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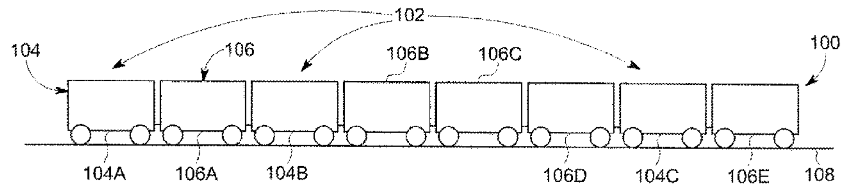

(57) Abstract: A system includes an application device, a control unit, a detection unit, an identification unit, and a secondary analysis module. The application device is configured to be at least one of conductively or inductively coupled with a route. The control unit is configured to control supply of electric current to inject an examination signal into the route via the application device. The detection unit is configured to monitor one or more electrical characteristics of the route. The identification unit is configured to examine the one or more electrical characteristics of the route to determine whether a section of the route is potentially damaged. The secondary analysis module is configured to perform a secondary analysis of the potentially damaged section of the route to at least one of confirm that damage has occurred, identify a type of damage, or assess a level of damage.

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ROUTE EXAMINING SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 61/681,843, which was filed on 10-August-2012, and is entitled "Adaptive Energy Transfer System And Method" (the "'843 Application"). The entire disclosure of the '843 Application is incorporated by reference. This application also claims priority to U.S. Provisional Application Serial No. 61/729,188, which was filed on 21-November-2012, is entitled "Route Examining System And Method," and the entire disclosure of which is incorporated by reference. This application also claims priority to U.S. Provisional Application Serial No. 61/860,469, which was filed on 31-July-2013, is entitled "Route Examining System And Method," and the entire disclosure of which is incorporated by reference. This application also claims priority to U.S. Provisional Application Serial No. 61/860,496, which was filed on 31-July-2013, is entitled "Route Examining System And Method," and the entire disclosure of which is incorporated by reference.

TECHNICAL FIELD

Embodiments of the subject matter disclosed herein relate to examining routes traveled by vehicles for damage to the routes, and more particularly to improved reliability of detection of broken rails or other defects in routes and/or reducing or minimizing false alarms related to potential route defects.

BACKGROUND

Routes that are traveled by vehicles may become damaged over time with extended use. For example, tracks on which rail vehicles travel may become damaged and/or broken. A variety of known systems are used to examine rail tracks to identify where the damaged and/or broken portions of the track are located. For example, some systems use cameras, lasers, and the like, to optically detect breaks and damage to the tracks. The cameras and lasers may be mounted on the rail vehicles, but the accuracy of the cameras and lasers may be limited by the speed at which the rail vehicles move during inspection of the route. As a result, the cameras and lasers may not be able to be used during regular operation (e.g., travel) of the rail vehicles.

Other systems use ultrasonic transducers that are placed at or near the tracks to ultrasonically inspect the tracks. These systems may require very slow movement of the transducers relative to the tracks in order to detect damage to the track. When a suspect location is found by an ultrasonic inspection vehicle, a follow-up manual inspection may be required for confirmation of defects using transducers that are manually positioned and moved along the track and/or are moved along the track by a relatively slower moving inspection vehicle. Inspections of the track can take a considerable amount of time, during which the inspected section of the route may be unusable by regular route traffic.

Other systems use wayside devices that send electric signals through the tracks. If the signals are not received by other wayside devices, then a circuit that includes the track is identified as being open and the track is considered to be broken. These systems are limited at least in that the wayside devices are immobile. As a result, the systems cannot inspect large spans of track and/or a large number of devices must be installed in order to inspect the large spans of track. Additionally, other anomalies, intentional or unintentional, may impact a test current and result in false alarms.

Other systems use human inspectors who move along the track to inspect for broken and/or damaged sections of track. This manual inspection is slow and prone to errors.

The discussion of the background to the invention included herein including reference to documents, acts, materials, devices, articles and the like is included to explain the context of the present invention. This is not to be taken as an admission or a suggestion that any of the material referred to was published, known or part of the common general knowledge in Australia or in any other country as at the priority date of any of the claims.

BRIEF DESCRIPTION

According to an aspect of the present invention, there is provided a system comprising one or more conductive bodies configured to be disposed onboard a first vehicle system traveling along a route and to be at least one of conductively or inductively coupled with the route during travel along the route; one or more processors configured to control supply of electric current from a power source to the one or more conductive bodies in order to electrically inject an examination signal into the route via the one or more conductive bodies, wherein the one or more conductive bodies also are configured to sense one or more electrical characteristics of the route in response to the examination signal being injected into the route, wherein the one or more processors are configured to examine the one or more electrical characteristics of the route in order to determine whether a section of the route is potentially damaged based on the one or more electrical characteristics, the one or more processors also configured to compare a location of the section of the route that is determined as being potentially damaged with one or more locations of one or more known anomalies along the route in order to determine that the section of the route is damaged, and wherein the one or more processors are configured to, responsive to determining that the section of the route is damaged by the one or more processors, perform a secondary analysis of the potentially damaged section of the route to at least one of confirm that damage has occurred to the potentially damaged section of the route, identify a type of damage that has occurred to the potentially damaged section of the route, or assess a level of damage to the potentially damaged section of the route.

According to another aspect of the present invention, there is provided a method comprising electrically injecting an examination signal into a route being traveled by a first vehicle system having at least a first vehicle, the examination signal being injected into the route using the first vehicle of the first vehicle system; monitoring one or more electrical characteristics of the route responsive to the examination signal; identifying, with one or more processors, a potentially damaged section of the route based on the one or more electrical characteristics; and performing, with the one or more processors and responsive to an identification of the potentially damaged section of the route by the one or more processors, a secondary analysis of the potentially damaged section of the route to at least one of confirm that damage has occurred to the potentially damaged section of the route, identify a type of damage that has occurred to the potentially damaged section of the route, or assess a level of damage to the potentially damaged section of the route, wherein the secondary analysis includes comparing a location of the potentially damaged section of the route with one or more locations of one or more known anomalies along the route in order to determine that the section of the route is damaged.

According to a further aspect of the present invention, there is provided a tangible and non-transitory computer readable medium configured to direct one or more processors to control injection of an examination signal into a route being traveled by a first vehicle system having at least a first vehicle, the examination signal being injected into the route using the first vehicle of the first vehicle system; monitor one or more electrical characteristics of the route responsive to the examination signal; identify a potentially damaged section of the route based on the one or more electrical characteristics; and perform, responsive to an identification of the potentially damaged section of the route by the identification unit, a secondary analysis of the potentially damaged section of the route to at least one of confirm that damage has occurred to the potentially damaged section of the route, identify a type of damage that has occurred to the potentially damaged section of the route, or assess a level of damage to the potentially damaged section of the route, wherein the secondary analysis includes comparing a location of the potentially damaged section of the, route with one or more locations of one or more known anomalies along the route in order to determine that the section of the route is damaged.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference is made to the accompanying drawings in which particular embodiments and further benefits of the invention are illustrated as described in more detail in the description below, in which:

Figure 1 is a schematic illustration of a vehicle system that includes an embodiment of a route examining system;

Figure 2 is a schematic illustration of an embodiment of an examining system;

Figure 3 illustrates a schematic diagram of an embodiment of plural vehicle systems traveling along the route;

Figure 4 is a flowchart of an embodiment of a method for examining a route being traveled by a vehicle system from onboard the vehicle system;

Figure 5 is a schematic illustration of an embodiment of an examining system.

Figure 6 is a schematic illustration of an embodiment of an examining system;

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Figure 7 is a schematic illustration of an embodiment of an examining system include first and secondary receive coils; and

Figure 8 is a flowchart of an embodiment of a method for examining a route being traveled by a vehicle system from onboard the vehicle system.

DETAILED DESCRIPTION

Embodiments of the inventive subject matter relate to methods and systems for examining a route being traveled upon by a vehicle system in order to identify potential sections of the route that are damaged or broken, and for examining the route to increase reliability and/or reduce false alarms. In various embodiments, for example, the vehicle system may examine the route using a first technique by injecting an examination signal into the route and monitoring one or more electrical characteristics of the route as the examination signal is transmitted through the route to identify one or more potential sections of the route that are potentially damaged (e.g., one or more sections having a broken or partially broken rail).

The vehicle system may then analyze potentially damaged sections using a second technique. The second technique may use the same or similar information used in identifying the potentially damaged section. For example, the vehicle system, for those locations identified as potentially damaged, may perform a more detailed analysis of a signature or other characteristic of an electrical signal detected in the track that results from the injection of the examination signal to determine if the location is damaged or not, and/or to determine the type or extent of any damage. Alternatively or additionally, the second technique may use information that is stored or otherwise accessible to the vehicle system. For example, the vehicle system may include or have access to a database that maps locations of known anomalies due to causes other than damage. It should be noted that databases or other sources of information (e.g., a database including locations of known anomalies due to causes other than damage, or a database including identified signatures associated with known non-damage anomalies, among others) may be maintained in one or more locations on-board the vehicle system and/or off-board the vehicle system in various embodiments. For example, in some embodiments, a database may be maintained in a central, dispatch, maintenance, or other office, and may be accessed by the vehicle system via digital communications. For example, a short message exchange between the vehicle system and a central office may support the determination of whether an indicated anomaly is a false alarm or not.

As just one example, insulated joints may be identified as potentially damaged sections of the track using the first technique based on the one or more electrical characteristics of the track receiving the examination signal. By tracking the locations indicated by the first technique using a geographic reference (e.g., position along a length of a track with reference to a mile marker or other marker, GPS coordinates, or the like), the locations may be compared with known locations of insulated joints, those sections identified as potentially damaged that coincide with the location of an insulated joint may be eliminated as a false positive and/or identified for further analysis. In some embodiments, the second technique may use second information that is different from information used by the first technique. For example, information from an accelerometer, additional electric coil, or video camera may be employed in various embodiments to further analyze, using a second technique, a section of a route identified by the first technique as potentially damaged.

In various embodiments, the route may be a track of a rail vehicle system and the vehicle system may be configured to identify a potentially broken or partially broken section of one or more rails of the track. The electrical signal that is injected into the route may be powered by an onboard energy storage device, such as one or more batteries, and/or an off-board energy source, such as a catenary and/or electrified rail of the route.

Generally, in various embodiments, a processor unit or module may receive an alarm or other indication from a first detection system that detects a probable, potential, or possible broken rail (or other damage to a route) based on electrical characteristics responsive to the injections of an examination signal. The processor unit than compares the alarm location to one or more verifying or excluding sources, and intercepts and excludes false alarms, for example, before a mitigating action is taken in response to a false alarm. In various embodiments, verifying or excluding sources may include one or more of parasitic eddy current detection, stored geographic data regarding known non-damage anomalies, live and/or stored video data, accelerometer data, signature information of variations in the transmitted or detected examination signal, or a supplemental detection sensor or coil configured to detect one or more additional electrical characteristics (e.g., electrical characteristics as measured from a different angle with respect to a rail).

A technical effect of at least one embodiment includes improved reliability in the identification of breaks or other damage along a route. A technical effect of at least one embodiment includes improved classification of type and/or extent of damage to a route. A technical effect of at least one embodiment includes reduced false alarms in the identification of damage to a route. A technical effect of at least one embodiment includes reduced cost and/or inconvenience due to mitigating actions taken in response to false alarms.

The term “vehicle” as used herein can be defined as a mobile machine that transports at least one of a person, people, or a cargo. For instance, a vehicle can be, but is not limited to being, a rail car, an intermodal container, a locomotive, a marine vessel, mining equipment, construction equipment, an automobile, and the like. A “vehicle system” includes two or more vehicles that are interconnected with each other to travel along a route. For example, a vehicle system can include two or more vehicles that are directly connected to each other (e.g., by a coupler) or that are indirectly connected with each other (e.g., by one or more other vehicles and couplers). A vehicle system can be referred to as a consist, such as a rail vehicle consist.

“Software” or “computer program” as used herein includes, but is not limited to, one or more computer readable and/or executable instructions that cause a computer or other electronic device to perform functions, actions, and/or behave in a desired manner. The instructions may be embodied in various forms such as routines, algorithms, modules or programs including separate applications or code from dynamically linked libraries. Software may also be implemented in various forms such as a stand-alone program, a function call, a servlet, an applet, an application, instructions stored in a memory, part of an operating system or other type of executable instructions. “Computer” or “processing element” or “computer device” as used herein includes, but is not limited to, any programmed or programmable electronic device that can store, retrieve, and process data. “Non-transitory computer-readable media” include, but are not limited to, a CD-ROM, a removable flash memory card, a hard disk drive, a magnetic tape, and a floppy disk. “Computer memory”, as used herein, refers to a storage device configured to store digital data or information which can be retrieved by a computer or processing element. “Controller,” “unit,” and/or “module,” as used herein, can to the logic circuitry and/or processing elements and associated software or program involved in controlling an energy storage system. The terms “signal”, “data”, and “information” may be used interchangeably herein and may refer to digital or analog forms.

Figure 1 is a schematic illustration of a vehicle system 100 that includes an embodiment of a route examining system 102. The vehicle system 100 includes several vehicles 104, 106 that are mechanically connected with each other to travel along a route 108. The vehicles 104 (e.g., the vehicles 104A-C) represent propulsion-generating vehicles, such as vehicles that generate tractive effort or power in order to propel the vehicle system 100 along the route 108. In an embodiment, the vehicles 104 can represent rail vehicles such as locomotives. The vehicles 106 (e.g., the vehicles 106A-E) represent non-propulsion generating vehicles, such as vehicles that do not generate tractive effort or power. In an embodiment, the vehicles 106 can represent rail cars. Alternatively, the vehicles 104, 106 may represent other types of vehicles. In another embodiment, one or more of the individual vehicles 104 and/or 106 represent a group of vehicles, such as a consist of locomotives or other vehicles.

The route 108 can be a body, surface, or medium on which the vehicle system 100 travels. In an embodiment, the route 108 can include or represent a body that is capable of conveying a signal between vehicles in the vehicle system 100, such as a conductive body capable of conveying an electrical signal (e.g., a direct current, alternating current, radio frequency, or other signal).

