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(54) **ULTRA-WIDEBAND WORK TRAIN PROTECTION**

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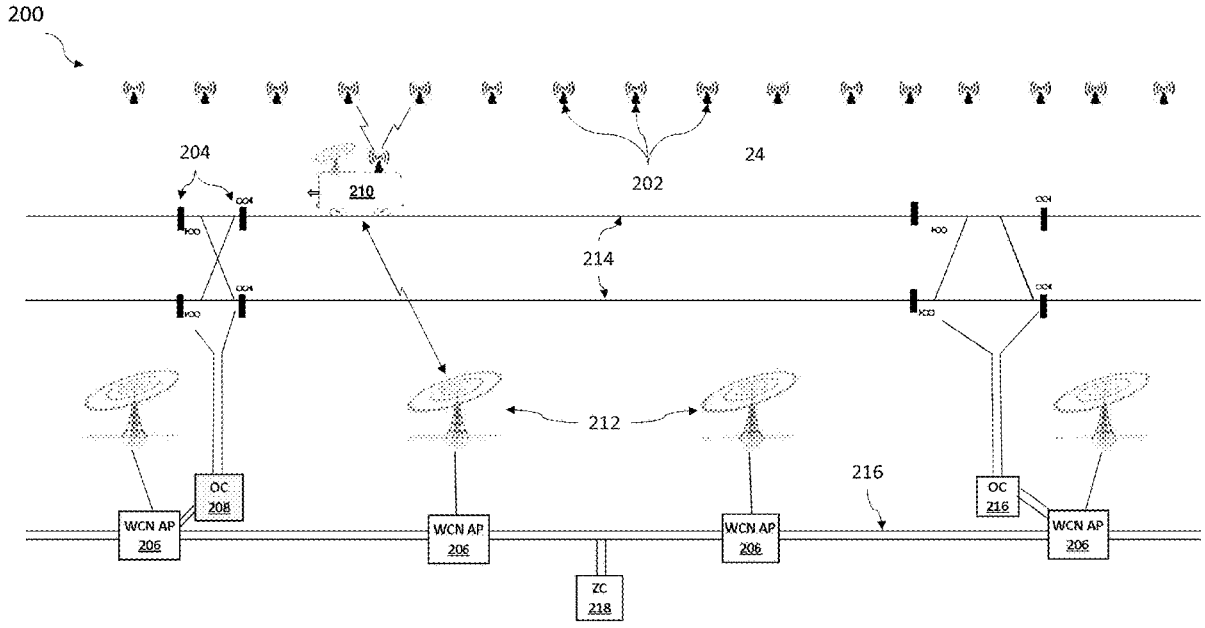
(57) **ABSTRACT**

Systems for protecting a work train using an ultra-wideband (UWB) ranging system are disclosed. Aspects include a plurality of UWB wayside beacons disposed along a track, each of the plurality of UWB beacons configured to broadcast a unique beacon identification number. Aspects also include an onboard UWB control system disposed on a work train, the onboard UWB control system having a processing system in communication with radio-frequency communication device and an onboard UWB beacon. The onboard UWB beacon is configured to receive the unique beacon identification number from at least one of the plurality of UWB wayside beacons. The processing system is configured to determine a position of the work train on the track based upon known locations of the plurality of UWB wayside beacons, to transmit this position to a wayside Zone Controller, and to enforce a movement authority limit provided by the wayside zone controller.



