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Sherlock

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(54) MULTI-USE DETECTION SYSTEM FOR WORK VEHICLE

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(58) **Field of Classification Search**
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USPC 342/70
See application file for complete search history.

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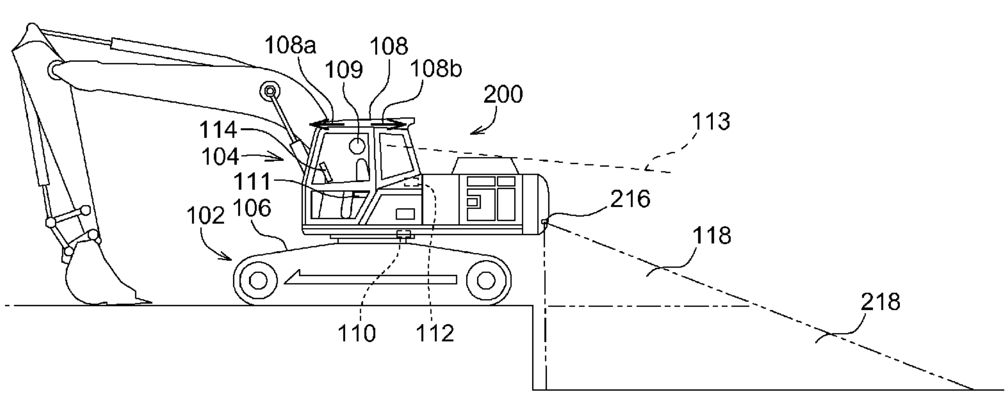
Primary Examiner — Peter M Bythrow

(57) **ABSTRACT**

A work vehicle may include a chassis, a plurality of ground-engaging devices connected to the chassis and configured to provide support and traction to the chassis along a ground surface, an operator station connected to the chassis, and a rear object detection system configured to detect a presence of an object in an area at least partially rearward of the operator station. The rear object detection system may be further configured to detect a presence of a depression of the ground surface in the area.

18 Claims, 4 Drawing Sheets



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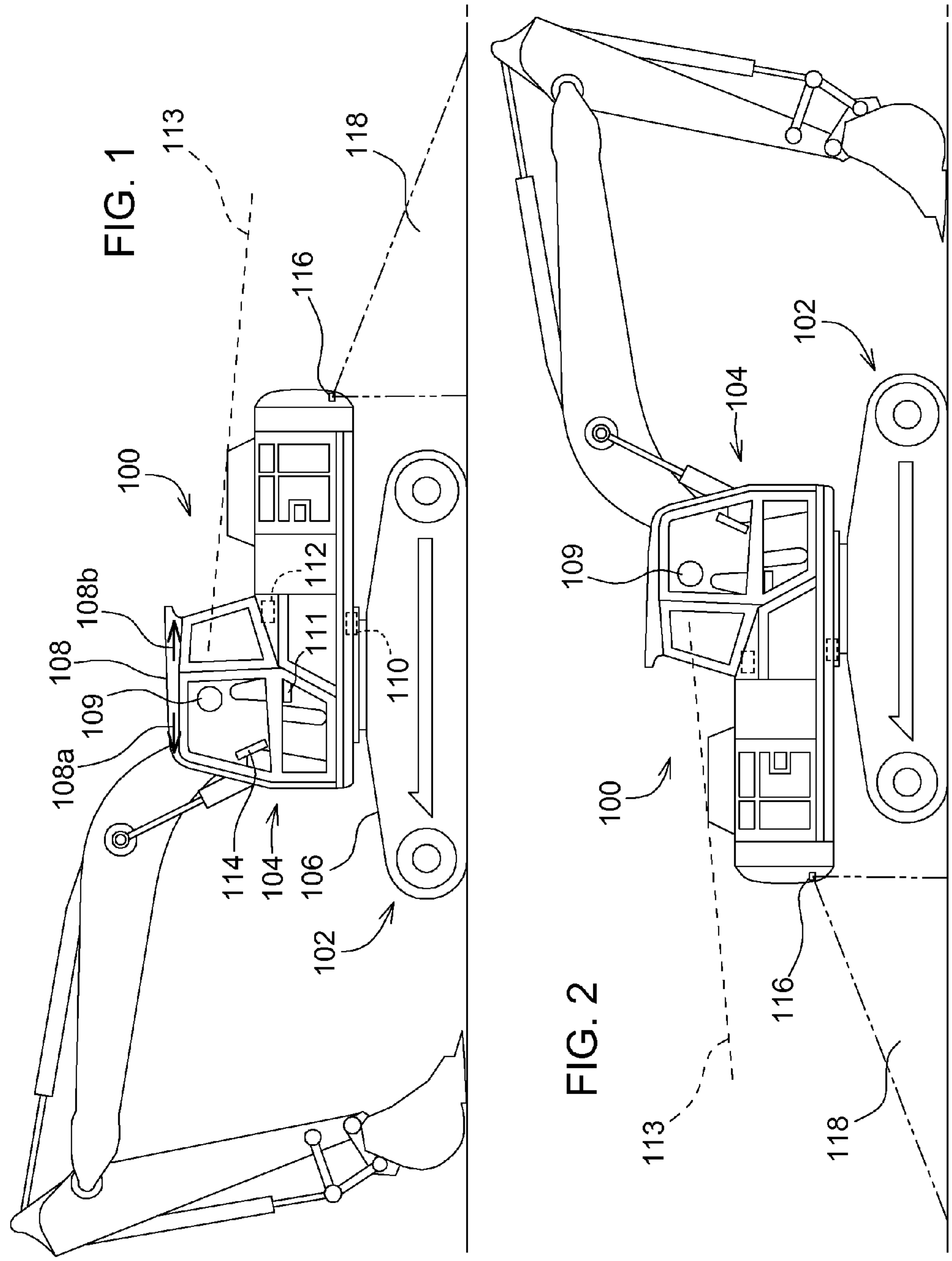
113
118
116
100
112
108b
108
111
109
110
108a
114
104
106
102
109
104
102
100
116
113
118

