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(54) Automatic train protection and stop system

(57) Automatic train protection and stop system (ATPSS) comprises a satellite positioning signal receiver (SPSR) with a satellite positioning antenna (SPA) or the means for connecting the system to external source of the train positioning, preferably an external SPSR (ESPSR). It also contains an operator vigilance check module (OVCM), a central processing unit (CPU), and at least one, preferably exchangeable, reference checkpoint memory module (RCMM) to store coordinates of the reference checkpoints, and additionally at least one, preferably exchangeable, route map memory module (RMMM) to store a map containing at least one route, preferably all routes on which the train can move, optionally with coordinates of the reference checkpoints. The OVCM comprises a deadman's handle (DMH) or it is connected to external DMH. Alternatively the OVCM comprises a train emergency stop unit (TESU), which controls an electro-mechanical air valve (EAV), preferably through a relay (R), to activate the train brakes in emergency. Besides, the OVCM contains a light signalling device (L), an acoustic signalling device (A) and manual or foot-operated switch (S) of both L and A devices, preferably containing a push-button and a sub-system switching-off both L and A signalling means. The ATPSS contains a velocity meter (V) and/or a recorder (P) of events, in particular the control events and the events of activation of emergency stopping braking, and/or it contains a tachograph (T) to record distance from certain reference point and velocity of the train and events. A train speed sensor (TSS) and/or a train distance sensor (TDS) are connected to the CPU, while the sensors TSS and TDS are preferably the sensors of the train wheels revolution and/or the Doppler sensors. In a method of automatic train protection and stop current coordinates (x_s,y_s) of the train are compared in the CPU with the reference checkpoints coordinates (x_c,y_c) taken out of the RCMM and at the moment of coincidence of current coordinates (x_s,y_s) of the train with any reference checkpoint coordinates (x_c,y_c) the CPU activates the OVCM, whereas current coordinates (x_s,y_s) of the train are derived from the signal of satellite positioning received by the SPSR equiped with the SPA, or they are taken from external source of the train positioning, preferably the ESPSR, by wire or wireless means, preferably realised in digital techology. Advantageously the values of current coordinates (x_s,y_s) of the train and the reference checkpoint coordinates (x_c,y_c) are compared with allowance to specified tolerances $(\Delta x_s, \Delta y_s)$. After activation of the OVCM the CPU switches-on the L device, and after first preset time interval Δt_1, the CPU switches-on the A device, and the CPU waits for pressing the switch (S) by the operator no longer than second preset time interval Δt_2, beginning from the moment of switching-on the L device, and in case the operator does not press the switch (S) during the time interval Δt_2 the CPU initiates the train emergency stopping braking, preferably by switching-on the EAV activating the train brakes. In case of fadeout of the satellite positioning signal, current coordinates (x_s,y_s) of the train are derived with use of the TSS and TDS. The recorder (P) or the tachograph (T) registers current coordinates (x_s,y_s) of the train derived from the satellite positioning signal and/or with use of the TSS and/or TDS, and the recorder (P) or tachograph (T) registers spatio-temporal coordinates (x_e,y_e,t_e) of events, in particular the control events, the events of activation of emergency stopping braking, the events of change of the source of the train positioning. In case of change of the train route the CPU registers the event of change of route and determines current changed route of the train and compares it to the route taken out of the RMMM, and determines current

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new reference checkpoints with use of coordinates taken out of the RMMM, and preferably registers this changed route together with new reference checkpoints in the recorder (P) or the tachograph (T).