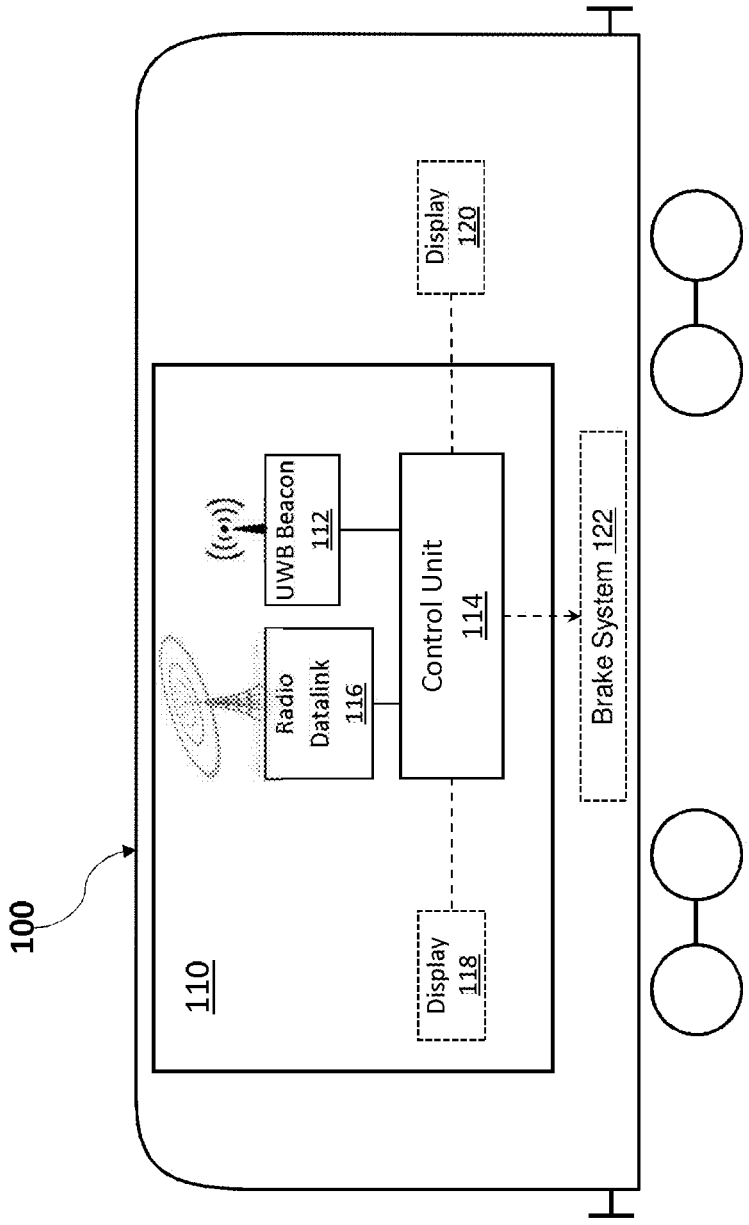

100
110
Display 120
UWB Beacon 112
Radio Datalink 116
Control Unit 114
Brake System 122
Display 118