The examining system 102 can be distributed between or among two or more vehicles 104, 106 of the vehicle system 100. For example, the examining system 102 may include two or more components that operate to identify potentially damaged sections of the route 108, with at least one component disposed on each of two different vehicles 104, 106 in the same vehicle system 100. If the examining system 102 identifies a potentially damaged portion of the route 108, the potentially damaged portions may be further analyzed to confirm whether the potentially damaged section is actually damaged, or if the identification is a false alarm. (See, e.g., Figures 6-8 and related discussion.) Returning to Figure 1, in the illustrated embodiment, the examining system 102 is distributed between or among two different vehicles 104. Alternatively, the examining system 102 may be distributed among three or more vehicles 104, 106. Additionally or alternatively, the examining system 102 may be distributed between one or more vehicles 104 and one or more vehicles 106, and is not limited to being disposed onboard a single type of vehicle 104 or 106. As described below, in another embodiment, the examining system 102 may be distributed between a vehicle in the vehicle system and an off-board monitoring location, such as a wayside device.

In operation, the vehicle system 100 travels along the route 108. A first vehicle 104 electrically injects an examination signal into the route 108. For example, the first vehicle 104A may apply a direct current, alternating current, radio frequency signal, or the like, to the route 108 as an examination signal. The examination signal propagates through or along the route 108. A second vehicle 104B or 104C may monitor one or more electrical characteristics of the route 108 when the examination signal is injected into the route 108.

The examining system 102 can be distributed among two separate vehicles 104 and/or 106. In the illustrated embodiment, the examining system 102 has components disposed onboard at least two of the propulsion-generating vehicles 104A, 104B, 104C. Additionally or alternatively, the examining system 102 may include components disposed onboard at least one of the non-propulsion generating vehicles 106. For example, the examining system 102 may be located onboard two or more propulsion-generating vehicles 104, two or more non-propulsion generating vehicles 106, or at least one propulsion-generating vehicle 104 and at least one non-propulsion generating vehicle 106.

In operation, during travel of the vehicle system 100 along the route 108, the examining system 102 electrically injects an examination signal into the route 108 at a first vehicle 104 or 106 (e.g., beneath the footprint of the first vehicle 104 or 106). For example, an onboard or off-board power source may be controlled to apply a direct current, alternating current, RF signal, or the like, to a track of the route 108. The examining system 102 monitors electrical characteristics of the route 108 at a second vehicle 104 or 106 of the same vehicle system 100 (e.g., beneath the footprint of the second vehicle 104 or 106) in order to determine if the examination signal is detected in the route 108. For example, the voltage, current, resistance, impedance, or other electrical characteristic of the route 108 may be monitored at the second vehicle 104, 106 in order to determine if the examination signal is detected and/or if the examination signal has been altered. If the portion of the route 108 between the first and second vehicles conducts the examination signal to the second vehicle, then the examination signal may be detected by the examining system 102. The examining system 102 may determine that the route 108 (e.g., the portion of the route 108 through which the examination signal propagated) is intact and/or not damaged.

On the other hand, if the portion of the route 108 between the first and second vehicles does not conduct the examination signal to the second vehicle (e.g., such that the examination signal is not detected in the route 108 at the second vehicle), then the examination signal may not be detected by the examining system 102. The examining system 102 may determine that the route 108 (e.g., the portion of the route 108 disposed between the first and second vehicles during the time period that the examination signal is expected or calculated to propagate through the route 108) is not intact and/or is damaged. For example, the examining system 102 may determine that the portion of a track between the first and second vehicles is broken such that a continuous conductive pathway for propagation of the examination signal does not exist. The examining system 102 can identify this section of the route as being a potentially damaged section of the route 108. In routes 108 that are segmented (e.g., such as rail tracks that may have gaps), the examining system 102 may transmit and attempt to detect multiple examination signals in order to prevent false detection of a broken portion of the route 108.

Because the examination signal may propagate relatively quickly through the route 108 (e.g., faster than a speed at which the vehicle system 100 moves), the route 108 can be examined using the examination signal when the vehicle system 100 is moving, such as transporting cargo or otherwise operating at or above a non-zero, minimum speed limit of the route 108.

Additionally or alternatively, the examining system 102 may detect one or more changes in the examination signal at the second vehicle. The examination signal may propagate through the route 108 from the first vehicle to the second vehicle. But, due to damaged portions of the route 108 between the first and second vehicles, one or more signal characteristics of the examination signal may have changed. For example, the signal-to-noise ratio, intensity, power, or the like, of the examination signal may be known or designated when injected into the route 108 at the first vehicle. One or more of these signal characteristics may change (e.g., deteriorate or decrease) during propagation through a mechanically damaged or deteriorated portion of the route 108, even though the examination signal is received (e.g., detected) at the second vehicle. The signal characteristics can be monitored upon receipt of the examination signal at the second vehicle. Based on changes in one or more of the signal characteristics, the examining system 102 may identify the portion of the route 108 that is disposed between the first and second vehicles as being a potentially damaged portion of the route 108. For example, if the signal-to-noise ratio, intensity, power, or the like, of the examination signal decreases below a designated threshold and/or decreases by more than a designated threshold decrease, then the examining system 102 may identify the section of the route 108 as being potentially damaged.

In response to identifying a section of the route 108 as being damaged or potentially damaged, the examining system 102 may initiate one or more responsive actions. For example, the examining system 102 can automatically slow down or stop movement of the vehicle system 100. The examining system 102 can automatically issue a warning signal to one or more other vehicle systems traveling nearby of the potentially damaged section of the route 108 and where the potentially damaged section of the route 108 is located. The examining system 102 may automatically communicate a warning signal to a stationary wayside device located at or near the route 108 that notifies the device of the potentially damaged section of the route 108 and the location of the potentially damaged section. The stationary wayside device can then communicate a signal to one or more other vehicle systems traveling nearby of the potentially damaged section of the route 108 and where the potentially damaged section of the route 108 is located. The examining system 102 may automatically issue an inspection signal to an off-board facility, such as a repair facility, that notifies the facility of the potentially damaged section of the route 108 and the location of the section. The facility may then send one or more inspectors to check and/or repair the route 108 at the potentially damaged section. Alternatively, the examining system 102 may notify an operator of the potentially damaged section of the route 108 and the operator may then manually initiate one or more responsive actions.

Figure 2 is a schematic illustration of an embodiment of an examining system 200. The examining system 200 may represent the examining system 102 shown in Figure 1. The examining system 200 is distributed between a first vehicle 202 and a second vehicle 204 in the same vehicle system. The vehicles 202, 204 may represent vehicles 104 and/or 106 of the vehicle system 100 shown in Figure 1. In an embodiment, the vehicles 202, 204 represent two of the vehicles 104, such as the vehicle 104A and the vehicle 104B, the vehicle 104B and the vehicle 104C, or the vehicle 104A and the vehicle 104C. Alternatively, one or more of the vehicles 202, 204 may represent at least one of the vehicles 106. In another embodiment, the examining system 200 may be distributed among three or more of the vehicles 104 and/or 106.

The examining system 200 includes several components described below that are disposed onboard the vehicles 202, 204. For example, the illustrated embodiment of the examining system 200 includes a control unit 208, an application device 210, an onboard power source 212 ("Battery" in Figure 2), one or more conditioning circuits 214, a communication unit 216, and one or more switches 224 disposed onboard the first vehicle 202. The examining system 200 also includes a detection unit 218, an identification unit 220, a detection device 230, and a communication unit 222 disposed onboard the second vehicle 204. Alternatively, one or more of the control unit 208, application device 210, power source 212, conditioning circuits 214, communication unit 216, and/or switch 224 may be disposed onboard the second vehicle 204 and/or another vehicle in the same vehicle system, and/or one or more of the detection unit 218, identification unit 220, detection device 230, and communication unit 222 may be disposed onboard the first vehicle 202 and/or another vehicle in the same vehicle system.

The control unit 206 controls supply of electric current to the application device 210. In an embodiment, the application device 210 includes one or more conductive bodies that engage the route 108 as the vehicle system that includes the vehicle 202 travels along the route 108. For example, the application device 210 can include a conductive shoe, brush, or other body that slides along an upper and/or side surface of a track such that a conductive pathway is created that extends through the application device 210 and the track. Additionally or alternatively, the application device 210 can include a conductive portion of a wheel of the first vehicle 202, such as the conductive outer periphery or circumference of the wheel that engages the route 108 as the first vehicle 202 travels along the route 108. In another embodiment, the application device 210 may be inductively coupled with the route 108 without engaging or touching the route 108 or any component that engages the route 108.

The application device 210 is conductively coupled with the switch 224, which can represent one or more devices that control the flow of electric current from the onboard power source 212 and/or the conditioning circuits 214. The switch 224 can be controlled by the control unit 206 so that the control unit 206 can turn on or off the flow of electric current through the application device 210 to the route 108. In an embodiment, the switch 224 also can be controlled by the control unit 206 to vary one or more waveforms and/or waveform characteristics (e.g., phase, frequency, amplitude, and the like) of the current that is applied to the route 108 by the application device 210.

The onboard power source 212 represents one or more devices capable of storing electric energy, such as one or more batteries, capacitors, flywheels, and the like. Additionally or alternatively, the power source 212 may represent one or more devices capable of generating electric current, such as an alternator, generator, photovoltaic device, gas turbine, or the like. The power source 212 is coupled with the switch 224 so that the control unit 206 can control when the electric energy stored in the power source 212 and/or the electric current generated by the power source 212 is conveyed as electric current (e.g., direct current, alternating current, an RF signal, or the like) to the route 108 via the application device 210.

The conditioning circuit 214 represents one or more circuits and electric components that change characteristics of electric current. For example, the conditioning circuit 214 may include one or more inverters, converters, transformers, batteries, capacitors, resistors, inductors, and the like. In the illustrated embodiment, the conditioning circuit 214 is coupled with a connecting assembly 226 that is configured to receive electric current from an off-board source. For example, the connecting assembly 226 may include a pantograph that engages an electrified conductive pathway 228 (e.g., a catenary) extending along the route 108 such that the electric current from the catenary 228 is conveyed via the connecting assembly 226 to the conditioning circuit 214. Additionally or alternatively, the electrified conductive pathway 228 may represent an electrified portion of the route 108 (e.g., an electrified rail) and the connecting assembly 226 may include a conductive shoe, brush, portion of a wheel, or other body that engages the electrified portion of the route 108. Electric current is conveyed from the electrified portion of the route 108 through the connecting assembly 226 and to the conditioning circuit 214.

The electric current that is conveyed to the conditioning circuit 214 from the power source 212 and/or the off-board source (e.g., via the connecting assembly 226) can be altered by the conditioning circuit 214. For example, the conditioning circuit 214 can change the voltage, current, frequency, phase, magnitude, intensity, waveform, and the like, of the current that is received from the power source 212 and/or the connecting assembly 226. The modified current can be the examination signal that is electrically injected into the route 108 by the application device 210. Additionally or alternatively, the control unit 206 can form the examination signal by controlling the switch 224. For example, the examination signal can be formed by turning the switch 224 on to allow current to flow from the conditioning circuit 214 and/or the power source 212 to the application device 210.

In an embodiment, the control unit 206 may control the conditioning circuit 214 to form the examination signal. For example, the control unit 206 may control the conditioning circuit 214 to change the voltage, current, frequency, phase, magnitude, intensity, waveform, and the like, of the current that is received from the power source 212 and/or the connecting assembly 226 to form the examination signal.

The examination signal is conducted through the application device 210 to the route 108, and is electrically injected into a conductive portion of the route 108. For example, the examination signal may be conducted into a conductive track of the route 108. In another embodiment, the application device 210 may not directly engage (e.g., touch) the route 108, but may be wirelessly coupled with the route 108 in order to electrically inject the examination signal into the route 108 (e.g., via induction).

The conductive portion of the route 108 that extends between the first and second vehicles 202, 204 during travel of the vehicle system may form a track circuit through which the examination signal may be conducted. The first vehicle 202 can be coupled (e.g., coupled physically, coupled wirelessly, among others) to the track circuit by the application device 210. The power source (e.g., the onboard power source 212 and/or the off-board electrified conductive pathway 228) can transfer power (e.g., the examination signal) through the track circuit toward the second vehicle 204.

By way of example and not limitation, the first vehicle 202 can be coupled to a track of the route 108, and the track can be the track circuit that extends and conductively couples one or more components of the examining system 200 on the first vehicle 202 with one or more components of the examining system 200 on the second vehicle 204.

In an embodiment, the control unit 206 includes or represents the manager component described in the ’843 Application. For example, the control unit 206 may represent the manager component 210 in the ’843 Application. Such a manager component can be configured to activate a transmission of electric current into the route 108 via the application device 210. In another instance, the manager component can activate or deactivate a transfer of the portion of power from the onboard and/or off-board power source to the application device 210, such as by controlling the switch and/or conditioning circuit. Moreover, the manager component can adjust parameter(s) associated with the portion of power that is transferred to the route 108. For instance, the manager component can adjust an amount of power transferred, a frequency at which the power is transferred (e.g., a pulsed power delivery, AC power, among others), a duration of time the portion of power is transferred, among others. Such parameter(s) can be adjusted by the manager component based on at least one of a geographic location of the vehicle or the device or an identification of the device (e.g., type, location, make, model, among others).

The manager component can leverage a geographic location of the vehicle or the device in order to adjust a parameter for the portion of power that can be transferred to the device from the power source. For instance, the amount of power transferred can be adjusted by the manager component based on the device power input. By way of example and not limitation, the portion of power transferred can meet or be below the device power input in order to reduce risk of damage to the device. In another example, the geographic location of the vehicle and/or the device can be utilized to identify a particular device and, in turn, a power input for such device. The geographic location of the vehicle and/or the device can be ascertained by a location on a track circuit, identification of the track circuit, Global Positioning Service (GPS), among others.

The detection unit 218 disposed onboard the second vehicle 204 as shown in Figure 2 monitors the route 108 to attempt to detect the examination signal that is injected into the route 108 by the first vehicle 202. The detection unit 218 is coupled with the detection device 230. In an embodiment, the detection device 230 includes one or more conductive bodies that engage the route 108 as the vehicle system that includes the vehicle 204 travels along the route 108. For example, the detection device 230 can include a conductive shoe, brush, or other body that slides along an upper and/or side surface of a track such that a conductive pathway is created that extends through the detection device 230 and the track. Additionally or alternatively, the detection device 230 can include a conductive portion of a wheel of the second vehicle 204, such as the conductive outer periphery or circumference of the wheel that engages the route 108 as the second vehicle 204 travels along the route 108. In another embodiment, the detection device 230 may be inductively coupled with the route 108 without engaging or touching the route 108 or any component that engages the route 108.

