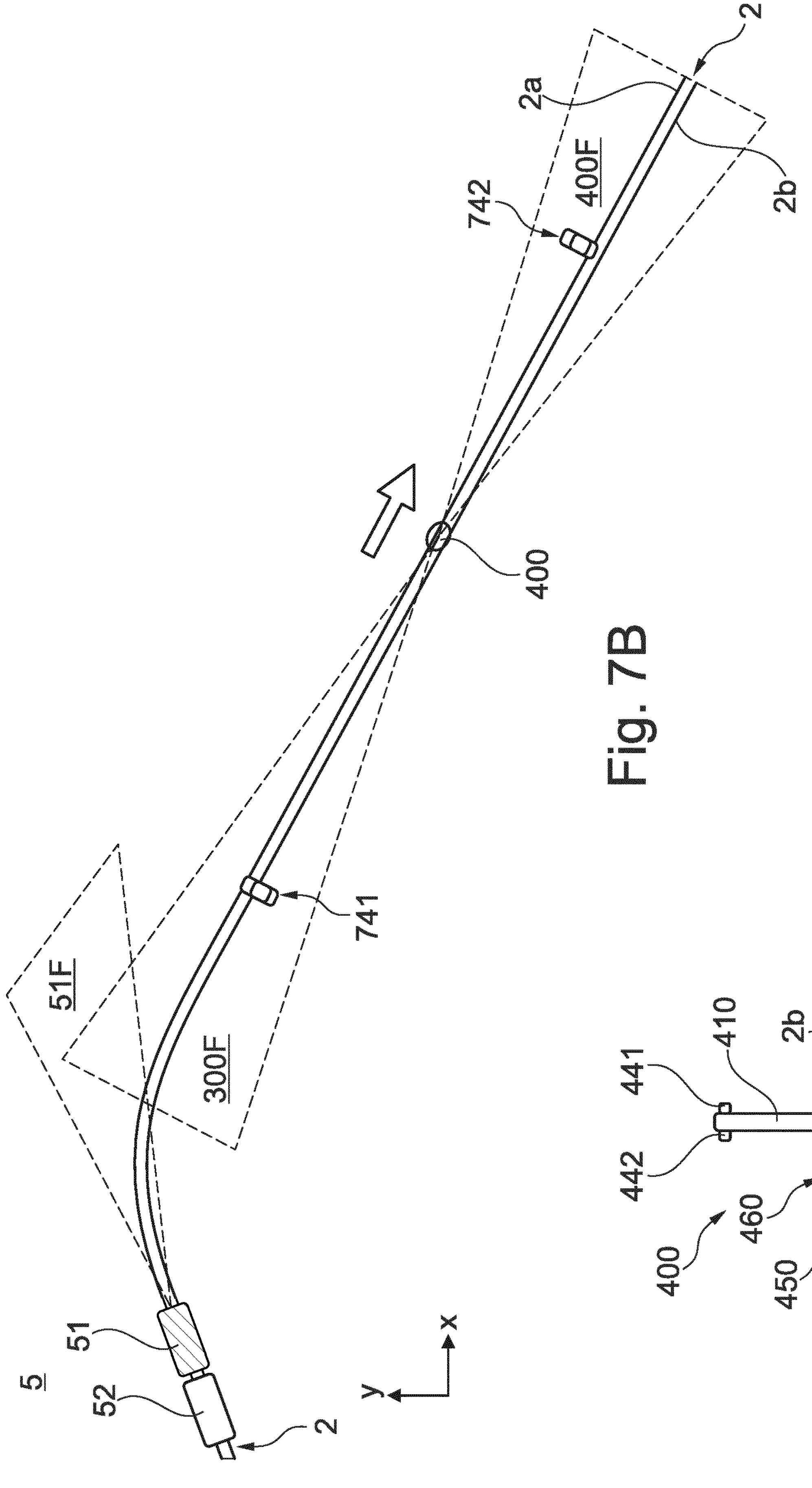
2
2a
2b
400F
742
400
741
300F
51F
51
52
5
2
x
y