FIG. 1

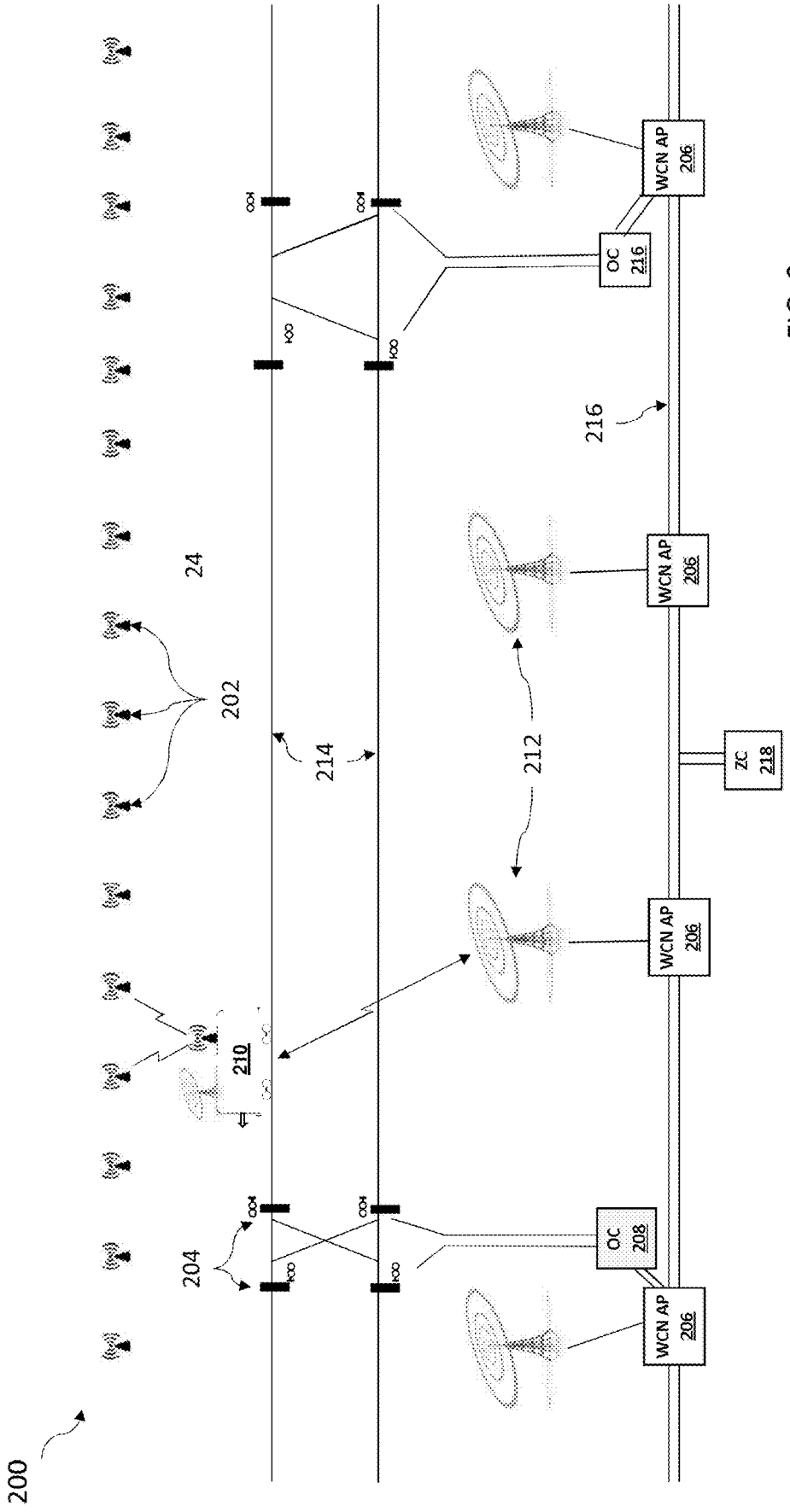

200
24
202
204
210
212
214
216
WCN AP 206
WCN AP 206
WCN AP 206
WCN AP 206
OC 216
OC 208
ZC 218

FIG. 2

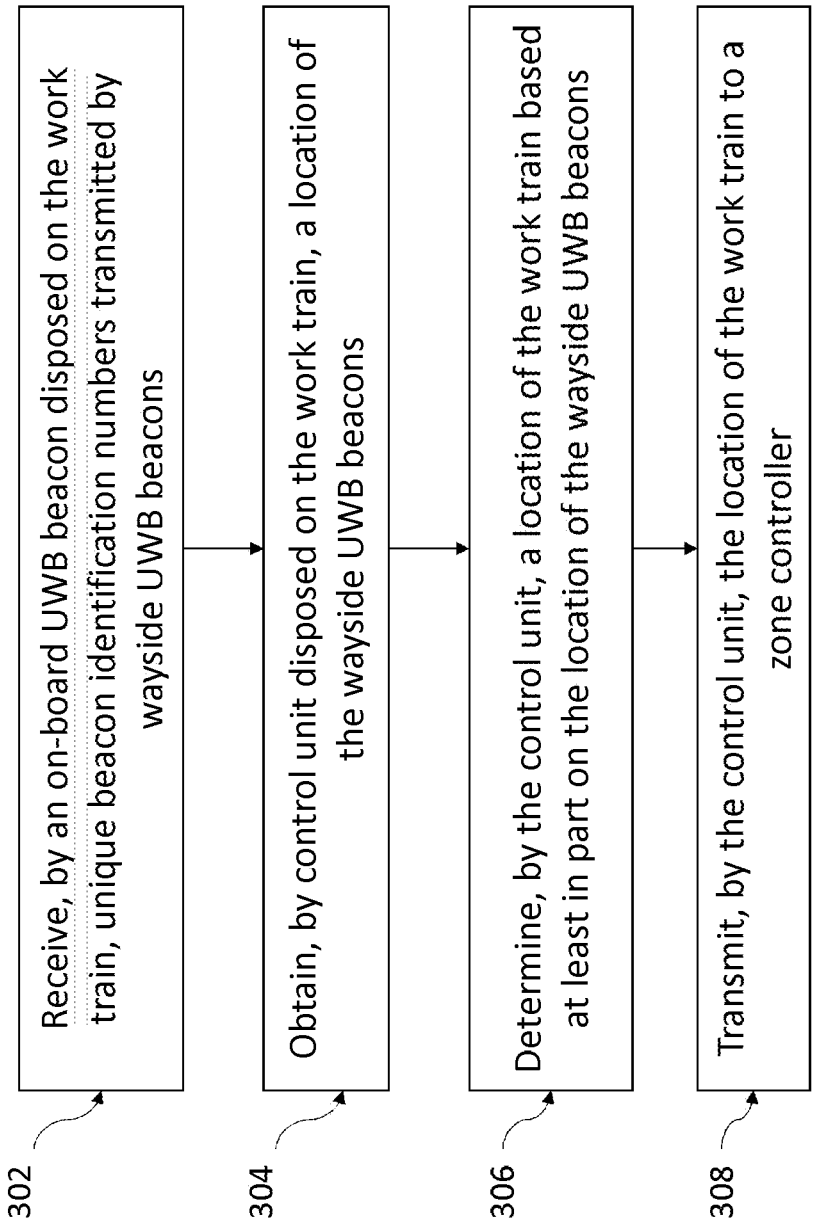

Receive, by an on-board UWB beacon disposed on the work train, unique beacon identification numbers transmitted by wayside UWB beacons
Obtain, by control unit disposed on the work train, a location of the wayside UWB beacons
Determine, by the control unit, a location of the work train based at least in part on the location of the wayside UWB beacons
Transmit, by the control unit, the location of the work train to a zone controller
302
304
306
308

FIG. 3

ULTRA-WIDEBAND WORK TRAIN PROTECTION

BACKGROUND

[0001] The present invention generally relates to work train protection systems, and more specifically, to an ultra-wideband (UWB) based work train protection system.

[0002] A work train is a is train having one or more train cars that are configured for non-revenue use by the railroad's operator. For example, work trains are often configured to provide track maintenance, maintenance of way, system cleanup, hauling, and the like. Equipping work trains with a fully functional onboard train control system such as communication-based train control (CBTC) is very expensive. In addition, installing under-car components such as transponder/tag reader, wheel speed sensor, doppler radar, etc. is not practical and often not mechanically possible. As a result, work trains are usually not equipped with any train control system. Having work trains without train control systems operating on the tracks can lead to safety issues and can negatively impact the operations on a track where most of the conventional signaling devices (e.g. signals or trip stops) have been eliminated.

SUMMARY

[0003] Embodiments of the present invention are directed by a system for protecting work trains using an ultra-wideband ranging system. The system includes a plurality of ultra-wideband (UWB) wayside beacons disposed along a track, each of the plurality of UWB beacons configured to broadcast a unique beacon identification number. The system also includes a onboard UWB control system disposed on a work train, the onboard UWB control system having a processing system in communication with radio-frequency (RF) communication device and an onboard UWB beacon, wherein the onboard UWB beacon is configured to receive the unique beacon identification number from at least one of the plurality of UWB wayside beacons. The processing system is configured to determine a position of the work train on the track based upon known locations of the at least one of the plurality of UWB wayside beacons.