The detection unit 218 monitors one or more electrical characteristics of the route 108 using the detection device 230. For example, the voltage of a direct current conducted by the route 108 may be detected by monitoring the voltage conducted by from the route 108 to the detection device 230 and/or the current (e.g., frequency, amps, phases, or the like) of an alternating current or RF signal being conducted by the route 108 may be detected by monitoring the current conducted by the route 108 to the detection device 230. As another example, the signal-to-noise ratio of a signal being conducted by the detection device 230 from the route 108 may be detected by the detection unit 218 examining the signal conducted by the detection device 230 (e.g., a received signal) and comparing the received signal to a designated signal. For example, the examination signal that is injected into the route 108 using the application device 210 may include a designated signal or portion of a designated signal. The detection unit 218 may compare the received signal that is conducted from the route 108 into the detection device 230 with this designated signal in order to measure a signal-to-noise ratio of the received signal.

The detection unit 218 determines one or more electrical characteristics of the signal (e.g., voltage, frequency, phase, waveform, intensity, or the like) that is received (e.g., picked up) by the detection device 230 from the route 108 and reports the characteristics of the received signal to the identification unit 220. If no signal is received by the detection device 230, then the detection unit 218 may report the absence of such a signal to the identification unit 220. For example, if the detection unit 218 does not detect at least a designated voltage, designated current, or the like, as being received by the detection device 230, then the detection unit 218 may not detect any received signal. Alternatively or additionally, the detection unit 218 may communicate the detection of a signal that is received by the detection device 230 only upon detection of the signal by the detection device 230.

In an embodiment, the detection unit 218 may determine the characteristics of the signals received by the detection device 230 in response to a notification received from the control unit 206 in the first vehicle 202. For example, when the control unit 206 is to cause the application device 210 to inject the examination signal into the route 108, the control unit 206 may direct the communication unit 216 to transmit a notification signal to the detection device 230 via the communication unit 222 of the second vehicle 204. The communication units 216, 222 may include respective antennas 232, 234 and associated circuitry for wirelessly communicating signals between the vehicles 202, 204, and/or with off-board locations. The communication unit 216 may wirelessly transmit a notification to the detection unit 218 that instructs the detection unit 218 as to when the examination signal is to be input into the route 108. Additionally or alternatively, the communication units 216, 222 may be connected via one or more wires, cables, and the like, such as a multiple unit (MU) cable, trainline, or other conductive pathway(s), to allow communication between the communication units 216, 222.

The detection unit 218 may begin monitoring signals received by the detection device 230. For example, the detection unit 218 may not begin or resume monitoring the received signals of the detection device 230 unless or until the detection unit 218 is instructed that the control unit 206 is causing the injection of the examination signal into the route 108. Alternatively or additionally, the detection unit 218 may periodically monitor the detection device 230 for received signals and/or may monitor the detection device 230 for received signals upon being manually prompted by an operator of the examining system 200.

The identification unit 220 receives the characteristics of the received signal from the detection unit 218 and determines if the characteristics indicate receipt of all or a portion of the examination signal injected into the route 108 by the first vehicle 202. Although the detection unit 218 and the identification unit 220 are shown as separate units, the detection unit 218 and the identification unit 220 may refer to the same unit. For example, the detection unit 218 and the identification unit 220 may be a single hardware component disposed onboard the second vehicle 204.

The identification unit 220 examines the characteristics and determines if the characteristics indicate that the section of the route 108 disposed between the first vehicle 202 and the second vehicle 204 is damaged or at least partially damaged. For example, if the application device 210 injected the examination signal into a track of the route 108 and one or more characteristics (e.g., voltage, current, frequency, intensity, signal-to-noise ratio, and the like) of the examination signal are not detected by the detection unit 218, then, the identification unit 220 may determine that the section of the track that was disposed between the vehicles 202, 204 is broken or otherwise damaged such that the track cannot conduct the examination signal. Additionally or alternatively, the identification unit 220 can examine the signal-to-noise ratio of the signal detected by the detection unit 218 and determine if the section of the route 108 between the vehicles 202, 204 is potentially broken or damaged. For example, the identification unit 220 may identify this section of the route 108 as being broken or damaged if the signal-to-noise ratio of one or more (or at least a designated amount) of the received signals is less than a designated ratio.

The identification unit 220 may include or be communicatively coupled (e.g., by one or more wired and/or wireless connections that allow communication) with a location determining unit that can determine the location of the vehicle 204 and/or vehicle system. For example, the location determining unit may include a GPS unit or other device that can determine where the first vehicle and/or second vehicle are located along the route 108. The distance between the first vehicle 202 and the second vehicle 204 along the length of the vehicle system may be known to the identification unit 220, such as by inputting the distance into the identification unit 220 using one or more input devices and/or via the communication unit 222.

The identification unit 220 can identify which section of the route 108 is potentially damaged based on the location of the first vehicle 202 and/or the second vehicle 204 during transmission of the examination signal through the route 108. For example, the identification unit 220 can identify the section of the route 108 that is within a designated distance of the vehicle system, the first vehicle 202, and/or the second vehicle 204 as the potentially damaged section when the identification unit 220 determines that the examination signal is not received or has a decreased signal-to-noise ratio.

Additionally or alternatively, the identification unit 220 can identify which section of the route 108 is potentially damaged based on the locations of the first vehicle 202 and the second vehicle 204 during transmission of the examination signal through the route 108, the direction of travel of the vehicle system that includes the vehicles 202, 204, the speed of the vehicle system, and/or a speed of propagation of the examination signal through the route 108. The speed of propagation of the examination signal may be a designated speed that is based on one or more of the material(s) from which the route 108 is formed, the type of examination signal that is injected into the route 108, and the like. In an embodiment, the identification unit 220 may be notified when the examination signal is injected into the route 108 via the notification provided by the control unit 206. The identification unit 220 can then determine which portion of the route 108 is disposed between the first vehicle 202 and the second vehicle 204 as the vehicle system moves along the route 108 during the time period that corresponds to when the examination signal is expected to be propagating through the route 108 between the vehicles 202, 204 as the vehicles 202, 204 move. This portion of the route 108 may be the section of potentially damaged route that is identified.

One or more responsive actions may be initiated when the potentially damaged section of the route 108 is identified. For example, in response to identifying the potentially damaged portion of the route 108, the identification unit 220 may notify the control unit 206 via the communication units 222, 216. The control unit 206 and/or the identification unit 220 can automatically slow down or stop movement of the vehicle system. For example, the control unit 206 and/or identification unit 220 can be communicatively coupled with one or more propulsion systems (e.g., engines, alternators/generators, motors, and the like) of one or more of the propulsion-generating vehicles in the vehicle system. The control unit 206 and/or identification unit 220 may automatically direct the propulsion systems to slow down and/or stop. In various embodiments, a second technique may be employed to determine if the potentially damaged section is indeed damaged, to identify a type of damage, and/or to assess an extent of damage. (See Figures 6-8 and related discussion.)

With continued reference to Figure 2, Figure 3 illustrates a schematic diagram of an embodiment of plural vehicle systems 300, 302 traveling along the route 108. One or more of the vehicle systems 300, 302 may represent the vehicle system 100 shown in Figure 1 that includes the route examining system 200. For example, at least a first vehicle system 300 traveling along the route 108 in a first direction 308 may include the examining system 200. The second vehicle system 302 may be following the first vehicle system 300 on the route 108, but spaced apart and separated from the first vehicle system 300.

In addition or as an alternate to the responsive actions that may be taken when a potentially damaged section of the route 108 is identified, the examining system 200 onboard the first vehicle system 300 may automatically notify the second vehicle system 302. The control unit 206 and/or the identification unit 220 may wirelessly communicate (e.g., transmit or broadcast) a warning signal to the second vehicle system 302. The warning signal may notify the second vehicle system 302 of the location of the potentially damaged section of the route 108 before the second vehicle system 302 arrives at the potentially damaged section. The second vehicle system 302 may be able to slow down, stop, or move to another route to avoid traveling over the potentially damaged section.

Additionally or alternatively, the control unit 206 and/or identification unit 220 may communicate a warning signal to a stationary wayside device 304 in response to identifying a section of the route 108 as being potentially damaged. The device 304 can be, for instance, wayside equipment, an electrical device, a client asset, a defect detection device, a device utilized with Positive Train Control (PTC), a signal system component(s), a device utilized with Automated Equipment Identification (AEI), among others. In one example, the device 304 can be a device utilized with AEI. AEI is an automated equipment identification mechanism that can aggregate data related to equipment for the vehicle. By way of example and not limitation, AEI can utilize passive radio frequency technology in which a tag (e.g., passive tag) is associated with the vehicle and a reader/receiver receives data from the tag when in geographic proximity thereto. The AEI device can be a reader or receiver that collects or stores data from a passive tag, a data store that stores data related to passive tag information received from a vehicle, an antenna that facilitates communication between the vehicle and a passive tag, among others. Such an AEI device may store an indication of where the potentially damaged section of the route 108 is located so that the second vehicle system 302 may obtain this indication when the second vehicle system 302 reads information from the AEI device.

In another example, the device 304 can be a signaling device for the vehicle. For instance, the device 304 can provide visual and/or audible warnings to provide warning to other entities such as other vehicle systems (e.g., the vehicle system 302) of the potentially damaged section of the route 108. The signaling devices can be, but not limited to, a light, a motorized gate arm (e.g., motorized motion in a vertical plane), an audible warning device, among others.

In another example, the device 304 can be utilized with PTC. PTC can refer to communication-based/processor-based vehicle control technology that provides a system capable of reliably and functionally preventing collisions between vehicle systems, over speed derailments, incursions into established work zone limits, and the movement of a vehicle system through a route switch in the improper position. PTC systems can perform other additional specified functions. Such a PTC device 304 can provide warnings to the second vehicle system 204 that cause the second vehicle system 204 to automatically slow and/or stop, among other responsive actions, when the second vehicle system 204 approaches the location of the potentially damaged section of the route 108.

In another example, the wayside device 304 can act as a beacon or other transmitting or broadcasting device other than a PTC device that communicates warnings to other vehicles or vehicle systems traveling on the route 108 of the identified section of the route 108 that is potentially damaged.

The control unit 206 and/or identification unit 220 may communicate a repair signal to an off-board facility 306 in response to identifying a section of the route 108 as being potentially damaged. The facility 306 can represent a location, such as a dispatch or repair center, that is located off-board of the vehicle systems 202, 204. The repair signal may include or represent a request for further inspection and/or repair of the route 108 at the potentially damaged section. Upon receipt of the repair signal, the facility 306 may dispatch one or more persons and/or equipment to the location of the potentially damaged section of the route 108 in order to inspect and/or repair the route 108 at the location.

Additionally or alternatively, the control unit 206 and/or identification unit 220 may notify an operator of the vehicle system of the potentially damaged section of the route 108 and suggest the operator initiate one or more of the responsive actions described herein.

In another embodiment, the examining system 200 may identify the potentially damaged section of the route 108 using the wayside device 304. For example, the detection device 230, the detection unit 218, and the communication unit 222 may be located at or included in the wayside device 304. The control unit 206 on the vehicle system may determine when the vehicle system is within a designated distance of the wayside device 304 based on an input or known location of the wayside device 304 and the monitored location of the vehicle system (e.g., from data obtained from a location determination unit). Upon traveling within a designated distance of the wayside device 304, the control unit 206 may cause the examination signal to be injected into the route 108. The wayside device 304 can monitor one or more electrical characteristics of the route 108 similar to the second vehicle 204 described above. If the electrical characteristics indicate that the section of the route 108 between the vehicle system and the wayside device 304 is damaged or broken, the wayside device 304 can initiate one or more responsive actions, such as by directing the vehicle system to automatically slow down and/or stop, warning other vehicle systems traveling on the route 108, requesting inspection and/or repair of the potentially damaged section of the route 108, and the like.

Figure 5 is a schematic illustration of an embodiment of an examining system 500. The examining system 500 may represent the examining system 102 shown in Figure 1. In contrast to the examining system 200 shown in Figure 2, the examining system 500 is disposed within a single vehicle 502 in a vehicle system that may include one or more additional vehicles mechanically coupled with the vehicle 502. The vehicle 502 may represent a vehicle 104 and/or 106 of the vehicle system 100 shown in Figure 1.

The examining system 500 includes several components described below that are disposed onboard the vehicle 502. For example, the illustrated embodiment of the examining system 500 includes a control unit 508 (which may be similar to or represent the control unit 208 shown in Figure 2), an application device 510 (which may be similar to or represent the application device 210 shown in Figure), an onboard power source 512 ("Battery" in Figure 5, which may be similar to or represent the power source 212 shown in Figure 2), one or more conditioning circuits 514 (which may be similar to or represent the circuits 214 shown in Figure 2), a communication unit 516 (which may be similar to or represent the communication unit 216 shown in Figure 2), and one or more switches 524 (which may be similar to or represent the switches 224 shown in Figure 2). The examining system 500 also includes a detection unit 518 (which may be similar to or represent the detection unit 218 shown in Figure 2), an identification unit 520 (which may be similar to or represent the identification unit 220 shown in Figure 2), and a detection device 530 (which may be similar to or represent the detection device 230 shown in Figure 2). As shown in Figure 5, these components of the examining system 500 are disposed onboard a single vehicle 502 of a vehicle system.

As described above, the control unit 506 controls supply of electric current to the application device 510 that engages or is inductively coupled with the route 108 as the vehicle 502 travels along the route 108. The application device 510 is conductively coupled with the switch 524 that is controlled by the control unit 506 so that the control unit 506 can turn on or off the flow of electric current through the application device 510 to the route 108. The power source 512 is coupled with the switch 524 so that the control unit 506 can control when the electric energy stored in the power source 512 and/or the electric current generated by the power source 512 is conveyed as electric current to the route 108 via the application device 510.

The conditioning circuit 514 may be coupled with a connecting assembly 526 that is similar to or represents the connecting assembly 226 shown in Figure 2. The connecting assembly 526 receives electric current from an off-board source, such as the electrified conductive pathway 228. Electric current can be conveyed from the electrified portion of the route 108 through the connecting assembly 526 and to the conditioning circuit 514.

The electric current that is conveyed to the conditioning circuit 514 from the power source 512 and/or the off-board source can be altered by the conditioning circuit 514. The modified current can be the examination signal that is electrically injected into the route 108 by the application device 510. Optionally, the control unit 506 can form the examination signal by controlling the switch 524, as described above. Optionally, the control unit 506 may control the conditioning circuit 514 to form the examination signal, also as described above.