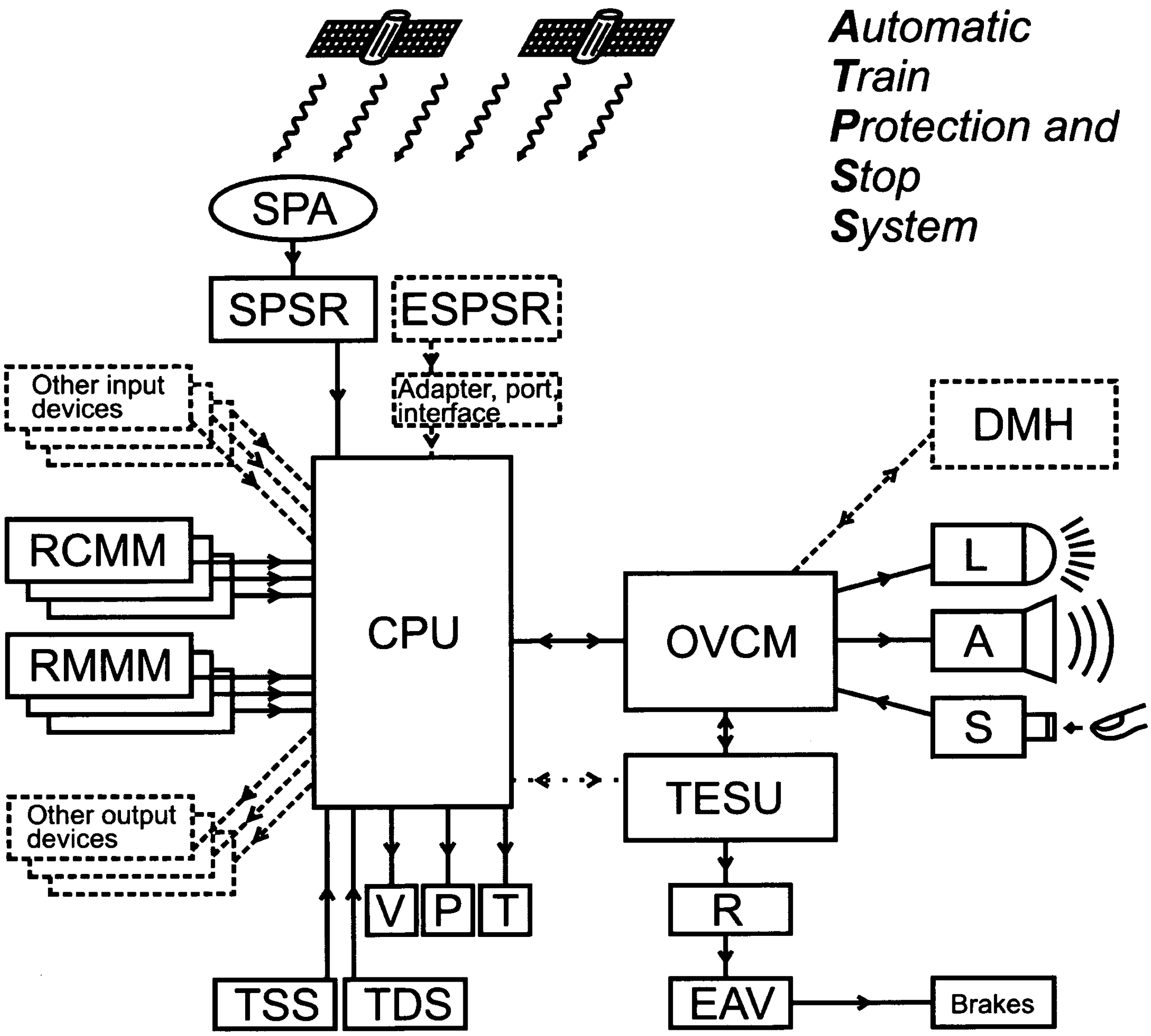


Fig. 1

Description

Domain of the invention

[0001] The railways form significant segment of transportation of people and goods. Many industrial forecasts anticipate rapid development of this sector as an alternative to the road transport due to increasing needs of contemporary globalised community for rapid, safe and economically efficient transportation. Apart from only few fully automatised, computer-controlled railway systems, like MAGLEV, all systems of railroad transportation depent on human factor. The operators in the locomotive cockpits are burdened with responsibility for safe guiding the trains. Present invention contributes to modem safety systems applied in railway vehicles and focuses on checking the operator's vigilance and readiness to properly react on events that occur on the railroads. More generally, proposed invention contributes to safety of public transportation.

Analysis of the state of the art

[0002] Most systems of checking the operator's vigilance are based on old concept of the dead-man's pedal, where the engine of some device works until the operator presses a pedal, switching-off the engine or stopping the vehicle if for any reason the operator cease to press the pedal. This solution is not directly applicable in the locomotives, because the operator shall be free to move within the cockpit. Therefore a modification of this appliance was invented where the pedal was replaced by a handle or a button and so called dead-man's handle was complemented with a control system initiating checking procedure in temporal intervals or in specific locations. Usually a lamp or a buzzer or both are switched-on and the operator is expected to switch them off by pressing a button, otherwise stopping braking is automatically executed.

[0003] Many attemps have been made to increase the level of safety of the railroads traffic. An example of the "dead man"-based train braking system was disclosed in British patent GB804672 B1 (Westinghouse Brake & Signal, Simmons A.W., GB, 19.11.1958), where a fluid pressure braking system for railway locomotives includes a train braking system and a locomotive automatic braking system with "dead man" and automatic train control devices, each arranged to cause on operation, a brake application in the locomotive automatic braking system. The locomotive automatic braking system comprises a "dead man's" pneumatic appliance and is arranged to cause, on the occurrence of a brake application in that system, a service application of the brakes in the train braking system which, dependent on the selective conditioning of the train braking system will be either immediate or delayed, whereby operation of the automatic train control device initiates indirectly such service application. The "dead man" device is further so arranged as to be capable of acting directly, when operated, on the train braking system in a manner causing therein an emergency application of the brakes, such action of the "dead man" device being immediate when the train braking system is conditioned for immediate application as aforesaid, and otherwise ineffective or subject to delay.

[0004] In another British patent GB 1021835 B1 (Oerlikon Maschinenfabrik, CH, 09.03.1966) a safety device for a railway vehicle controlled by an unaccompanied driver includes means for producing warning signals and for stopping the train if a dead man's handle is released and for producing the same action each time the train has travelled through a predetermined distance unless the driver takes preventive action. The device responds, quickly to the first condition and slowly to the second. Warning device and switching circuit for stopping the train can be operated by associated bi-stable circuits build from AND and OR gates. Logical circuit follows the operator's actions and adequately controles the braking system.

[0005] British patent GB1324956 B1 (Rheinstahl AG, DE, 25.07.1973) reveals a deadman's handle arrangement for a rail vehicle which comprises compressed air operated fluidic elements wherein, upon inattentiveness of the driver, an audible signal is operated ignorance of which results, after a predetermined interval, in automatic braking. Pneumatic switch has to be closed at regular intervals to confirm vigilance. Logical circuit is built, likewise in preceding patent document, from fluidic gates, AND, OR and NOR.

[0006] In a train vigilance control system disclosed in British patent document GB 1244601 B1 (Davies & Metcalf Ltd., GB, 02.09.1971) two modes of operation are provided, first a vigilance mode in which a vigilance period is followed by a warning period before application of the train brakes and second a safety mode in which on release of a dead man's pedal, the train runs for a very short period followed by a short warning period before application of the train brakes. On operation of the dead man's pedal a relay picks up and triggers an electronic logical circuit. For the warning signal generated by this circuit the operator has to react since the apparatus can only now be returned to its initial state by momentary opening and closing of the dead man's pedal. If this action is not taken the circuit releases an electro pneumatic valve to operate the train brake. The vigilance and warning cycles are 1 minute and 30 seconds repeatively. The safety mode comes into operation when the dead man's pedal is released but with first period of two seconds and a second warning period of five seconds before the brakes are applied.