[0004] Embodiments of the present invention are directed by a method for protecting work trains using an ultra-wideband ranging system. An example of the method includes receiving, by an onboard UWB beacon disposed on the work train, unique beacon identification numbers transmitted by one or more wayside UWB beacons. The method also includes obtaining, by control unit disposed on the work train, a location of the one or more wayside UWB beacons and determining, by the control unit, a location of the work train based at least in part on the location of the one or more wayside UWB beacons. The method further includes transmitting, by the control unit, the location of the work train to a zone controller.

[0005] Embodiments of the present invention are directed by a system for protecting work trains using an ultra-wideband ranging system. The system includes a plurality of ultra-wideband (UWB) wayside beacons disposed along a track, each of the plurality of UWB beacons configured to broadcast a unique beacon identification number. The system also includes a work train disposed on the track, the work train having an onboard UWB control system. The onboard UWB control system including a control unit, a radio-frequency (RF) communication device in communication with the control unit, and an onboard UWB beacon in communication with the control unit, wherein the onboard UWB beacon is configured to receive the unique beacon identification number from one or more of the plurality of UWB wayside beacons and wherein the control unit is configured to determine a position of the work train on the track based upon known locations of the one or more UWB wayside beacons. The system also includes a zone controller configured to track a presence of the work train on the track using a vital track vacancy detection system disposed on the track.

[0006] Additional technical features and benefits are realized through the techniques of the present invention. Embodiments and aspects of the invention are described in detail herein and are considered a part of the claimed subject matter. For a better understanding, refer to the detailed description and to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The specifics of the exclusive rights described herein are particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features and advantages of the embodiments of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0008] FIG. **1** depicts a schematic diagram of a work train for use in an ultra-wideband protection system according to one or more embodiments described herein;

[0009] FIG. **2** depicts a schematic diagram of an ultra-wideband protection system for work trains according to one or more embodiments described herein; and

[0010] FIG. **3** depicts a flow diagram of a method for protecting work trains using ultra-wideband beacons according to one or more embodiments described herein.

[0011] The diagrams depicted herein are illustrative. There can be many variations to the diagrams or the operations described therein without departing from the spirit of the invention.

DETAILED DESCRIPTION

[0012] Turning now to an overview of the aspects of the invention, one or more embodiments of the invention address the above-described shortcomings of the prior art by providing an ultra-wideband (UWB) based protection system for work trains using wayside UWB beacons. In exemplary embodiments, a work train is equipped with an onboard UWB based control system that provides a valuable level of protection without the challenges of implementing standard CBTC equipment. In one embodiment, the onboard UWB control system is configured to be removably affixed to the work train and can be moved from one work train to another.

[0013] In exemplary embodiments, a plurality of wayside UWB beacons are disposed along a train track in known locations and the onboard UWB control system is configured to use UWB ranging to determine the position of the work train relative to the wayside UWB beacons. The onboard UWB control system is used to control the movement of the work-train based on information received from a zone controller, which is configured to manage the portion of the train track that the work train is located on.

[0014] In general, UWB beacons are well known in the art. Ultra-wideband (UWB) is a radio frequency communication technology that uses a very low energy level for short-range, high-bandwidth communications over a large portion of the radio spectrum, i.e., greater than five-hundred MHz. UWB is well-suited for use in real-time location systems and has been used in precision radar-imaging technology, precision locating and tracking (using distance measurements between radios—often referred to as UWB ranging), and precision time-of-arrival-based localization approaches. In exemplary embodiments, the effective range of a UWB beacon in the UWB ranging system is approximately 300-500 m.

[0015] Referring now to FIG. **1**, a work train **100** for use in an ultra-wideband protection system according to one or more embodiments is shown. As illustrated, the work train **100** includes an onboard UWB control system **110**. In exemplary embodiments, the onboard UWB control system **110** includes an onboard UWB beacon **112**, a radio datalink **116** and a display **118** in communication with a control unit **114**. The control unit **114** is a processing system and includes one or more processing units, memory, and communications interfaces. The control unit **114** is configured to utilize the onboard UWB beacon **112** to communicate with wayside UWB beacons. The memory of the control unit **114** includes a database that contains a location and identification number of all of the wayside UWB beacons. The control unit **114** is configured to determine the position of the work train **100** relative to the wayside UWB beacons using UWB ranging. In exemplary embodiments, the control unit **114** is configured to communicate with a zone controller via the radio datalink **116**. The control unit **114** controls the movement of the work-train based on information received from the zone controller, which may provide a movement authority limit, a speed limit, etc.

