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Sandbrook

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(54) **VEHICLE BARRIER GATE SYSTEM**

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E05F 15/00 (2015.01)
E01F 13/06 (2006.01)

(52) **U.S. Cl.**
CPC ***E01F 13/06*** (2013.01); ***E05F 15/00*** (2013.01); *E05Y 2201/46* (2013.01); *E05Y 2900/402* (2013.01)

(58) **Field of Classification Search**
CPC E01F 13/06; E01F 15/00; E05Y 2201/46; E05Y 2900/402
USPC 49/49
See application file for complete search history.

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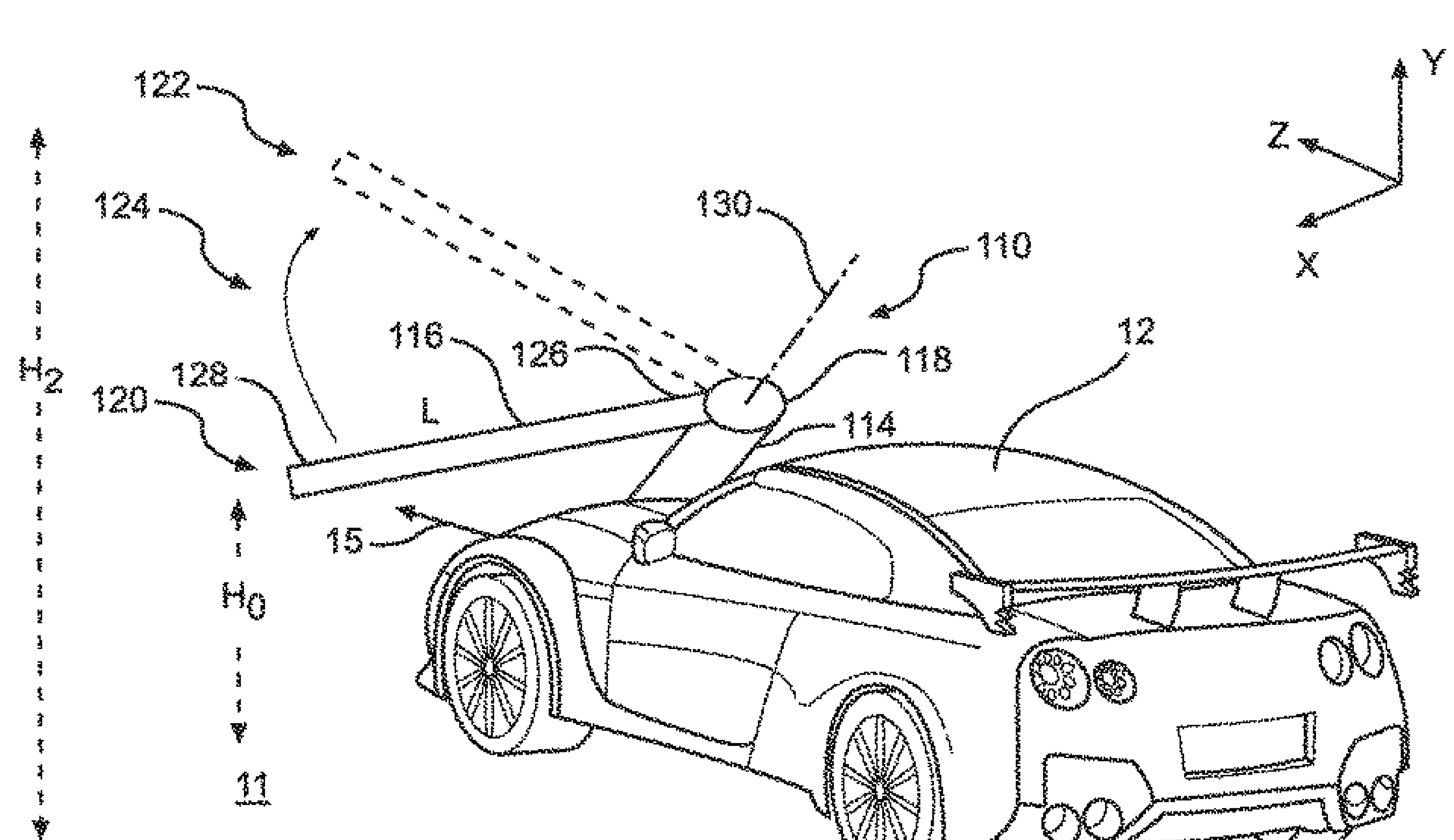
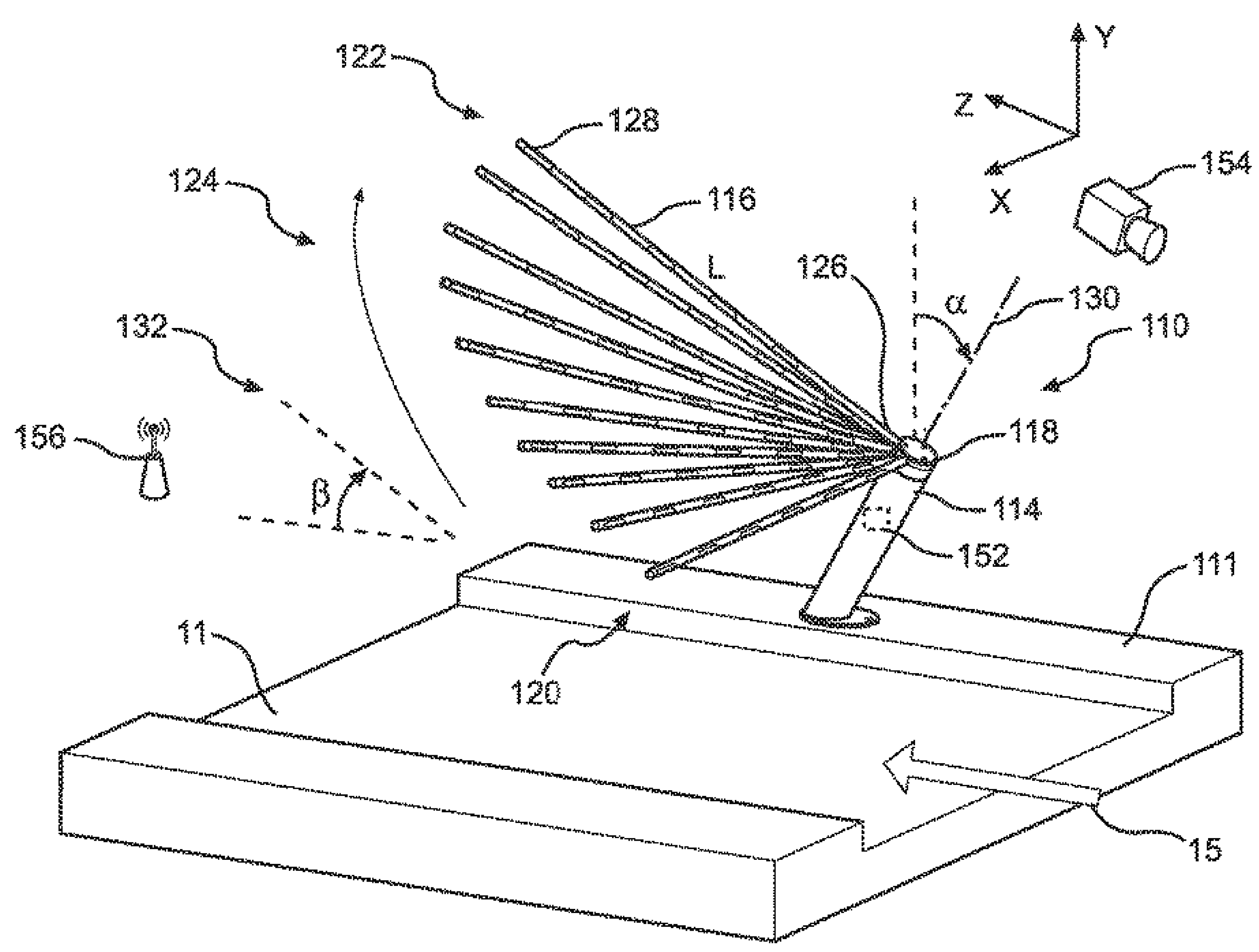
(74) *Attorney, Agent, or Firm* — Neustel Law Offices