FIG. 1

FIG. 2

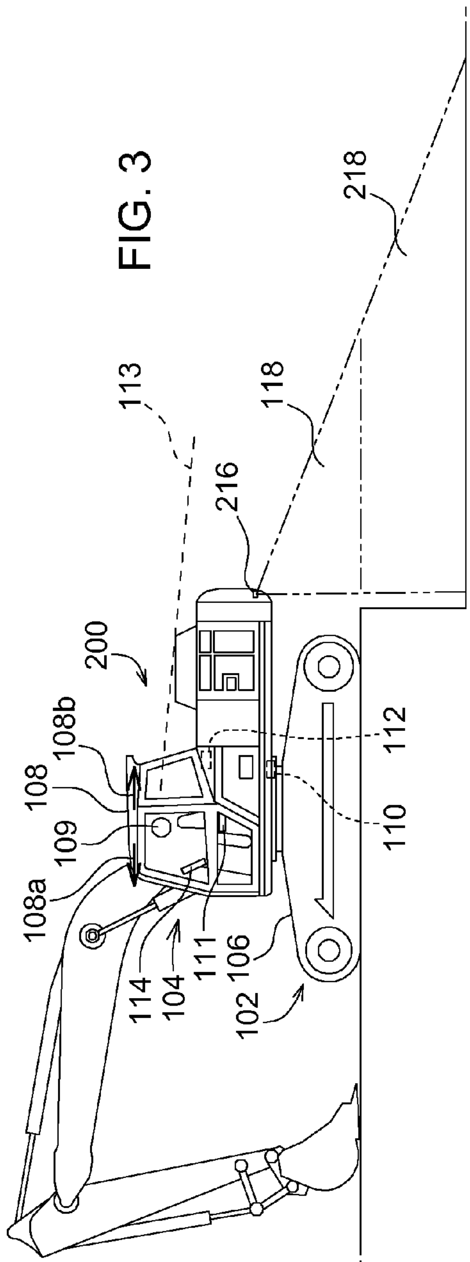
113
118
218
216
200
108b
108
109
108a
112
110
114
104
111
106
102