The examination signal is conducted through the application device 510 to the route 108, and is electrically injected into a conductive portion of the route 108. The conductive portion of the route 108 that extends between the application device 510 and the detection device 530 of the vehicle 502 during travel may form a track circuit through which the examination signal may be conducted.

The control unit 506 may include or represent the manager component described in the ’843 Application. For example, the control unit 506 may represent the manager component 210 in the ’843 Application. Such a manager component can be configured to activate a transmission of electric current into the route 108 via the application device 510. In another instance, the manager component can activate or deactivate a transfer of the portion of power from the onboard and/or off-board power source to the application device 510, such as by controlling the switch and/or conditioning circuit. Moreover, the manager component can adjust parameter(s) associated with the portion of power that is transferred to the route 108.

The detection unit 518 monitors the route 108 to attempt to detect the examination signal that is injected into the route 108 by the application device 510. In one aspect, the detection unit 518 may follow behind the application device 510 along a direction of travel of the vehicle 502. The detection unit 518 is coupled with the detection device 530 that engages or is inductively coupled with the route 108, as described above.

The detection unit 518 monitors one or more electrical characteristics of the route 108 using the detection device 530. The detection unit 518 may compare the received signal that is conducted from the route 108 into the detection device 530 with this designated signal in order to measure a signal-to-noise ratio of the received signal.

The detection unit 518 determines one or more electrical characteristics of the signal by the detection device 530 from the route 108 and reports the characteristics of the received signal to the identification unit 520. If no signal is received by the detection device 530, then the detection unit 518 may report the absence of such a signal to the identification unit 520. In an embodiment, the detection unit 518 may determine the characteristics of the signals received by the detection device 530 in response to a notification received from the control unit 506, as described above.

The detection unit 518 may begin monitoring signals received by the detection device 530. For example, the detection unit 518 may not begin or resume monitoring the received signals of the detection device 530 unless or until the detection unit 518 is instructed that the control unit 506 is causing the injection of the examination signal into the route 108. Alternatively or additionally, the detection unit 518 may periodically monitor the detection device 530 for received signals and/or may monitor the detection device 530 for received signals upon being manually prompted by an operator of the examining system 500.

In one aspect, the application device 510 includes a first axle 528 and/or a first wheel 529 that is connected to the axle 528 of the vehicle 502. The axle 528 and wheel 529 may be connected to a first truck 532 of the vehicle 502. The application device 510 may be conductively coupled with the route 108 (e.g., by directly engaging the route 108) to inject the examination signal into the route 108 via the axle 528 and the wheel 529, or via the wheel 529 alone. The detection device 530 may include a second axle 534 and/or a second wheel 536 that is connected to the axle 534 of the vehicle 502. The axle 534 and wheel 536 may be connected to a second truck 538 of the vehicle 502. The detection device 530 may monitor the electrical characteristics of the route 108 via the axle 534 and the wheel 536, or via the wheel 536 alone. Optionally, the axle 534 and/or wheel 536 may inject the signal while the other axle 528 and/or wheel 529 monitors the electrical characteristics.

The identification unit 520 receives the characteristics of the received signal from the detection unit 518 and determines if the characteristics indicate receipt of all or a portion of the examination signal injected into the route 108 by the application device 510. The identification unit 520 examines the characteristics and determines if the characteristics indicate that the section of the route 108 disposed between the application device 510 and the detection device 530 is damaged or at least partially damaged, as described above.

The identification unit 520 may include or be communicatively coupled with a location determining unit that can determine the location of the vehicle 502. The distance between the application device 510 and the detection device 530 along the length of the vehicle 502 may be known to the identification unit 520, such as by inputting the distance into the identification unit 520 using one or more input devices and/or via the communication unit 516.

The identification unit 520 can identify which section of the route 108 is potentially damaged based on the location of the vehicle 502 during transmission of the examination signal through the route 108, the direction of travel of the vehicle 502, the speed of the vehicle 502, and/or a speed of propagation of the examination signal through the route 108, as described above.

One or more responsive actions may be initiated when the potentially damaged section of the route 108 is identified. For example, in response to identifying the potentially damaged portion of the route 108, the identification unit 520 may notify the control unit 506. The control unit 506 and/or the identification unit 520 can automatically slow down or stop movement of the vehicle 502 and/or the vehicle system that includes the vehicle 502. For example, the control unit 506 and/or identification unit 520 can be communicatively coupled with one or more propulsion systems (e.g., engines, alternators/generators, motors, and the like) of one or more of the propulsion-generating vehicles in the vehicle system. The control unit 506 and/or identification unit 520 may automatically direct the propulsion systems to slow down and/or stop.

Figure 4 is a flowchart of an embodiment of a method 400 for examining a route being traveled by a vehicle system from onboard the vehicle system. The method 400 may be used in conjunction with one or more embodiments of the vehicle systems and/or examining systems described herein. Alternatively, the method 400 may be implemented with another system.

At 402, an examination signal is injected into the route being traveled by the vehicle system at a first vehicle. For example, a direct current, alternating current, RF signal, or another signal may be conductively and/or inductively injected into a conductive portion of the route 108, such as a track of the route 108.

At 404, one or more electrical characteristics of the route are monitored at another, second vehicle in the same vehicle system. For example, the route 108 may be monitored to determine if any voltage or current is being conducted by the route 108.

At 406, a determination is made as to whether the one or more monitored electrical characteristics indicate receipt of the examination signal. For example, if a direct current, alternating current, or RF signal is detected in the route 108, then the detected current or signal may indicate that the examination signal is conducted through the route 108 from the first vehicle to the second vehicle in the same vehicle system. As a result, the route 108 may be substantially intact between the first and second vehicles. Optionally, the examination signal may be conducted through the route 108 between components joined to the same vehicle. As a result, the route 108 may be substantially intact between the components of the same vehicle. Flow of the method 400 may proceed to 408. On the other hand, if no direct current, alternating current, or RF signal is detected in the route 108, then the absence of the current or signal may indicate that the examination signal is not conducted through the route 108 from the first vehicle to the second vehicle in the same vehicle system or between components of the same vehicle. As a result, the route 108 may be broken between the first and second vehicles, or between the components of the same vehicle. Flow of the method 400 may then proceed to 412.

At 408, a determination is made as to whether a change in the one or more monitored electrical characteristics indicates damage to the route. For example, a change in the examination signal between when the signal was injected into the route 108 and when the examination signal is detected may be determined. This change may reflect a decrease in voltage, a decrease in amps, a change in frequency and/or phase, a decrease in a signal-to-noise ratio, or the like. The change can indicate that the examination signal was conducted through the route 108, but that damage to the route 108 may have altered the signal. For example, if the change in voltage, amps, frequency, phase, signal-to-noise ratio, or the like, of the injected examination signal to the detected examination signal exceeds a designated threshold amount (or if the monitored characteristic decreased below a designated threshold), then the change may indicate damage to the route 108, but not a complete break in the route 108. As a result, flow of the method 400 can proceed to 412.

On the other hand, if the change in voltage, amps, frequency, phase, signal-to-noise ratio, or the like, of the injected examination signal to the detected examination signal does not exceed the designated threshold amount (and/or if the monitored characteristic does not decrease below a designated threshold), then the change may not indicate damage to the route 108. As a result, flow of the method 400 can proceed to 410.

At 410, the section of the route that is between the first and second vehicles in the vehicle system or between the components of the same vehicle is not identified as potentially damaged, and the vehicle system may continue to travel along the route. Additionally examination signals may be injected into the route at other locations as the vehicle system moves along the route.

At 412, the section of the route that is or was disposed between the first and second vehicles, or between the components of the same vehicle, is identified as a potentially damaged section of the route. For example, due to the failure of the examination signal to be detected and/or the change in the examination signal that is detected, the route may be broken and/or damaged between the first vehicle and the second vehicle, or between the components of the same vehicle.

At 414, one or more responsive actions may be initiated in response to identifying the potentially damaged section of the route. As described above, these actions can include, but are not limited to, automatically and/or manually slowing or stopping movement of the vehicle system, warning other vehicle systems about the potentially damaged section of the route, notifying wayside devices of the potentially damaged section of the route, requesting inspection and/or repair of the potentially damaged section of the route, and the like.

Figure 6 is a schematic illustration of an embodiment of an examining system 600. The examining system 600 depicted in Figure 6 may be generally similar to the examining system 500 depicted in Figure 5 in many respects. However, as shown in Figure 6, the examining system 600 includes a secondary analysis module 640 configured to perform additional analysis (e.g., utilizing a different technique) of any sections of the route 108 that are identified as potentially damaged based on use of the examination signal. The secondary analysis module 640 depicted in Figure 6 includes a secondary determination unit 650 and a secondary detection unit 660 that in turn includes a secondary detection device 670 to which the secondary detection unit 660 is operably coupled. Other arrangements may be employed. For example, in some embodiments, the secondary analysis module 640 may include more than one secondary determination unit 650 and/or secondary detection unit 660 (and/or secondary detection device 670), while in other embodiments, the secondary analysis module 640 may be devoid of a secondary detection unit and/or secondary detection device. In the illustrated embodiment, the secondary analysis module 640 is configured to be disposed on-board the same vehicle as the detection unit 618 and identification unit 620 as well as the application device 610. However, in various embodiments one or more aspects of the secondary analysis module 640 may be disposed off-board the vehicle 602, for example on a separate vehicle of the same vehicle system, on a separate vehicle system, or at a wayside or other off-board station.

The secondary analysis module 640, by providing a second methodology of analyzing a potentially damaged section of the route 108, may provide improved reliability in assessing whether a section of the route 108 is damaged and, if damaged, the type and/or extent of damage. Further, the secondary analysis module 640 may employ techniques that may not be practical or effective if utilized without the first technique. As just one example, it may not be practical to provide the video acquisition, processing, and/or storage capabilities required to continuously analyze the route 108 for damage using a video camera. However, use of video may be employed in various embodiments only when use of the first technique indicates a potentially damaged section, thereby reducing the storage or processing capability required to use video analysis of the route 108. As another example, a second technique may be subject to an overly large likelihood of false positives. Thus, employment of a second technique may only be invoked when indicated by an initial analysis employing the first technique, helping to eliminate or reduce false positives that may result from using either of the first or second techniques in isolation.

Generally, various components or aspects of the examining system 600 of figure 6 may be configured generally similarly in certain respects to corresponding components or aspects of the examining system 500 of Figure 5. For example, similarly named (e.g., application device 610 similar to application device 620, detection unit 618 similar to detection unit 518, and so on) components may be configured generally similarly in certain respects.

For example, as with the examining system 500 depicted in Figure 5, the examining system 600 includes several components described below that are disposed onboard the vehicle 602. In the illustrated embodiment, the examining system 600 includes a control unit 606, an application device 610, an onboard power source 612, one or more conditioning circuits 614, a communication unit 616, and one or more switches 624. The examining system 600 also includes a detection unit 618, an identification unit 620, and a detection device 630. As shown in Figure 6, these components of the examining system 600 are disposed onboard a single vehicle 602 of a vehicle system. In various alternate embodiments, one or more components or aspects may be disposed off-board the vehicle 602 (e.g., onboard a different vehicle of the vehicle system, onboard a different vehicle system, or at a station such as a wayside station).

As described above, the control unit 606 controls supply of electric current to the application device 610 that engages or is inductively coupled with the route 108 as the vehicle 602 travels along the route 608. The application device 610 is conductively coupled with the switch 624 to control the flow of electric current through the application device 610 to the route 108.

The conditioning circuit 614 may be coupled with a connecting assembly 626 that is similar to or represents the connecting assembly 226 shown in Figure 2. The connecting assembly 626 receives electric current from an off-board source, such as the electrified conductive pathway 228. Electric current can be conveyed from the electrified portion of the route 108 through the connecting assembly 626 and to the conditioning circuit 614.

Similar to the above discussion regarding Figure 5, the examination signal is conducted through the application device 610 to the route 108, and is electrically injected into a conductive portion of the route 108. The conductive portion of the route 108 that extends between the application device 610 and the detection device 630 of the vehicle 602 during travel may form a track circuit through which the examination signal may be conducted.

The detection unit 618 monitors the route 108 to attempt to detect the examination signal that is injected into the route 108 by the application device 610. In one aspect, the detection unit 618 may follow behind the application device 610 along a direction of travel of the vehicle 602. The detection unit 618 is coupled with the detection device 630 that engages or is inductively coupled with the route 108, as described above.

The detection unit 618 monitors one or more electrical characteristics of the route 108 using the detection device 630. The detection unit 618 may compare the received signal that is conducted from the route 108 into the detection device 630 with this designated signal in order to measure a signal-to-noise ratio of the received signal. The detection unit 618 determines one or more electrical characteristics of the signal by the detection device 630 from the route 108 and reports the characteristics of the received signal to the identification unit 620. If no signal is received by the detection device 630, then the detection unit 618 may report the absence of such a signal to the identification unit 620. In an embodiment, the detection unit 618 may determine the characteristics of the signals received by the detection device 630 in response to a notification received from the control unit 606, as described above.

In one aspect, the application device 610 includes a first axle 628 and/or a first wheel 629 that is connected to the axle 628 of the vehicle 602. The axle 628 and wheel 629 may be connected to a first truck 632 of the vehicle 602. The application device 610 may be conductively or inductively coupled with the route 108 to inject the examination signal into the route 108 via the axle 628 and the wheel 629, or via the wheel 629 alone. The detection device 630 may include a second axle 634 and/or a second wheel 636 that is connected to the axle 634 of the vehicle 602. The axle 634 and wheel 636 may be connected to a second truck 638 of the vehicle 602. The detection device 630 may monitor the electrical characteristics of the route 108 via the axle 634 and the wheel 636, or via the wheel 636 alone. Optionally, the axle 634 and/or wheel 636 may inject the signal while the other axle 628 and/or wheel 629 monitors the electrical characteristics.

The identification unit 620 may be configured to identify which section of the route 108 is potentially damaged based on the location of the vehicle 602 during transmission of the examination signal through the route 108, the direction of travel of the vehicle 602, the speed of the vehicle 602, and/or a speed of propagation of the examination signal through the route 108, as described above.