(57) **ABSTRACT**

Vehicle barrier systems that can selectively move a barrier arm between a first position that prevents a vehicle from passing, or a second position that allows the vehicle to pass, wherein the barrier arm moves both upwardly away from a travel path and laterally along the travel path in a direction away from the vehicle. The barrier arm movement thereby leads the driver of the vehicle through the barrier system in a sweeping or leading movement. In some embodiments, an actuator assembly of the barrier system includes a breakaway assembly coupled to the barrier arm. In the event that an abnormal force (e.g. vehicle strike, vandalism, etc.) applied to the barrier arm exceeds a predetermined threshold, one or more drive magnets of the breakaway assembly disengage from the one or more magnetically-attractive elements to prevent damage to the barrier system.

22 Claims, 11 Drawing Sheets





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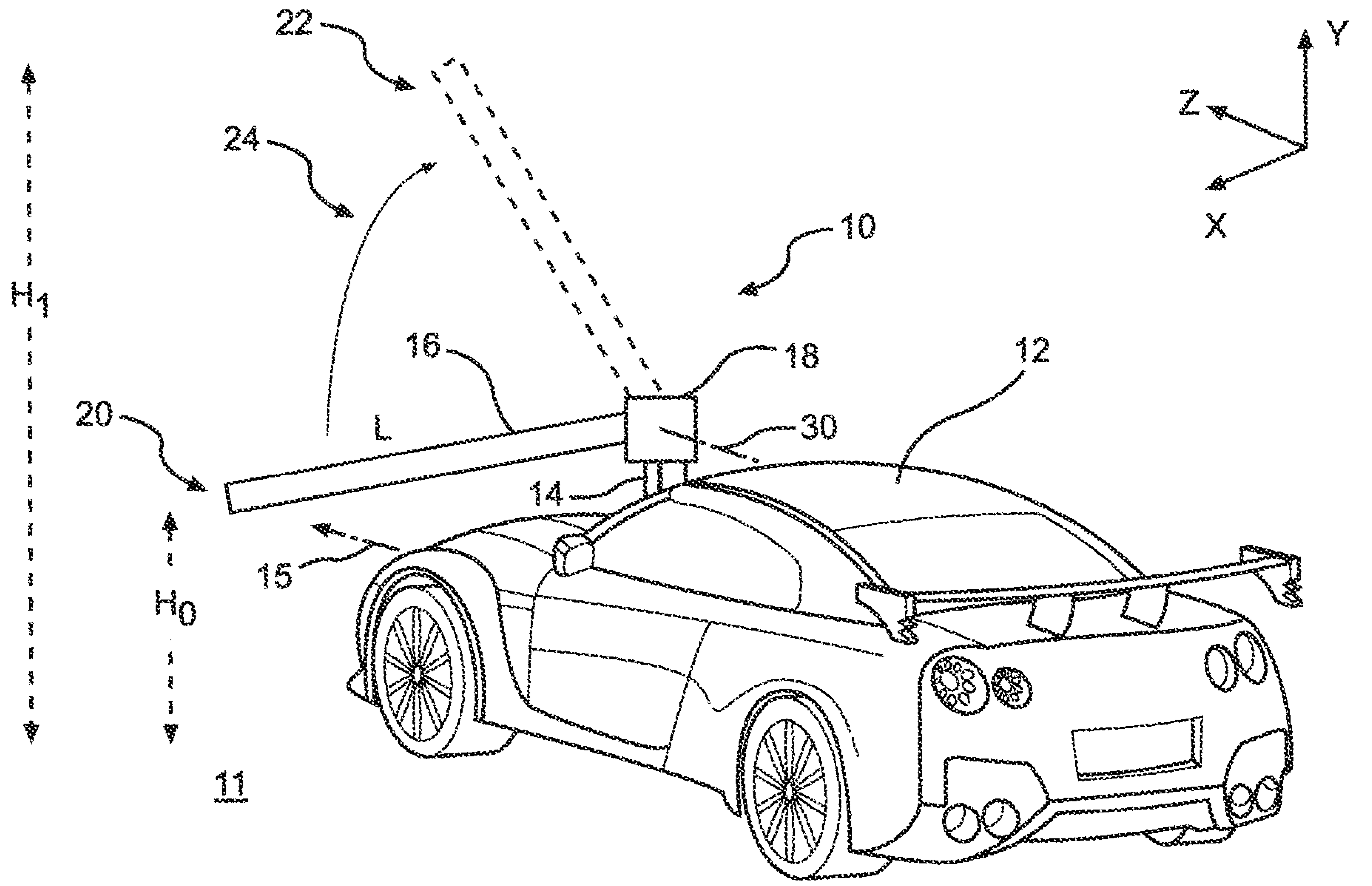


FIG. 1
(PRIOR ART)