[0016] In one embodiment, the onboard UWB control system **110** includes a display **118** for use by the operator of the work train. In another embodiment, the onboard UWB control system **110** is configured to communicate with a display **120** that is a part of the work train **100**. The displays **118** and **120** are configured to display operational information regarding the work train **100** such as the position of the work train **100** on the track, the current speed of the work train **100**, an approved speed of the work train **100**, and the like. In one embodiment, the onboard UWB control system **110** is configured to communicate with a braking system **122** of the work train **100**.

[0017] In exemplary embodiments, the onboard UWB control system **110** can be installed permanently on a work train, or can be packaged as a piece of portable equipment, for instance in a suitcase, for more flexible use. When used as a portable solution, a worst-case default configuration (brake rate, train length, etc) can be used. This default configuration can be manually adjusted for the specific temporary application to improve performance.

[0018] Referring now to FIG. **2**, a schematic diagram of an ultra-wideband protection system **200** for work trains according to one or more embodiments is shown. As illustrated, the system **200** includes a plurality of wayside UWB **202**, disposed along a train track **214**. Each of the plurality of wayside UWB beacons **202** are located close enough from each other and from the train track **214**, such that two wayside UWB beacons **202** are nominally within communications range of an onboard UWB beacon mounted on a work train **210**.

[0019] In exemplary embodiments, the work train **210** is configured to utilize wayside radio datalink equipment **212** and wayside communication network (WCN) access points **206** to communicate with a WCN **216**. The WCN **216** includes a zone controller **218** that is configured to, among other things, track the presence and location of work trains **210** on the train track **214** within a geographical zone. The work train **210**, or other work equipment, is tracked by the zone controller **218** based on the reported position of the work train **210**.

[0020] The work train **210** utilizes UWB ranging to determine its position on the track and to report its determined position to the zone controller **218**. In exemplary embodiments, the locations of each of the plurality of wayside UWB beacons **202** are known by the onboard UWB control system on the work train **210**. In exemplary embodiments, various known UWB ranging techniques can be used by the onboard UWB control system to calculate the position of the work train **210** relative to the wayside UWB beacons **202**. In exemplary embodiments, the position of the beginning and end of the work train **210** and the speed of the work train **210** are also calculated by the onboard UWB control system based on the received UWB ranging data.

[0021] In exemplary embodiments, the tracking of trains and equipment is not based exclusively on the UWB beacons and UWB ranging because the UWB beacon system cannot detect a train or equipment which is not equipped with UWB beacons or which UWB beacons are failed and not emitting. As a result, embodiments include a wayside based train tracking system providing fail safe track occupancy status to the zone controller. In exemplary embodiments, the track vacancy detection equipment **204** is part of a wayside vital track vacancy detection system that is connected to an object controller **208**, which is configured to communicate with the zone controller **218** via the WCN **216**. The track vacancy detection equipment **204** includes track-circuits, an axle counting system, or the like. In exemplary embodiments, the zone controller **218** will not track the work train **210** based on its provided localization, as this localization has not been established vitally and could be erroneous. Instead, the zone controller **218** will track the work train as any non-CBTC equipped train, based on the track vacancy detection equipment **204** system which is vital. In exemplary embodiments, the zone controller **218** is configured to track the presence of a work train **210** as non-CBTC trains, while providing work trains **210** with a movement authority limit, based on the reported position of the work trains **210**.