In the embodiment illustrated in Figure 6, responsive to an identification of potentially damaged section of the route by the identification unit 620, the secondary analysis module 640 is configured to perform a secondary analysis of the potentially damaged section of the route 108 to at least one of confirm whether or not damage has occurred to the potentially damaged section of the route, identify a type of damage that has occurred to the potentially damaged section of the route, or assess a level of damage to the potentially damaged section of the route. The secondary analysis module, for example, may be configured to discriminate damage to the track from other anomalies (intentional or unintentional) such as insulated joints in the track, an unbonded rail joint, a switch frog, or the like. In some embodiments, the secondary analysis module 640 may be configured to provide information and/or analysis to the identification unit 620 or other module or aspect of a vehicle system or transportation network, with the identification unit 620 (or the other module or aspect of a vehicle system or transportation network) configured to use the information and/or analysis provided by the secondary analysis module 640 to confirm damage that has occurred, identify a type of damage, or assess a level of damage. In the illustrated embodiment, the secondary analysis module 650 is depicted as separate from the identification unit 620; however, it may be noted that in various embodiments one or more aspects of the secondary analysis module 640 may be incorporated into the identification unit 620.

In some embodiments, the secondary analysis module 640 may access a database to further analyze a potentially damaged section of the route 108. For example, a potentially damaged section of the route 108 may be identified by the identification unit 620 as being located at a specific position as described by geographic information system (GIS) information, such as GPS information. The identified location may then be compared with known anomalies in a GIS information database. For example, the database may map locations (e.g., provide tabulated coordinates) of known unbonded rails, insulated joints, switch frogs, or the like present along the route 108. Thus, the secondary analysis module 640 may be configured to determine if a potentially damaged section of the route 108 identified by the identification unit 620 coincides with a known feature of the track to rule out false reports of damage due to the known feature.

Additionally or alternatively, the secondary analysis module 640 may utilize information corresponding to information used by the identification module 620 employing the first technique. For example, a transmitted and/or detected examination signal may be analyzed in a different way or to a different extent than the signal was analyzed by the identification module 620. In various embodiments, the secondary analysis module 640 is configured to analyze a signature of the one or more electrical characteristics and to perform the secondary analysis using the signature. For example, a given type of non-damage anomaly (e.g., switch frog) may have a different signature in a detected examination signal than a different type of non-damage anomaly (e.g., insulated joint) and/or a given type of damaged track. Generally, various non-damage anomalies and types of damage may be physically or mechanically different, resulting in a different change to the examination signal being transmitted through the route 108. In various embodiments, one or more configurations of examination signal (e.g., sine wave, square wave, pulse) may be transmitted to provide different signature responses used to discriminate between damage and non-damage anomalies in the route 108. Various signatures may be associated with particular anomalies, for example, based on experimental results or field testing.

As just one example, a switch frog may be understood as occurring along a route where two tracks cross. A switch frog has a particular pattern of gaps and masses of metal that may result in an identifiably different signature of a detected examination signal relative to signatures due to features such as insulated joints or transverse breaks, among others.

Further, an extent of damage may be discernible in various embodiments based on a signature of a detected examination signal. Thus, for example, an amplitude of a detected examination signal may be analyzed to identify a potentially damaged section of the track, and, for sections identified as potentially damaged, a more in-depth analysis of the section including signature analysis may be performed to determine if the section is damaged (or an extent or type of damage) or if the identification as potentially damaged was due to a structure or feature of the track such as a switch frog or insulated joint. In some embodiments, if the anomaly is determined to be a route feature such as an insulated joint, the location may be analyzed using a GIS information database as discussed above to confirm the determination of route feature.

Alternatively or additionally, the secondary analysis module 640 (e.g., the secondary determination unit 650 of the secondary analysis module) may use information from one or more secondary detection units 660 to analyze, using a second technique, one or more sections of the route 108 identified as potentially damaged by the identification unit 620 using the first technique. For example, the secondary analysis module 640 may include a secondary detection unit 660 configured to obtain secondary data regarding the potentially damaged section of the route 108. The secondary detection unit 660 may include or be operably connected to the secondary detection device 670. In some embodiments, the detection unit 630 and the secondary detection unit 670 may be disposed onboard the vehicle 602. In various embodiments, the detection unit 630 may be configured to be disposed on-board the vehicle 602, and the secondary detection unit 670 may be configured to be disposed on-board a different vehicle of the same vehicle system as the vehicle 602.

As one example, the secondary detection unit 660 may include an accelerometer. The accelerometer may be configured to measure an acceleration of the vehicle 602, for example in a generally vertical direction (e.g., away from the route 108). Thus, the accelerometer may be used to confirm a force likely imparted by a break, or to identify a section of the track for which the accelerometer senses a force (or acceleration) beneath a threshold value as a false alarm.

Generally, the secondary detection unit 660 may include or be coupled with one or more secondary detection devices 670, and be configured to monitor one or more characteristics of the route 108. The secondary detection unit 660 (and/or the secondary detection device 670) may be operated responsive to an identification by the identification unit 620 of a potentially damaged section of the route 108. As one example, data may be collected by the secondary detection device 670 and/or obtained by the secondary detection unit 660 generally continuously, but not analyzed or saved (e.g., not saved beyond a buffer amount), and instead disposed. However, the secondary detection unit 660 may save a selected or identified portion (e.g., identified based on a location and/or time corresponding to a potentially damaged section of the route 108 as identified by the identification module 620) of data from secondary detection device 670 for analysis and/or transmission to another aspect of the examining system 600 for analysis. As another example, in other embodiments, the secondary detection unit 660 and/or the secondary detection device 670 may remain in an idle or off position until instructed by another aspect of the examining system (e.g., identification unit 620 or secondary determination unit 650) to collect or obtain information.

As one example, the identification unit 620 may identify a potentially damaged section of the route 108, and communicate the time of detection (e.g., a range of time including a determined time of detection) of the potentially damaged section to the secondary analysis module 640. The secondary analysis module 640 may then determine a corresponding time at which the second detection device 670 will pass over the potentially damaged section of track, for example based on the distance between the detection device 630 and the secondary detection device 670 as well as the speed of the vehicle 602. The secondary analysis module 640 may then control the secondary detection unit 660 and/or the secondary detection unit to collect or obtain information at the determined time. The secondary analysis module 640 may then utilize the obtained information to determine if the potentially damaged section of the route 108 is actually damaged, and, in some embodiments, to determine a type and/or extent of damage if the potentially damaged section is damaged.

In various embodiments, the secondary detection unit 660 may include a video camera and related processing equipment. For example, the secondary detection unit 660 may include pattern recognition software configured to identify breaks, extent of breaks (e.g., partial breaks, full breaks, a depth of break), and/or types of breaks (e.g., a surface portion of route missing, transverse break, or the like). Video information may be obtained live or from storage. For example, a section of the route may be identified by the identification unit 620 using timing information and/or GIS information. A portion of data recorded by a video camera of the section of the route 108 identified by the identification unit 620 may be analyzed. For example, the time at which the video camera recorded the identified section may be determined by adjusting the time at which the detection unit 630 detected the potentially damaged section to account for the distance from the detection unit 630 to the video camera and the speed of the vehicle 602. Thus, the storage and/or processing capacities required for use of a video camera may be minimized or reduced by selectively operating the camera to collect and/or save data only when a potentially damaged section is identified by the identification unit 620. For example, the camera may be activated when the identification unit 620 identifies a potentially damaged section of the route 108, and remain active only long enough to obtain information for the potentially damaged section of the route. As another example, the camera may save information for a relatively low buffer time period, and discard the saved information if no indication from the identification module 620 of a corresponding potentially damaged section of the route 108 is received. Thus, in various embodiments, the video camera is configured to be disposed on-board the vehicle 602, and video data is obtained using timing information corresponding to a time when the vehicle 602 passed over the potentially damaged section of the route 108.

Alternatively or additionally, in various embodiments, a laser inspection system may be used with one or more secondary analysis modules. For example, a secondary inspection method may add the use of laser scans of a route to enhance the effectiveness of a video inspection. In various embodiments, a secondary (or verifying) inspection may include laser line scan imaging or video enhanced by a laser scan at a trailing end of an inspection window span (e.g., a window of time configured to include the time when one or more detection units disposed on a single vehicle pass over a given section of track). The secondary inspection may also be conducted at a subsequent time when detection units on a subsequent vehicle pass over an initially identified section of a route, with the secondary inspection triggered by or responsive to an initial detection. In some embodiments, the secondary inspection may be performed only when triggered by or responsive to an initial detection to help minimize or reduce data size (e.g., amount of data collected via a secondary technique). Thus, in various embodiments, more than one type of detection unit (e.g., video detection enhanced by laser detection) may be used to verify an initial identification of potentially damaged track.

It may be noted that, in some embodiments, a signal other than an injection signal may be detected and employed by one or both of the identification unit 620 and the secondary analysis module 640. For example, for some vehicles (e.g., a locomotive with AC drive), high noise levels may be picked up by detection coils (e.g., the detection device 630). At least a portion of such noise may be attributable to motor switching being induced in a test loop. The noise may disappear or become substantially reduced when a break or other anomaly in the route is passed over. Various embodiments may utilize or take into account such noise and/or a reduction in noise over a break or other anomaly in a route.

As one example, when an injected and received examination signal has interference from drive currents (e.g., locomotive drive currents in either propulsion or dynamic braking modes), the component of interference in a section of route being examined may be used for a continuity check of the route. In some embodiments, an examining module may receive inputs from the control system of the vehicle regarding the propulsion and/or braking state of the vehicle, while in other embodiments the examining module may not receive such inputs. The interfering signal may be used in addition to or in lieu of the injected test signal. The interfering signal may be used with a first technique to initially identify a potentially damaged section of track and/or a secondary technique to confirm (or exclude) an initial identification of a potentially damaged section of track.

In various embodiments, the control of the vehicle may be altered for examining the route via one or more of the first and second techniques. For example, a first vehicle of a vehicle system may be operated according to predetermined settings during the examination of a portion of a route by the first technique by a first vehicle as the first vehicle passes over the portion of the route, and the second vehicle of a vehicle system may have one or more aspects of control of the second vehicle altered during a subsequent examination of the portion of the route by the second vehicle as the second vehicle passes over the portion of the route. In one example scenario, a first powered vehicle of a vehicle system is disposed ahead of (in the direction of travel) a second powered vehicle of the vehicle system. All powered vehicles of the system may be operated according a predetermined and/or operator specified control plan in the absence of a detection of potentially damaged track. As the vehicle system traverses the route, an examining system onboard the first vehicle may detect a potentially damaged section of the track using an injected examination signal. Responsive to the initial detection of the potential damage, control of the second vehicle may be altered when the second vehicle passes over the potentially damaged section (as determined, for example, using a geographic identification of the section and/or computing a time based on the speed of the vehicle system and a distance between the first and second powered vehicles) in order to eliminate, reduce, or otherwise alter noise that may be detected by an examining system disposed onboard the second powered vehicle.

For example, the second vehicle may momentarily discontinue propulsion or dynamic braking while passing over the potentially damaged section of track to reduce or eliminate interference with an injected examination signal being detected by the second vehicle. In some embodiments, propulsion (or dynamic braking) may be discontinued for all axles of the second vehicle, while in other embodiments, propulsion (or dynamic braking) may be discontinued only for axles adjacent to or near a test loop. Because the discontinuances of propulsion may be limited to a short period of time (e.g., a time range include the time when the detection unit of the second vehicle passes over the potentially damaged section), the discontinuances may have a minimal or small impact on operation of the vehicle system. Thus, in some embodiments, a first technique for identifying a potentially damaged section of a route may involve examination of a first injected test signal for a first vehicle, and a second technique for verifying the initial identification may involve examination of a second injected test signal for a second vehicle, with the control of the second vehicle altered from a predetermined control scheme to minimize interference with the second injected test signal.

It should be noted that the embodiments of secondary detection techniques (e.g., techniques to confirm an identification of a potentially damaged section of a route and/or to exclude an identification of a potentially damaged section as a false alarm) described herein are meant by way of example and not limitation. Additional or alternative secondary techniques, such as x-ray or acoustic readings of a rail may be employed in various embodiments.

As one more example, the secondary detection device 670 may be configured as a coil configured to receive electrical signals transmitted through the route 108, such as the examination signal. For example, in various embodiments, the detection device detection device 630 may be configured as a coil, and the secondary detection device 670 may be configured as a supplemental coil oriented in a different direction than the detection device 630 and configured, for example, to detect current diverted by shorts on the route 108 to help exclude false alarms indicated by the identification unit 620 (or confirm damage to section of the track indicated as potentially damaged by the identification unit 620). In some embodiments, the detection unit 618 includes a first receive coil oriented in a first direction toward a rail of the route 108 and the secondary detection unit 670 includes a secondary receive coil disposed at about 90 degrees to the first direction toward the rail of the route 108.

Figure 7 illustrates a detection system 700 that includes coils oriented in different directions toward a rail in accordance with an embodiment. The detection system 700 includes a first detector 710 oriented toward a rail 702 in a first direction 712, and maintained at a distance 714. In the illustrated embodiment, the first detector 710 is configured as a coil that may be spaced from the rail 702 at a distance because the first detector 710 is configured to inductively receive signals from the rail 702. For example, in the illustrated embodiment, the distance 714 is about six inches. The first detector 710 is oriented toward the rail in a first direction 712 that is substantially vertical (e.g., substantially perpendicular to the horizon). The detection system 700 includes a second detector 720 oriented toward the rail 702 in a second direction 722 at a distance 724. The second detector 720 may be configured as a coil configured to inductively receive signals from the rail 702, and the distance 724 may be about six inches. In various embodiments, the distance 724 (and/or the distance 714) may have a different value. In the illustrated embodiment, the second direction 722 is substantially horizontal (e.g. substantially parallel to the horizon) or about 90 degrees from the direction 712. The second detector 720 may be configured to detect parasitic eddy currents and/or to provide additional information regarding the signature of the examination signal as the examination signal is transmitted through the rail 702. In the illustrated embodiment, the first detector 710 and the second detector 720 are depicted as mounted to a frame or body 704 of a vehicle supported over the rail 702 by a wheel (not shown for clarity). In various embodiments, additional or alternate first and/or second detectors may be positioned at alternate locations of a vehicle (e.g., at or near one or more additional wheels). For example, a pair of first and second detectors oriented at different angles to the track 702 may be positioned near each wheel of a vehicle. The illustrated arrangement is intended by way of example, and not exclusion, as other arrangements may be utilized in different embodiments. For example, the directions at which one or both of the first and second detectors are oriented may be varied from the directions shown in alternate embodiments.