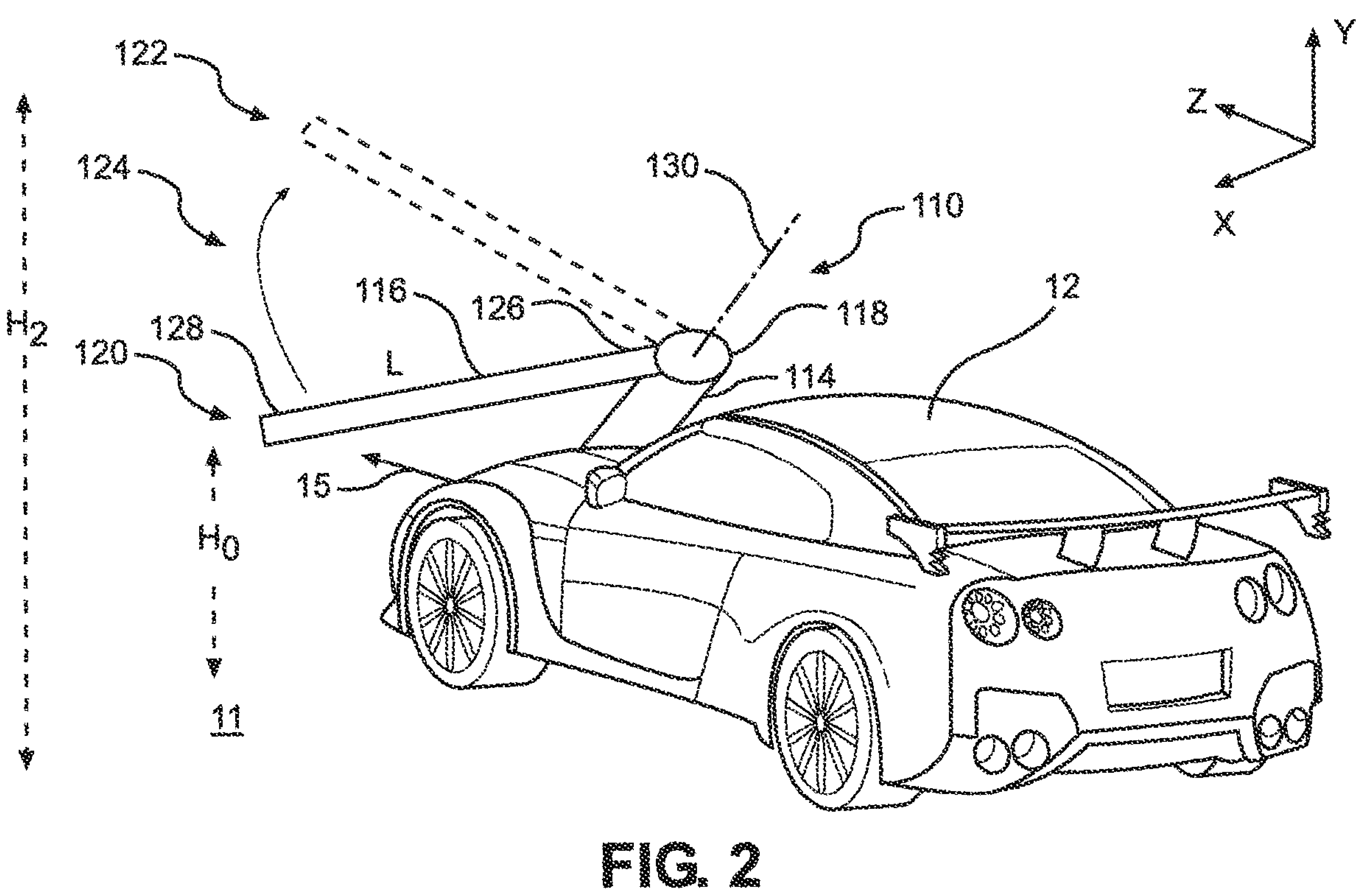


FIG. 2

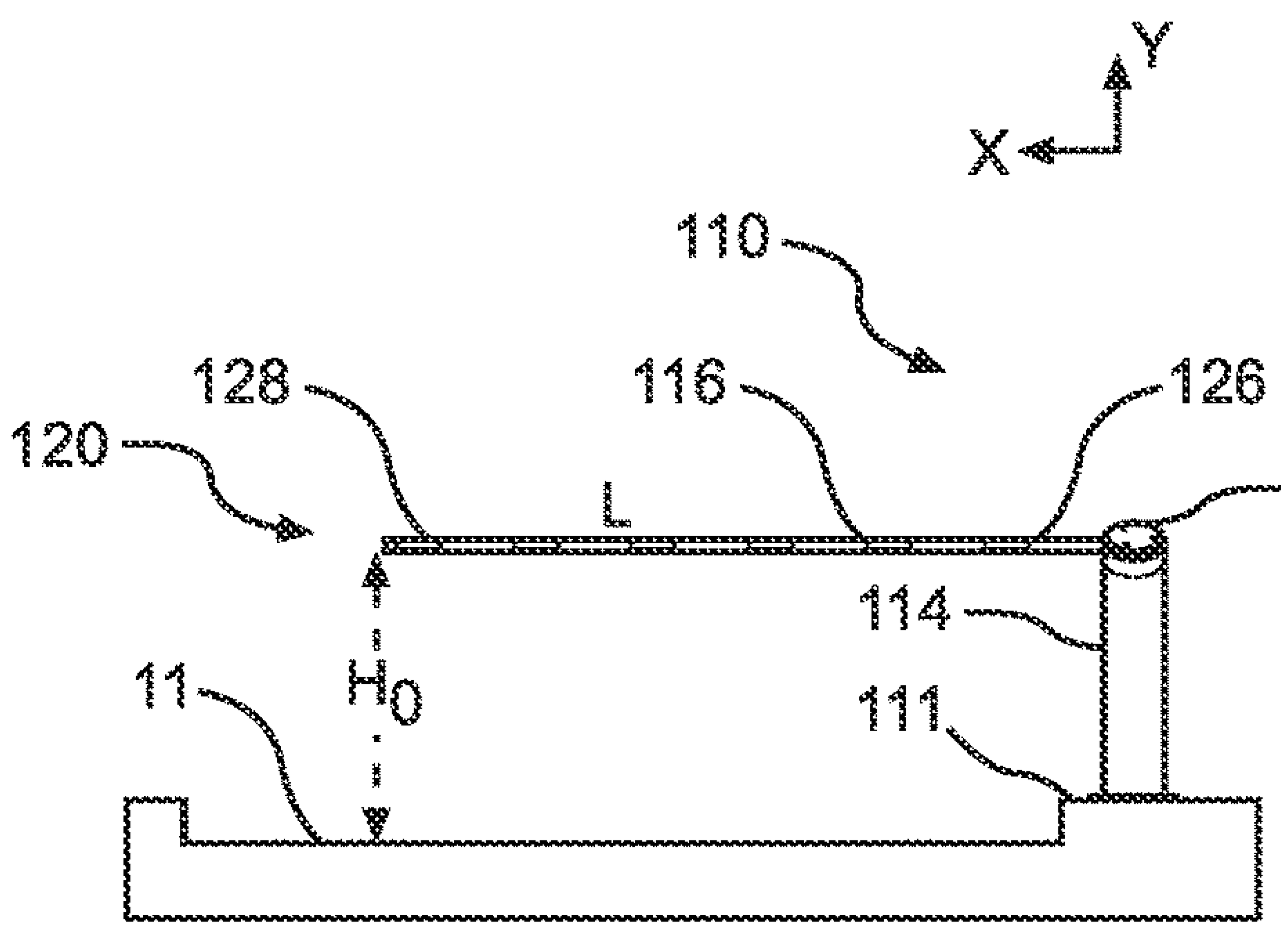


FIG. 3

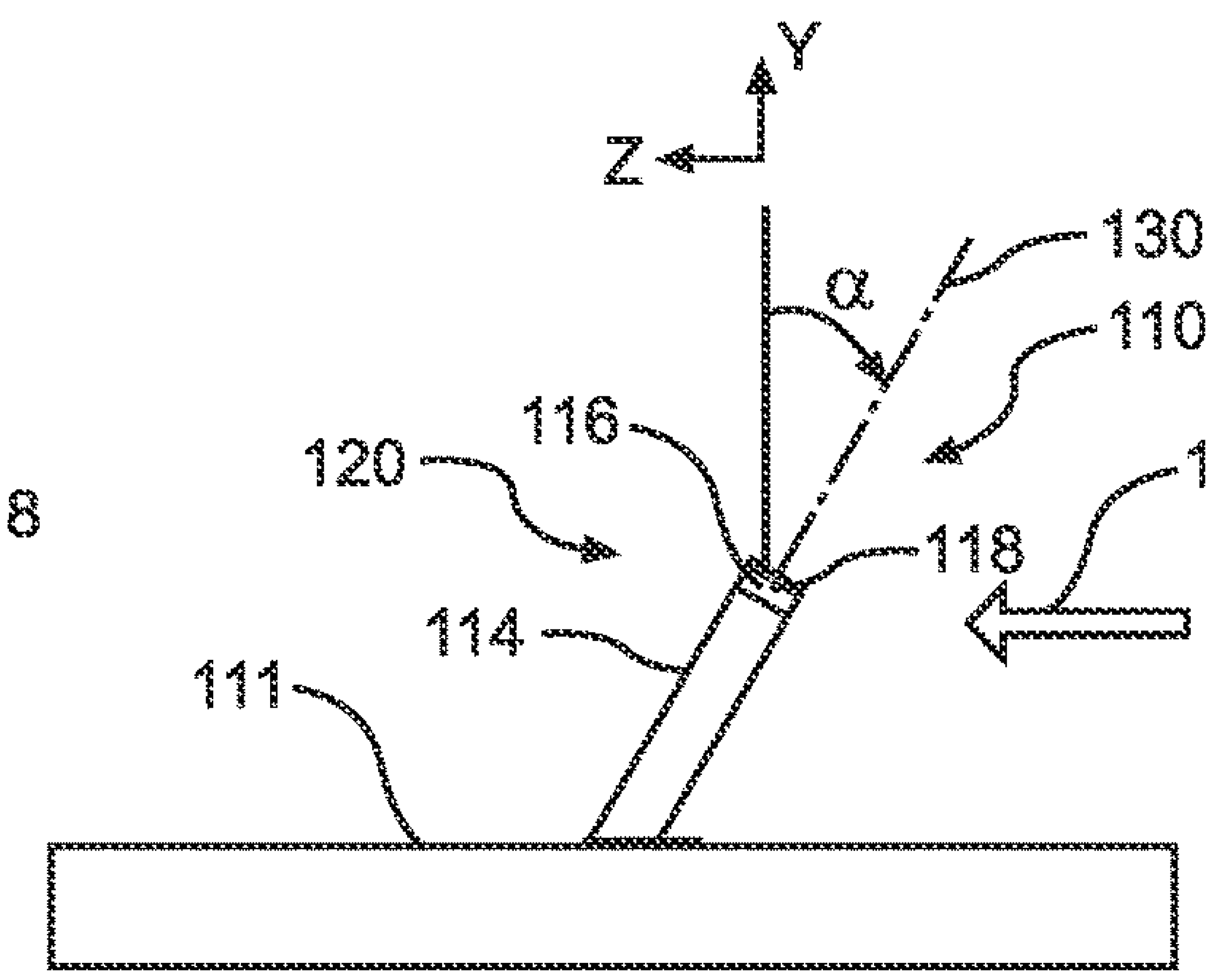


FIG. 4

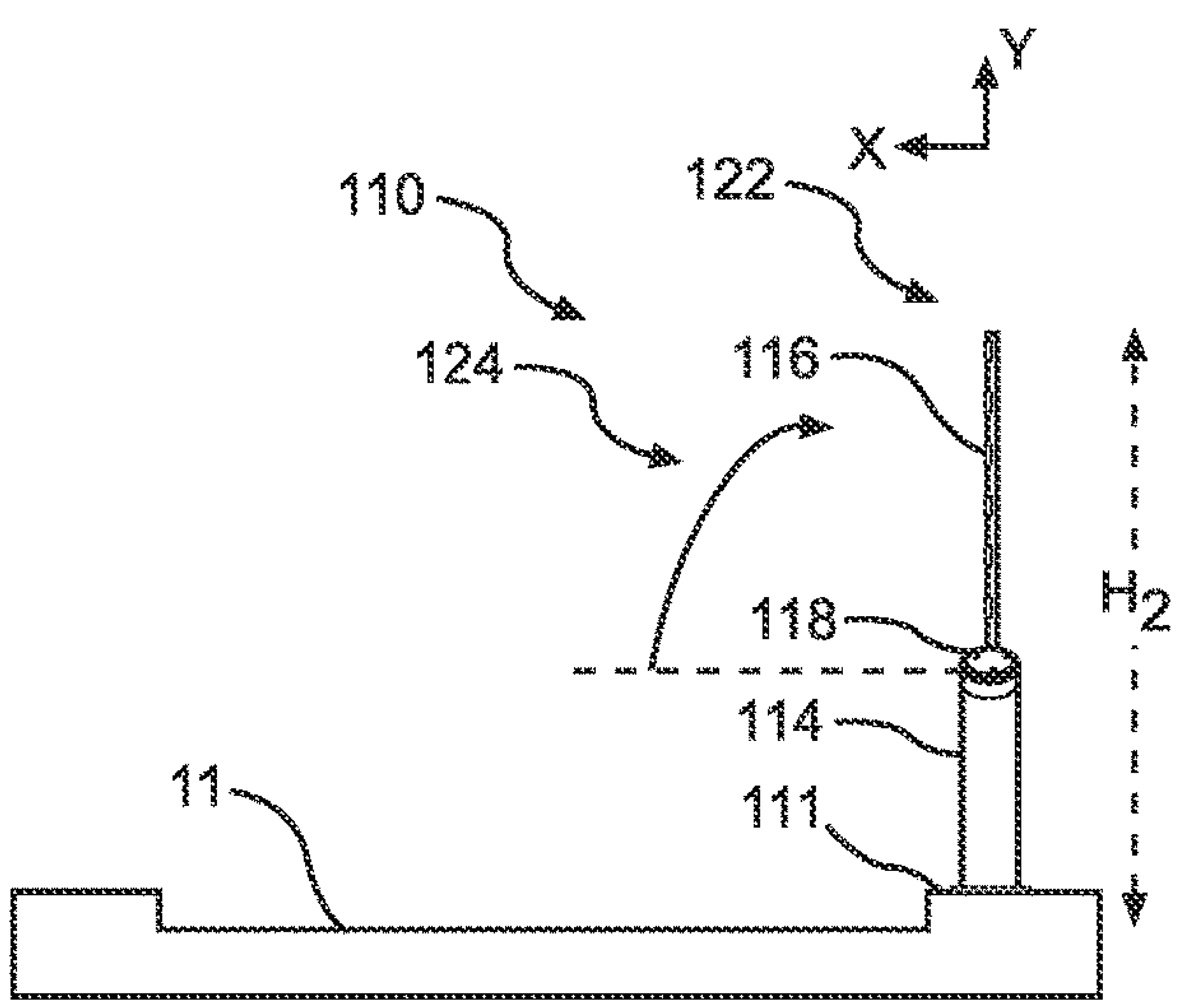