FIG. 3

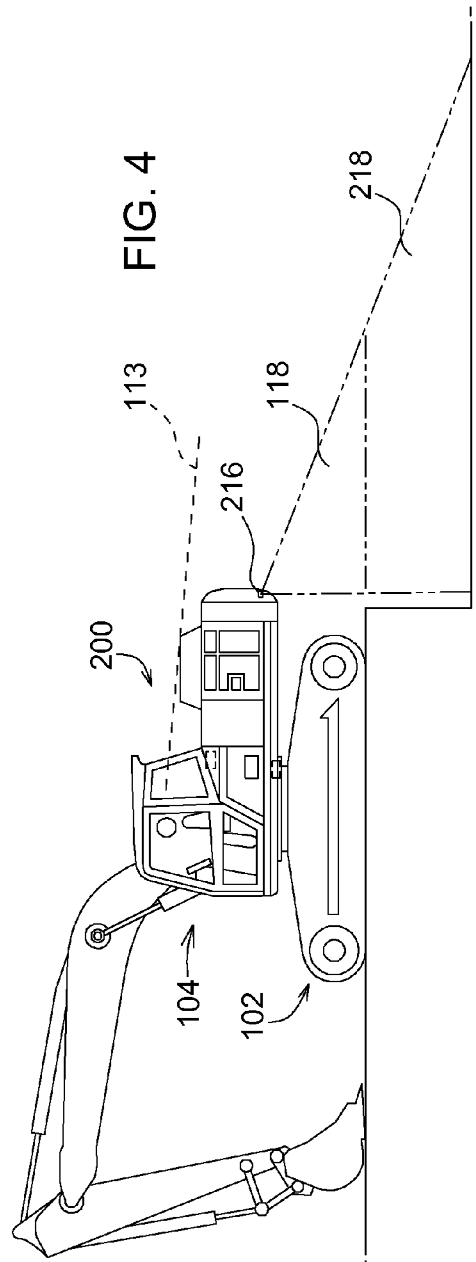
113
118
218
216
200
104
102

FIG. 4

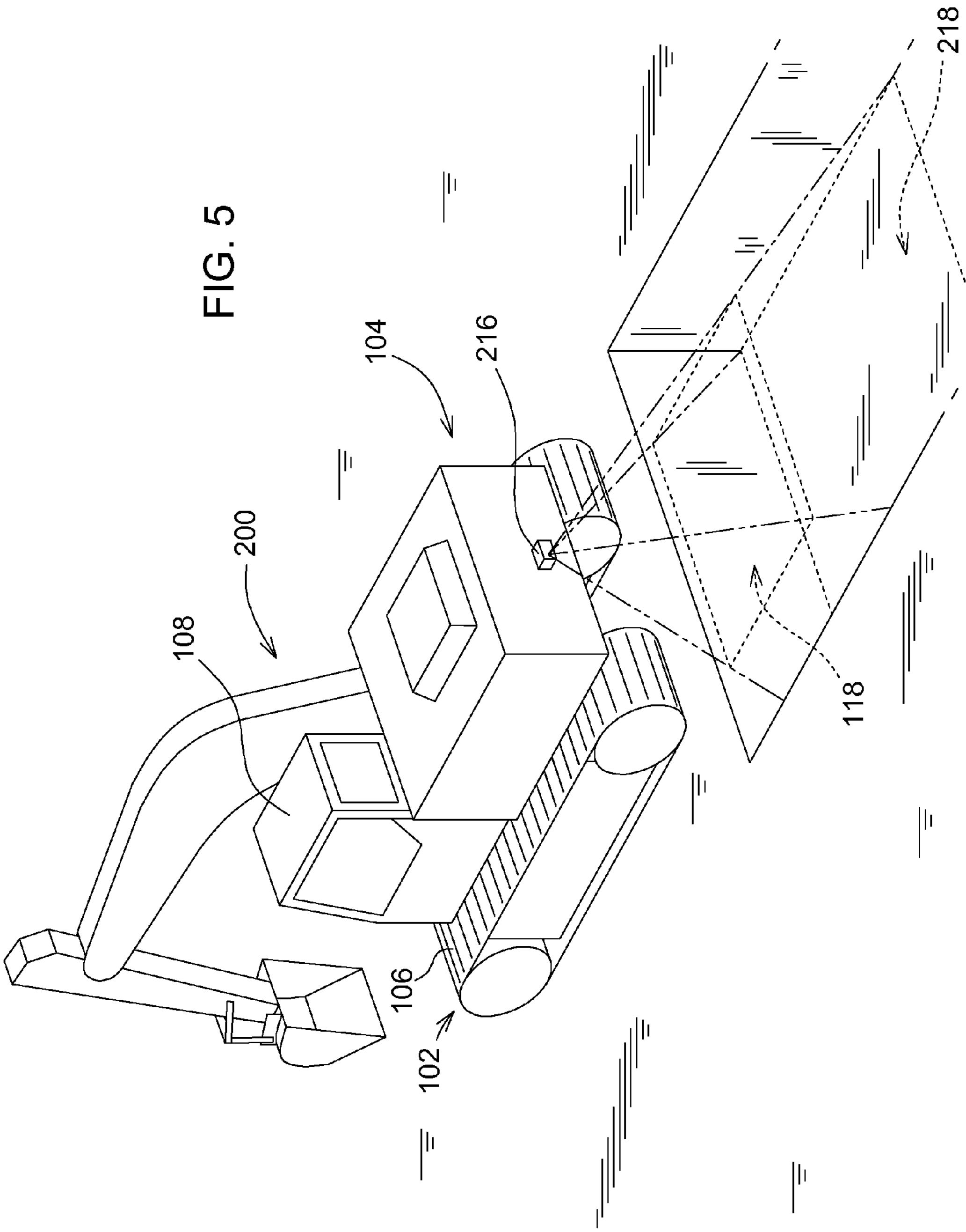

FIG. 5

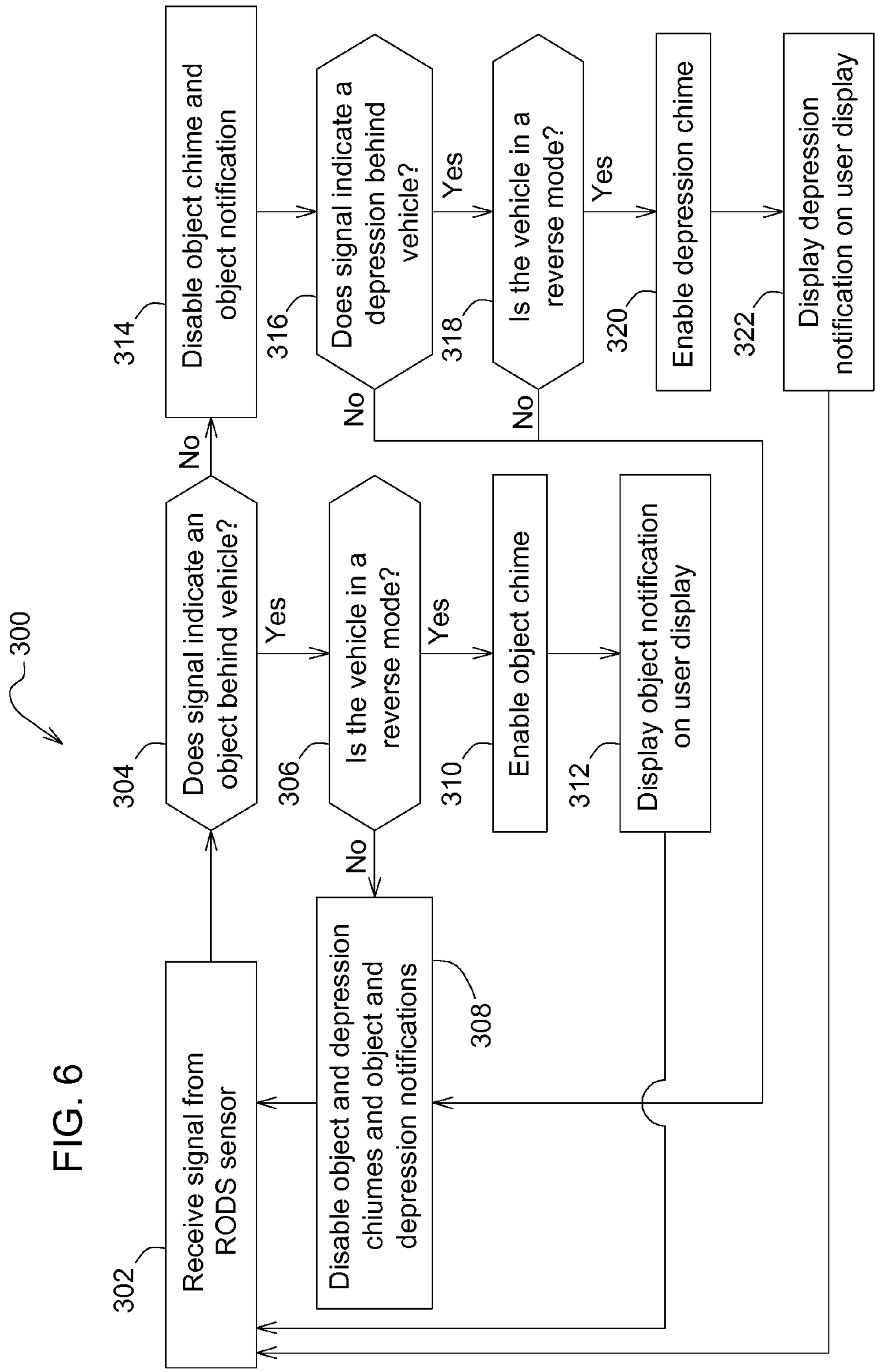
300
302
Receive signal from RODS sensor
304
Does signal indicate an object behind vehicle?
Yes
No
306
Is the vehicle in a reverse mode?
Yes
No
308
Disable object and depression chiumes and object and depression notifications
310
Enable object chime
312
Display object notification on user display
314
Disable object chime and object notification
316
Does signal indicate a depression behind vehicle?
Yes
No
318
Is the vehicle in a reverse mode?
Yes
No
320
Enable depression chime
322
Display depression notification on user display

FIG. 6

MULTI-USE DETECTION SYSTEM FOR WORK VEHICLE

FIELD OF THE DISCLOSURE

The present disclosure relates to a machine and a method. An aspect of the present disclosure relates to a backup detection system for a work vehicle and a method of alerting a user backing up a work vehicle.

BACKGROUND

Work vehicles may be operated in a forward mode in which the work vehicle travels in a certain direction, often the direction the operator is facing, and a reverse mode (backing up), often the opposite direction of the direction the operator is facing. Work vehicles may be equipped with a system to detect objects located behind the work vehicle.

SUMMARY

According to an aspect of the present disclosure, a work vehicle may include a chassis, a plurality of ground-engaging devices, an operator station, and a rear object detection system. The plurality of ground-engaging devices may be connected to the chassis and configured to provide support and traction to the chassis along a ground surface. The operator station may be connected to the chassis. The rear object detection system may be configured to detect a presence of an object in an area at least partially rearward of the operator station. The rear object detection system may be further configured to detect a presence of a depression of the ground surface in the area.

According to another aspect of the present disclosure, the rear object detection system may be configured to send radio waves, receive radio waves, and analyze the received radio waves to detect the presence of an object and the presence of a depression.