Figure 8 illustrates a flowchart of a method 800 for examining a route being traveled by a vehicle system in accordance with one embodiment. The method 800 may be performed, for example, using certain components, equipment, structures, or other aspects of embodiments discussed above. In certain embodiments, certain steps may be added or omitted, certain steps may be performed simultaneously or concurrently with other steps, certain steps may be performed in different order, and certain steps may be performed more than once, for example, in an iterative fashion. In various embodiments, portions, aspects, and/or variations of the method 800 may be able to be used as one or more algorithms to direct hardware to perform operations described herein. The method 800 may be used in conjunction with one or more embodiments of the vehicle systems and/or examining systems described herein. Alternatively, the method 800 may be implemented with another system.

At 802, an examination signal is injected into the route being traveled by the vehicle system at a first vehicle. For example, a direct current, alternating current, RF signal, or another signal may be conductively and/or inductively injected into a conductive portion of the route 108, such as a track of the route 108.

At 804, one or more electrical characteristics of the route are monitored. In some embodiments, the electrical characteristics are monitored at the same vehicle from which the examination signal is injected into the route, while in other embodiments the electrical characteristics may be monitored at a different vehicle of the vehicle system, for example a vehicle trailing the vehicle from which the examination signal is injected into the route along a direction of travel of the vehicle system. For example, the route 108 may be monitored to determine if any voltage or current is being conducted by the route 108.

At 806, a determination is made as to whether the one or more monitored electrical characteristics indicate receipt of the examination signal. For example, if a direct current, alternating current, or RF signal is detected in the route (e.g., route 108), then the detected current or signal may indicate that the examination signal is conducted through the route from the first vehicle to the second vehicle in the same vehicle system. As a result, the route may be substantially intact between the first and second vehicles. Optionally, the examination signal may be conducted through the route between components joined to the same vehicle. As a result, the route may be substantially intact between the components of the same vehicle. If there is an indicated receipt of the examination signal, the method 800 may proceed to 808. On the other hand, if no direct current, alternating current, or RF signal is detected in the route, then the absence of the current or signal may indicate that the examination signal is not conducted through the route from the first vehicle to the second vehicle in the same vehicle system or between components of the same vehicle. As a result, the route 108 may be broken between the first and second vehicles, or between the components of the same vehicle. The method 800 may then proceed to 812.

At 808, a determination is made as to whether a change in the one or more monitored electrical characteristics indicates potential damage to the route. For example, a change in the examination signal between when the signal was injected into the route and when the examination signal is detected may be determined. This change may reflect a decrease in voltage, a decrease in amps, a change in frequency and/or phase, a decrease in a signal-to-noise ratio, or the like. The change can indicate that the examination signal was conducted through the route, but that damage to the route may have altered the signal. For example, if the change in voltage, amps, frequency, phase, signal-to-noise ratio, or the like, of the injected examination signal to the detected examination signal exceeds a designated threshold amount (or if the monitored characteristic decreased below a designated threshold), then the change may indicate damage to the route, but not a complete break in the route. As a result, the method 800 may proceed to 812 if the change in one or more electrical characteristics indicates a potentially damaged section of the route.

On the other hand, if the change in voltage, amps, frequency, phase, signal-to-noise ratio, or the like, of the injected examination signal to the detected examination signal does not exceed the designated threshold amount (and/or if the monitored characteristic does not decrease below a designated threshold), then the change may not indicate damage to the route 108. As a result, the method 800 may proceed to 810.

At 810, if the section of the route that is between the first and second vehicles in the vehicle system or between the components of the same vehicle is not identified as potentially damaged, the vehicle system may continue to travel along the route. Additionally examination signals may be injected into the route at other locations as the vehicle system moves along the route.

At 812, the section of the route that is or was disposed between the first and second vehicles, or between the components of the same vehicle, is identified as a potentially damaged section of the route. For example, due to the failure of the examination signal to be detected and/or the change in the examination signal that is detected, the route may be broken and/or damaged between the first vehicle and the second vehicle, or between the components of the same vehicle. The section of the route 812 may be identified, for example, by timing information corresponding to a time that a signal corresponding to the potentially damaged section was detected and/or geographic information (e.g., GIS information) corresponding to a location of the potentially damaged section.

At 814, secondary information is obtained. The secondary information may be obtained to one or more of verify if the potentially damaged section is actually damaged, to identify a type of damage, or to assess a level or amount of damage. The secondary information may be obtained from one or more of a database (e.g., a database including information corresponding to geographic locations along the route), from the examination signal, or from one or more secondary detection units and/or devices. For example, the secondary information may include information regarding or corresponding to a signature of the examination signal. The secondary information may include a geographic location for the section of the route indicated as potentially damaged, as well as tabulated information describing geographic locations of known features of the route that may trigger potential damage indications based on the examination signal (e.g., unbonded rail joints, insulated joints, switch frogs). The secondary information may include information from a secondary detection device, such as a video camera, accelerometer, secondary coil (e.g., a coil directed at about 90 degrees from a primary coil), or the like.

At 816, it is determined if the secondary information indicates damage. The determination may be made using one or more types of secondary information obtained at 814. For example, if the location of the potentially damaged section of the track does not match a known location of a route feature such as an insulated joint or switch frog, damage may be indicated. As another example, if video information obtained and/or analyzed responsive to an initial determination of potential damage shows no damage (or a negligible amount of damage). As just one more example, if the signature of the examination signal is similar to or corresponds to a damage mode (e.g., a signature for a transverse break), then damage may be indicated, while if the signature is similar to or corresponds to a non-damage mode (e.g., insulated joint), then no damage may be indicated. If no damage is indicated, the method 800 may proceed to 810 and continue travel along the route; however, if damage is indicated based on the secondary information obtained at 814, the method 800 proceeds to 818. It may be noted that one or both of the obtaining secondary information and determining if the secondary information indicates damage may be performed autonomously without operator intervention, for example, onboard a vehicle, responsive to the determination at 812 that a section of the route is potentially damaged.

At 818, the damage determined to be present at 816 is assessed. For example, a type of damage (e.g., transverse fissure, detail fracture, base break etc.) may be determined. Additionally or alternatively, the extent, level, or amount of damage may be determined. For example, it may be determined, using video information and/or signature information, if a crack extends all the way through, or partially through a rail. Further, it may be determined how far a crack or fissure penetrates a rail (e.g. 10%, 25%, 50%, or the like). It may be noted that, in various embodiments, one or more types of secondary information may be used to determine if damage indicated, and one or more additional or different types of secondary information may be used to determine the type and/or extent of the damage. It may further be noted that, in various embodiments, the presence of damage and type or extent of damage may be determined substantially simultaneously (e.g., video information may be analyzed to determine the presence and extent of damage).

At 820, one or more responsive actions may be initiated in response to identifying the damaged section (and/or extent of damage) of the route. As described above, these actions may include, but are not limited to, automatically and/or manually slowing or stopping movement of the vehicle system, warning other vehicle systems about the potentially damaged section of the route, notifying wayside devices of the potentially damaged section of the route, requesting inspection and/or repair of the potentially damaged section of the route, and the like. The particular responsive action may be determined based on the amount or type of damage. By utilizing secondary information to confirm whether or not damage is present, various embodiments help avoid or reduce unnecessary mitigating actions for false alarms. Further, by providing additional detail regarding level or amount of damage, various embodiments improve selection of an appropriate mitigating action or actions.

In an embodiment, a system (e.g., a route examination system) includes an application device, a control unit, a detection unit, an identification unit, and a secondary analysis module. The application device is configured to be disposed onboard a first vehicle of a first vehicle system traveling along a route and to be at least one of conductively or inductively coupled with the route during travel along the route. The control unit is configured to control supply of electric current from a power source to the application device in order to electrically inject an examination signal into the route via the application device. The detection unit is configured to monitor one or more electrical characteristics of the route in response to the examination signal being injected into the route. The identification unit is configured to examine the one or more electrical characteristics of the route in order to determine whether a section of the route extending between the application device and the detection unit is potentially damaged based on the one or more electrical characteristics. The secondary analysis module is configured to, responsive to an identification of a potentially damaged section of the route by the identification unit, perform a secondary analysis of the potentially damaged section of the route to at least one of confirm that damage has occurred to the potentially damaged section of the route, identify a type of damage that has occurred to the potentially damaged section of the route, or assess a level of damage to the potentially damaged section of the route.

In another aspect, the secondary analysis module is configured to analyze a signature of the one or more electrical characteristics and to perform the secondary analysis using the signature.

In another aspect, the second analysis module includes a secondary detection unit configured to obtain secondary data regarding the potentially damaged section of the track. For example, the detection unit may be configured to be disposed on-board the first vehicle, and the secondary detection unit may be configured to be disposed on-board a second vehicle of the first vehicle system.

In another aspect, the secondary detection unit comprises a video camera. The video camera may be configured to be disposed on-board the first vehicle, and the secondary data may be obtained using timing information corresponding to a time when the first vehicle passed over the potentially damaged section of the route.

In another aspect, the secondary detection unit may include an accelerometer.

In another aspect, the detection unit includes a first receive coil oriented in a first direction toward a rail of the route and the secondary detection unit comprises a secondary receive coil disposed at about 90 degrees to the first direction toward the rail of the route.

In an embodiment, a method (e.g., for examining a route being traveled by a vehicle system) includes electrically injecting an examination signal into a route being traveled by a first vehicle system having at least a first vehicle, with the examination signal being injected into the route using the first vehicle of the first vehicle system. The method also includes monitoring one or more electrical characteristics of the route responsive to the examination signal. Also, the method includes identifying, with an identification unit, a potentially damaged section of the route based on the one or more electrical characteristics. The method also includes performing, with a secondary analysis module, responsive to an identification of the potentially damaged section of the route by the identification unit, a secondary analysis of the potentially damaged section of the route to at least one of confirm that damage has occurred to the potentially damaged section of the route, identify a type of damage that has occurred to the potentially damaged section of the route, or assess a level of damage to the potentially damaged section of the route.

In another aspect, the one or more electrical characteristics of the route are detected using a detection unit disposed onboard the first vehicle, and secondary information utilized by the secondary analysis module is detected using a secondary detection unit. In another aspect, the secondary detection unit may be disposed onboard a second vehicle of the vehicle system.

In another aspect, the secondary detection unit is activated responsive to the identification of a potentially damaged section of the route by the identification unit.

In another aspect, the secondary information is obtained using timing information corresponding to a time when the first vehicle passed over the potentially damaged section of the route.

In an embodiment, a tangible and non-transitory computer readable medium is provided that includes one or more computer software modules configured to direct one or more processors to control injection of an examination signal into a route being traveled by a first vehicle system having at least a first vehicle, with the examination signal being injected into the route using the first vehicle of the first vehicle system. The one or more computer software modules are also configured to direct the one or more processors to monitor one or more electrical characteristics of the route responsive to the examination signal. Also, the one or more computer software modules are configured to direct the one or more processors to identify a potentially damaged section of the route based on the one or more electrical characteristics. The one or more computer software modules are further configured to direct the one or more processors to perform, responsive to an identification of the potentially damaged section of the route by the identification unit, a secondary analysis of the potentially damaged section of the route to at least one of confirm that damage has occurred to the potentially damaged section of the route, identify a type of damage that has occurred to the potentially damaged section of the route, or assess a level of damage to the potentially damaged section of the route.

In another aspect, the computer readable medium is further configured to direct the one or more processors to detect the one or more electrical characteristics of the route using a detection unit disposed onboard the first vehicle, and to detect secondary information for use with the secondary analysis using a secondary detection unit.

In another aspect, the secondary detection unit is disposed onboard a second vehicle of the vehicle system.

In another aspect, the computer readable medium is further configured to direct the one or more processors to activate the secondary detection unit responsive to the identification of a potentially damaged section of the route by the identification unit.

In another aspect, the computer readable medium is further configured to direct the one or more processors to obtain the secondary information using timing information corresponding to a time when the first vehicle passed over the potentially damaged section of the route.

In another aspect, the computer readable medium is further configured to direct the one or more processors to perform the secondary analysis using a signature of the one or more electrical characteristics.

Various components and modules described herein may be implemented as part of one or more computers, computing systems, or processors. The computer, computing system, or processor may include a microprocessor. The microprocessor may be connected to a communication bus. The computer or processor may also include a memory. The memory may include Random Access Memory (RAM) and Read Only Memory (ROM). The computer or processor further may include a storage system or device, which may be a hard disk drive or a removable storage drive such as a floppy or other removable disk drive, optical disk drive, and the like. The storage system may also be other similar means for loading computer programs or other instructions into the computer or processor. The instructions may be stored on a tangible and/or non-transitory computer readable storage medium coupled to one or more servers.

As used herein, the term "computer" or "computing system" may include any processor-based or microprocessor-based system including systems using microcontrollers, reduced instruction set computers (RISC), application specific integrated circuits (ASICs), logic circuits, and any other circuit or processor capable of executing the functions described herein. The above examples are exemplary only, and are thus not intended to limit in any way the definition and/or meaning of the term “computer” or “computing system.”

The set of instructions may include various commands that instruct the computer or processor as a processing machine to perform specific operations such as the methods and processes described herein. The set of instructions may be in the form of a software program. The software may be in various forms such as system software or application software. Further, the software may be in the form of a collection of separate programs, a program module within a larger program or a portion of a program module. The software also may include modular programming in the form of object-oriented programming. The processing of input data by the processing machine may be in response to user commands, or in response to results of previous processing, or in response to a request made by another processing machine.

[0002] As used herein, the terms “software” and “firmware” are interchangeable, and include any computer program stored in memory for execution by a computer, including RAM memory, ROM memory, EPROM memory, EEPROM memory, and non-volatile RAM (NVRAM) memory. The above memory types are exemplary only, and are thus not limiting as to the types of memory usable for storage of a computer program.

[0003] It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the inventive subject matter without departing from its scope. While the dimensions and types of materials described herein are intended to define the parameters of the inventive subject matter, they are by no means limiting and are exemplary embodiments. Many other embodiments will be apparent to one of ordinary skill in the art upon reviewing the above description. The scope of the inventive subject matter should, therefore, be determined with reference to the appended clauses, along with the full scope of equivalents to which such clauses are entitled. In the appended clauses, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Moreover, in the following clauses, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following clauses are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. § 112, sixth paragraph, unless and until such clause limitations expressly use the phrase "means for" followed by a statement of function void of further structure.

[0004] This written description uses examples to disclose several embodiments of the inventive subject matter and also to enable a person of ordinary skill in the art to practice the embodiments of the inventive subject matter, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the inventive subject matter may include other examples that occur to those of ordinary skill in the art. Such other examples are intended to be within the scope of the clauses if they have structural elements that do not differ from the literal language of the clauses, or if they include equivalent structural elements with insubstantial differences from the literal languages of the clauses.