FIG. 5

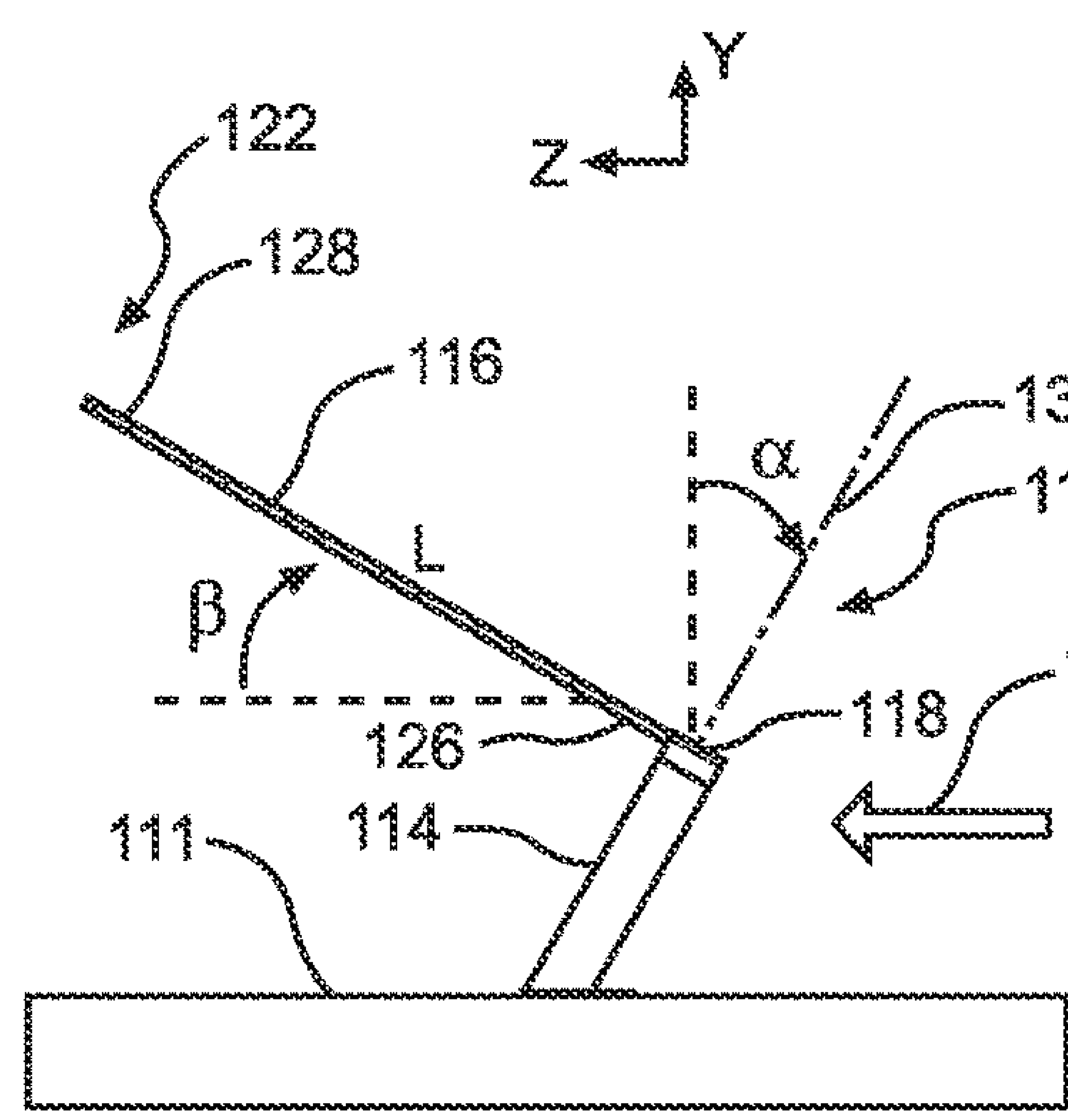


FIG. 6

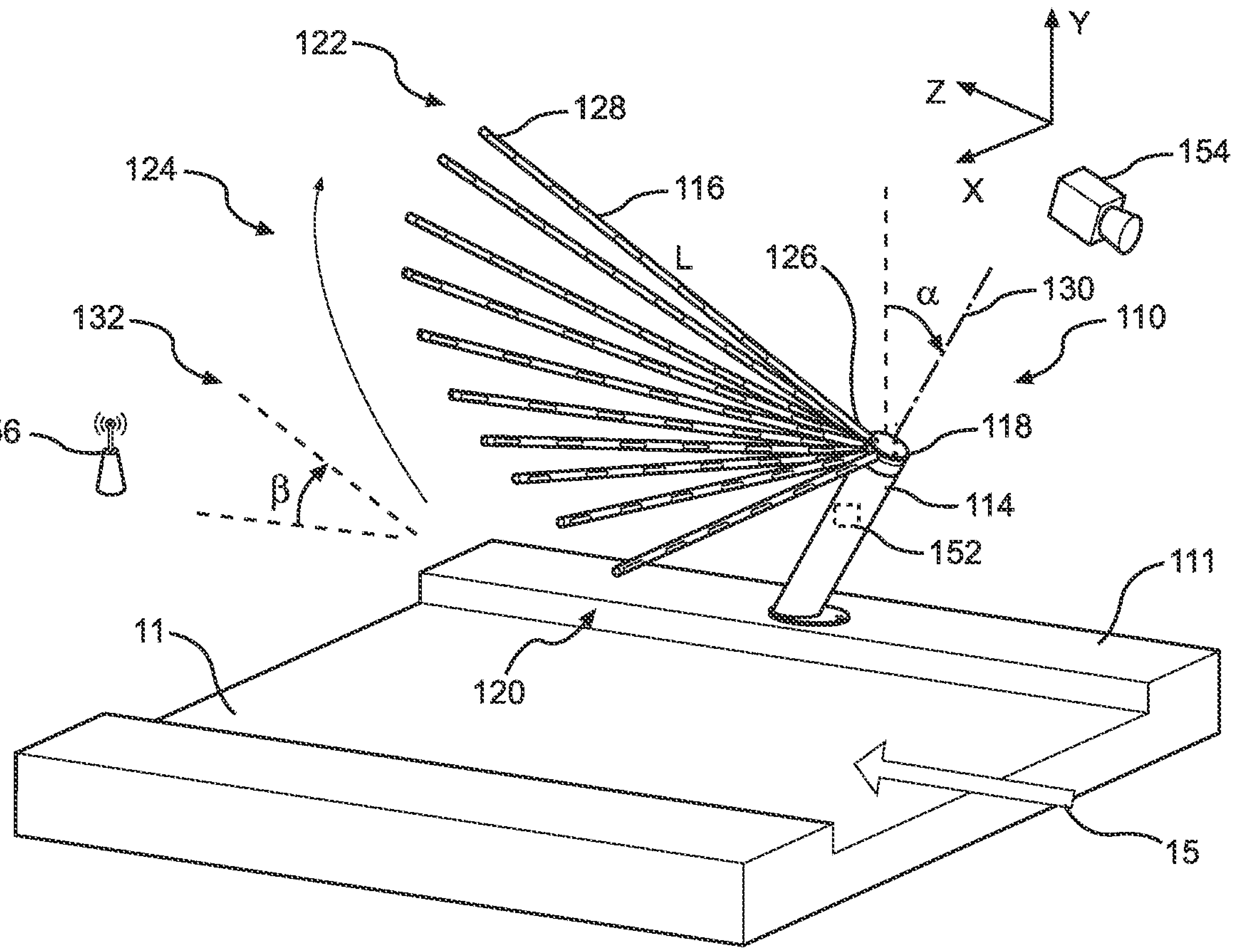

122
128
124
116
Y
Z
X
154
L
126
α
130
110
132
156
118
