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(54) **MONITORING SYSTEM FOR A RAILWAY INFRASTRUCTURE**

(57) It is disclosed a monitoring system for a railway infrastructure comprising a signalling entity to be monitored. The system comprises an acquisition radio module configured to be connected to one or more sensors configured to acquire measurement data relating to one or more physical parameters indicative of an operating state of said signalling entity; and a gateway radio module configured to be connected to the acquisition radio module

by means of a first wireless link, so as to receive from the acquisition radio module the measurement data, the gateway radio module being further configured to provide, based on the measurement data, by means of a second wireless link, a stream of compressed data to a location remote from the signalling entity, in order to monitor the operating state thereof.

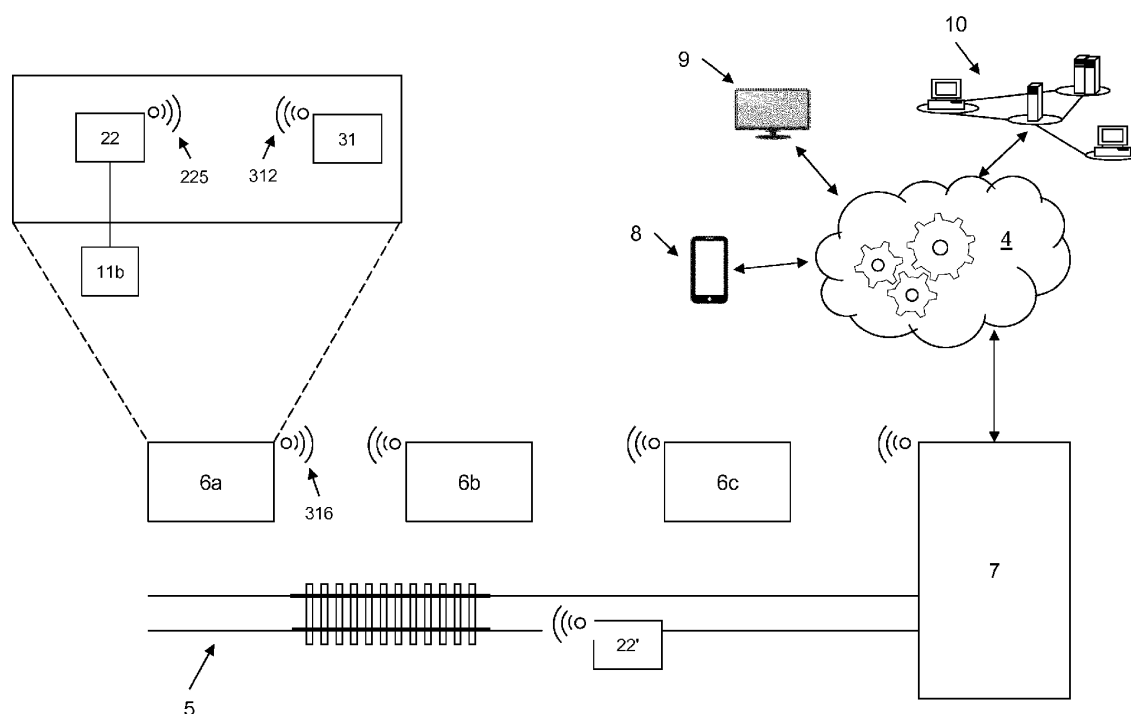


Fig. 6

Description

Technical field

[0001] The present invention generally relates to the field of railway infrastructures. More particularly, the present invention relates to a monitoring system for a railway infrastructure.

Background art

[0002] As is known, a railway infrastructure may be provided with a system known as a "Centralized Diagnostic System" (in Italian, "Sistema di Diagnostica Centralizzato", SDC) for monitoring a number of parameters of the station and line signalling entities (signals, switching points, level crossings, track circuits, sentry stations, etc.). Typically the parameters which may be monitored are voltages and/or currents.

[0003] A known centralized diagnostic system typically comprises a centralized server which collects measurement data from a plurality of servers arranged inside the stations along the railway line, so as to be able to indicate the state of the various entities to an operator who is able, if necessary, to take action in the event of faults or malfunctions. In turn, each of the station servers collects data from various data collection units (in Italian, "unità di raccolta dati", URD) present both in the station and along the railway line, for example inside the sentry stations (also referred to as technology centres) which are typically arranged at a few kilometres from each other. The URDs are typically configured to collect measurement data (voltages and currents) acquired from the various signalling entities to be monitored. The connection between the URDs along the line and the server station is typically provided via a twisted-pair telephone cable by means of a data transmission unit (in Italian, "unità di invio dati", UID) present in the sentry station. The connection between the servers is typically provided by means of a LAN (Local Area Network). Each URD acquires data, in digital and/or analog form, from one or more diagnostic interfaces connected together and to the URD by means of a CAN (Controller Area Network) bus. The station URDs typically are connected to the station server by means of a LAN port.

Summary of the invention

[0004] The known centralized diagnostic systems have a number of drawbacks.

[0005] In the known systems, the devices which collect the measurement data (namely the diagnostic interfaces) are connected to terminal blocks of the signalling entities in order to measure dc voltages, ac voltages, currents and the associated phase-displacement of the said signalling entities. These terminal blocks are typically terminals strips positioned in the technology centres to which the diagnostic interfaces are linked. Each terminal

strip contains all the analog signals (currents and voltages) received from the signalling entities present at the technology centre.

[0006] The known systems are costly because it is required to connect via cable the diagnostic interfaces of a technology centre as far as the URD. Since this cabling operation is performed using at least 4 wires for each interface, via the CAN bus, and the number of signalling entities and associated diagnostic interfaces present in a technology centre is decidedly high (on average 200-300), the cost is very high.

[0007] Moreover, these systems are invasive since their operation requires a new electronic installation between the diagnostic interfaces and the URDs, in order to manage the data supplied by the CAN bus by means of, for example, multiplexing and demultiplexing devices.

[0008] The known systems are also costly from the point of view of data processing. These systems are in fact based on methods for processing the measurement data, in particular sampling methods (for example, high resolution or so-called "HiRes" sampling methods) which require the use of specially designed integrated devices with a high performance, in particular in terms of memory, able to provide good quality measurements. This results in high costs for the design and manufacture of these devices and limited flexibility of the system. Moreover, in the light of that described above, each diagnostic interface is connected to a CAN bus inside the station or the sentry station, and each sentry station is connected to the station by means of a twisted-pair telephone cable. This results in high installation and maintenance costs.

[0009] Finally, the known systems envisage measuring and monitoring only electrical parameters such as voltages and currents. In fact, typically the number of types of diagnostic interfaces is limited (the known systems typically have five types of diagnostic interfaces: coded current track circuit interface, automatic block reversal interface, fixed current track circuit interface, switching point interface, and non-trailability electromagnetic interface). This means that the known systems are limited to providing only some types of measurements.

[0010] An object of the present invention is therefore to provide a monitoring system for a railway infrastructure which solves at least one of the aforementioned problems.

[0011] In particular, an object of the present invention is to provide a monitoring system for a railway infrastructure which (i) allows remote monitoring of said infrastructure without using cabled transmission lines; (ii) allows monitoring of a greater number of parameters than the known systems, in particular mechanical and thermal parameters in addition to the electrical parameters already mentioned; (iii) allows a reduction in the costs for design and manufacture of the integrated devices for processing the measurement data, and the costs for installation and maintenance of the communication lines, and (iv) is not invasive, i.e. does not require the modification of devices and apparatuses already installed in the railway infra-

structure for standard diagnostic and control purposes.

[0012] According to embodiments of the present invention, a monitoring system for a railway infrastructure is provided, the railway infrastructure comprising a signalling entity to be monitored, the monitoring system comprising:

- an acquisition radio module configured to be connected to one or more sensors configured to acquire measurement data relating to one or more physical parameters of the signalling entity, the physical parameters being indicative of an operating state of the signalling entity; and
- a gateway radio module configured to be connected to the acquisition radio module via a first wireless link, so as to receive from the acquisition radio module the measurement data, the gateway radio module being further configured to provide, based on the measurement data, by means of a second wireless link, a stream of compressed data to a location remote from the signalling entity, in order to monitor the operating state thereof.

[0013] Preferably, the acquisition radio module comprises an acquisition unit comprising at least one diagnostic interface connected to the one or more sensors for acquiring the measurement data.

[0014] Preferably, the one or more sensors comprise a temperature sensor for measuring a temperature of the signalling entity and/or a vibration sensor for measuring one or more parameters indicative of a vibration of the signalling entity.

[0015] Preferably, the acquisition radio module comprises a processing unit connected to the acquisition unit, the processing unit comprising first and second processing sub-units connected in so-called "failover" mode so as to process the measurement data acquired by the at least one diagnostic interface.

[0016] Preferably, the acquisition radio module comprises a short-range radio link unit configured to be connected to the gateway radio module by means of the first wireless link. In particular, the first wireless link may be realized by means of the Wi-Fi technology.

[0017] Preferably, the acquisition radio module is configured to send to the gateway radio module the measurement data by means of the so-called "message queue telemetry transport" protocol.

[0018] Preferably, the acquisition radio module has a modular hardware structure.

[0019] Preferably, the gateway radio module comprises a short-range radio link unit and a long-range radio link unit, the short-range radio link unit being configured to be connected to the short-range radio link unit of the acquisition radio module by means of the first wireless link, and the long-range radio link unit being configured to be connected to the remote location by means of the second wireless link.

[0020] Preferably, the second wireless link is imple-

mented by means of LoRa (Long Range) technology or SIGFOX technology.