[0005] The foregoing description of certain embodiments of the inventive subject matter will be better understood when read in conjunction with the appended drawings. To the extent that the figures illustrate diagrams of the functional blocks of various embodiments, the functional blocks are not necessarily indicative of the division between hardware circuitry. Thus, for example, one or more of the functional blocks (for example, processors or memories) may be implemented in a single piece of hardware (for example, a general purpose signal processor, microcontroller, random access memory, hard disk, and the like). Similarly, the programs may be stand-alone programs, may be incorporated as subroutines in an operating system, may be functions in an installed software package, and the like. The various embodiments are not limited to the arrangements and instrumentality shown in the drawings.

[0006] As used herein, an element or step recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural of said elements or steps, unless such exclusion is explicitly stated. Furthermore, references to "an embodiment" or "one embodiment" of the inventive subject matter are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Moreover, unless explicitly stated to the contrary, embodiments "comprising," "including," or "having" an element or a plurality of elements having a particular property may include additional such elements not having that property.

[0007] Since certain changes may be made in the above-described systems and methods without departing from the spirit and scope of the inventive subject matter herein involved, it is intended that all of the subject matter of the above description or shown in the accompanying drawings shall be interpreted merely as examples illustrating the inventive concept herein and shall not be construed as limiting the inventive subject matter.

2013299501 14 Feb 2017

The claims defining the invention are as follows:

1. A system comprising:

one or more conductive bodies configured to be disposed onboard a first vehicle system traveling along a route and to be at least one of conductively or inductively coupled with the route during travel along the route;

one or more processors configured to control supply of electric current from a power source to the one or more conductive bodies in order to electrically inject an examination signal into the route via the one or more conductive bodies,

wherein the one or more conductive bodies also are configured to sense one or more electrical characteristics of the route in response to the examination signal being injected into the route, and

wherein the one or more processors are configured to examine the one or more electrical characteristics of the route in order to determine whether a section of the route is potentially damaged based on the one or more electrical characteristics, the one or more processors also configured to compare a location of the section of the route that is determined as being potentially damaged with one or more locations of one or more known anomalies along the route in order to determine that the section of the route is damaged, and

wherein the one or more processors are configured to, responsive to determining that the section of the route is damaged by the one or more processors, perform a secondary analysis of the potentially damaged section of the route to at least one of confirm that damage has occurred to the potentially damaged section of the route, identify a type of damage that has occurred to the potentially damaged section of the route, or assess a level of damage to the potentially damaged section of the route.

2. The system of claim 1, wherein the one or more processors are configured to analyze a signature of the one or more electrical characteristics and to perform the secondary analysis using the signature.

3. The system of claim 1 or 2, wherein the one or more conductive bodies include one or more first conductive bodies configured to sense the one or more electrical characteristics and one or more second conductive bodies configured to obtain secondary data regarding the potentially damaged section of the route.

4. The system of claim 3, wherein the one or more first conductive bodies are configured to be disposed on-board a first vehicle of the first vehicle system, and the one or more second conductive bodies are configured to be disposed on-board a second vehicle of the first vehicle system.

5. The system of any one of claims 1 to 4, further comprising a video camera configured to obtain secondary data regarding the potentially damaged section of the route.

6. The system of claim 5, wherein the video camera and the one or more conductive bodies are configured to be disposed on-board a first vehicle of the vehicle system that also includes at least a second vehicle, and the secondary data is obtained using timing information corresponding to a time when the first vehicle passed over the potentially damaged section of the route.

7. The system of any one of claims 1 to 6, further comprising an accelerometer configured to obtain secondary data regarding the potentially damaged section of the route.

8. The system of any one of claims 1 to 7, wherein the one or more conductive bodies include a first receive coil oriented in a first direction toward a rail of the route, and further comprising a secondary receive coil disposed at 90 degrees to the first direction toward the rail of the route.

9. The system of any one of claims 1 to 8, wherein the one or more known anomalies include one or more unbonded rails, insulated joints, or switches in the route identified prior to a current trip of the first vehicle system along the route.

10. A method comprising:

electrically injecting an examination signal into a route being traveled by a first vehicle system having at least a first vehicle, the examination signal being injected into the route using the first vehicle of the first vehicle system;

monitoring one or more electrical characteristics of the route responsive to the examination signal;

identifying, with one or more processors, a potentially damaged section of the route based on the one or more electrical characteristics; and performing, with the one or more processors and responsive to an identification of the potentially damaged section of the route by the one or more processors, a secondary analysis of the potentially damaged section of the route to at least one of confirm that damage has occurred to the potentially damaged section of the route, identify a type of damage that has occurred to the potentially damaged section of the route, or assess a level of damage to the potentially damaged section of the route,

wherein the secondary analysis includes comparing a location of the potentially damaged section of the route with one or more locations of one or more known anomalies along the route in order to determine that the section of the route is damaged.

11. The method of claim 10, wherein the monitoring the one or more electrical characteristics of the route comprises detecting the examination signal using the one or more processors disposed onboard the first vehicle, and further comprising detecting secondary information related to the route using the one or more processors.

12. The method of claim 11, wherein the secondary information is obtained onboard a second vehicle of the vehicle system.

13. The method of claim 11 or 12, further comprising obtaining the secondary information responsive to the identification of the potentially damaged section of the route by the one or more processors.

14. The method of any one of claims 11 to 13, wherein the secondary information is obtained using timing information corresponding to a time when the first vehicle passed over the potentially damaged section of the route.

15. The method of any one of claims 10 to 14, wherein the performing the secondary analysis comprises analyzing a signature of the one or more electrical characteristics.

16. The method of any one of claims 10 to 15, wherein the one or more known anomalies include one or more unbonded rails, insulated joints, or switches in the route identified prior to a current trip of the first vehicle system along the route.

17. A tangible and non-transitory computer readable medium configured to direct one or more processors to:

control injection of an examination signal into a route being traveled by a first vehicle system having at least a first vehicle, the examination signal being injected into the route using the first vehicle of the first vehicle system;

monitor one or more electrical characteristics of the route responsive to the examination signal;

identify a potentially damaged section of the route based on the one or more electrical characteristics; and

perform, responsive to an identification of the potentially damaged section of the route by the identification unit, a secondary analysis of the potentially damaged section of the route to at least one of confirm that damage has occurred to the potentially damaged section of the route, identify a type of damage that has occurred to the potentially damaged section of the route, or assess a level of damage to the potentially damaged section of the route,

wherein the secondary analysis includes comparing a location of the potentially damaged section of the, route with one or more locations of one or more known anomalies along the route in order to determine that the section of the route is damaged.

18. The computer readable medium of claim 17, wherein the computer readable medium is further configured to direct the one or more processors to detect the one or more electrical characteristics of the route using a detection unit disposed onboard the first vehicle, and to detect secondary information for use with the secondary analysis.

19. The computer readable medium of claim 18, wherein the secondary information is obtained onboard a second vehicle of the vehicle system.

20. The computer readable medium of claim 18 or 19, wherein the computer readable medium is further configured to direct the one or more processors to obtain the secondary information responsive to the identification of a potentially damaged section of the route by the one or more processors.

21. The computer readable medium of any one of claims 18 to 20, wherein the computer readable medium is further configured to direct the one or more processors

to obtain the secondary information using timing information corresponding to a time when the first vehicle passed over the potentially damaged section of the route.

22. The computer readable medium of any one of claims 17 to 21, wherein the computer readable medium is further configured to direct the one or more processors to perform the secondary analysis using a signature of the one or more electrical characteristics.

23. The computer readable medium of any one of claims 17 to 22, wherein the one or more known anomalies include one or more unbonded rails, insulated joints, or switches in the route identified prior to a current trip of the first vehicle system along the route.

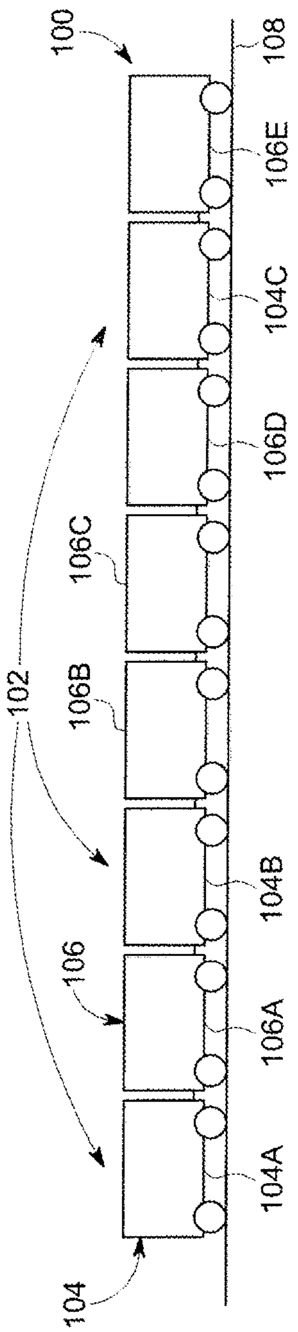

100
108
106E
104C
106D
106C
102
106B
104B
106
106A
104A
104

FIG. 1

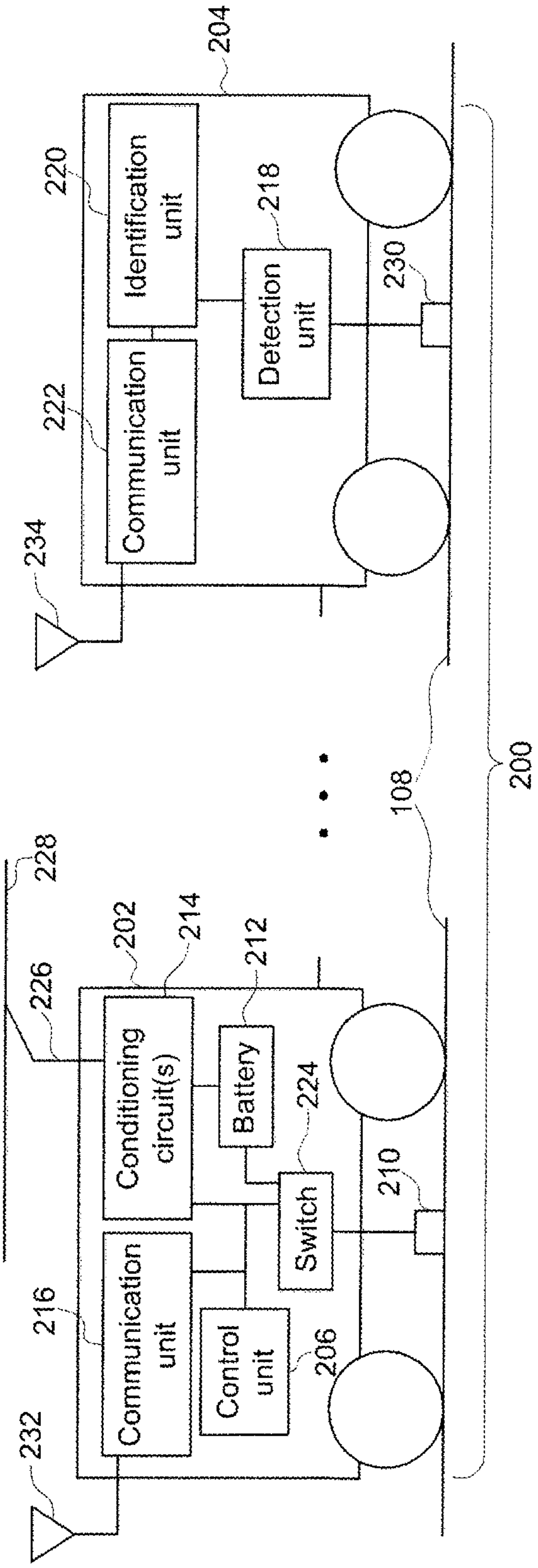

204
220
Identification unit
218
Detection unit
230
222
Communication unit
234
108
200
228
202
214
212
Conditioning circuit(s)
Battery
226
224
Switch
210
216
Communication unit
Control unit
206
232