According to another aspect of the present disclosure, the rear object detection system may include a radio wave transmitter, a radio wave receiver, and a processor. The radio wave transmitter may be configured to transmit radio waves to the area. The radio wave receiver may be configured to receive radio waves traveling from the area to the radio wave receiver. The processor may be configured to analyze the received radio waves to detect the presence of an object. The processor may also be configured to analyze the received radio waves to detect the presence of a depression.

According to another aspect of the present disclosure, the processor may be configured to detect the presence of a depression by comparing the received radio waves to a baseline indicative of an absence of a depression of the ground surface in the area.

According to another aspect of the present disclosure, the processor may be configured to detect the presence of a depression by comparing a signal strength of the received radio waves to a signal strength of the baseline.

According to another aspect of the present disclosure, an operator seat may be included in the operator station. The area may be at least partially out of a line-of-sight of an operator seated in the operator seat.

According to another aspect of the present disclosure, the area may be at least partially out of a line-of-sight of the operator seat.

According to another aspect of the present disclosure, the area may be at least partially out of a line-of-sight of the operator station.

According to another aspect of the present disclosure, a work vehicle may include an upper chassis, a lower chassis pivotally connected to the upper chassis, a plurality of ground-engaging devices, an operator station, a sensor assembly, a rear object detection system, and a controller. The plurality of ground-engaging devices may be connected to the lower chassis and configured to provide support and traction to the work vehicle along a ground surface. The operator station may be connected to the upper chassis. The sensor assembly may be configured to provide a position signal indicative of the position of the upper chassis relative to the lower chassis. The rear object detection system may be connected to the upper chassis and configured to provide an object signal indicative of a presence of an object in an area rearward of the operator station. The controller may be configured to receive the position signal and the object signal and provide an alarm signal based on the position signal and the object signal.

According to another aspect of the present disclosure, the operator station may include an operator input. The operator input may provide a command signal indicative of a commanded direction of movement of at least one of the ground-engaging devices. The controller may receive the command signal and be configured to provide the alarm signal based on the position signal, the object signal, and the command signal.

According to another aspect of the present disclosure, the alarm signal may indicate an alarm when the position signal and the command signal indicate a commanded movement in a rearward direction for the upper chassis. The object signal may indicate the presence of an object in the area.

According to another aspect of the present disclosure, the rear object detection system, au be further configured to provide a depression signal indicative of a presence of a depression of the ground surface in the area. The controller may be configured to receive the depression signal and provide the alarm signal based on the position signal, the object signal, the depression signal, and the command signal.

According to another aspect of the present disclosure, the rear object detection system may include a radio wave transmitter, a radio wave receiver, and a processor. The radio wave transmitter may be configured to transmit radio waves to the area. The radio wave receiver may be configured to receive radio waves traveling from the area to the radio wave receiver. The processor may be configured to provide the object signal based on the received radio waves. The processor may also be configured to provide the depression signal based on the received radio waves.

According to another aspect of the present disclosure, the processor may be configured to provide the depression signal based on a comparison of the received radio waves to a baseline, where the baseline is indicative of an absence of a depression of the ground surface in the area.

According to another aspect of the present disclosure, the processor may be configured to provide the depression signal based on a comparison of a signal strength of the received radio waves to a signal strength of the baseline.

According to another aspect of the present disclosure, the alarm signal may indicate an alarm when the position signal and the command signal indicate a commanded movement in a rearward direction for the upper chassis, and the depression signal indicates the presence of a depression in the area.

According to another aspect of the present disclosure, a method may include transmitting radio waves into an area rearward of a work vehicle, sensing radio waves received from the direction of the area, providing an object signal indicative of a presence of an object in the area based on the sensed radio waves, providing an depression signal indicative of a presence of a depression of the ground surface in the area based on the sensed radio waves, receiving a command signal indicative of a command from an operator to move the work vehicle along a ground surface, activating an object alarm if the object signal indicates the presence of an object and the command signal indicates a command to move the vehicle rearward, and activating a depression alarm if the depression signal indicates the presence of a depression and the command signal indicates a command to move the vehicle rearward.

According to another aspect of the present disclosure, the method may include receiving a position signal indicative of a position of an upper chassis of the work vehicle relative to a lower chassis of the work vehicle and activating the object alarm if the object signal indicates the presence of an object and (i) the command signal indicates a command to move the lower chassis of the vehicle rearward and the position signal indicates a heading of the upper chassis is within 90 degrees of a heading of the lower chassis or (ii) the command signal indicates a command to move the lower chassis of the vehicle forward and the position signal indicates the heading of the upper chassis is not within 90 degrees of the heading of the lower chassis.

According to another aspect of the present disclosure, the method may include receiving a position signal indicative of a position of an upper chassis of the work vehicle relative to a lower chassis of the work vehicle and activating the depression alarm if the depression signal indicates the presence of a depression and (i) the command signal indicates a command to move the lower chassis of the vehicle rearward and the position signal indicates a heading of the upper chassis is within 90 degrees of a heading of the lower chassis or (ii) the command signal indicates a command to move the lower chassis of the vehicle forward and the position signal indicates the heading of the upper chassis is not within 90 degrees of the heading of the lower chassis.

According to another aspect of the present disclosure, the method may include providing a first tone pattern upon activation of the object alarm and a second tone pattern upon activation of the depression alarm, where the first tone pattern is different than the second tone pattern.

The above and other features will become apparent from the following description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description of the drawings refers to the accompanying figures in which:

FIG. **1** is a side view of a first work vehicle with a rear object detection system configured to detect objects behind the work vehicle, with an upper chassis oriented in the same direction as a lower chassis.

FIG. **2** is a side view of the first work vehicle with the upper chassis oriented in the opposite direction as the lower chassis.

FIG. **3** is a side view of a second work vehicle with a rear object detection system configured to detect the presence of an object behind the work vehicle or the presence of a depression on a ground surface behind the work vehicle, with an upper chassis oriented in the same direction as a lower chassis.

FIG. **4** is a side view of the second work vehicle, with the upper chassis oriented in the opposite direction as the lower chassis.

FIG. **5** is a perspective view of the second work vehicle, with the upper chassis oriented in the opposite direction as the lower chassis.

FIG. **6** is a flowchart of a method for alerting an operator to the presence of an object or depression located behind a work vehicle.

Like reference numerals are used to indicate like elements throughout the several figures.