[0021] Preferably, the gateway radio module comprises a first processing unit and a second processing unit connected in so-called "failover" mode, each of the first and second processing units being configured to aggregate the measurement data on the basis of one or more measurement types and to compare said data with pre-determined thresholds, each of the thresholds being indicative of an expected value for a respective type of measurement.

[0022] Preferably, each of the first and second processing units is configured to implement an alarm procedure in case the measurement data exceed one of the pre-determined thresholds.

[0023] Preferably, each of the first and second processing units is configured to compress the measurement data according to a compression algorithm of the "compressive sampling" type.

[0024] Preferably, the monitoring system comprises a "cloud" architecture to receive the measurement data and present it, in the remote location, to an operator able to use this data to program interventions of maintenance on the railway infrastructure.

[0025] Preferably, the "cloud" architecture comprises a database configured to store the data received from the gateway radio module.

Brief description of the drawings

[0026] The present invention will be illustrated in greater detail by means of the attached drawings which are provided by way of a non-limiting example and in which:

- Figure 1 schematically shows the architecture of a monitoring system 1 for a railway infrastructure, according to embodiments of the present invention.
- Figure 2 is an exemplary block diagram of an acquisition radio module according to an embodiment of the present invention;
- Figure 3 is an exemplary block diagram of an acquisition unit of the acquisition radio module according to an embodiment of the present invention;
- Figure 4 is an exemplary block diagram of a gateway radio module according to an embodiment of the present invention;
- Figure 5 schematically shows the software architecture of a data presentation level of the monitoring system according to embodiments of the present invention; and
- Figure 6 schematically shows the monitoring system according to the present invention in a possible application scenario.

Detailed description of preferred embodiments of the invention

[0027] Figure 1 schematically shows the architecture

of a monitoring system 1 for a railway infrastructure, according to embodiments of the present invention. The monitoring system 1 preferably has a three-level architecture. In particular, the monitoring system 1 comprises a data acquisition level 2, a network level 3 and a data presentation level 4.

[0028] The data acquisition level 2 preferably comprises hardware and software modules (indicated below as "acquisition radio modules") able to acquire data from station signalling entities and line signalling entities belonging to the railway infrastructure to be monitored. The signalling entities typically belong to five categories: light signals, turnouts, level crossings, track circuits, sentry stations. The light signals comprises dichroic mirror light signals and light signals with fan devices. These devices are known and will not be described further below. Figure 1 schematically shows a plurality of signalling entities 11a, 11b, 11c, 11d, 11e of the railway infrastructure to be monitored. In particular, Figure 1 schematically shows five signalling entities, which for example each belong to one of the five categories of signalling entities mentioned above, i.e.: a light signal 11a, a turnout 11b, a level crossing 11c, a track circuit 11d and a sentry station 11 e.

[0029] The network level 3 preferably comprises a data communication network, in particular a wireless communication network, able to connect the signalling entities to the sentry stations of the railway line, the sentry stations to each other and the sentry stations to the (central) stations of the railway infrastructure. Moreover, the network level 3 preferably comprises hardware and software modules (indicated below as gateway radio modules) able to acquire data from the acquisition radio modules and carry out on them aggregation, filtering and compression operations.

[0030] The data presentation level 4 preferably comprises hardware and software modules able to implement a "cloud" architecture to receive from the network level 3 the measurement data acquired by the acquisition level 2, process it, store it in the memory and present it to operators who are able to use this data for carrying out or programming, where necessary, maintenance interventions on the railway infrastructure or for providing it to the railway network manager. In particular, the data presentation level 4 preferably comprises a software infrastructure able to acquire the processed data from the gateway radio modules and provide it to the operators responsible for the railway infrastructure maintenance and monitoring operations by means of special terminals (for example, mobile devices such as smartphones or tablets) or provide said data to control centres or the data networks of the railway infrastructure manager.

[0031] In the present description below, the term "station" will indicate a service location, bounded by protection signals, where the train movement operations (precedence, diversions or intersections) are performed and the passenger and goods access the railway network. The term "sentry station" or, the equivalent term "technology centre", will indicate a service location situated

along the railway line, not accessible to the public, comprising devices having functions associated with the movement of the trains and control of the signalling entities, as well as network equipment for data communication.

[0032] The railway infrastructure to be monitored according to the present invention comprises a railway line portion and is schematically shown in Figure 6. The railway line portion to be monitored is indicated by the reference number 5. The line portion to be monitored may comprise a section of a few tens or hundreds of kilometres. A plurality of sentry stations 6a, 6b, 6c are present along the line. Typically, the distance between one sentry station and the next one is about 2 km. The line portion to be monitored may also comprise a station 7. The railway infrastructure may be for example an underground railway infrastructure or a suburban railway infrastructure.

[0033] As mentioned above, the acquisition level 2 preferably comprises a number of acquisition radio modules. Figure 6 shows two acquisition radio modules, indicated by the reference numbers 22 and 22'. The acquisition radio modules 22, 22' are preferably arranged along the railway line to be monitored and are connected to the signalling entities to be monitored via suitable ports and interfaces, as will be described in detail herein below.

[0034] According to embodiments of the present invention, the acquisition of the data from the signalling entities takes place inside the sentry stations 6a, 6b, 6c. This data acquisition mode will be indicated below also as "indoor acquisition mode". According to these embodiments, the acquisition radio modules 22 (indicated also as "indoor acquisition radio modules") are positioned inside the sentry stations 6a, 6b, 6c. According to these embodiments, each sentry station 6a, 6b, 6c may contain one or more indoor acquisition radio modules 22. According to these embodiments, each indoor acquisition radio module 22 may be connected (via connectors, cables or jacks) to a terminal block of a respective signalling entity to be monitored, present in the sentry station, for collecting electrical measurement data (voltages and currents). In particular, a terminal block may comprise a terminal strip. Said terminal strip may be a 12-pole terminal strip cabled according to the V410 (line) and V409 (station) schemes. In addition or alternatively, the indoor acquisition radio module 22 may be connected to non-invasive sensors connected directly to the cables from the signalling element, as will be described in greater detail below.

[0035] According to other embodiments of the present invention, which are an alternative to or complement the embodiments described above and related to the indoor acquisition mode, the acquisition of data from the signalling entities takes place at the signalling entity itself. This data acquisition mode will be indicated below also as "outdoor acquisition mode". According to these embodiments, one or more acquisition radio modules 22' (indicated also as "outdoor acquisition radio modules") may be positioned along the railway line at respective signal-

ling entities to be monitored, in order to collect measurement data relating to physical parameters to be measured directly on the signalling entity in question, such as voltage and currents, vibrations, temperatures, forces and pressures. According to these embodiments, each outdoor acquisition radio module 22' is installed at a respective signalling entity and may be connected (by means of connectors, cables or jacks) to a terminal block (e.g. a terminal strip) of a respective signalling entity to be monitored. In addition or alternatively, the outdoor acquisition radio module 22' may also be connected to non-invasive sensors connected directly to the cables from the signalling element, as will be described in greater detail below.

[0036] As described above, each indoor or outdoor acquisition radio module is preferably connected to a respective signalling entity and is therefore associated with it. This means that the data acquired by the acquisition radio module, once processed and transferred to the gateway radio module and to the apparatuses of the data presentation level, in order to be made available to the railway infrastructure manager and the operators responsible for the maintenance and control operations, is uniquely associated with the corresponding signalling element.

[0037] Figure 2 shows a block diagram of an indoor acquisition radio module 22 according to embodiments of the present invention. Preferably, in the system according to the present invention, all the indoor acquisition radio modules have the same block diagram, which is shown in Figure 2.

[0038] The indoor acquisition radio module 22 preferably comprises an acquisition unit 221 connected to a processing unit 222. In turn, the processing unit 222 is connected to a viewing (or display) unit 223 and to a short-range radio link unit 224. The short-range radio link unit 224 is preferably connected to an antenna 225.

[0039] Figure 3 shows a block diagram of the acquisition unit 221. The acquisition unit 221 preferably comprises one or more ports, each configured to house a number of diagnostic interfaces for connecting to the indoor acquisition radio module 22 a corresponding number of sensors configured to measure a given type of physical parameters associated with the signalling entities to be monitored. According to the preferred embodiment of the present invention shown in Figure 3, the acquisition unit 221 preferably comprises one or more of the following ports:

- a first port 21a, indicated also as MS-IF port, comprising in turn a first number of interfaces for connecting to the indoor acquisition radio module 22 sensors configured to measure mechanical parameters such as, for example, force, torque, mass, damping force, torsion or pressure;
- a second port 21b, indicated also as TS-IF port, comprising in turn a second number of interfaces for connecting to the indoor acquisition radio module 22

sensors configured to measure thermodynamic parameters such as, for example, temperature and thermal conductivity; and

- a third port 21c, indicated also as ES-IF port, comprising in turn a third number of interfaces for connecting to the indoor acquisition radio module 22 sensors configured to measure electrical parameters such as, for example, voltages, currents, resistances and inductances.

[0040] The acquisition unit 221 may comprise a variable number of diagnostic interfaces depending on the electrical parameters to be measured for the signalling entity in question. From a hardware point of view, the interfaces are programmable modules which comprise the sensors configured to measure the mentioned parameters. The sensors may be integrated in the corresponding interfaces or be linked or connected to them by means of suitable connectors and/or cables and/or jacks. In particular, as regards the electrical parameters, for measurement of alternating currents and voltages, the sensors preferably comprise non-invasive "Hall effect" sensors, for example consisting of clip transformers configured to be connected to the current cable to be monitored, supplied from the signalling element. For measurement of direct currents and voltages, the sensors preferably comprise invasive sensors such as transformers or voltage dividers which require the cabling of two wires between the terminal strip and the sensor itself.