FIG. 2

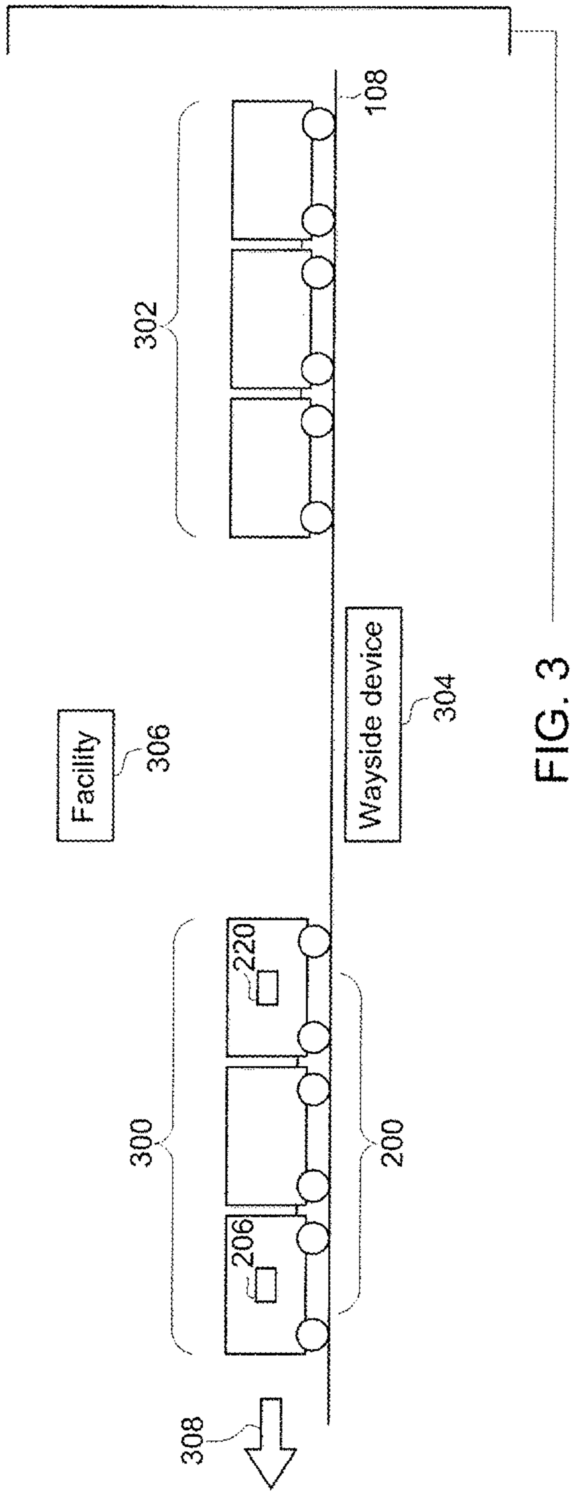


FIG. 3

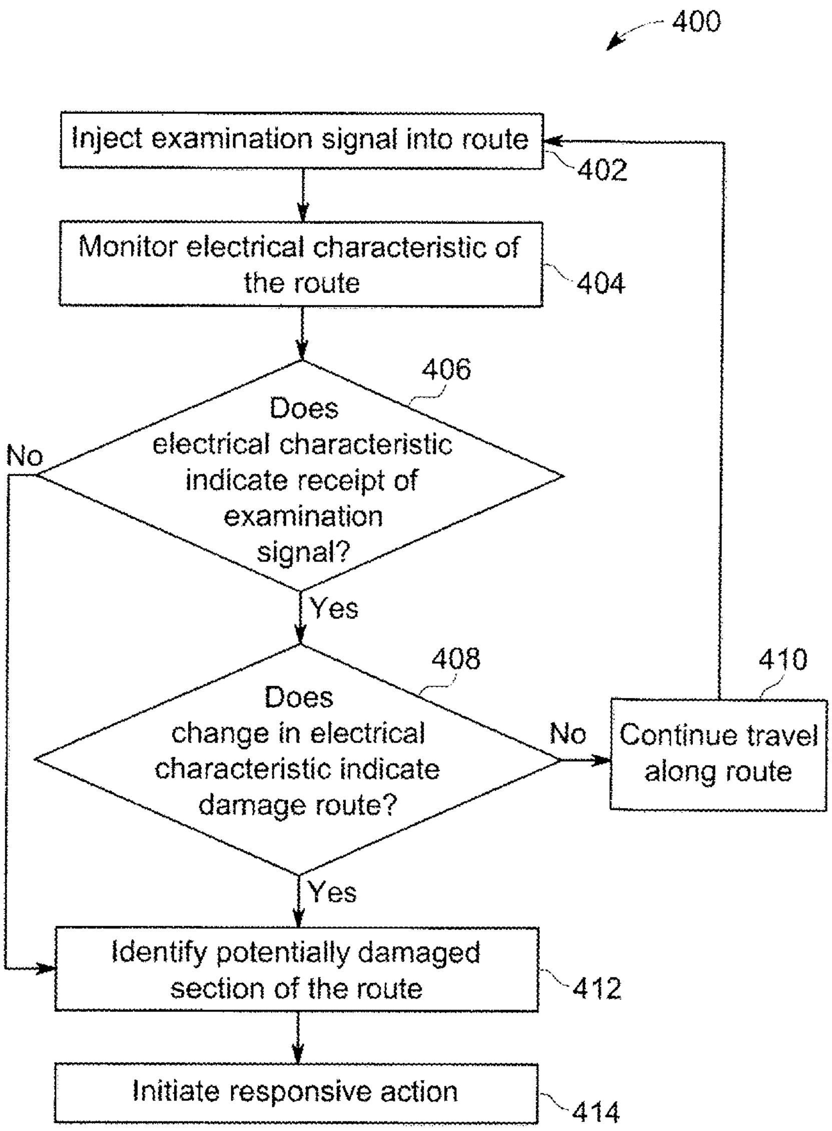

400
Inject examination signal into route
402
Monitor electrical characteristic of the route
404
406
Does electrical characteristic indicate receipt of examination signal?
No
Yes
408
Does change in electrical characteristic indicate damage route?
No
410
Continue travel along route
Yes
Identify potentially damaged section of the route
412
Initiate responsive action
414

FIG. 4

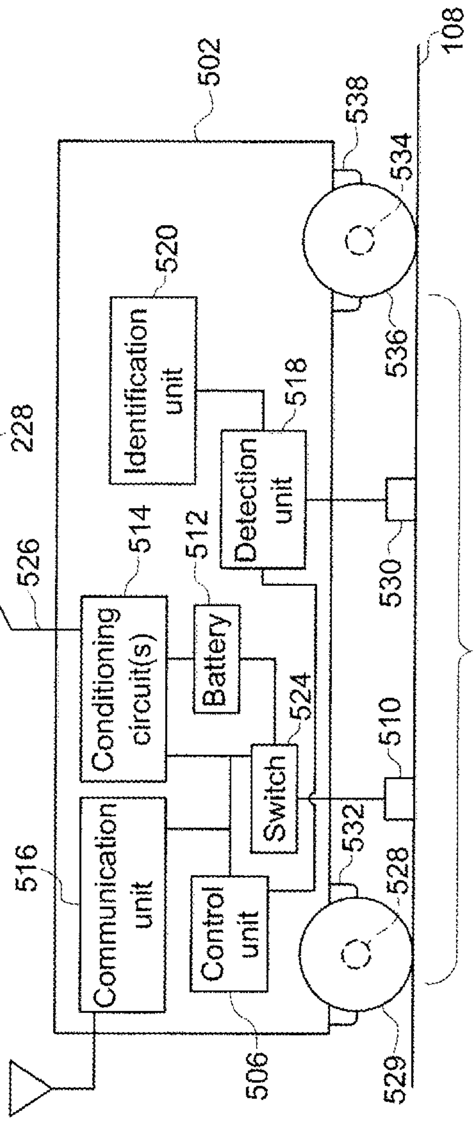
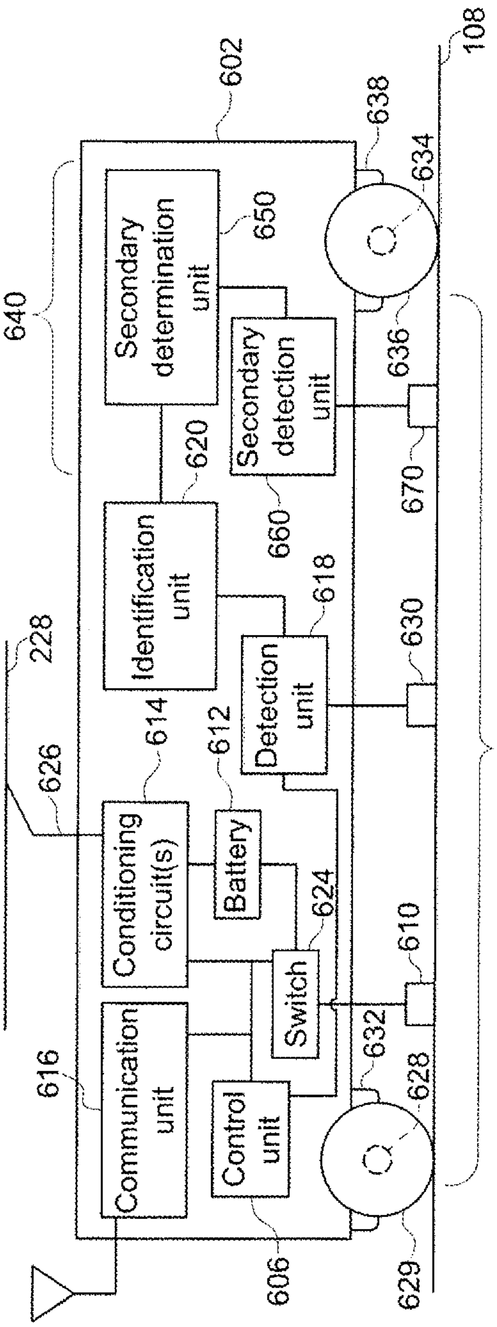

502
108
538
534
520
Identification unit
518
Detection unit
228
526
514
Conditioning circuit(s)
512
Battery
524
Switch
516
Communication unit
Control unit
506
532
528
529
510
530
536
500

FIG. 5


Secondary determination unit
Secondary detection unit
Identification unit
Detection unit
Conditioning circuit(s)
Battery
Switch
Communication unit
Control unit
602
108
638
634
650
640
636
670
620
660
618
630
228
626
614
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628
606
629

FIG. 6

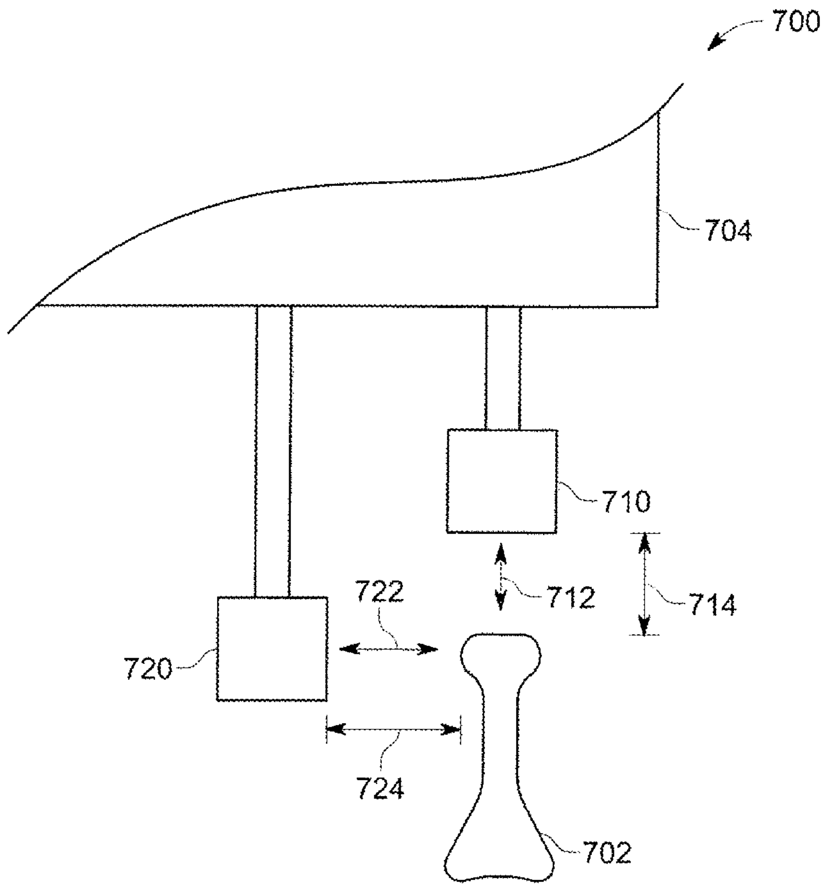

FIG. 7

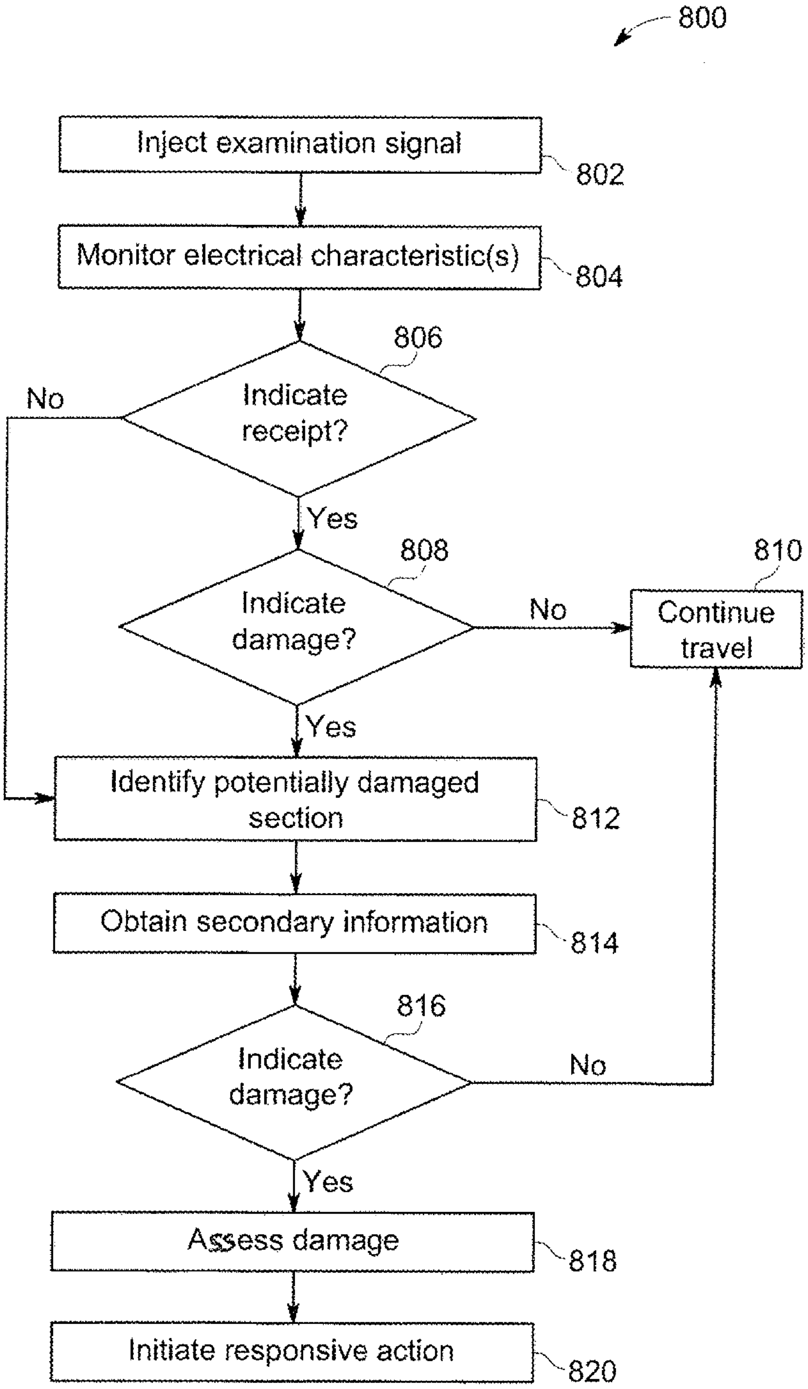
800
Inject examination signal
802
Monitor electrical characteristic(s)
804
806
Indicate receipt?
No
Yes
808
Indicate damage?
No
810
Continue travel
Yes
Identify potentially damaged section
812
Obtain secondary information
814
816
Indicate damage?
No
Yes
Assess damage
818
Initiate responsive action
820

FIG. 8