DETAILED DESCRIPTION

FIG. **1** and FIG. **2** illustrate work vehicle **100** including lower chassis **102** in contact with a ground surface and upper chassis **104** connected to lower chassis **102**. Lower chassis **102**, which may also be referred to as an undercarriage, supports work vehicle **100** and provides tractive effort through ground-engaging devices **106**. Ground-engaging devices **106** provide support and traction to work vehicle **100** along a ground surface, and may be driven by an engine of work vehicle **100** to drive work vehicle **100** forward or rearward. Ground-engaging devices **106** are illustrated as a pair of tracks but may alternatively be wheels in other embodiments. Work vehicle **100** is illustrated as an excavator, but may be any number of construction, forestry, or other off-road work vehicles.

Upper chassis **104** is pivotally connected to lower chassis **102** so as to allow upper chassis **104** to rotate 360 degrees about lower chassis **102**, which may also be referred to as slewing or swinging. Due to this arrangement, upper chassis **104** may be oriented in any direction (i.e., heading) relative to lower chassis **102**. While movement by lower chassis **102** results in movement of upper chassis **104** in the same direction relative to the ground, the direction of movement experienced by an operator in operator station **108** may vary depending on the orientation of upper chassis **104** relative to lower chassis **102**. For example, in FIG. **1** upper chassis **104** is oriented in the same direction as lower chassis **102**, and thus forward movement of lower chassis **102** results in forward movement for upper chassis **104**. Conversely, in FIG. **2** upper chassis **104** is oriented in the opposite direction as lower chassis **102**, and thus forward movement of lower chassis **102** results in rearward movement for upper chassis **104** and movement in rearward direction **108***b*. Work vehicle **100** may be referred to as traveling rearward, reversing, in a reverse mode, or backing up when operator station **108** is moving in rearward direction **108***b*, which is rearward relative to the direction of operator **109** seated normally in operator station **108**, even if the lower chassis **102** is moving in a forward direction.

Sensor assembly **110** is positioned near the pivotal joint interconnecting upper chassis **104** and lower chassis **102**, and is configured to provide a position signal indicative of the position of upper chassis **104** relative to lower chassis **102**. For example, sensor assembly **110** may be a rotary position sensor which is configured to measure the relative angle between upper chassis **104** and lower chassis **102**. Alternatively, sensor assembly **110** may be a switch which is configured to detect whether upper chassis **104** is positioned in the same direction as lower chassis **102** (i.e., the heading of upper chassis **104** within 90 degrees of the heading of lower chassis **102**), or an opposite direction as lower chassis **102** (i.e., the heading of upper chassis **104** is 90-270 degrees away from the heading of lower chassis **102**). As another alternative, sensor assembly **110** may consist of a first sensor disposed on lower chassis **102** and configured to provide a first direction signal indicative of the direction of lower chassis **102** and a second sensor disposed on upper chassis **104** and configured to provide a second direction signal indicative of the direction of upper chassis **104**. The relative positioning of lower chassis **102** and upper chassis **104** may then be determined by comparing the first direction signal and the second direction signal.

Sensor assembly **110** may communicate its measurement to a controller on work vehicle **100**, such as controller **112**. Controller **112** may then determine the expected direction of movement of upper chassis **104** based on the measurement from sensor assembly **110** and the operator's commanded direction of movement for lower chassis **102**. For example, if controller **112** receives an operator command signal indicating a command for forward movement of lower chassis **102** and receives a position signal from sensor assembly **110** indicating that upper chassis **104** is positioned 180 degrees relative to lower chassis **102** (i.e., the forward direction for upper chassis **104** is the same as the rearward direction for lower chassis **102**), controller **112** can determine that upper chassis **104** will be moving in its rearward direction and thus operator station **108** will be moving in rearward direction **108*b*** and work vehicle **100** will be reversing.

Operator station **108** is mounted on upper chassis **104**, and configured to provide a place for an operator to control work vehicle **100**, such as operator **109**. Operator **109** is seated within operator station **108** on operator seat **111**, and from this position operator **109** may input drive commands for work vehicle **100**, such as commanding lower chassis **102** to move in a forwards direction or a rearwards direction. The operator may input these commands through the use of one or more pedals. For example, the operator may depress a pedal in a forward direction to command forward movement of ground-engaging devices **106** and depress the same pedal in a backward direction to command reverse movement of ground engaging devices **106**. The operator may also be able to command the left and right ground-engaging devices **106** of work vehicle **100** at differing rates, such as commanding the left ground-engaging devices **106** forward at a greater speed than the right ground-engaging devices **106** to turn the vehicle rightward, or in differing directions, such as to turn the vehicle sharply or rotate it in place.

When seated within operator station **108**, operator **109** may have direct visibility in forward direction **108*a*** of operator station **108**, and operator **109** may turn his or her head while seated to look in rearward direction **108*b*** of operator station **108**. However, operator **109** may not have full visibility around the periphery of work vehicle **100**. For example, while looking in rearward direction **108*b*** of operator station **108**, the lowest operator **109** would be able to see from a seated position on operator seat **111** are objects at or above sight-line **113**, which is the sight-line from the operator to a top portion of upper chassis **104**. Certain areas surrounding the upper chassis **104** may not have any direct line-of-sight to an operator seated on operator seat **111**.

Operator station **108** may also include an operator display **114** which may be used to display information relating to work vehicle **100**, such as information about what is immediately behind work vehicle **100**, or which may be used by the operator to input commands or data. Operator display **114** may also be capable of generating sounds for the operator, including warning tones or speech, but in alternative embodiments a separate device such as a standalone speaker may be utilized for audio communications. Operator display **114** is in communication with controller **112**, enabling controller **112** to communicate with operator display **114** to display messages or generate audible warnings or speech for the operator.

Work vehicle **100** is equipped with a rear object detection system (RODS) **116** which is mounted to the rear of upper chassis **104**. RODS **116** is connected to upper chassis **104** and faces outward from the rear of upper chassis **104**, giving a line-of-sight to the ground and objects behind upper chassis **104**. RODS **116** may be utilized to detect objects located behind upper chassis **104** within a certain distance of work vehicle **100**, the distance determined by the capabilities of RODS **116**. In this embodiment, RODS **116** utilizes radar to sense objects located behind work vehicle **100** in area **118**, but other detection systems may utilize different sensing technologies, including laser (e.g., lidar), sound (e.g., ultrasound/sonar), or image capture (e.g., via one or more cameras). RODS **116** comprises a radio wave transmitter, a radio waver receiver, and a processor. RODS **116** functions by generating radio waves and transmitting them rearward of operator station **108** and rearward of upper chassis **104**, into area **118** via the radio wave transmitter, receiving (i.e., sensing) the radio waves after they are reflected off surfaces behind upper chassis **104** and return to RODS **116** via the radio wave receiver, and analyzing the sensed data to determine whether objects are present via the processor. In RODS **116**, the radio wave transmitter and radio wave receiver may both be included in a transceiver, a component capable of transmitting and receiving radio waves.