β
114
152
111
11
120
15

FIG. 7

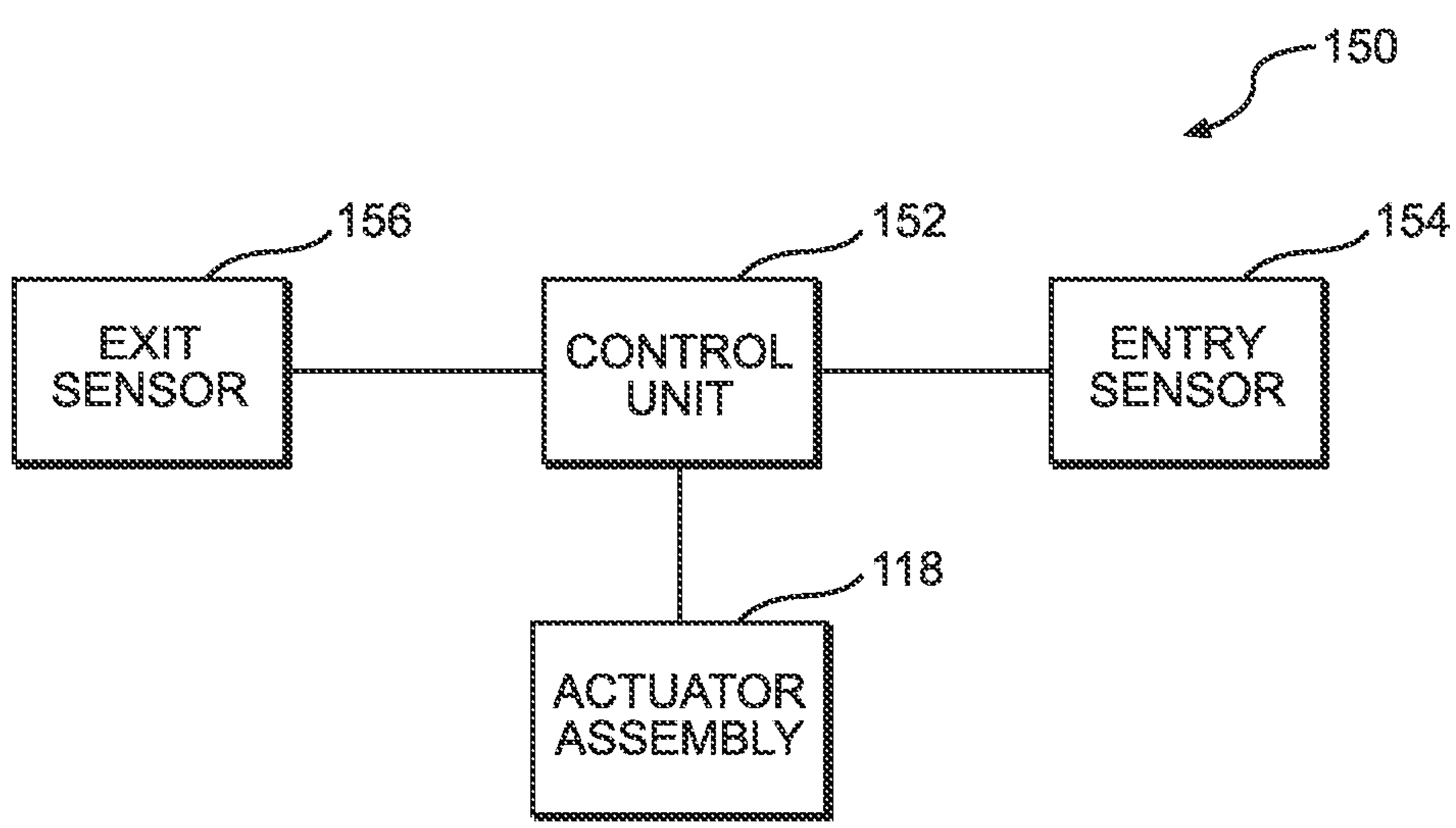

150
156
152
154
EXIT SENSOR
CONTROL UNIT
ENTRY SENSOR
118
ACTUATOR ASSEMBLY

FIG. 8