[0007] In more advanced vigilance checking and warning systems the locomotive is equipped with a receiver of signals emitted by low-range electromagnetic beacons installed close to the rails, i.e. at the railroad side or under the rails, in reasonable distance before signalling lamps or other points on the railroad that require special attention from the locomotive operator, like the railroad switches. The systems based on railroad beacon appliances are expensive because specialised railroad devices are expensive themselves, they have to be installed in very big number to make the system complete and reliable, supply with energy has to be secured and the maintenance costs are high. The overall costs can be so high that railway companies developing railroads in less favoured countries may be unable to deploy such systems, obviously with detriment to safety.

[0008] An interesting example of the systems of automatic train protection (ATP) and automatic train stop (ATS) based on railroad-side devices was described in international patent application WO2005002944 A1 (Shalom Engineering Co. Ltd., Kim Bong-taek, KR, 13.01.2005). Proposed invention relates to an automatic train protection stop (ATPS) device, provided with both the functions of ATP and ATS by adding a K-Balise, on the ground, which is capable of transmitting ground information using a small air-gap data communication, and a ground information memory pack on a train. Typically, a device transmitting ground information for the automatic train stop is called Balise. The Balise is a device for transmitting, using data communication, ground information such as ground operation conditions, distance and position of the beacon, and a target speed from a ground equipment to an on-board equipment. Particularly, it includes a Euro Balise and is called as K-Balise in this invention. Described invention includes an on-board equipment including a main device, an on-board antenna, a speed detector connected to a shaft of wheel, an operation switch, a train controller, and a communication module, and a ground equipment including an ATS beacon connected to a track occupancy detection device, a K-Balise using data communication, and a program part for inputting ground information data to the K-Balise. According to this invention, it is possible to implement the high-speed data communication and to secure the security and reliability by operating in an available distance in electric source free scheme. Also, it has advantages of self-testing and operation recoding and maintaining functions and the improvement of the stability by protecting the no reaction and malfunctioning. This invention however does not provide a system checking the operator's vigilance and it is focused on providing the operator with the voice information such as "The current section is the below-150km/h section" or "The current section is underworking section" so as to alarm the operator for secure operation.

[0009] In another invention proposed in Japanese patent application JP 7227009 A (Hitachi Ltd., JP, 22.08.1995) the train is equipped with a controller, reader, receiving device, and warning device. The controller is connected to a brake and tachometer generator under the floor of the train. A member of the crew of the train sets an IC card in the reader when he goes on board and the controller reads the running route information stored in the card. Then the controller compares the read running route information with running route information transmitted from the ground side through rails. When an error is found in the read running route information, the controller outputs it to the warning device. Again the off-locomotive devices are used to control the train route and to transmit information to the on-board system which additionally works on personalised set of data stored in electronic card, but no checking of the operator's vigilance is performed.

[0010] Efforts were done to make the on-board systems less dependent or independent from the on-the-ground installations. In Japanese patent application JP 2006131219 A (Hokkaido Ryokaku Tetsudo KK, Hokkaido JR Cybernet Co. Ltd., JP, 25.05.2006) the inventors attempted to provide a vehicle position display device capable of detecting the position of a railroad vehicle even when any fixed track circuit is not present, and realizing the railroad operation with less dependency on a ground installation.

[0011] In another Japanese patent application JP 2007135292 A (Nat. Traffic Safety & Environment, JP, 31.05.2007) the authors showed how to inhibit excess of speed at the time of run by applying brake exactly when a limit speed is exceeded even if ATC is not introduced and even on a route with no track circuit. They proposed the brake system comprising a speed generator, a GPS receiver and a GPS antenna, an ATS receiver, and a processor. According to this invention a distance-standard speed curve, a distance-limit speed curve, and positional information of a reference fixed point are inputted previously to the processor. Signals from the speed generator, and the like, are received and when a train is located at a fixed point, that fact is inputted and then the train position is matched to the positional information of the reference fixed point. During the train is travel a distance-actual speed curve is determined from the speed information of the speed generator. When the train is located at the reference fixed point, the calculated train position is corrected to the positional data of the reference fixed point. If actual speed exceeds a speed limit, a brake signal is delivered to a brake controller. When the actual speed drops below the distance-limit speed curve, the brake signal is released. The distance-actual speed curve, and the like, are recorded and stored.

[0012] The satellite positioning signals or satellite navigation has been exploited also in other inventions related to the railways traffic safety. Comming from the same applicant sister application JP 2007135291 A (Nat. Traffic Safety & Environment, JP, 31.05.2007) solves the problem of performing operation management for managing the traveling position and speed of a train precisely even if the ATC is not introduced and even on a route with no track circuit. According to the solution a speed generator, a GPS receiver and a GPS antenna, an ATS receiver, and a processor are mounted on a vehicle. Positional information of a reference fixed point is inputted previously to the processor. Output signal from each of the above mentioned devices is received and when a train is located at the fixed point, that fact is inputted and the train position is matched to the positional information of the reference fixed point inputted previously. When the train is traveling, train speed and train position are calculated from the speed information of the speed generator and a distance-actual speed curve is made. At the moment the train is located at the reference fixed point, the calculated train position is corrected to the positional data of the reference fixed point. The distance-actual speed curve, correction of the reference fixed point to positional data, GPS positioning data, and input of detection of an ATS ground unit are recorded and stored.

[0013] International application WO 2005048000 A2 (Lockheed Corp. i in., US, 26.05.2005; analogue of WO02059635 A2, 01.08.2002) discloses a locomotive location system and method which utilizes inertial measurement inputs, including orthogonal acceleration inputs and turn rate information. In combination with wheel-mounted tachometer information and GPS/DGPS position the system fixes to provide processed outputs indicative of track occupancy, position, direction of travel, velocity, etc. Various navigation solutions are combined together to provide the desired information outputs using an optimal estimator designed specifically for rail applications and subjected to motion constraints reflecting the physical motion limitations of a locomotive. The system utilizes geo-reconciliation to minimize errors and solutions that identify track occupancy when traveling through a turnout.