In normal operation, RODS **116** may be configured to detect an object rearward of operator station **108** and rearward of upper chassis **104** by determining whether it senses an object closer than a threshold distance, which may be pre-set or adjustable so as to avoid the ground setting off RODS **116**. RODS **116** may also be configured so as to require a detected object be larger than a threshold size before being considered an object, and this threshold size may be pre-set or adjustable, such as based on the distance to the object. In the embodiment illustrated in FIG. **1** and FIG. **2**, RODS **116** includes a processor which analyzes the sensed radio waves to determine whether an object is present in area **118** and then communicates an object signal indicative of the presence of an object in area **118** to controller **112**. In the embodiment illustrated in FIG. **1** and FIG. **2**, the object signal from RODS **116** is a value which indicates the absence of an object (e.g., 0) or the proximity of the object to RODS **116** (e.g., 1, 2, or 3 as the proximity increases). In alternative embodiments, the object signal from RODS **116** may not itself communicate the presence or absence of an object in area **118**, but may instead communicate a value representative of the signal strength of the radio waves received by RODS **116** (e.g., from 1-100) which is indicative of the presence of an object in area **118** (or the absence of such an object), and controller **112** may perform further determines using this object signal (e.g., indicating an object if the object signal is 50 or greater). In yet other alternative embodiments, RODS **116** may communicate other data to controller **112**, or data in an alternative format, to allow controller **112** to determine whether an object is present in area **118**.

In the embodiment illustrated in FIG. **1** and FIG. **2**, RODS **116** communicates to controller **112** whether an object is detected rearward of upper chassis **104**, within area **118**. In alternative embodiments, RODS **116** may communicate further information such as the size of, or distance to, the detected object, to enable controller **112** to take different actions based on the size or distance of the detected object. Area **118** is located rearward of operator station **108** and rearward of upper chassis **104**, and is not within a direct line-of-sight to an operator seated on operator seat **111**, such as operator **109**, although portions may be visible through indirect lines-of-sight such as via mirrors placed on work vehicle **100**. In alternative embodiments, area **118** may not be located entirely rearward of upper chassis **104**, but may instead be located only partially rearward of upper chassis **104**, or may not be entirely outside a direct line-of-sight to an operator seated on operator seat **111**.

FIG. **3**, FIG. **4**, and FIG. **5** illustrate a work vehicle **200**, which includes RODS **216**. Similar to FIG. **1**, FIG. **3** illustrates work vehicle **200** with the upper chassis **104** oriented in the same direction as the lower chassis, and thus forward movement of the lower chassis **102** results in forward movement for the upper chassis **104**. Similar to FIG. **2**, FIG. **4** illustrates work vehicle with upper chassis **104** oriented in the opposite direction as lower chassis **102**, and thus forward movement of lower chassis **102** results in rearward movement for operator station **108** and upper chassis **104**.

RODS **216**, like RODS **116**, utilizes radar to detect objects rearward of operator station **108** and upper chassis **104** in area **118**. Unlike RODS **116**, RODS **216** is configured to additionally detect the presence of a depression in the ground surface below and rearward of operator station **108** and upper chassis **104** in area **218**, and communicate a depression signal to controller **112** indicative of a presence of a depression in area **218** (or the absence of such a depression). RODS **216** may be configured in this manner by hardware changes, including by changes to the radio wave transmitting and receiving elements within RODS **216**, and/or by changing how the sensed data is analyzed via the processor in RODS **216**. RODS **216** is configured to detect objects within area **118** in the same manner as RODS **116**, but additionally analyzes the reflected radio waves to determine whether a ground surface is sensed where area **118** intersects the ground surface, or within area **218**. If a ground surface is not detected, or detected at a distance greater than a threshold setting, RODS **216** communicates to controller **112** that a depression is detected below and rearward of upper chassis **104**. Similar to RODS **116**, the radio wave transmitter and radio wave receiver of RODS **216** may both be included in a transceiver, a component capable of transmitting and receiving radio waves.

For example, RODS **216** may be configured to detect an object if the reflected radio waves result in a signal above a threshold signal strength, the threshold indicative of the expected return signal when no object is present and the radio waves reflect off a ground surface where area **118** meets area **218**. This expected return signal may also be referred to as a baseline. In alternative embodiments, the baseline may not be indicative of a particular signal strength, but may instead be indicative of other qualities of the expected return signal such as frequency, distribution, phase, or timing. In the embodiment illustrated in FIGS. **3**-**5**, if the signal falls below the threshold signal strength, RODS **216** may indicate that a depression exists. RODS **216** may be programmed to require the signal strength to vary from the threshold by an amount, which may be pre-set or adjustable, before an indication of either an object or a depression is communicated, thereby changing the size of objects or depressions necessary to trigger RODS **216**. By analyzing the reflected radio waves to determine whether the expected signature of the ground surface is present, and present at the expected distance, RODS **216** may be utilized as a multi-use detection system capable of detecting both objects in area **118** and ground surface depressions in area **218** without the need for additional hardware.

RODS **216** may be configured such that it communicates a detected depression to controller **112** only when it detects a depression of sufficient volume, surface area, depth, or some combination of these and other factors. In alternative embodiments, RODS **216** may communication further information such as the size or distance of the detected depression, to enable controller **112** to take different actions based on the size or distance of the detected depression.

FIG. **6** is a flowchart of control system **300** of enabling object and depression chimes and displaying object and depression notifications on work vehicle **200** equipped with RODS **216**. In step **302**, controller **112** receives a signal from RODS **216**. In step **304**, controller **112** determines whether the signal received in step **302** indicates that an object is behind work vehicle **200**. For example, RODS **216** may communicate a message on a Controller-Area Network (CAN) which indicates a normal status, an object status, or a depression status, and this message may be received on the CAN by controller **112**.