[0022] Referring now to FIG. **3**, a flowchart diagram of a method for work train protection using ultra-wideband beacons in accordance with one or more embodiments is shown. As shown at block **302**, the method includes receiving, by an onboard UWB beacon disposed on the work train, unique beacon identification numbers transmitted by one or more UWB beacons. Next, as shown at block **304**, the method includes obtaining, by control unit disposed on the work train, a location of the wayside UWB beacons. In exemplary embodiments, the location of the wayside UWB beacons is obtained from a database stored in a memory of the control unit. The method further includes determining, by the con-

trol unit, a location of the work train on the location of the wayside UWB beacons, as shown at block **306**.

[0023] In exemplary embodiments, the control unit and the onboard UWB beacon are part of an onboard UWB control system that is removably affixed to the work train and the onboard UWB control system further includes a radio datalink that is configured to communicate with a zone controller. As shown at block **308**, the method also includes transmitting, by the control unit, the location of the work train to the zone controller. The zone controller is configured to provide the onboard UWB control system with a movement authority limit. The onboard UWB control system responsively controls the operation of the work train to enforce the movement authority limit. In one embodiment, the control unit enforces the movement authority limit by monitoring a change in the location of the work train and by responsively engaging a braking system of the work train.

[0024] In exemplary embodiments, the UWB based work train protection system presents a cost reasonable and practical way to equip work trains with a simplified train control system. The UWB based work train protection system provides safeguards against potentially dangerous train operator errors, eliminates the need for a complex conventional signaling system to be installed on the wayside in addition to an advanced train control system such as CBTC, thereby reducing significantly implementation and maintenance costs, and increasing reliability.

[0025] The present invention may be a system, a method, and/or a computer program product at any possible technical detail level of integration. The computer program product may include a computer readable storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out aspects of the present invention.

[0026] Various embodiments of the invention are described herein with reference to the related drawings. Alternative embodiments of the invention can be devised without departing from the scope of this invention. Various connections and positional relationships (e.g., over, below, adjacent, etc.) are set forth between elements in the following description and in the drawings. These connections and/or positional relationships, unless specified otherwise, can be direct or indirect, and the present invention is not intended to be limiting in this respect. Accordingly, a coupling of entities can refer to either a direct or an indirect coupling, and a positional relationship between entities can be a direct or indirect positional relationship. Moreover, the various tasks and process steps described herein can be incorporated into a more comprehensive procedure or process having additional steps or functionality not described in detail herein.

[0027] The following definitions and abbreviations are to be used for the interpretation of the claims and the specification. As used herein, the terms "comprises," "comprising," "includes," "including," "has," "having," "contains" or "containing," or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a composition, a mixture, process, method, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but can include other elements not expressly listed or inherent to such composition, mixture, process, method, article, or apparatus.

[0028] Additionally, the term "exemplary" is used herein to mean "serving as an example, instance or illustration." Any embodiment or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments or designs. The terms "at least one" and "one or more" may be understood to include any integer number greater than or equal to one, i.e. one, two, three, four, etc. The terms "a plurality" may be understood to include any integer number greater than or equal to two, i.e. two, three, four, five, etc. The term "connection" may include both an indirect "connection" and a direct "connection."

[0029] The terms "about," "substantially," "approximately," and variations thereof, are intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application. For example, "about" can include a range of ±8% or 5%, or 2% of a given value.

[0030] For the sake of brevity, conventional techniques related to making and using aspects of the invention may or may not be described in detail herein. In particular, various aspects of computing systems and specific computer programs to implement the various technical features described herein are well known. Accordingly, in the interest of brevity, many conventional implementation details are only mentioned briefly herein or are omitted entirely without providing the well-known system and/or process details.

[0031] Aspects of the present invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer readable program instructions.

[0032] These computer readable program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks. These computer readable program instructions may also be stored in a computer readable storage medium that can direct a computer, a programmable data processing apparatus, and/or other devices to function in a particular manner, such that the computer readable storage medium having instructions stored therein comprises an article of manufacture including instructions which implement aspects of the function/act specified in the flowchart and/or block diagram block or blocks.