[0014] Also Canadian patent document CA 2273400 A1 (Westinghouse Air Brake Co., US, 09.12.1999) proposes a system including GPS receivers and wheel tachometers for providing alternate sources of information for position determination. An apparatus for determining the presence of a third rail disposed between parallel railroad tracks as a train progresses along said parallel railroad tracks and further for determining the relative direction of motion of said third rail with respect to said first two rails and further for determining the rate at which the third rail moves with respect to the first rails is disclosed, which is a low power radar sensor disposed underneath the rail vehicle and directed toward the rail on the opposing side of the vehicle. In a preferred embodiment, two rail detectors are shown which are disposed on opposite sides of the rail vehicle. The radar detectors are coupled with an onboard computing device and with other components of an advanced train control system which can be used for precisely locating the train on closely spaced parallel tracks and further for updating and augmenting position information used by the advanced train control system.

[0015] The American patent US 5129605 B1 (Rockwell International Corp., US, 14.07.1992) also follows the line of satellite navigation. The invention is carried out in a "trackside transponder-less" fashion, in the sense that the large numbers of trackside transponders which would be necessary if they were the sole source of position determination are substantially reduced along a large majority of the track length. Instead, the rail vehicle positioning system, utilizes a multiplicity of sources including track circuits, transponders, and GPS data to update the wheel tachometer and further uses GPS data to affect wheel tachometer calibrations.

[0016] Finally, international patent application WO2005002944 A1 summarised above shall be referred to again because the system proposed in this document may be complemented with the GPS receiver to provide the position information of the train using the global positioning system (GPS). In one embodiment of the invention the voice output alarm device checks the current position of the train using the GPS and then outputs the voice signal by backup of the ground information (fixed information and variable information) on the corresponding section.

[0017] As follows from the state of the art discussed thereinbefore, no automatic train protection and stop system based on the operator's vigilance checking and provided with reliable data of current geographical location of the vehicle while independent from any railroad-side specialised devices has been proposed up to this date. Present invention solves the problem of providing reliable and relatively cheap system taking advantage of satellite navigation and cooperating with commercially available satellite positioning receivers.

Description of the invention

[0018] The aim of the invention is to provide an automatic train protection and stop system that will assist the locomotive operator by checking his vigilance in predetermined geographical locations and that will automatically trigger stopping braking procedure in case the operator's vigilance may be questioned, the system that will use the satelite navigation technology and on-board measuring devices to determine current position in space thus being independent from railroad-side devices, the system that will be universal, flexible, interoperable with other on-board computerised systems and relatively cheap.

[0019] According to the invention the automatic train protection and stop system is proposed. This system comprises a satellite positioning signal receiver provided with a satellite positioning antenna to collect signals emitted from the satellites networked in any of existing or deployed global navigation satellite systems, like GPS-NAVSTAR, GLONASS, Galileo, Beidou, IRNSS and others, with corrections provided by errors correction systems, like DGPS or WAAS/EGNOS. Alternatively the system may comprise the means like adapters or interfaces or sockets controlled with dedicated software for connecting the system to external source of the train positioning, preferably external satellite positioning signal receiver. This option is useful for example if for any reasons the locomotive has already been or will be equipped with another satellite positioning signal receiver. However the external source of the train positioning may also be based on on-the-ground telecommunication systems, in particular those arranged in cellular networks and using high-speed data transfer protocols, i.e. the telecommunication systems like GSM, GPRS, UMTS, EDGE, HSDPA, etc. Other external sources of the train positioning are embraced by this invention as well, the speed and/or positioning measurement systems containing velocity and/or distance sensors and adequate cicuitry, mounted on the locomotive, are particular examples. Apart from the train positioning source, whether internal or external, proposed system contains an operator vigilance check module, which is a functional analogue of so called dead-man's handle. However one shall stress, that the operator vigilance check module is much more powerfull subsystem than the dead-man's handle, as will be explained hereinafter, and it shall be understood in its broadest sense.

[0020] The system comprises central processing unit, which runs dedicated software and calculates output data from input data, memorised data and other system variables and parameters. Some parts or entire software may be stored in electronic modules. Central processing unit controls whole system, I/O (input and output) devices included. To execute procedure of checking the operator's vigilance and his readiness to properly react to any visual and/or acoustic stimuli, the system works on preset information about reference checkpoints distributed along the route of the train. This information is taken from at least one memory module where the information about spatial coordinates of the reference checkpoints is stored, for example in a table of records containing alphanumeric identifier of given reference checkpoint and its geographical coordinates. This module is called a reference checkpoint memory module. It is preferably exchangeable to facilitate exchange of information about the reference checkpoints, which is necessary if the locomotive is intended to change the route. Such exchangeable memory module may also be personalised which makes proposed system more flexible and interoperable with other systems based on personalised memory modules, e.g. electronic chip-cards assigned to authorised operators. Good examples are the access authorisation systems to the locomotive door, engine key, or locomotive control system, which are activated after inserting personal chip-card into a slot. These dedicated systems may be embedded in proposed automatic train protection and stop system, thus creating another series of preferred embodiments of the invention.

[0021] Functionality of proposed system relies on permanent monitoring of the locomotive geographical position and running checking procedure of the operator's vigilance in preset reference checkpoints. However unexpected change of route of the train may happen, e.g. because of an accident, delay or other change of traffic in the railway network. Therefore the system comprises additionally at least one, preferably exchangeable, memory module to store information about a map containing at least one route, preferably all routes along which the train can move, called route map memory module. Exchangeability of the memory module facilitates updating, and adaptation of the system to specific requirements of the railway company. This module preferably contains identifiers and coordinates of all reference checkpoints distributed along all routes. Resulting redundancy of information about spatial distribution of the reference checkpoints along current route is advantageous, because it protects the system from the critical data loss, e.g. in case of the memory module failure.