[0041] Below, the diagnostic interfaces which may be present in an acquisition unit 221 will be briefly described with reference to the respective signalling entity and the measurements which they may provide.

[0042] As regards the light signals, the diagnostic interfaces may comprise a light signal interface with fan devices (indicated also as IF-SLV) and a dichroic-mirror light signal interface (indicated also as IF-SLD). These diagnostic interfaces preferably provide a coded ac power supply voltage measurement within the range from 0 Vac to 150 Vac. The aforementioned measurements are known to the person skilled in the art and may be derived from the specification RFI TCSSTB SF IS 18 755 A "RFI-Interfacce per diagnostica IS secondo V409 e V410 con uscita digitale" [RFI interfaces for IS diagnostics according to V409 and 410 with digital output]. These measurements will therefore not be further described.

[0043] As regards the turnouts, the diagnostic interfaces may comprise:

- a turnout interface (IF-DEV), which allows the turnout operating currents and voltages to be measured;
- a non-trailability electromagnet interface (IF-EL), which allows operating currents and voltages to be measured.

[0044] Preferably, the interface IF-DEV provides the following measurements:

- bipolar dc power supply voltage measurement of the relay KD-KD from -60 Vdc to +60 Vdc;
- unipolar dc power supply voltage measurement of the turnout from 0 Vdc to 160 Vdc;
- unipolar dc power supply voltage measurement of the turnout from 0 Vdc to 160 Vdc (counter-manoeuvre);
- absorption current measurement of the turnout from 0 A to 25 A.

[0045] Preferably, the interface IF-EL provides the following measurements:

- unipolar dc voltage measurement of the relay KED from 0 Vdc to 60 Vdc;
- unipolar dc power supply voltage measurement of the electromagnet from 0 Vdc to 60 Vdc;
- absorption current measurement of the electromagnet from 0 A to 1.5 A.

[0046] The aforementioned measurements are known to the person skilled in the art and may be derived from the specification RFI TCSSTB SF IS 18 755 A "RFI-Interfacce per diagnostica IS secondo V409 e V410 con uscita digitale" [RFI interfaces for IS diagnostics according to V409 and 410 with digital output]. These measurements will therefore not be further described.

[0047] As regards the level crossings, the diagnostic interfaces may comprise:

- a level crossing interface (IF-PL), which allows operating currents and voltages to be measured;
- an audiofrequency track circuit interface (IF-CBAF).

[0048] Preferably, the interface IF-PL provides the following measurements:

- bipolar dc power supply voltage measurement of the relay KLP-KPL from -60 Vdc to +60 Vdc;
- unipolar dc power supply voltage measurement of the manoeuvring box from 0 Vdc to 160 Vdc;
- unipolar dc power supply voltage measurement of the manoeuvring box from 0 Vdc to 160 Vdc (counter-manoeuvre);
- absorption current measurement of the manoeuvring box from 0 A to 25 A.

[0049] Preferably, the interface IF-CBAF provides a coded ac power supply voltage measurement from 0 Vac to 150 Vac.

[0050] The aforementioned measurements are known to the person skilled in the art and may be derived from the specification RFI TCSSTB SF IS 18 755 A "RFI-Interfacce per diagnostica IS secondo V409 e V410 con uscita digitale" [RFI interfaces for IS diagnostics according to V409 and 410 with digital output]. These measurements will therefore not be further described.

[0051] As regards the track circuits, the diagnostic interfaces may comprise:

- fixed current track circuit interface (IF-CBCF), which allows measurement of the local and field voltage from which the phase-displacement angle and the torque applied to the disk relay are obtained;
- coded current track circuit interface (IF-CBCC), which allows measurement of the voltage and current useful for calculating the period and duty-cycle of the code;
- track temperature sensor interface (IF-T), which allows measurement of the track temperature;
- track vibration sensor interface (IF-V), which allows the track vibrations to be measured.

[0052] Preferably, the interface IF-CBCF provides the following measurements:

- measurement of the local power supply voltage of the disk relay from 0 Vac to 100 Vac with frequency at 50 Hz;
- measurement of the field power supply voltage of the disk relay from 0 Vac to 50 Vac with frequency at 50 Hz;
- measurement of the disk relay logic state dc voltage driven by the said relay from 0 Vdc to 60 Vdc.

[0053] Preferably, the interface IF-CBCC provides the following measurements:

- measurement of the coded ac power supply voltage from 0 Vac to 170 Vac;
- measurement of the power supply absorption current from 0 A to 1.5 A.

[0054] The aforementioned measurements are known to the person skilled in the art and may be derived from the specification RFI TCSSTB SF IS 18 755 A "RFI-Interfacce per diagnostica IS secondo V409 e V410 con uscita digitale" [RFI interfaces for IS diagnostics according to V409 and 410 with digital output]. These measurements will therefore not be further described.

[0055] According to the present invention, the interface IF-T provides a temperature measurement expressed in degrees Celsius within the range from 0°C to 70°C.

[0056] Moreover, according to the present invention, the interface IF-V provides vibration, shock, acceleration and movement measurements. The factors which influence the level of vibrations produced along the rail by the passing of a train may be classified in three categories:

- operating factors associated with the vehicle, such as the speed of passing of the trains, rigidity of vehicle suspension, the wheel characteristics;
- factors associated with the tracks: the type of railway superstructure (mass and rigidity of its components)

and maintenance conditions; and

- factors of a geotechnical nature such as the stratigraphic and mechanical properties of the ground on which the rail is laid;

[0057] In particular, the interface IF-PV may provide measurements which are indicative of the following vibration parameters: acceleration, speed and displacement. The interface IF-V may for example incorporate a triaxial acceleration piezoelectric sensor (X, Y, Z axes) with frequency response of up to 60 kHz and scale end value of 500 g. According to the present invention, the interface IF-V, by means of the sensor, preferably receives at its input the vibrations along the three axes X, Y, Z and may provide at its output the components, along the three axes mentioned above, of a voltage indicative of the velocity of the vibration along the axis of the rail. The vibrations along the X axis are typically due to the movement of the train, the vibrations along the Y axis are typically due to landslip or breakage of the rail, while the vibrations along the Z axis are typically due to the falling of objects (such as rocks or animals) onto the rail.

[0058] As regards the sentry stations, the diagnostic interfaces may comprise:

- an automatic block reversal interface (IF-IBA), which allows measurement of block reversal relation voltages;
- bush temperature detection interface (IF-RTB);
- line relations interface (IF-RL).

[0059] Preferably, the interface IF-IBA provides the following measurements:

- bipolar dc power supply voltage measurement from -60 Vdc to +60 Vdc;
- bipolar dc power supply voltage measurement from -60 Vdc to +60 Vdc.

[0060] The aforementioned measurements are known to the person skilled in the art and may be derived from the specification RFI TCSSTB SF IS 18 755 A "RFI-Interfacce per diagnostica IS secondo V409 e V410 con uscita digitale" [RFI interfaces for IS diagnostics according to V409 and 410 with digital output]. These measurements will therefore not be further described.

[0061] According to the present invention, the interface IF-RTB provides a measurement of the temperature of the bushes expressed in degrees Celsius within the range 0°C to 70°C.

[0062] According to the present invention, the interface IF-RL analyzes whether the so-called line relations are satisfied, namely the safety logic conditions for railway travel between two railway stations (in fact at least one sentry station is typically present between two stations), such as the following:

- the preceding train left the section;

- the section must be free from vehicles and obstacles;
- the track must be intact;
- the signal appearance must be clearly visible and correct;
- 5 - the line section between two movement places must be not occupied by trains travelling in the opposite direction.

[0063] Preferably, the interface IF-RL checks for the fulfilment of the aforementioned conditions and provides the following measurements:

- measurement of sigmALL voltage (logic interface) operating on two levels: 48 V for relations controlled at a distance of less than 5 km and 144 V for relations controlled at distances greater than 5 km;
- 15 - measurement of sigma BA voltage (automatic block) from 48 V to 144 V.

[0064] The aforementioned measurements are known to the person skilled in the art and may be derived from the specification RFI TCSSTB SF IS 18 755 A "RFI-Interfacce per diagnostica IS secondo V409 e V410 con uscita digitale" [RFI interfaces for IS diagnostics according to V409 and 410 with digital output]. These measurements will therefore not be further described.

[0065] Considering again the block diagram of Figure 22, the processing unit 222 is preferably configured to receive, from the acquisition unit 221, the data from the diagnostic interfaces of the signalling entities and transmit said data to the display unit 223 and to the short-range radio link unit 224. The processing unit 222 preferably comprises two processing and control sub-units (not shown in the Figure). Each processing and control sub-unit preferably comprises a respective microprocessor or microcontroller. The two microprocessors are connected together in so-called "failover" mode. According to said mode, in the event of a fault or breakdown of a processing and control sub-unit, the operativity of the processing unit 222 is ensured by the presence of the second processing and control sub-unit.

[0066] The first processing and control sub-unit consists of two stages (not shown in the Figures). The first stage is preferably configured to sample the data from the acquisition unit 221, process it, filter it and provide a stream of filtered data to the second stage of the first processing and control sub-unit.