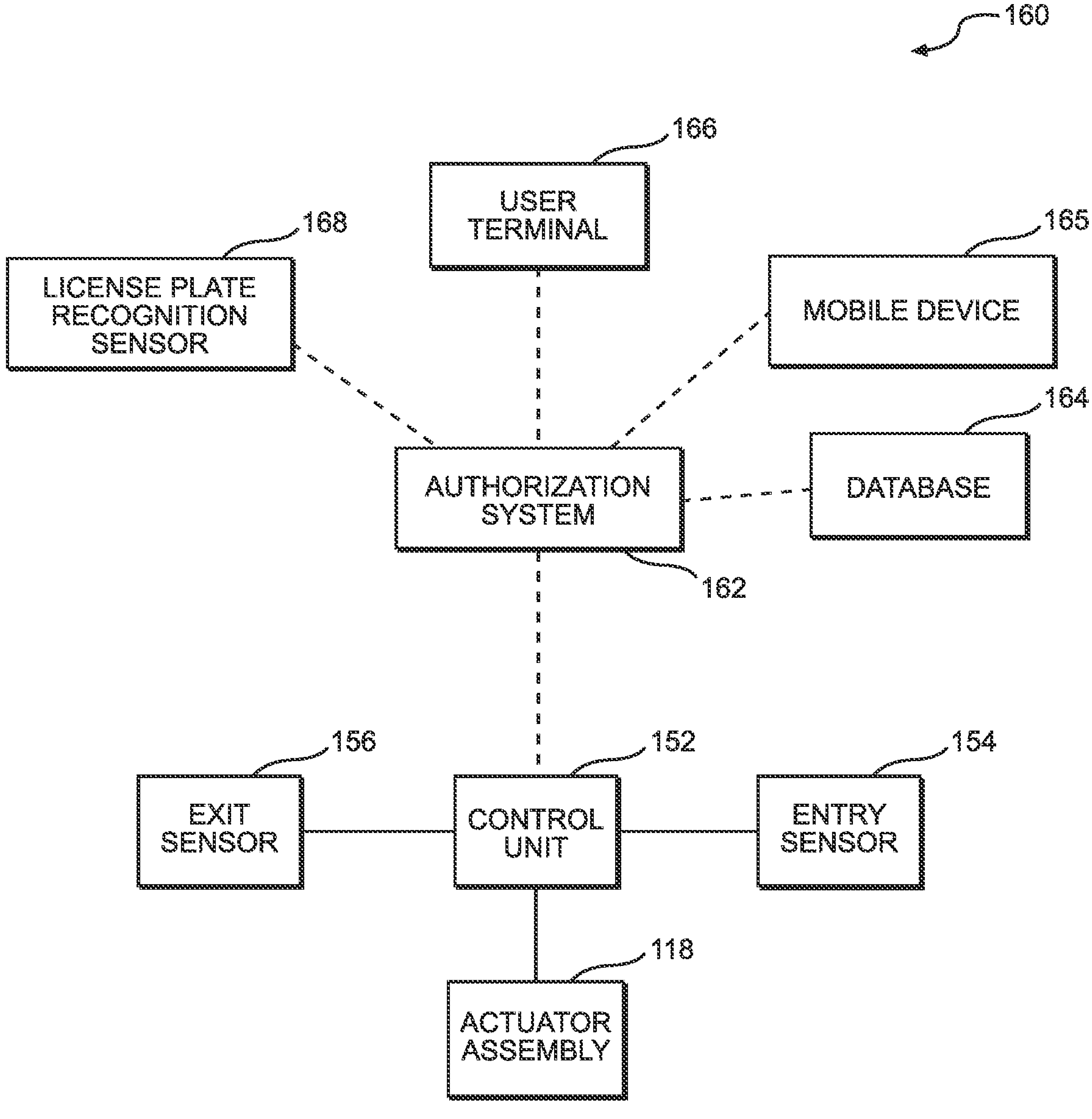

160
166
USER TERMINAL
168
LICENSE PLATE RECOGNITION SENSOR
165
MOBILE DEVICE
164
DATABASE
AUTHORIZATION SYSTEM
162
156
152
154
EXIT SENSOR
CONTROL UNIT