[0022] In basic embodiment of the invention the operator vigilance check module of proposed system comprises a dead-man's handle. This is advantageous e.g. in upgrading of older models of locomotives, because this operation is relatively cheap since existing appliances and braking system may be used.

[0023] In more sophisticated embodiments of the system the operator vigilance check module comprises a subsystem called train emergency stop unit where checking procedure of the operator's vigilance is combined with emergency braking procedure executed if the operator fails to react in time for testing stimuli generated in course of checking procedure.

[0024] The embodiment of the train emergency stop unit, generally described above, may control an electro-mechanical air valve, i.e. the one that can be controlled by electro-mechanical actuator such as electric motor or solenoid, preferably through the relay, to activate the train brakes in state of emergency. By activation of the train brakes one generally understands opening the air valve in pneumatical braking circuitry, however proposed automatic train protection and stop system is intended to cooperate with any other than pneumatic braking system as well.

[0025] In preferred embodiment of the invention the operator vigilance check module contains light signalling device, e.g. a lamp on control desk in the cockpit, acoustic signalling device, e.g. a buzzer, and manual or foot-operated switch to switch-off light and acoustic signalling devices, preferably containing a push-button and electronic sub-system switching-off both light and acoustic signalling devices.

[0026] All events related to operation of the train shall be recorded, therefore proposed system in advantageous embodiment contains a velocity meter and/or a recorder of events. This recorder collects and stores information about control events, the operator's vigilance checking procedures included, and the events of activation of emergency stopping braking. The system may contain also, or instead of the velocity meter and the recorder, a tachograph to record a distance from reference point, normally starting point, and velocity of the train, and events, in particular the control events, the operator's vigilance checking procedures included, and the events of activation of emergency stopping braking.

[0027] In mostly preferred embodiment the system comprises a train speed sensor and/or a train distance sensor, the latter measuring the distance from arbitrary reference point, e.g. from starting point, along the route.

Both sensors are connected to central processing unit and provide it with respective input data on linear velocity and distance from starting point. Preferably the speed and distance sensors measure the train wheels revolutions and/or the Doppler effect.

[0028] For proposed automatic train protection and stop system an automatic method of referring the train position to memorised reference checkpoints has been elaborated. Within this method current geographical coordinates of the locomotive are compared in the central processing unit with the reference checkpoints geographical coordinates, taken out of the reference checkpoint memory module. At the moment of coincidence of the vehicle current coordinates with any reference checkpoint coordinates, the central processing unit activates the operator vigilance check module and begins the procedure of checking readiness of the operator to safely guide the train. Current geographical coordinates of the train are derived in recurrent loop from the signal of satellite positioning received by the satellite positioning signal receiver equipped with the satellite positioning antenna, or from external source of the train positioning, the latter preferably being external satellite positioning signal receiver, however the invention is not limited to this particular solution as was thoroughly explained hereinbefore. Both internal and external satellite positioning signal receivers may transfer respective encoded information about current geographical position by wire or wireless means. The analogue signal transfer is accepted within the invention, however digital means are preferred. These can be for example the protocols based on cellular networks, like GSM, GPRS, UMTS, EDGE, HSDPA mentioned above for the on-the-ground positioning sources. However if external source of the train positioning is remote but mounted on the locomotive, both wire and wireless means of data transfer can be used, like IRDa, Bluetooth, WLAN and other technologies.

[0029] It shall be stressed, that generally the geographical coordinates comprise three values, namely longitude, latitude and altitude above the sea level. In the coordinates derived from the satellite navigation system, third coordinate, altitude, is less accurate than the former two coordinates, longitude and latitude, nevertheless it may be exploited by invented system in determination of current position and in detection of the reference checkpoints, e.g. in the aircrafts. Although focused on trains, proposed invention is not limited to the railways technology, but applies with necessary modifications to the land vehicles, water crafts and aircrafts. The modification may consist, for example in the airplanes, in changing the train emergency stop unit to an auto-pilot (obviously the engines should not be stopped) if the system shall check the pilot's vigilance.

[0030] Due to limited accuracy of geographical positioning with satellite or other signals and taking into account that current position of the locomotive is determined recurrently in finite temporal intervals, some differences between measured coordinates in the location of the reference checkpoint and respective memorised coordinates may occur. In spite of such differences the reference checkpoint may not be omitted by the system, because this would create dangerous situation when operator's readiness has not been tested before entering a zone where his vigilance is particularly required. To avoid omission of any reeference checkpoint the values of current coordinates of the train and the reference checkpoint coordinates are compared with allowance to specified tolerances. In any case it is strongly recommended to run an extra checking procedure instead of omitting one in location of the reference checkpoint.

[0031] Within invented method when location of reference checkpoint is detected, the operator vigilance check module is activated. This module generates a command for central processing unit to switch-on the light signalling device, and after first preset time interval, preferably from 1 to 10 seconds, to switch-on the acoustic signalling device, and to wait for the operator's reaction. The central processing unit waits for pressing manual or foot-operated switch by the operator no longer than second preset time interval, preferably from 2 to 20 seconds, beginning from the moment of switching-on the light signalling device. If the operator reacts in time, the procedure is terminated. The operator may even react before acoustic signal is switched-on, however to avoid accidental, erroneous or automatised pressing the off-button, it is recommended to instruct the operator to wait untill the acoustic signal device is switched-on and to press the off-switch again. The software controlling the light and acoustic switches and the off-switch shall be modified accordingly. However in case the operator does not press the manual or foot-operated switch during second time interval, the central processing unit initiates the train emergency stopping braking, preferably by switching-on the electronic air valve activating the train brakes.