[0067] In particular, the first stage is preferably configured to:

- sample the signals from the acquisition unit. This operation comprises establishing a serial connection with the acquisition unit in order to sample, at a predetermined frequency, the signals from the sensors of the acquisition unit 221;
- 55 - calibrate the amplitudes of these samples to significant amplitudes in relation to the signalling entity in question. For example, if the used sensors operate

providing voltages within the range 0-5 volts, the calibration performed in this first stage allows the amplitudes of the samples to be adjusted from the values mentioned to values for example comprised within the power supply range of 0-220 volts of the signalling element; and

- filter the calibrated data. This operation comprises reducing the measurement mean error by means of averaging operations and corrections applied to the data, using known methods which will not be further described since they do not form the subject of the present invention. Optionally, the filtering operation may further comprise compressing the data by applying a data compression algorithm. The data compression algorithm may be a known so-called "compressive sampling" algorithm. Such an algorithm is for example described in E. Candès and Micheal B.Wakin, "An Introduction To Compressive Sampling" IEEE. Signal Processing Magazine March 2008; Bajwa, W. U., Haupt, J., Sayeed, A. M., Nowak, R., Compressive wireless sensing. In Proc. 5th Intl. Conf. on Information Processing in Sensor Networks (IPSN '06), Nashville, TN 2006, 134-142.

[0068] The first stage may moreover perform measurement data processing operations, before the calibration and filtering operations described hereinabove. As regards the data provided by the interface IF-V, the first stage may execute an algorithm which compares, for each axis X, Y, Z, the measured voltage which is indicative of the vibration velocity along the respective axis with a reference voltage corresponding to a known vibration pattern. In the case where one of the measured voltages differs from the corresponding known vibration pattern, an alarm is preferably generated. In this case, since the diagnostic interface IF-V is preferably housed in an outdoor acquisition radio module 22' positioned along the track, the outdoor acquisition radio module 22' may send the processed data (namely, data indicative of whether or not the vibration pattern corresponds to a known vibration pattern) to the gateway radio module 31 located in the sentry station 31. The gateway radio module 31 stores this data and sends to the apparatuses of the data presentation level 4 an alarm message which activates a corresponding alarm notification for the monitored signalling entity (in this case the track) on a graphical user interface of the data presentation level 4. This alarm notification may be a video and/or audio indication which may be used, for example, by an operator at a control centre. The alarm notification may be, for example, the opening of a window or pop-up frame on the graphical interface, or a change (for example in colours) in the display of graphical elements relating to the specific signalling entity.

[0069] As regards the data provided by the interface IF-RL, the first stage may execute an algorithm which performs reading of the line relations, namely checks that

they are satisfied, outputting a voltage value indicative of the instantaneous safety condition along the considered railway line section. For example, if all the logic conditions mentioned above are satisfied, the first stage may output a voltage indicating that all the safety logic conditions have been satisfied, for example a dc voltage having the value of 5 Volts. If instead at least one of the safety logic conditions is not satisfied, the first stage may provide at its output a zero voltage value which may generate an alarm. In this case, as already described above with reference to the interface IF-V, the gateway radio module 31 which collects the measurement data may store this data and send to the apparatuses of the data presentation level 4 an alarm message which activates a corresponding alarm notification for the monitored signalling entity (in this case, the sentry station) on a graphical user interface of the data presentation level 4.

[0070] The second stage of the first processing and control sub-unit of the processing unit 222 is preferably configured to adapt the data from the first stage in order to send it to the display unit 223. In particular, this operation comprises establishing a serial connection with the display unit 223.

[0071] The second processing and control sub-unit of the processing unit 222 consists of two stages (not shown in the Figures). The first stage is preferably configured to sample the data from the acquisition unit 221, process it, filter it and provide a stream of data, which may also be compressed, to the second stage of the second processing and control sub-unit, as already described above with reference to the first stage of the first processing and control sub-unit.

[0072] It should be noted that, as regards the data processing operations described above with reference to the interface IF-V, each of the two first stages of the processing and control sub-units operates on the measurement data in parallel. As regards instead processing of the measurement data of the interface IF-RL, each processing sub-unit may generate a respective output voltage indicating whether or not all the safety logic conditions have been satisfied. If at least one of the two output voltages has a zero value, an alarm may be generated.

[0073] The second stage of the second processing and control sub-unit is preferably configured to monitor the data from the first stage before sending it to the short-range radio link unit 224. In particular, this operation comprises establishing a serial connection with the short-range radio link unit 224.

[0074] From the hardware point of view, the processing unit 222 may consist of an FPGA which implements an SoC (system on chip).

[0075] The display unit 223 is preferably configured to display locally the data processed by the processing unit 222 and then make it available for an operator able to connect to it. The display unit 223 may consist of a high resolution graphical display with 128x64 matrix.

[0076] The short-range radio link unit 224 is preferably

a radio transceiver and is preferably configured to send wirelessly, via the antenna 225, the data processed by the processing unit 222 to another indoor acquisition radio module 22 or to a gateway radio module. The short-range radio link unit 224 is also preferably configured to receive the processed data at another indoor acquisition radio module and to forward this data to a further indoor acquisition radio module or to a gateway radio module, again via the antenna 225. The short-range radio link unit 224 is preferably configured to operate using a wireless communication technology, such as the Wi-Fi technology, according to one of the protocols of the IEEE 802.11 family (IEEE 802.11n or IEEE 802.11ac). In this case, the radio channel may be chosen for example from among the 14 channels available in Wi-Fi 802.11n technology operating at 2.4 GHz and the 23 channels available in Wi-Fi 802.11n technology operating at 5 GHz. Other technologies which may be used are, for example, the Zigbee technology and the Bluetooth technology (IEEE 802.15). Moreover, the short-range radio link unit 224 is configured to send and receive data using preferably a messaging protocol, in particular a "light" messaging protocol, such as for instance the "Message Queue Telemetry Transport" (MQTT) protocol. The use of the MQTT protocol is particularly advantageous because it allows the energy consumption to be reduced, while preserving in any case a queue of messages in the event of interruption of the communication. Other protocols which may be used are for example SMQTT (Secure MQTT), AMQP (Advanced Message Queuing Protocol) and XMPP (Extensible Messaging and Presence Protocol).

[0077] An outdoor acquisition radio module 22' has a block diagram which is architecturally similar to that of the indoor acquisition radio module 22 shown in Figure 2.

[0078] According to the present invention, both the indoor acquisition radio module 22 and the outdoor acquisition radio module 22' have a modular hardware structure. In particular, each of these modules preferably comprises a base board (which comprises for example the processing unit 222), said base board providing a set of housings, connectors and links which is identical for all the modules. In particular, as mentioned above, the base board provides a set of ports MS-IF, TS-IF, ES-IF, identical for all the modules, for housing the diagnostic interfaces with the sensors, which may instead differ from each other depending on the type of physical parameters to be measured.

[0079] Figure 4 shows a block diagram of a gateway radio module 31 according to embodiments of the present invention. The gateway radio module 31 preferably comprises a short-range radio link unit 311, connected to a first antenna 312, a first processing unit 313, connected to the short-range radio link unit 311, a second processing unit 314 connected to the short-range radio link unit 311, and a long-range radio link unit 315 connected to the first processing unit 313 and to the second processing unit 314 and to a second antenna 316. Preferably, each gateway radio module 31 of the system ac-

cording to the present invention is positioned in a respective sentry station 61, 6b, 6c.

[0080] The short-range radio link unit 311 is preferably a radio transceiver and is configured to receive, via the first antenna 312, the data processed in one or more acquisition radio modules 22, 22'. The short-range radio link unit 311 is preferably configured to operate using a wireless communication technology, such as the Wi-Fi technology, based on one of the protocols of the IEEE 802.11 family (IEEE 802.11n or IEEE 802.11ac). Other technologies which may be used are, for example, the Zigbee technology and the Bluetooth technology (IEEE 802.15). Moreover, the short-range radio link unit 311 is configured to receive data using preferably a messaging protocol, in particular a "light" messaging protocol, such as the MQTT protocol. Other protocols which may be used are, for example, SMQTT, AMQP and XMPP.

[0081] The first processing unit 313 is preferably configured to receive data from the short-range radio link unit 311, said data coming from one or more acquisition radio modules 22, 22'. The first processing unit 313 preferably comprises two stages. The first stage is preferably configured to:

- control the serial communication with the short-range radio link unit 311 and synchronize the incoming data flows from the various acquisition radio modules 22, 22';
- aggregate the data received from the various acquisition radio modules 22, 22', discarding redundant data and any corrupt packets;
- send the data received from the various acquisition radio modules 22, 22' to the second stage which performs data compression, as will be described in greater detail herein below.

[0082] The second stage is preferably configured to compress the data from the first stage before sending it to the long-range radio link unit 315. In greater detail, the second stage is preferably configured to:

- compress the data from the first stage; and
- send the compressed data to the long-range radio link unit 315.

[0083] The first data processing unit 313, from the point of view of hardware, is an SoC integrated circuit implemented using an FPGA component.

[0084] The second processing unit 314 is preferably configured to receive data from the short-range radio link unit 311, said data coming from one or more acquisition radio modules 22, 22', and to process this data in a similar manner to that performed by the first processing unit 313. It is connected to the first processing unit 313 in so-called "failover" mode. The second data processing unit 314, from the hardware point of view, is also an SoC integrated circuit implemented using an FPGA component.

[0085] Preferably, each gateway radio module 31

present along the railway line portion to be monitored collects measurement data from a respective type of signalling entities present along the line. For example, a first gateway radio module may collect measurement data from the turnouts present along the line section, by connecting to the acquisition radio modules which acquire said data; a second gateway radio module may collect measurement data from the level crossings present along the line section, by connecting to the acquisition radio modules which acquire such data; and so on.

[0086] The aforementioned data compression mechanism implemented by the second stage of the first processing unit 313 of the gateway radio module 31 comprises preferably three data processing procedures:

- aggregation and comparison with pre-determined thresholds for each measurement type;
- filtering; and
- compression.