Fig. 7B

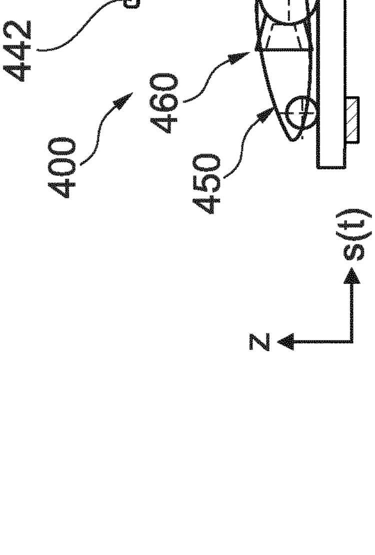
441
410
2b
442
460
400
450
s(t)
z

Fig. 7A

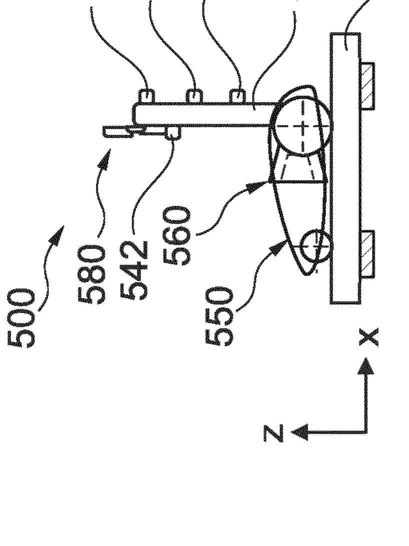

Fig. 8A

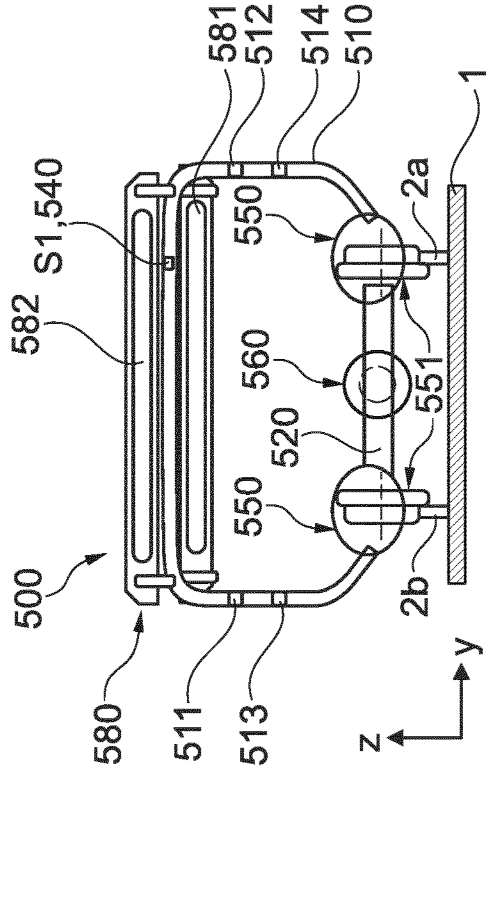

Fig. 8B

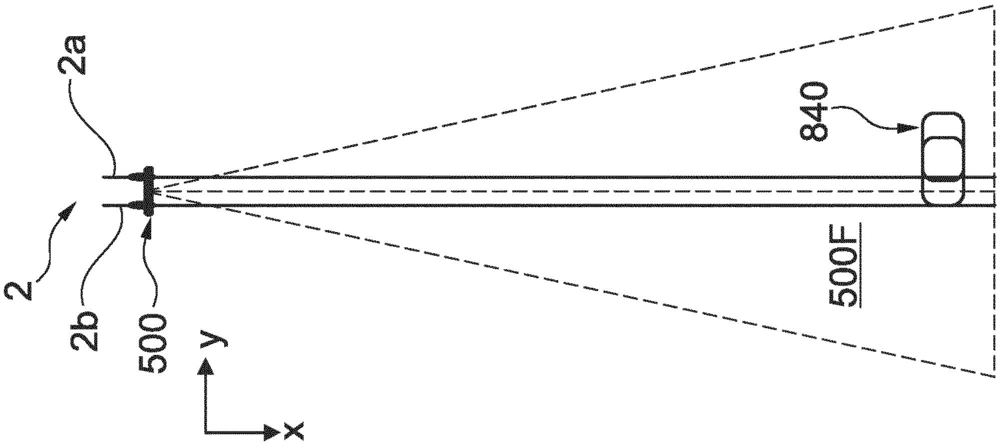

Fig. 8C

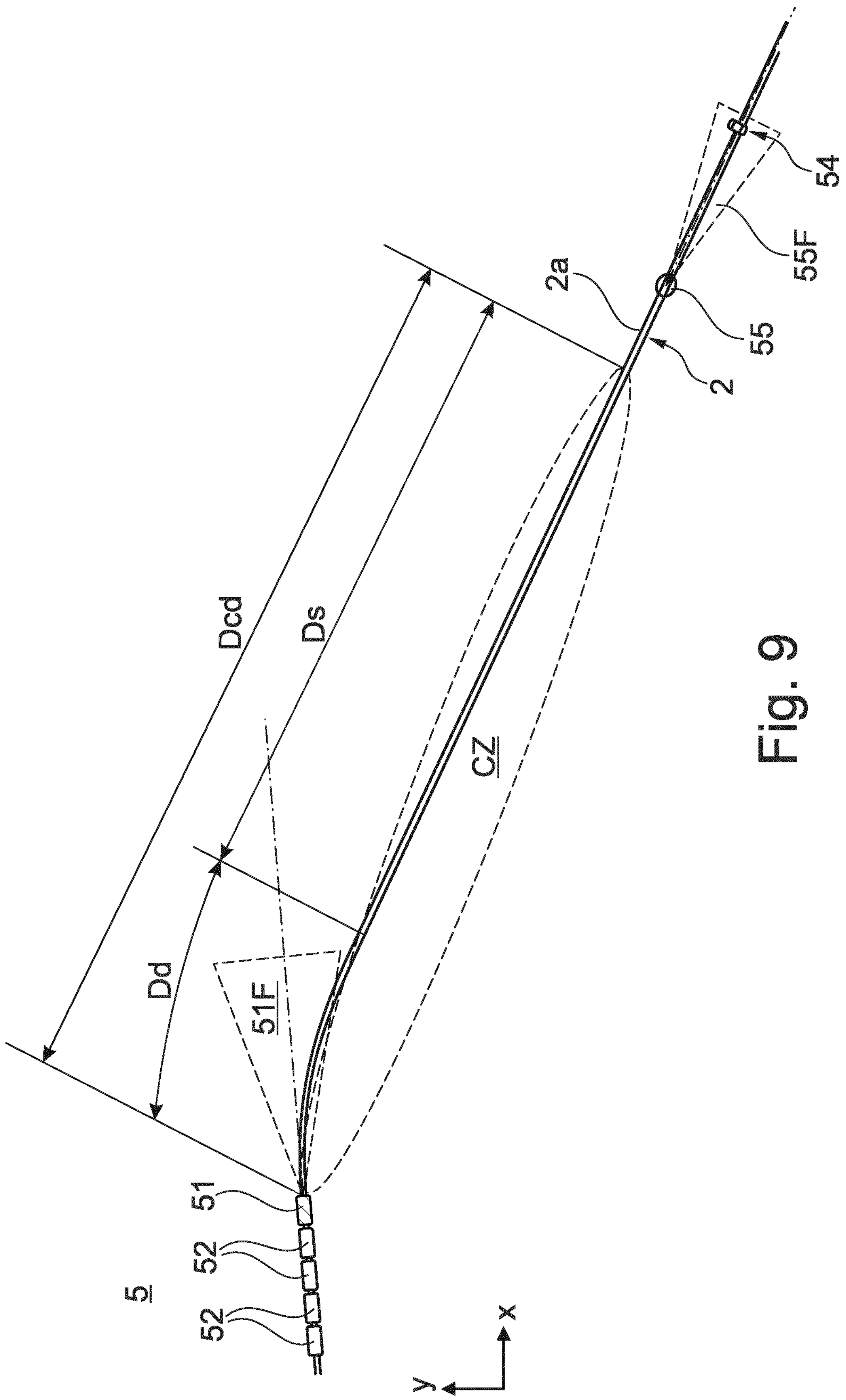

Fig. 9

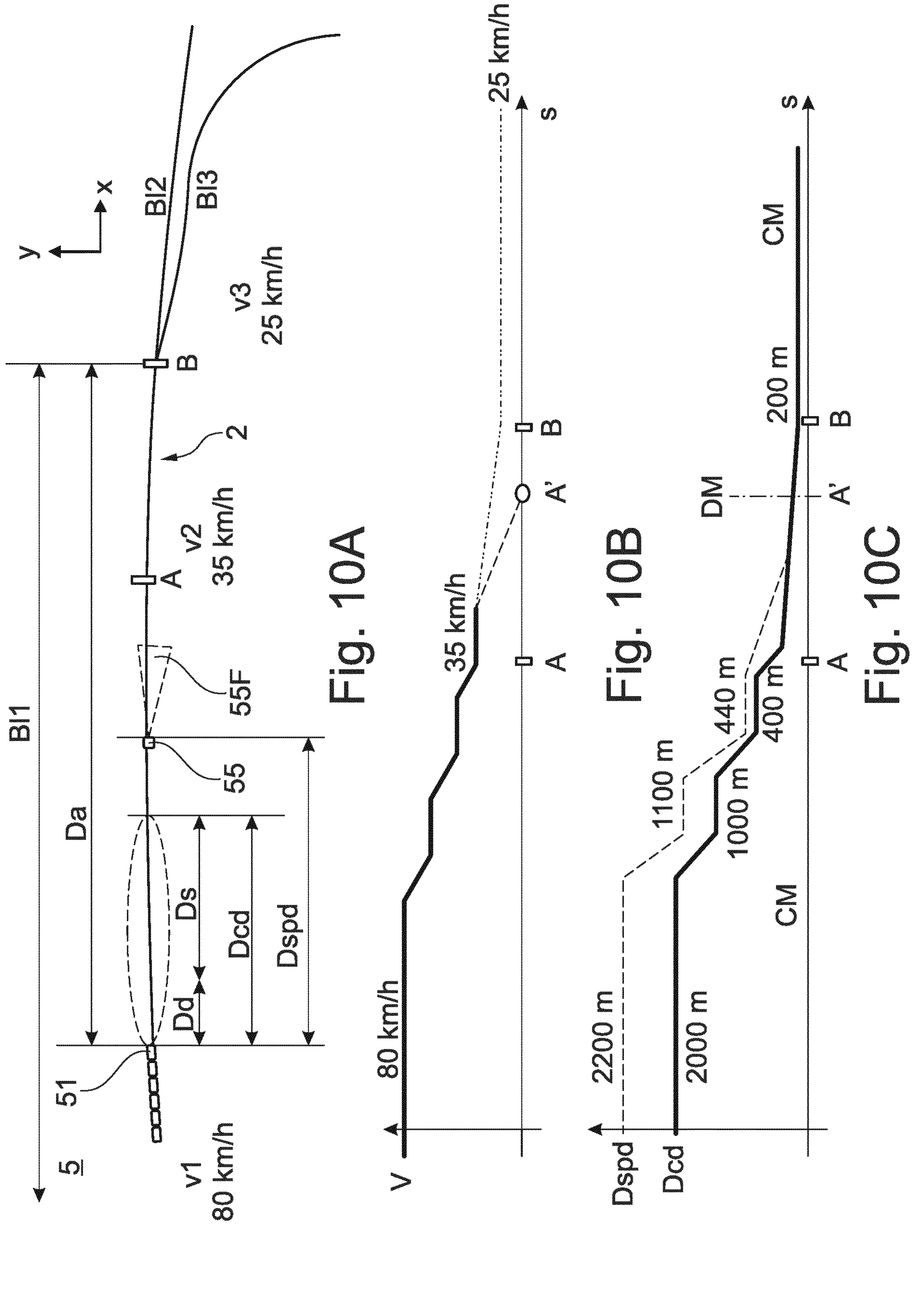

Fig. 10A

Fig. 10B

Fig. 10C

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/070689

A. CLASSIFICATION OF SUBJECT MATTER
INV. B61L23/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B61L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2017/305442 A1 (VIVIANI GARY [US]) 26 October 2017 (2017-10-26) abstract; figures 1,2,5 paragraphs [0001] - [0066], [0076] - [0085]	1-3,5-8, 10-14,16 4,9,15
X Y	DE 299 22 808 U1 (SASSENBERG, FRANK) 24 February 2000 (2000-02-24) the whole document	1-8, 11-14 4
Y	WO 99/25598 A1 (CAPANNA F) 27 May 1999 (1999-05-27) abstract; figures page 5, line 32 - page 6, line 2	9,15

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 December 2019	07/01/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Robinson, Victoria

3

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 198 41 246 A1 (TAUSCHECK EBERHARD [DE]) 15 June 2000 (2000-06-15) abstract; figure 3 column 2, line 16 - column 4, line 15 column 5, lines 10-39 column 7, lines 25-32 -----	1-3,5-8, 10-16
A	WO 2017/214678 A1 (MCMAHON JOHN BARRIE [AU]) 21 December 2017 (2017-12-21) paragraphs [0023] - [0025] paragraphs [0034] - [0052] paragraphs [0059] - [0065] -----	1-16

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2019/070689

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 2017305442	A1	26-10-2017	NONE			
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