[0033] The descriptions of the various embodiments of the present invention have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments. The terminology used herein was chosen to best explain the principles of the embodiments, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the embodiments described herein.

What is claimed is:

1. A system for protecting work trains, the system comprising:

a plurality of ultra-wideband (UWB) wayside beacons disposed along a track, each of the plurality of UWB beacons configured to broadcast a unique beacon identification number;

a onboard UWB control system disposed on a work train, the onboard UWB control system having a processing system in communication with radio-frequency (RF) communication device and an onboard UWB beacon, wherein the onboard UWB beacon is configured to receive the unique beacon identification number from at least one of the plurality of UWB wayside beacons, and

wherein the processing system is configured to determine a position of the work train on the track based upon known locations of the at least one of the plurality of UWB wayside beacons.

2. The system of claim **1**, wherein the processing system is further configured to transmit, via the RF communications device, the position of the work train on the track to a zone controller.

3. The system of claim **2**, wherein the processing system is further configured to receive, via the RF communications device, a movement authority limit from the zone controller.

4. The system of claim **1**, wherein the onboard UWB control system is a portable device that is not affixed to the work train.

5. The system of claim **1**, wherein the onboard UWB control system is affixed to the work train and is in communication with a braking system of the work train.

6. The system of claim **1**, further comprising a wayside vital track vacancy detection system in communication with a zone controller, wherein the zone controller tracks a presence of a work train based on the track vacancy detection system.

7. The system of claim **1**, wherein the processing system is configured to obtain the known locations of the at least one of the plurality of UWB wayside beacons from a database stored on the onboard UWB control system.

8. A method for protecting a work train using ultra-wideband (UWB) beacons, the method comprising:

receiving, by an onboard UWB beacon disposed on the work train, unique beacon identification numbers transmitted by one or more wayside UWB beacons;

obtaining, by control unit disposed on the work train, a location of the one or more wayside UWB beacons;

determining, by the control unit, a location of the work train based at least in part on the location of the one or more wayside UWB beacons; and

transmitting, by the control unit, the location of the work train to a zone controller.

9. The method of claim **8**, wherein the location of the one or more wayside UWB beacons is obtained from a database stored in a memory of the control unit.

10. The method of claim **8**, further comprising receiving, by the control unit, a movement authority limit from the zone controller.

11. The method of claim **10**, further comprising enforcing, by the control unit, the movement authority limit by monitoring a change in the location of the work train and by responsively engaging a braking system of the work train.

12. The method of claim **8**, wherein the control unit and the onboard UWB beacon are part of an onboard UWB control system that is removably affixed to the work train.

13. The method of claim **12**, wherein onboard UWB control system further includes a radio datalink that is configured to communicate with the zone controller.

14. A system for protecting work trains, the system comprising:

a plurality of ultra-wideband (UWB) wayside beacons disposed along a track, each of the plurality of UWB beacons configured to broadcast a unique beacon identification number;

a work train disposed on the track, the work train having an onboard UWB control system, the onboard UWB control system comprising:

a control unit;

a radio-frequency (RF) communication device in communication with the control unit;

an onboard UWB beacon in communication with the control unit, wherein the onboard UWB beacon is configured to receive the unique beacon identification number from one or more of the plurality of UWB wayside beacons and wherein the control unit is configured to determine a position of the work train on the track based upon known locations of the one or more UWB wayside beacons; and

a zone controller configured to track a presence of the work train on the track using a vital track vacancy detection system disposed on the track.

15. The system of claim **14**, wherein the control unit is further configured to transmit, via the RF communications device, the position of the work train on the track to the zone controller.

16. The system of claim **15**, wherein the zone controller is further configured to provide a movement authority limit to the control unit.

17. The system of claim **14**, wherein the onboard UWB control system is a portable device that is not affixed to the work train.

18. The system of claim **14**, wherein the onboard UWB control system is affixed to the work train and is in communication with a braking system of the work train.

19. The system of claim **14**, wherein the control unit includes a memory having a database of known locations for each of the plurality of UWB wayside beacons.

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