[0087] The aggregation procedure comprises aggregating the data received depending on the type of measurement which generated said data. This operation comprises, at each gateway radio module 31, reading the measurement data collected by the acquisition radio modules for the considered signalling entity and grouping together this measurement data according to the type of measurement (e.g. for the "turnout" type signalling entity, bipolar dc power supply voltage measurements, absorption current measurements, etc.; for the "track circuit" type signalling entity, disk relay local power supply voltage measurements, coded ac power supply voltage measurements, absorption current measurements, temperature measurements, etc.) so as to have one or more vectors with homogeneous values corresponding to the values of the parameters measured for the considered signalling entities, all of the same type.

[0088] For example, at a gateway radio module 31, in particular at the second stage of the first processing unit 313 of the gateway radio module 31, a first vector may group together measured voltage values of the various signalling entities of a certain type (for example the unipolar dc power supply voltages of the turnouts), a second vector may group together measured current values of the various signalling entities of the same type (for example, the absorption currents of the turnouts), a third vector may group together values of another parameter to be measured of the various signalling entities of the same type (for example, the bipolar dc power supply voltages of the relay KD-KD), and so on.

[0089] Once the data has been aggregated as described above, the values of each vector are preferably compared one by one with a predetermined threshold value stored in the second stage of the first processing unit 313 of the gateway radio module 31. The predetermined threshold value for a given measurement is preferably an expected value for that measurement determined on the basis of activation tests carried out on the

considered signalling entity by specialized operators. For example, as regards the signalling entity of the "dichroic mirror light signal" type, a predetermined threshold value for the coded ac power supply voltage may be equal to 150 Vac $\pm$ 6%.

[0090] The second stage of the first processing unit 313 of the gateway radio module 31 therefore preferably compares, for each measurement data aggregation vector, each value of this vector with the respective threshold value. If a value of the considered vector exceeds the threshold value, the second stage of the first processing unit 313 of the gateway radio module 31 preferably implements an alarm procedure for the signalling entity, the measurement value of which is not within the threshold.

The alarm procedure may consist in sending an alarm message to the apparatuses of the data presentation level 4, which activates a corresponding alarm notification for the signalling entity monitored on a graphical user interface of the data presentation level 4, as already described above. This alarm procedure may result in preventive maintenance of the signalling entity, because, based on the alarm, action may be taken on the signalling entity before it breaks down.

[0091] With reference to the aforementioned example, the second stage of the first processing unit 313 of the gateway radio module 31 compares the ac voltage signal present at the terminals of the green lamp with the predetermined threshold value (150 Vac $\pm$ 6%). If this value lies between 141 Vac and 159 Vac then the system is functioning correctly and alarms are not generated. In the case where a voltage less than 141 Vac or greater than 159 Vac is detected, then an alarm is generated.

[0092] The filtering procedure implemented at the second stage of the first processing unit 313 of the gateway radio module 31 preferably comprises the following steps:

- elimination of redundancies between measurement waveforms acquired at two consecutive instants. Preferably, a measurement waveform (for example consisting of the bipolar dc power supply voltage samples of a turnout) is acquired continuously for a predefined time interval, which may be periodically repeated. The operation of redundancy elimination involves comparing the waveforms acquired during consecutive periods and comparing these waveforms. If the two waveforms are the same, this procedure envisages eliminating the oldest waveform and storing the most recent waveform. If the two waveforms are different, the procedure envisages storing both waveforms. This operation is preferably repeated for each acquired waveform.
- noise reduction. This step may comprise carrying out a configurable averaging operation on the measurement samples (for example, on samples of the bipolar dc power supply voltage of a turnout) which in turn comprises storing a certain number of samples for a given time period and calculating an aver-

age value thereof. The number of considered samples may be variable and, once a predefined sampling frequency has been fixed, depends on the precision which is to be obtained. For example, the configurable averaging operation may comprise storing one measurement sample per second and calculating the average of 60 samples every 60 seconds (low precision) or storing ten measurement samples per second and calculating the average of 100 samples every 10 seconds (high precision).

- filtering in the frequency domain. The operation of filtering the data in the frequency domain is typically known and may be for example carried out by applying to the data spectrum a predefined window, for example a Hanning window.

[0093] The procedure of compression of the filtered data preferably comprises applying a "compressive sampling" (CS) algorithm. Such an algorithm may be the known algorithm described in E. Candès and Micheal B. Wakin, "An Introduction To Compressive Sampling" IEEE. Signal Processing Magazine March 2008; Bajwa, W. U., Haupt, J., Sayeed, A. M., Nowak, R., Compressive wireless sensing. In Proc. 5th Intl. Conf. on Information Processing in Sensor Networks (IPSN '06), Nashville, TN 2006, 134-142. The inventor has noted that the use of the compressive sampling technique results in the possibility of obtaining compression ratios of up to 70%. In fact, advantageously, by applying such an algorithm it is possible to reconstruct a signal from a number of samples smaller than that envisaged using the known "Nyquist frequency". Therefore, advantageously, the use of the compressive sampling method allows the transmission of a small amount of data compared to conventional methods, resulting in the possibility of using low-cost integrated devices with limited hardware (for example memory) resources as well as shorter processing times.

[0094] The long-range radio link unit 315 is preferably a radio transceiver and is configured to transmit, via the second antenna 316, the data processed in the gateway radio module 31, in particular the stream of data supplied by the first processing unit 313 and by the second processing unit 314 (therefore, a stream of compressed data) to another gateway radio module or to a station of the railway line. This data may also be sent directly from the long-range radio link unit 315 of the gateway radio module 31 to the apparatuses of the cloud computing infrastructure which implements the data presentation level 4. The long-range radio link unit 315 is preferably configured to operate by means of a wireless communication technology, such as the LoRa technology, using a frequency channel for example at about 433 MHz, about 868 MHz or about 915 MHz. Alternatively, the long-range radio link unit 315 may operate using the SIGFOX wireless communication technology, using a frequency channel for example at about 868 MHz or about 902 MHz. Moreover, the short-range radio link unit 311 is configured to receive data using a messaging protocol, in par-

ticular a "light" messaging protocol, such as the MQTT protocol.

[0095] Figure 5 schematically shows the software architecture of the data presentation level 4 of the monitoring system according to embodiments of the present invention.

[0096] Preferably, the software architecture of the data presentation level 4 according to the present invention comprises a web server 41 configured to publish in HTTP format the data from the gateway radio modules 31.

[0097] Moreover, the software architecture of the data presentation level 4 preferably comprises a first module 42 of the "scripting engine" type configured to decompress the data supplied by the gateway radio modules 31 present along the railway infrastructure to be monitored, applying the reverse procedure of the compression procedure performed in the said gateway radio modules 31, as described here above.

[0098] The software architecture of the data presentation level 4 preferably also comprises a database 43 configured to store the data received from the gateway radio modules 31.

[0099] The software architecture of the data presentation level 4 preferably also comprises a plurality (five, in the embodiment shown in Figure 5, indicated schematically by the reference numbers 44a, 44b, 44c, 44d, 44e) of interface plug-ins, each of which comprises a software component able to manage data from the diagnostic interfaces relating to a respective type of signalling element. In particular, the data presentation level 4 preferably comprises:

- a light signal interface plug-in for enabling the display, on a graphical user interface, of the data from the diagnostic interfaces for these signalling entities (namely the interfaces IF-SLV and IF-SLD). Using the displayed data it will be possible, for an operator or automatically, to determine maintenance periods for the light signals and transmit alarms and corresponding alarm reports. As already described above, an alarm may be activated by means of an alarm notification for the monitored signalling entity (in this case the light signals) on a graphical user interface of the data presentation level 4. This alarm notification may be, for example, a video and/or audio indication which can be used, for example, by an operator at a control central, such as for example, the opening of a window or a pop-up frame on the graphical interface, or a change (for example in colours) in the display of graphical elements relating to the specific signalling element;
- a turnout interface plug-in for enabling the display, on a graphical user interface, of the data from the diagnostic interfaces for these signalling entities (namely the interfaces IF-DEV and IF-EL). Using the displayed data it will be possible, for an operator or automatically, to determine maintenance periods for the turnouts and transmit alarms and corresponding

- alarm reports, as already described above.
- a level crossing interface plug-in for enabling the display, on a graphical user interface, of the data from the diagnostics interfaces for these signalling entities (namely the interfaces IF-PL and IF-CBAF). Using the displayed data it will be possible, for an operator or automatically, to determine maintenance periods for the level crossings and transmit alarms and corresponding alarm reports, as already described above.
- a track circuit interface plug-in for enabling the display, on a graphical user interface, of the data from the diagnostic interface for these signalling entities (namely the interfaces IF-CBCF, IFCBCC, IF-T and IF-V), in particular for preventing collisions of railway convoys with objects present on the tracks, such as trees or rocks which have fallen onto the track, or animals. Using the displayed data it will be possible, for an operator or automatically, to determine maintenance periods for the track circuits and transmit alarms and corresponding alarm reports, as already described above;
- a sentry station interface plug-in for enabling the display, on a graphical user interface, of the data from the diagnostic interfaces for these signalling entities (namely the interfaces IF-IBA, IF-RTB and IF-RL). Using the displayed data it will be possible, for an operator or automatically, to determine maintenance periods for the sentry stations and transmit alarms and corresponding alarm reports, as already described above.