ENTRY SENSOR
118
ACTUATOR ASSEMBLY

FIG. 9

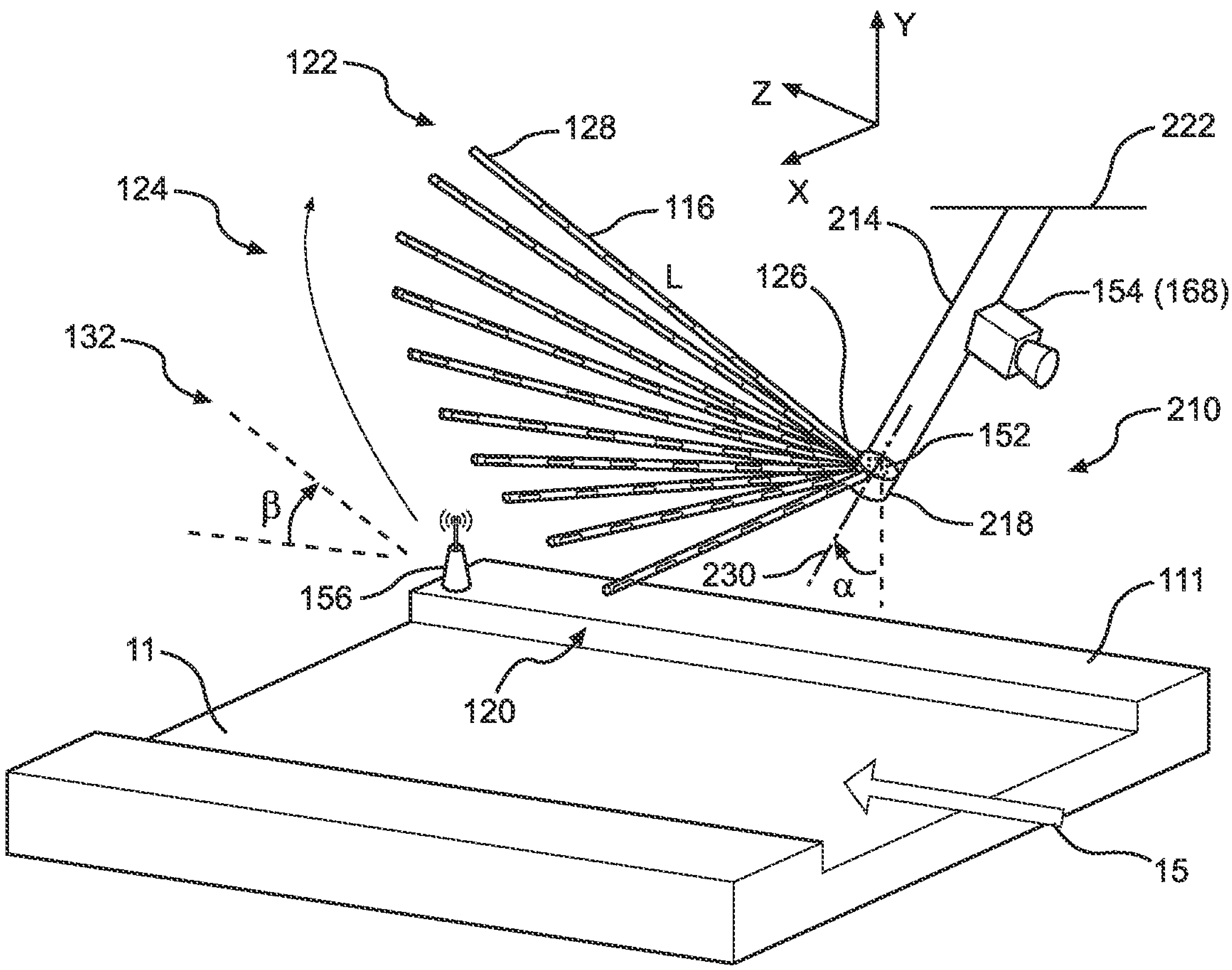

122
128
124
116
L
132
β
126
Y
Z
X
222
214
154 (168)
210
152
218
230
α
156
111
11
120
15