[0032] The satellite or on-the-ground positioning system may unexpectedly fail to emit positioning signals, or the receiver in the train may fail, or the train may enter a zone where radio-signals are shadowed, e.g. in tunnels. In any of the above cases the system detects loss of data from internal or external positioning sources. However the system shall continue operator's vigilance checking procedure, the more so that all situations mentioned above are potentially dangerous because general level of safety is diminished. When signal fadeout is detected, invented method proposes to change instantaneously the way of determining the reference checkpoints untill the signal is recovered. In other words, by-passing procedure of determination of the reference checkpoints is executed. In particular variant of the method, in case of fadeout of satellite positioning signal, current coordinates of the train are derived with use of the train speed sensor and/or the train distance sensor, measuring distance from arbitrary reference point selected on the route, preferably the starting point. Within by-passing procedure both speed and distance sensors play the role of external sources of the train positioning.

[0033] All important data about events related to control of the locomotive and of the operator shall be recorded. In proposed method the recorder or the tachograph register current coordinates of the train derived from the satellite positioning signal and/or with use of the train speed sensor and/or the train distance sensor. Besides, the recorder or tachograph register spatio-temporal coordinates of events, in particular the control events, the events of activation of emergency stopping braking, the events of change of the source of the train positioning.

[0034] The train may happen to change original route, because of various reasons related to traffic on the railway network. In such a case the central processing unit registers the event of change of route and determines current changed route of the train. The central processing unit further compares it to the route taken out of the route map memory module, and determines current new reference checkpoints with use of coordinates taken out of the route map memory module, and registers this changed route together with reference checkpoints in the recorder or the tachograph. Original set of the reference checkpoints is preserved in the reference checkpoint memory module and respective original route is stored in the route map memory module, but new itinerary with new set of the reference checkpoints is stored in the system memory (random access memory, disc memory, flash memory, etc.) and preferably it is recorded in the recording device.

[0035] The system as disclosed in this specification can consist of physically separate modules connected by wires or with use of wireless technology, but it may also be built in single casing with necessary sockets, plugs, switches, indicators and energy supplier such as battery, feeder cable, transformer, etc. The system incorporated in single casing can be made as a portable device.

Description of figures

[0036] Preferred and alternative embodiments of the automatic train protection and stop system according to the invention are schematically shown on Fig. 1, where used acronyms are those introduced in following section. Preferred embodiments are marked with solid lines while alternative embodiments are indicated with dashed lines. Other inputs and outputs of proposed system, necessary for its flexibility and interoperability are also marked with dashed lines. The arrows point at main directions of flow of data within the system. Dotted line between the central processing unit and the train emergency stop unit shows that invented system can be modified to perform other tasks, like emergency stop braking in cases other than lack of the operator's reaction to visual and acoustic stimuli. Just to give an example, one may consider automatic detection of an obstacle on the railroad, which may be invisible to the operator (snow, fog), commanding the central processing unit to trigger the procedure of emergency stop braking.

Preferred embodiments

[0037] In preferred embodiment the automatic train protection and stop system (ATPSS) comprises the satellite positioning signal receiver (SPSR) with the satellite positioning antenna (SPA). Alternatively it comprises the means for connecting the system to external source of the train positioning, preferably external satellite positioning signal receiver (ESPSR). The ATPSS also contains the operator vigilance check module (OVCM).

[0038] The ATPSS comprises the central processing unit (CPU), and at least one reference checkpoint memory module (RCMM) with information about coordinates of the reference checkpoints. The RCMM is preferably exchangeable.

[0039] Additionally the ATPSS comprises at least one route map memory module, (RMMM), also preferably exchangeable, with digital map containing at least one route, preferably all routes on which the train can move, with coordinates of respective reference checkpoints.

[0040] In basic embodiment the operator vigilance check module (OVCM) comprises a dead-man's handle (DMH), but it is preferred to provide the OVCM with the train emergency stop unit (TESU). The latter unit, TESU, controls an electro-mechanical air valve (EAV), preferably through the relay (R), to activate the train brakes in emergency.

[0041] The operator vigilance check module (OVCM) contains light signalling device (L), acoustic signalling device (A) and manual or foot-operated switch (S) of light signalling device (L) and acoustic signalling device (A). The switch (S) contains a push-button and a sub-system switching-off both light signalling device (L) and acoustic signalling device (A).

[0042] The ATPSS contains the velocity meter (V) and the recorder (P) of events, like control events and the events of activation of emergency stopping braking. Alternatively or aside to V and P, it contains a tachograph (T) recording the distance and velocity of the train, and events as mentioned above.

[0043] Finally, the train speed sensor (TSS) and the train distance sensor (TDS) measure the train wheels revolution and/or the Doppler effect, and they are connected to the central processing unit (CPU).

[0044] In the embodiment described above the method of automatic train protection and stop is applied. Within this method current coordinates (x_s,y_s) of the train are compared in the central processing unit (CPU) with the reference checkpoints coordinates (x_c,y_c) taken out of the reference checkpoint memory module (RCMM) and at the moment of coincidence of current coordinates (x_s, y_s) of the train with any reference checkpoint coordinates (x_c,y_c) the central processing unit (CPU) activates the operator vigilance check module (OVCM). Current coordinates (x_s,y_s) of the train are derived from the signal of satellite positioning received by the satellite positioning signal receiver (SPSR) with the satellite positioning antenna (SPA). Alternatively current coordinates (x_s,y_s) of the train are taken from external source of the train positioning, like the external satellite positioning signal receiver (ESPSR), by wire or wireless means worked in digital technology.