[0100] Finally, the software architecture of the data presentation level 4 comprises a graphical user interface 45 (GUI) comprising a second module of the "scripting engine" type configured to make available the data for display by a user (for example, a maintenance operator), in a manner which may be easily used by the user. By means of the GUI the user may interrogate the database 43 in order to recover data relating to the monitoring of the various considered signalling entities. Moreover, as described above, the GUI may display the alarm notifications for the various monitored signalling entities.

[0101] The software architecture of the presentation level 4 of the system according to the present invention is preferably implemented in a cloud computing infrastructure which is accessible, on the one hand, by the stations of the railway infrastructure, in order to transmit and, where necessary, recover the data collected by the acquisition level 2 of the system and, on the other hand, by the maintenance operators (via mobile devices such as smartphones or tablets, or via control rooms) and by the railway network manager. This architecture comprises the hardware resources and apparatuses (for example, multiprocessor machines, mass memories, etc.) which house the software modules described hereinabove and provide the required processing, transmission and archiving resources.

[0102] With reference to Figure 6, the operation of the monitoring system 1 according to preferred embodiments of the present invention will now be described, with reference to two use cases of the present system.

[0103] As already mentioned, Figure 6 shows a railway line section 5 being monitored by the monitoring system 1 according to the present invention. The Figure also shows three sentry stations 6a, 6b, 6c, which are located along the railway line and are typically arranged at a distance of about 2 km from each other, and a station 7. The sentry stations 6a, 6b, 6c and the station 7 are connected wirelessly together. The wireless link is realized, for example, by means of the LoRa technology and the data is exchanged via MQTT protocol, as described above.

[0104] According to the situation shown by way of example in the Figure, the sentry station 6a comprises an indoor acquisition radio module 22 connected to a signalling element, for example a turnout 11b, via, for example, the 12-pole terminal strip present in the sentry station 6a. The indoor acquisition radio module 22 is also connected to the gateway radio module 31 by means of WiFi technology and both the modules 22 and 31 are configured to exchange data by means of the MQTT protocol. Moreover, the system according to the embodiment shown in Figure 6 comprises an outdoor acquisition radio module 22' positioned on the tracks along the railway line and connected to a signalling entity, for example a track circuit 11d. The outdoor acquisition radio module 22' is for example also connected to the gateway radio module 31 and both the modules 22' and 31 are configured to exchange data by means of the MQTT protocol.

[0105] In order to monitor, for example, the turnout signalling entity 11b, the indoor acquisition radio module 22 according to the present invention collects the measurement data via one or more diagnostic interfaces of the turnout, namely the interface IF-DEV and the interface IF-EL. The measurements collected are those indicated previously. The measurement data is transferred from the short-range radio link unit of the indoor acquisition module 22 to the short-range radio link unit of the gateway radio module 31. The gateway radio module 31 processes the received data as described above, in particular applies the aggregation, filtering and compression procedures described above, and sends the processed data to a further gateway radio module or to the station 7, via the associated long-range radio link unit. The data collected at the station or at a gateway radio module is finally sent to the cloud computing infrastructure of the data presentation level 4 of the present system. This infrastructure decompresses the data and stores it in the database so that the decompressed data is available to the operators responsible for maintenance of the railway infrastructure (the data being displayed, for example, on a tablet 8 or in the control room 9, following connection to the database) as well as to the railway network manager via, for example, a proprietary data network 10 connected to the database by means of ADSL.

[0106] According to a further example of use of the system according to the present invention, in order to monitor, for example, the track circuit 11d and in particular analyze the vibrations acting on the track (these, as mentioned above, may provide information useful for detecting the presence of an object such as a tree, an animal or a rock on the tracks), the second outdoor acquisition radio module 22' collects the measurement data via the interface IF-V directly at the signalling element. The measurements collected are sent to the gateway radio module 31 and then to the cloud computing infrastructure in the same manner described above.

[0107] The system according to the present invention is particularly efficient and advantageous from a cost point of view. It in fact allows the use of a plurality of low-cost integrated devices (FPGA microcontrollers, DSP processors) which process the measurement data of the signalling entities, acquired continuously along the railway line, and send said data wirelessly to a cloud computing infrastructure by means of which it is made available to a plurality of users. The processing performed at the acquisition level and the network level of the system advantageously allows the data to be compressed so as to transmit a small number of digital samples, which allows using low-cost integrated devices with limited hardware (for example memory) resources. The wireless transmission of the data may therefore be performed by means of low frequency and low capacity radio devices. The system is not invasive since it involves the introduction in the sentry station of modules which operate entirely independently of the standard equipment and communicate wirelessly inside the sentry station and externally, without interfering with the conventional existing cable communications. The use of low energy wireless communication technologies such as the LoRa technology results in a longer working life of the used batteries, especially in the outdoor radio modules which cannot be powered by the mains voltage.

[0108] Moreover, advantageously, with the monitoring system according to the present invention it is possible to:

- monitor remotely and continuously the state of the signalling entities both as regards the electrical parameters involved and as regards the mechanical parameters such as vibrations and temperature of the track, in order to effectively program in due time and in a predictive manner the maintenance work on the railway network;
- efficiently monitor the conditions of the track so as to avoid the collisions of train convoys passing along the track with any objects accidentally present thereon, such as trees, rocks or animals.
- gradually eliminate the copper cables between the sentry stations and between the sentry stations and the stations of the railway line, so as to drastically reduce the cable installation and maintenance costs and avoid the serious problems arising from the theft of said cables or tampering thereof; and

- effectively re-scale the measurement data distribution network in the event of new users being authorized for viewing of the data.

Claims

1. Monitoring system (1) for a railway infrastructure, said railway infrastructure comprising a signalling entity (11a, 11b, 11c, 11d, 11e) to be monitored, said monitoring system (1) comprising:
 - an acquisition radio module (22; 22') configured to be connected to one or more sensors configured to acquire measurement data relating to one or more physical parameters of said signalling entity (11a, 11b, 11c, 11d, 11e), said physical parameters being indicative of an operating state of said signalling entity (11a, 11b, 11c, 11d, 11e); and
 - a gateway radio module (31) configured to be connected to said acquisition radio module (22; 22') via a first wireless link, to receive from the acquisition radio module (22; 22') said measurement data, said gateway radio module (31) being further configured to provide, based on said measurement data, by means of a second wireless link, a stream of compressed data to a location remote from said signalling entity (11a, 11b, 11c, 11d, 11e), in order to monitor the operating state thereof.
2. The monitoring system (1) according to claim 1, wherein said acquisition radio module (22; 22') comprises an acquisition unit (221) comprising at least one diagnostic interface connected to said one or more sensors for acquiring said measurement data.
3. The monitoring system (1) according to claim 2, wherein said one or more sensors comprise a temperature sensor for measuring a temperature of said signalling entity (11a, 11b, 11c, 11d, 11 e) and/or a vibration sensor for measuring one or more parameters indicative of a vibration of said signalling entity (11a, 11b, 11c, 11d, 11 e).
4. The monitoring system (1) according to claim 2 or 3, wherein said acquisition radio module (22; 22') comprises a processing unit (222) connected to said acquisition unit (221), said processing unit (222) comprising a first processing and control sub-unit and a second processing and control sub-unit connected in so-called "failover" mode so as to process said measurement data acquired by said at least one diagnostic interface.
5. The monitoring system (1) according to any one of the preceding claims, wherein said acquisition radio

module (22; 22') comprises a short-range radio link unit (224) configured to be connected to said gateway radio module (31) by means of said first wireless link.

6. The monitoring system (1) according to claim 5, wherein said first wireless link is realized by means of the Wi-Fi technology.
7. The monitoring system (1) according to claim 5 or 6, wherein said acquisition radio module (22; 22 ') is configured to send to said gateway radio module (31) said measurement data by means of the so-called "message queue telemetry transport" protocol.
8. The monitoring system (1) according to any one of the preceding claims, wherein said acquisition radio module (22; 22') has a modular hardware structure.
9. The monitoring system (1) according to claim 5 or 6, wherein said gateway radio module (31) comprises a short-range radio link unit (311) and a long-range radio link unit (315), said short-range radio link unit (311) being configured to be connected to said short-range radio link unit (224) of said acquisition radio module (22) by means of said first wireless link, and said long-range radio link unit (315) being configured to be connected to said remote location by means of said second wireless link.
10. The monitoring system (1) according to any one of the preceding claims, wherein said second wireless link is implemented by means of LoRa technology or SIGFOX technology.
11. The monitoring system (1) according to any one of the preceding claims, wherein said gateway radio module (31) comprises a first processing unit (313) and a second processing unit (314) connected in so-called "failover mode", each of said first and second processing units (313, 314) being configured to aggregate said measurement data on the basis of one or more measurement types and to compare said data with pre-determined thresholds, each of said thresholds being indicative of an expected value for a respective type of measurement.
12. The monitoring system (1) according to claim 11, wherein each of said first and second processing units (314) is configured to implement an alarm procedure in case said measurement data exceed one of said pre-determined thresholds.
13. The monitoring system (1) according to claim 11 or 12, wherein each of said first and second processing units (313, 314) is configured to compress said measurement data according to a compression algorithm of the "compressive sampling" type.

14. The monitoring system (1) according any to one of the preceding claims, said monitoring system (1) comprising a cloud architecture (4) for receiving said measurement data and providing it, at said remote location, to an operator able to use said measurement data to schedule maintenance operations on said railway infrastructure.

15. The monitoring system (1) according to claim 14, wherein said architecture (4) comprises a database (43) configured to store the data received from said gateway radio module (31).