If controller **112** determines that the signal indicates an object is behind work vehicle **200**, it may proceed to step **306**, in which it determines whether work vehicle **200** is in a reverse mode. Controller **112** may determine whether work vehicle **200** is in a reverse mode by a number of different methods. For example, it may keep track of the state of work vehicle **200** and change states when it receives certain inputs from an operator in operator station **108** such as a shift from forward to reverse or a depression of a reverse throttle pedal. As another example, it may determine whether work vehicle **200** is in a reverse mode by monitoring a message from a Transmission Control Unit (TCU) which broadcasts the current state of the transmission of work vehicle **200**. As yet another example, it may determine whether work vehicle **200** is in a reverse mode by monitoring the pressure or flow delivered to hydraulic motors which drive ground-engaging devices **106**. For work vehicle **200**, controller **112** determines whether the vehicle is in a reverse mode by receiving a signal from sensor assembly **110** indicating the position of lower chassis **102** relative to upper chassis **104**, and receiving a signal from operator station **108** indicating the direction that the operator is commanding for ground-engaging devices **106**. Using both of these as inputs, controller **112** determines whether the operator's command will result in operator station **108** moving in rearward direction **108*b*** and thus whether work vehicle **200** is in a reverse mode. If work vehicle **200** is not in a reverse mode, step **308** is performed next, and any current object or depression chimes or notifications are disabled.

If work vehicle **200** is in a reverse mode, step **310** is performed next. In step **310**, controller **112** enables an object chime. This object chime may take multiple forms. In control system **300**, a specific chime may be sounded by a speaker in operator station **108**, for example a repeating tone, or beeping, which indicates to the operator that an object has been detected behind work vehicle **200** by RODS **216**. In alternative embodiments, the object chime may vary depending on the distance or size of the object detected by RODS **216**, for example with the object chime growing louder or with shorter intervals between beeps for objects which are larger or closer. Step **312** is performed next, with controller **112** communicating with operator display **114** to display an object notification. This message may take many forms. In the embodiment disclosed in FIG. **6**, the notification may be displayed text of the form "Object detected behind vehicle." In alternative embodiments, the text may vary or the notification may include non-text components, such as highlighting or other coloring of the detected object on a video feed from a camera placed to view behind work vehicle **200**. After step **312**, controller **112** returns to the beginning of the loop with step **302**.

If the signal from RODS **216** is not determined to indicate an object behind work vehicle **200** in step **304**, then step **314** is performed next. In step **314**, any pre-existing object chime or object notification is disabled as no object has been detected, and step **316** is performed next. In step **316**, controller **112** determines whether the signal from RODS **216** indicates a depression behind work vehicle **200**. If not, controller **112** performs step **308** next, after which controller **112** returns to step **302**.

If a depression is detected behind work vehicle **200**, step **318** is performed next and controller **112** determines whether work vehicle **200** is in a reverse mode. Similar to step **306**, controller **112** may determine whether work vehicle **200** is in a reverse mode by monitoring the state of work vehicle **200**, messages from a TCU, inputs from an operator in operator station **108**, or monitoring flows and pressures to drive components for ground-engaging devices **106**. If work vehicle **200** is not in a reverse mode, step **308** is performed next, after which controller **112** returns to step **302**. If work vehicle **200** is in a reverse mode, step **320** is performed next.

In step **320**, controller **112** enables a depression chime. Similar to the object chime, the depression chime may take multiple forms. In control system **300**, a specific chime which is different than the object chime may be sounded by a speaker in operator station **108**, for example a repeating tone, or beeping, which is of a different tone, frequency, intensity, or character than the object chime, may be sounded by a speaker in operator station **108**. Similar to the object chime, the depression chime may be varied to indicate the distance to, or size of, the detected depression, including by growing louder or more frequent as the distance to the detected depression is decreased or the size of the detected depression is increased.

In step **320**, controller **112** or RODS **216** may optionally analyze the sensed radio waves to determine characteristics of the depression on the ground surface in the area **218** and enable the depression chime based on these characteristics. As one example, controller **112** may analyze a message received from RODS **216** indicative of the size of a depression in the area **218**. Controller **112** may enable the depression chime only when the size (e.g., width, depth, volume) indicated by the message is greater than a threshold, and the threshold may be preset, operator adjustable, or set based on a feature of the work vehicle **200** such as a dimension of a ground-engaging device **106** (e.g., length). In this way, controller **112** may vary whether the depression chime is enabled depending on the size of the depression relative to the size of a feature of work vehicle **200**. As another example, RODS **216** may analyze the sensed radio waves to determine the position of the depression relative to ground-engaging devices **106** and may communicate a positive indication of a depression to controller **112** only when the depression is determined to be within the expected path of at least one of ground-engaging devices **106**.

Step **322** is performed next, with controller **112** communicating with operator display **114** to display a depression notification. This message may take many forms, including displayed text, such as of the form "Depression detected behind vehicle." In alternative embodiments, the text may vary or the notification may include non-text components, such as highlighting or a zoomed-in view of the detected depression on a video feed from a camera placed to view behind work vehicle **200**. After step **322**, controller **112** returns to the beginning of the loop with step **302**.

After step **322**, controller **112** may optionally derate work vehicle **200** based on a communication from RODS **216**. For example, controller **112** may derate (e.g., limit the maximum speed, acceleration, or power of) work vehicle **200** or force work vehicle **200** to stop if RODS **216** communicates the presence of an object or a depression within a certain distance of one of ground-engaging devices **106** or upper chassis **104**. As another example, controller **112** may derate work vehicle **200** if RODS **216** indicates the presence of a depression positioned in the path of one of ground-engaging devices **106**, and may eventually prevent further movement of ground-engaging devices **106** toward the depression if the depression is close enough to one of ground-engaging devices **106**.

Although FIG. **6** is illustrated as a flowchart, the disclosure is not limited to such steps and the order of steps presented, and it would be well within the skill of one of ordinary skill in the art to reorder, combine, or split many of the steps and achieve the same result.

In alternative embodiments, when both an object and a depression are detected, controller **112** may be configured to operate differently than the embodiment illustrated in FIG. **6**. For example, controller **112** may be configured to enable the depression chime and display the depression notification when both an object and a depression are detected. As another example, controller **112** may be configured to enable both the object and depression chimes and display both the object and depression notifications. As yet another example, the chimes and notifications may be the same for both objects and depressions, simplifying control system **300** down to enabling the chime or notification is either an object or depression is detected.

While the disclosure has been illustrated and described in detail in the drawings and foregoing description, such illustration and description is not restrictive in character, it being understood that illustrative embodiment(s) have been shown and described and that all changes and modifications that come within the spirit of the disclosure are desired to be protected. Alternative embodiments of the present disclosure may not include all of the features described yet still benefit from at least some of the advantages of such features. Those of ordinary skill in the art may devise their own implementations that incorporate one or more of the features of the present disclosure and fall within the spirit and scope of the appended claims.