[0045] In proposed method the values of current coordinates (x_s,y_s) of the train and reference checkpoint coordinates (x_c,y_c) are compared with allowance to the tolerances (Δx_s, Δy_s) specified accordingly to the accuracy of the data provided by the SPSR or ESPSR and to anticipated maximum speed of the train. The tolerances may range from 2-3 meters up to several dozens meters.

[0046] In the method applied to preferred embodiment of invented system, after activation of the operator vigilance check module (OVCM) the central processing unit (CPU) switches-on the light signalling device (L), and after preset time interval Δt_1, preferably from 1 to 10 seconds, in realised embodiment 2,5 seconds, the central processing unit (CPU) switches-on the acoustic signalling device (A), and the central processing unit (CPU) waits for pressing the manual or foot-operated switch (S) by the operator no longer than preset time interval Δt_2, preferably from 2 to 20 seconds, in working embodiment 5 seconds, beginning from the moment of switching-on the light signalling device. In case the operator does not press the manual or foot-operated switch (S) during the time interval Δt_2 the central processing unit (CPU) initiates the train emergency stopping braking by switching-on the electro-mechanical air valve (EAV) activating the train brakes.

[0047] In case of fadeout of satellite positioning signal, current coordinates (x_s,y_s) of the train are derived with use of the train speed sensor (TSS) and/or the train distance sensor (TDS), being the external sources of the train positioning during the time of lack of data from internal or external satellite positioning signal receivers.

[0048] According to invented method, the recorder (P) or the tachograph (T) registers current coordinates (x_s, y_s) of the train derived from the satellite positioning signal and/or with use of the train speed sensor (TSS) and/or the train distance sensor (TDS), and the recorder (P) or tachograph (T) registers spatio-temporal coordinates (x_e, y_e,t_e) of events, in particular the control events, the events of activation of emergency stopping braking, the events of change of the source of the train positioning.

[0049] In case of change of the train route the method anticipates that the central processing unit (CPU) registers the event of change of route and determines current changed route of the train and compares it to the route taken out of the route map memory module (RMMM), and determines current new reference checkpoints with use of coordinates taken out of the route map memory module (RMMM). In one embodiment this changed route together with reference checkpoints is registered in the recorder (P) or the tachograph (T), however this step may be omitted, since all information about changed route may be derived afterwards from the data stored in the system.

Claims

1. Automatic train protection and stop system (ATPSS) **characterised in that** it comprises a satellite positioning signal receiver (SPSR) with a satellite positioning antenna (SPA) or it comprises the means for connecting the system to external source of the train positioning, preferably an external satellite positioning signal receiver (ESPSR), and it contains an operator vigilance check module (OVCM).

2. The system according to claim 1 **characterised in that** it comprises a central processing unit (CPU), and at least one, preferably exchangeable, memory module to store information about coordinates of the reference checkpoints (reference checkpoint memory module, RCMM).

3. The system according to claim 1 **characterised in that** it comprises additionally at least one, preferably exchangeable, memory module to store information about a map containing at least one route, preferably all routes on which the train can move (route map memory module, RMMM), preferably with coordinates of the reference checkpoints.

4. The system according to any of claims 1-3 **characterised in that** the operator vigilance check module (OVCM) comprises a dead-man's handle (DMH) or is connected to external dead-man's handle.

5. The system according to any of claims 1-4 **characterised in that** the operator vigilance check module (OVCM) comprises a train emergency stop unit (TESU).

6. The system according to claim 5 **characterised in that** the train emergency stop unit (TESU) controls an electro-mechanical air valve (EAV), preferably through the relay (R), to activate the train brakes in emergency.

7. The system according to any of claims 1-6 **characterised in that** the operator vigilance check module (OVCM) contains a light signalling device (L), an acoustic signalling device (A) and manual or foot-operated switch (S) of the light signalling device (L) and the acoustic signalling device (A), preferably containing a push-button and a subsystem switching-off both the light signalling device (L) and the acoustic signalling device (A).

8. The system according to any of claims 1-7 **characterised in that** it contains a velocity meter (V) and/or it contains a recorder (P) of events, in particular the control events and the events of activation of emergency stopping braking, and/or it contains a tachograph (T) to record distance from reference point and

velocity of the train and events, in particular the control events, and the events of activation of emergency stopping braking.

9. The system according to any of claims 1-8 **characterised in that** a train speed sensor (TSS) and/or a train distance sensor (TDS) are connected to the central processing unit (CPU), while the sensors TSS and TDS are preferably the sensors of the train wheels revolution and/or the Doppler sensors.

10. A method of automatic train protection and stop **characterised in that** current coordinates (x_s,y_s) of the train are compared in the central processing unit (CPU) with the reference checkpoints coordinates (x_c,y_c) taken out of the reference checkpoint memory module (RCMM) and at the moment of coincidence of current coordinates (x_s,y_s) of the train with any reference checkpoint coordinates (x_c,y_c) the central processing unit (CPU) activates the operator vigilance check module (OVCM), whereas current coordinates (x_s,y_s) of the train are derived from the signal of satellite positioning received by the satellite positioning signal receiver (SPSR) with the satellite positioning antenna (SPA), or current coordinates (x_s,y_s) of the train are taken from external source of the train positioning, preferably the external satellite positioning signal receiver (ESPSR), by wire or wireless means, preferably realised in digital techology.