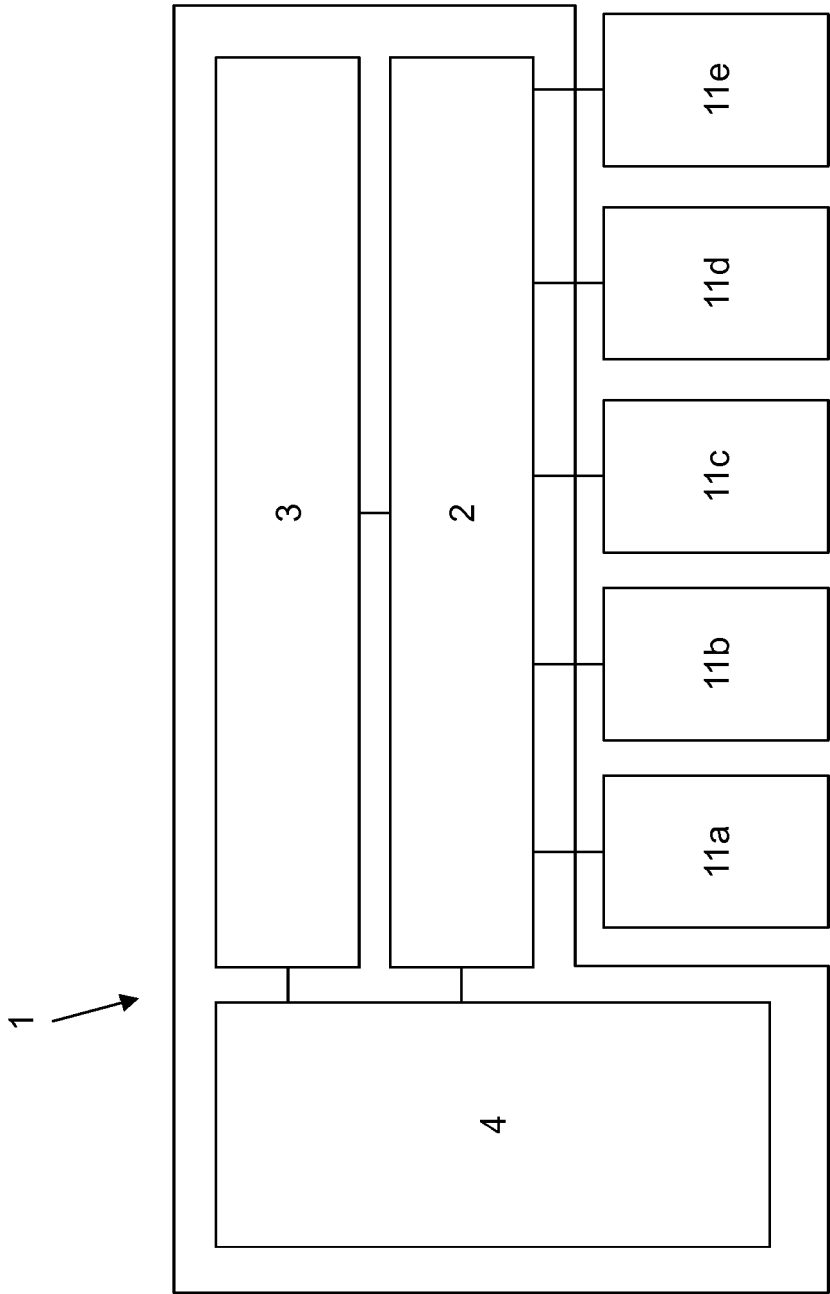


Fig. 1

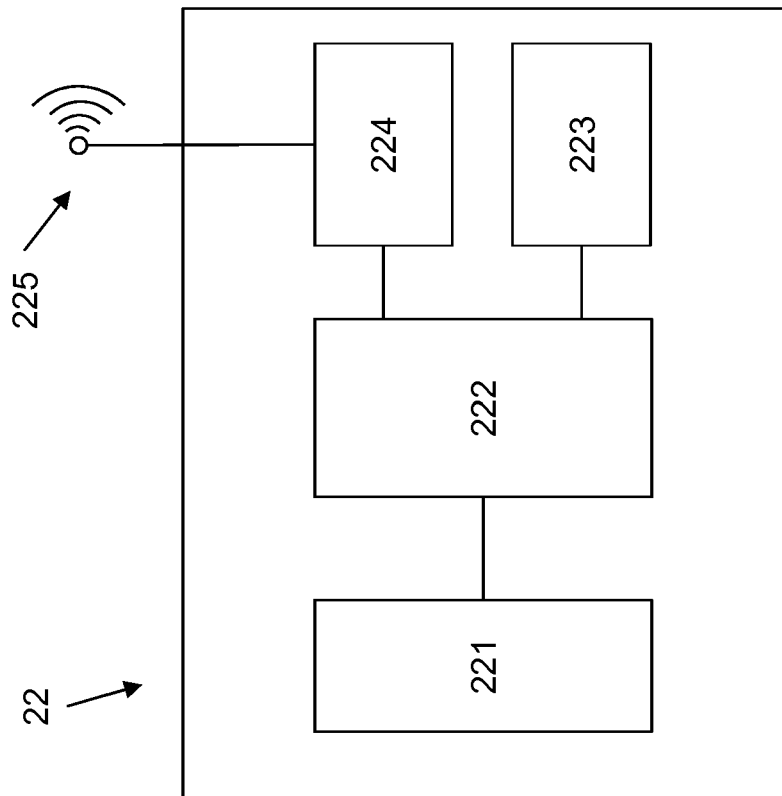


Fig. 2

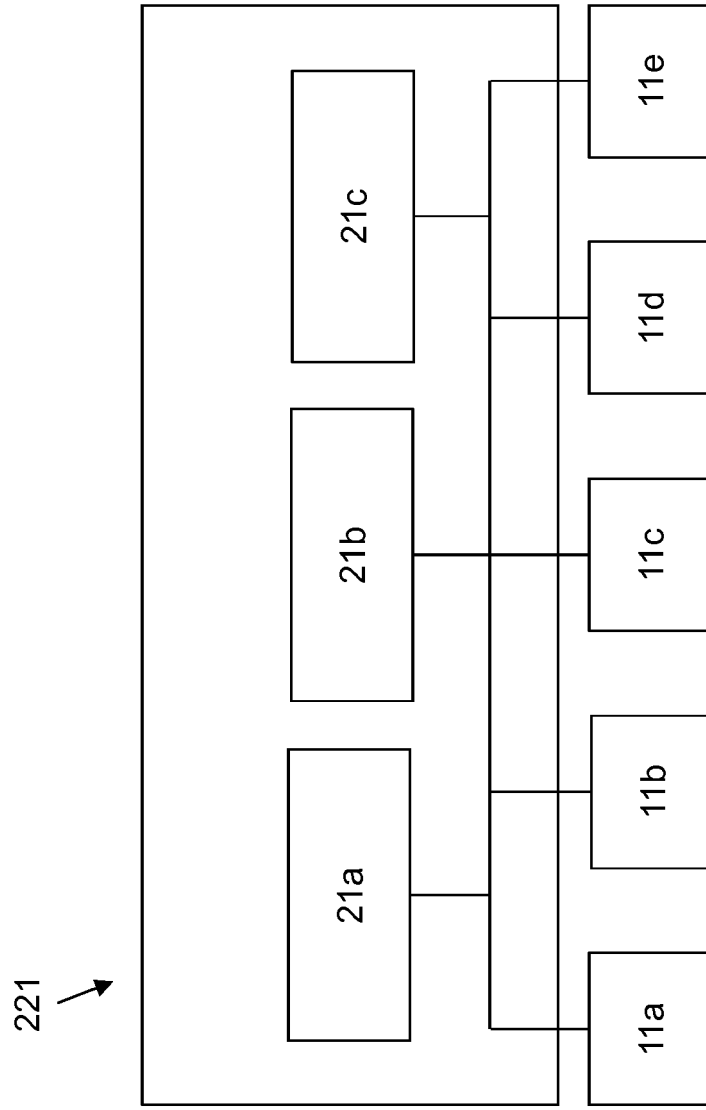


Fig. 3

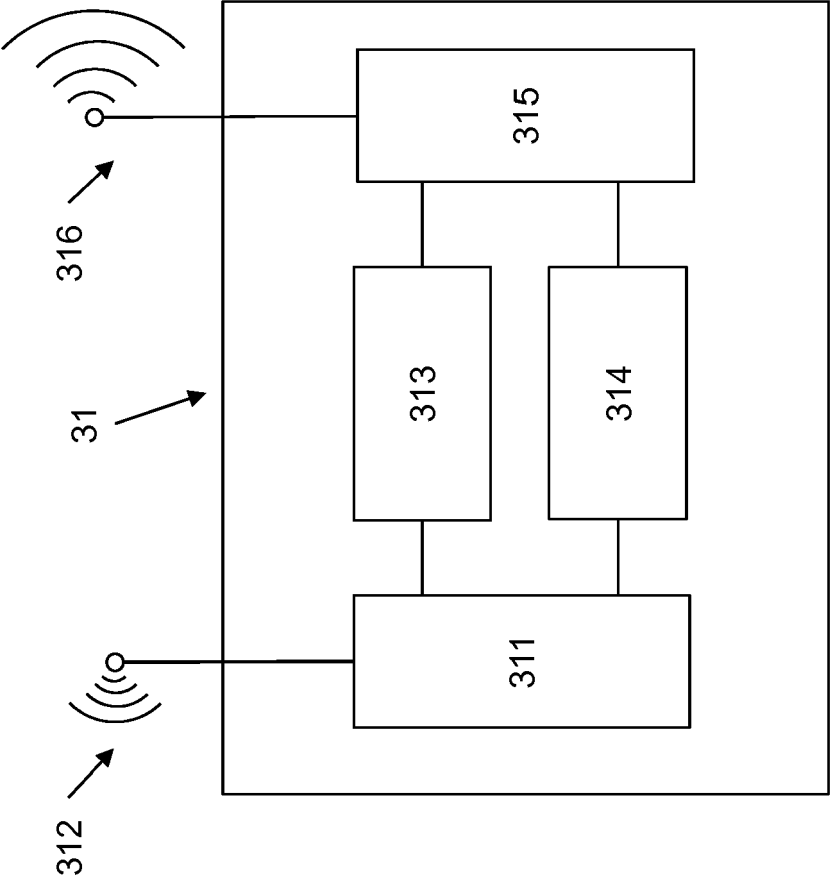


Fig. 4

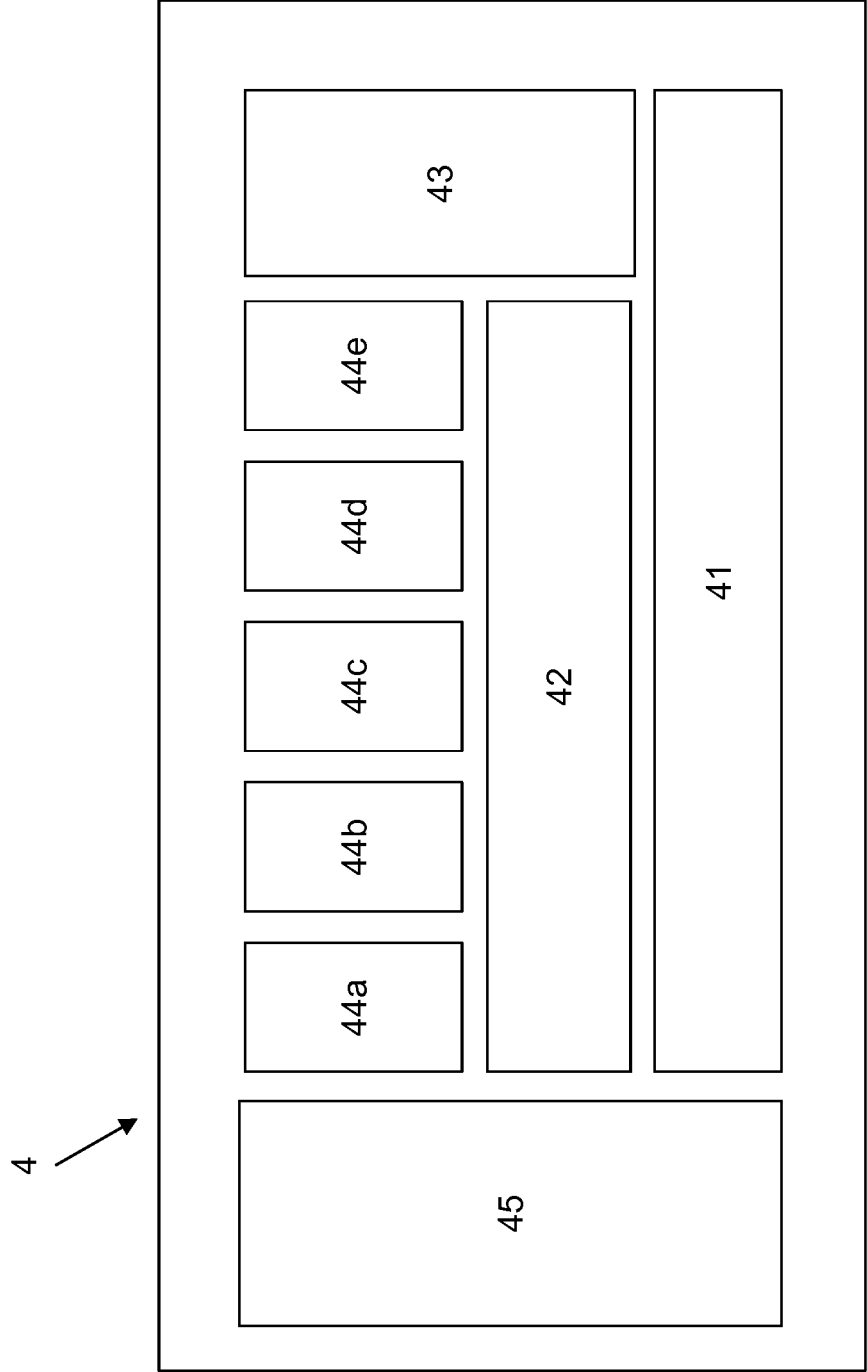


Fig. 5

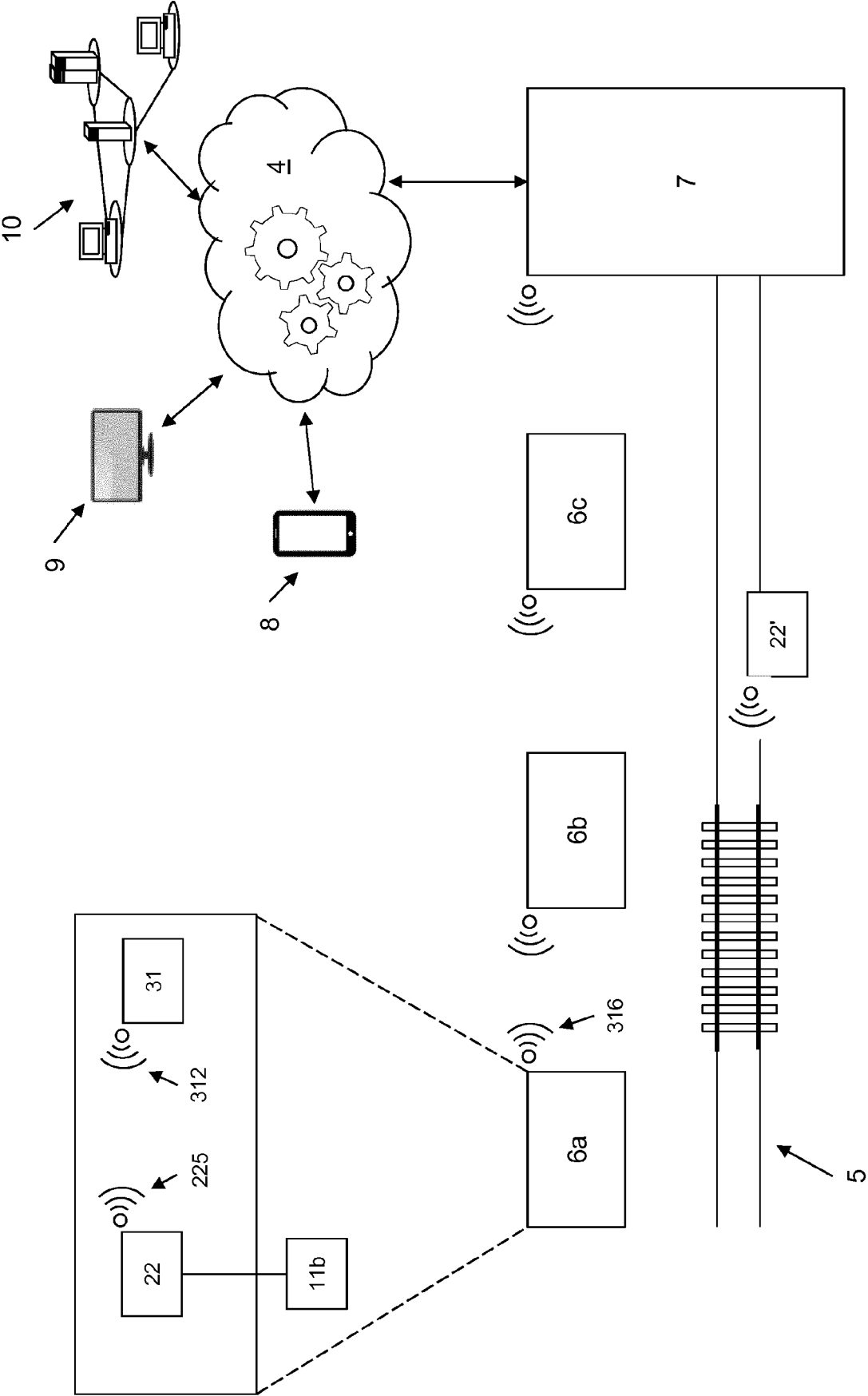


Fig. 6



EUROPEAN SEARCH REPORT

 Application Number
 EP 18 16 1375

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	WO 02/090166 A1 (SAFETRAN SYSTEMS CORP [US]; INVENSYS SYS INC [US]; WESTINGHOUSE SIGNAL) 14 November 2002 (2002-11-14) * page 8, line 9 - page 14, line 10; figures 1,2 *	1-15	INV. B61L27/00
Y	GB 2 526 091 A (SENCEIVE LTD [GB]) 18 November 2015 (2015-11-18) * page 2, line 25 - page 3, line 4; figures 1,2 *	1-15	
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Y	DE 20 2016 004730 U1 (S C T N GMBH [DE]) 19 September 2016 (2016-09-19) * paragraph [0002] *	10	
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Y	WO 2016/190931 A1 (POWER FINGERPRINTING INC [US]) 1 December 2016 (2016-12-01) * page 6, line 26 - page 7, line 3 *	13	TECHNICAL FIELDS SEARCHED (IPC) B61L
Y	WO 2015/081278 A1 (AMSTED RAIL CO INC [US]) 4 June 2015 (2015-06-04) * paragraphs [0010], [0102] *	14,15	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 11 June 2018	Examiner Mäki-Mantila, M
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EUROPEAN SEARCH REPORT

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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