What is claimed is:

1. A work vehicle comprising:

an upper chassis;

a lower chassis pivotally connected to the upper chassis;

a plurality of ground-engaging devices connected to the chassis and configured to provide support and traction to the chassis along a ground surface;

an operator station connected to the upper chassis, the operator station includes an operator input, the operator input provides a command signal indicative of a commanded direction of movement of at least one of the ground-engaging devices;

a sensor assembly configured to provide a position signal indicative of the position of the upper chassis relative to the lower chassis; and

a rear object detection system configured to detect a presence of an object in an area, the area at least partially rearward of the operator station;

wherein the rear object detection system is further configured to detect a presence of a depression of the ground surface in the area,

a controller coupled to the sensor assembly and the rear object detection system, and configured to provide an alarm signal based on the command signal, the position signal and one of the presence of the object in the area and the presence of the depression of the ground surface in the area;

wherein the alarm signal indicates an alarm when the position signal and the command signal indicate a commanded movement in a rearward direction for the upper chassis, and the object signal indicates the presence of the object in the area.

2. The work vehicle of claim **1**, wherein the rear object detection system is configured to send radio waves, receive radio waves, and analyze the received radio waves to detect the presence of the object and the presence of the depression.

3. The work vehicle of claim **2**, wherein the rear object detection system comprises a radio wave transmitter, a radio wave receiver, and a processor, the radio wave transmitter is configured to transmit radio waves to the area, the radio wave receiver is configured to receive radio waves traveling from the area to the radio wave receiver, the processor is configured to analyze the received radio waves to detect the presence of the object, and the processor is configured to analyze the received radio waves to detect the presence of the depression.

4. The work vehicle of claim **3**, wherein the processor is configured to detect the presence of the depression by comparing the received radio waves to a baseline, the baseline indicative of an absence of the depression of the ground surface in the area.

5. The work vehicle of claim **4**, wherein the processor is configured to detect the presence of the depression by comparing a signal strength of the received radio waves to a signal strength of the baseline.

6. The work vehicle of claim **3**, further comprising an operator seat included in the operator station, wherein the area is at least partially out of a line-of-sight which is extended from an operator seated in the operator seat to a top portion of the upper chassis.

7. The work vehicle of claim **3**, further comprising an operator seat included in the operator station, wherein the area is at least partially out of a line-of-sight which is extended from the operator seat to a top portion of the upper chassis.

8. The work vehicle of claim **3**, wherein the area is at least partially out of a line-of-sight which is extended from the operator station to a top portion of the upper chassis.

9. A work vehicle comprising:

an upper chassis;

a lower chassis pivotally connected to the upper chassis;

a plurality of ground-engaging devices connected to the lower chassis and configured to provide support and traction to the work vehicle along a ground surface;

an operator station connected to the upper chassis, the operator station includes an operator input, the operator input provides a command signal indicative of a commanded direction of movement of at least one of the ground-engaging devices;

a sensor assembly configured to provide a position signal indicative of the position of the upper chassis relative to the lower chassis;

a rear object detection system connected to the upper chassis, the rear object detection system configured to provide an object signal indicative of a presence of an object in an area rearward of the operator station; and

a controller configured to receive the command signal, the position signal, and the object signal, the controller configured to provide an alarm signal based on the command signal, the position signal, and the object signal;

wherein the alarm signal indicates an alarm when the position signal and the command signal indicate a commanded movement in a rearward direction for the upper chassis, and the object signal indicates the presence of the object in the area.

10. The work vehicle of claim **9**, wherein the rear object detection system is further configured to provide a depression signal indicative of a presence of a depression of the ground surface in the area, the controller is configured to receive the depression signal, and the controller is configured to provide the alarm signal based on the position signal, the object signal, the depression signal, and the command signal.

11. The work vehicle of claim **10**, wherein the rear object detection system comprises a radio wave transmitter, a radio wave receiver, and a processor, the radio wave transmitter is configured to transmit radio waves to the area, the radio wave receiver is configured to receive radio waves traveling from the area to the radio wave receiver, the processor is configured to provide the object signal based on the received radio waves, and the processor is configured to provide the depression signal based on the received radio waves.

12. The work vehicle of claim **11**, wherein the processor is configured to provide the depression signal based on a comparison of the received radio waves to a baseline, the baseline indicative of an absence of a depression of the ground surface in the area.

13. The work vehicle of claim **12**, wherein the processor is configured to provide the depression signal based on a comparison of a signal strength of the received radio waves to a signal strength of the baseline.

14. The work vehicle of claim **10**, wherein the alarm signal indicates an alarm when the position signal and the command signal indicate a commanded movement in a rearward direction for the upper chassis, and the depression signal indicates the presence of a depression in the area.

15. A method comprising:

transmitting radio waves into an area rearward of a work vehicle;

sensing radio waves received from the direction of the area;

providing an object signal indicative of a presence of an object in the area based on the sensed radio waves;

providing an depression signal indicative of a presence of a depression of the ground surface in the area based on the sensed radio waves;

receiving a command signal indicative of a command from an operator to move the work vehicle along a ground surface;

receiving a position signal indicative of a position of an upper chassis of the work vehicle relative to a lower chassis of the work vehicle;

activating an object alarm if the object signal indicates the presence of an object, and the position signal and the command signal indicates a command to move the vehicle rearward; and

activating a depression alarm if the depression signal indicates the presence of a depression, and the position signal and the command signal indicates a command to move the vehicle rearward.

16. The method of claim **15**, further comprising: activating the object alarm if the object signal indicates the presence of an object and (i) the command signal indicates a command to move the lower chassis of the vehicle rearward and the position signal indicates a heading of the upper chassis is within 90 degrees of a heading of the lower chassis or (ii) the command signal indicates a command to move the lower chassis of the vehicle forward and the position signal indicates the heading of the upper chassis is not within 90 degrees of the heading of the lower chassis.

17. The method of claim **15**, further comprising: activating the depression alarm if the depression signal indicates the presence of a depression and (i) the command signal indicates a command to move the lower chassis of the vehicle rearward and the position signal indicates a heading of the upper chassis is within 90 degrees of a heading of the lower chassis or (ii) the command signal indicates a command to move the lower chassis of the vehicle forward and the position signal indicates the heading of the upper chassis is not within 90 degrees of the heading of the lower chassis.

18. The method of claim **15**, further comprising providing a first tone pattern upon activation of the object alarm and a second tone pattern upon activation of the depression alarm, the first tone pattern different than the second tone pattern.

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