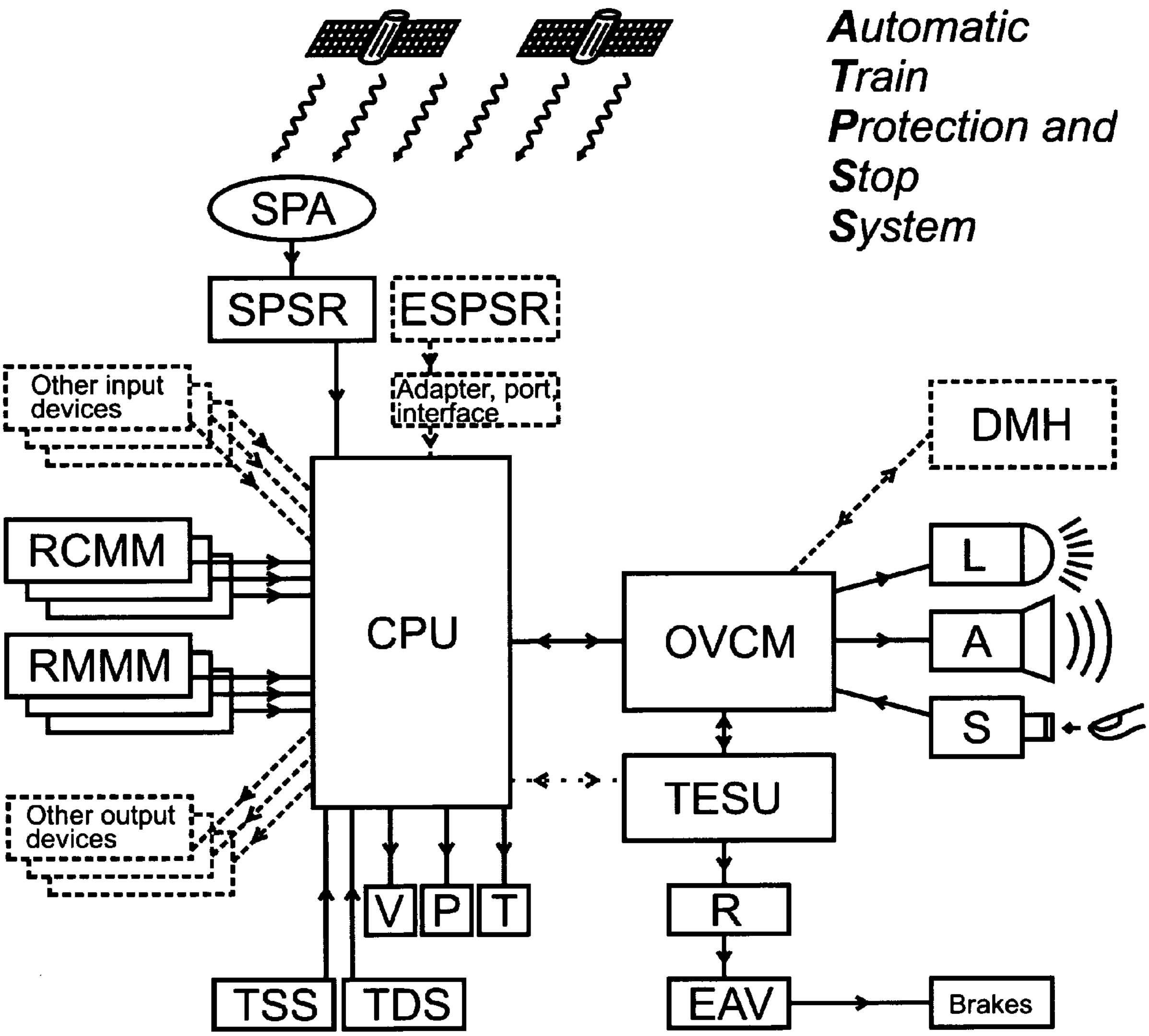
11. The method according to claim 10 **characterised in that** the values of current coordinates (x_s,y_s) of the train and the reference checkpoint coordinates (x_c, y_c) are compared with allowance to specified tolerances (Δx_s, Δy_s).

12. The method according to claims 10 or 11 **characterised in that** after activation of the operator vigilance check module (OVCM) the central processing unit (CPU) switches-on the light signalling device (L), and after preset time interval Δt_1, preferably from 1 to 10 seconds, the central processing unit (CPU) switches-on the acoustic signalling device (A), and the central processing unit (CPU) waits for pressing the manual or foot-operated switch (S) by the operator no longer than preset time interval Δt_2, preferably from 2 to 20 seconds beginning from the moment of switching-on the light signalling device, and in case the operator does not press the manual or foot-operated switch (S) during the time interval Δt_2 the central processing unit (CPU) initiates the train emergency stopping braking, preferably by switching-on the electro-mechanical air valve (EAV) activating the train brakes.

13. The method according to any of claims 10-12 **characterised in that** in case of fadeout of satellite positioning signal, current coordinates (x_s,y_s) of the train are derived with use of the train speed sensor (TSS) and/or the train distance sensor (TDS), being the external sources of the train positioning during the time of lack of data from internal or external satellite positioning signal receivers.

14. The method according to any of claims 10-13 **characterised in that** the recorder (P) or the tachograph (T) registers current coordinates (x_s,y_s) of the train derived from the satellite positioning signal and/or with use of the train speed sensor (TSS) and/or the train distance sensor (TDS), and the recorder (P) or tachograph (T) registers spatio-temporal coordinates (x_e,y_e,t_e) of events, in particular the control events, the events of activation of emergency stopping braking, the events of change of the source of the train positioning.

15. The method according to any of claims 10-14 **characterised in that** in case of change of the train route the central processing unit (CPU) registers the event of change of route and determines current changed route of the train and compares it to the route taken out of the route map memory module (RMMM), and determines current new reference checkpoints with use of coordinates taken out of the route map memory module (RMMM), and preferably registers this changed route together with reference checkpoints in the recorder (P) or the tachograph (T).


Automatic
Train
Protection and
Stop
System
SPA
SPSR
ESPSR
Adapter, port, interface
Other input devices
DMH
RCMM
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CPU
OVCM
A
RMMM
S
TESU
Other output devices
V
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EAV
Brakes

Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 09 46 0006

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
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