FIG. 10

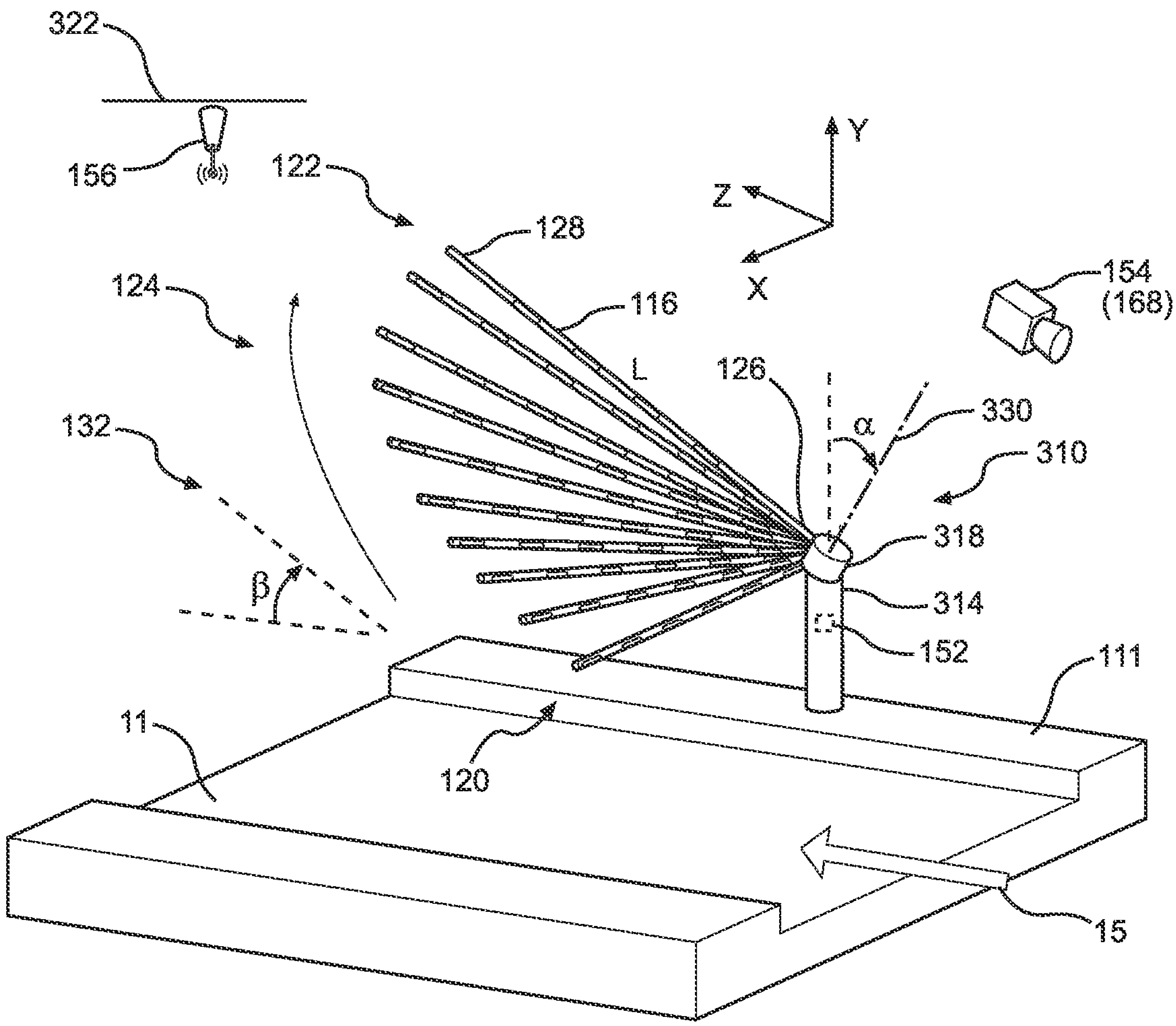
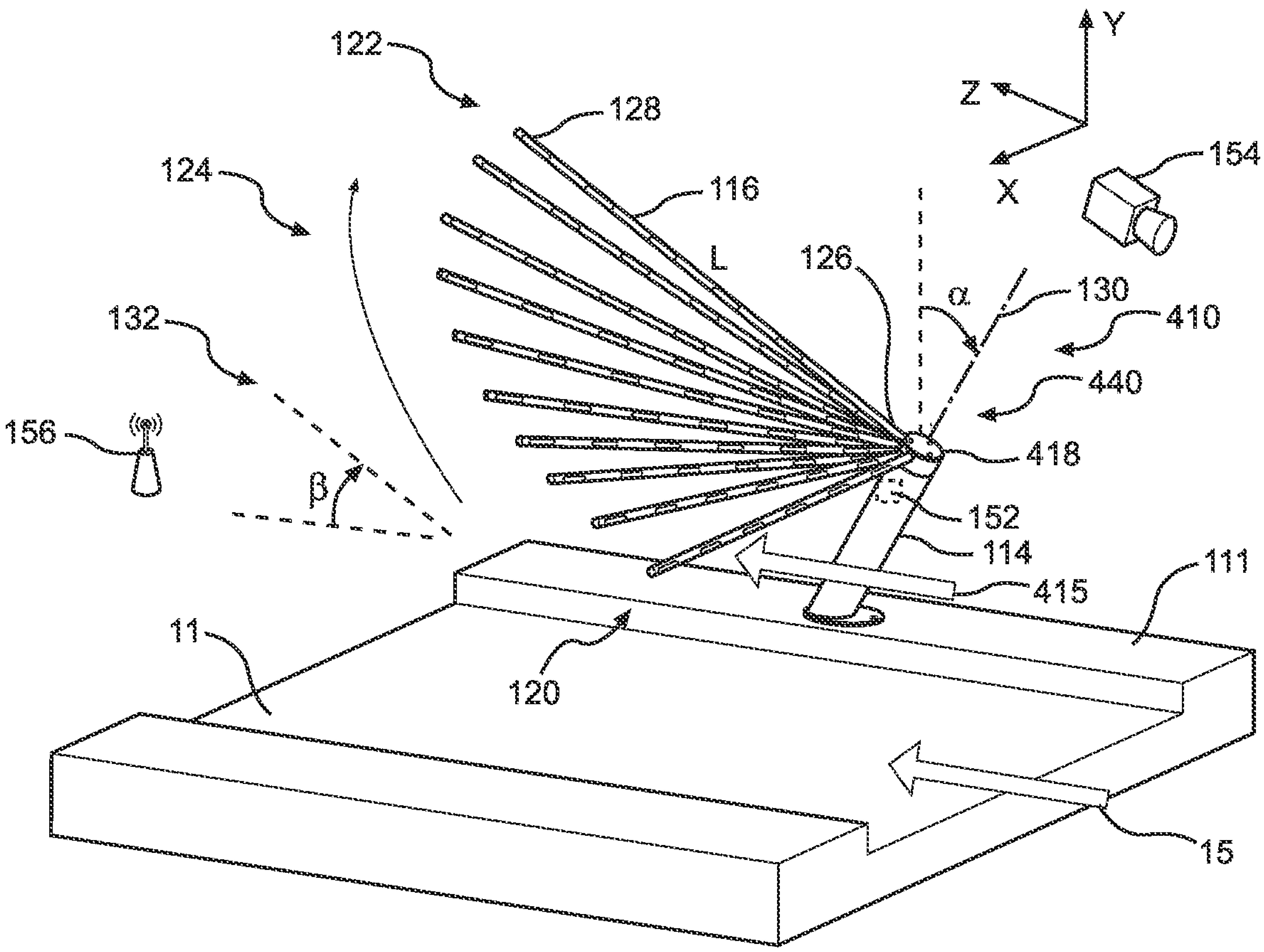

322
156
122
128
116
124
L
126
Y
Z
X
154
(168)
330
α
310
132
318
β
314
152
111
11
120
15

FIG. 11



122
128
124
116
L
Y
Z
X
154
126
α
130
410
132
440
156
418
β
152
114
415
111
11
120
15

FIG. 12

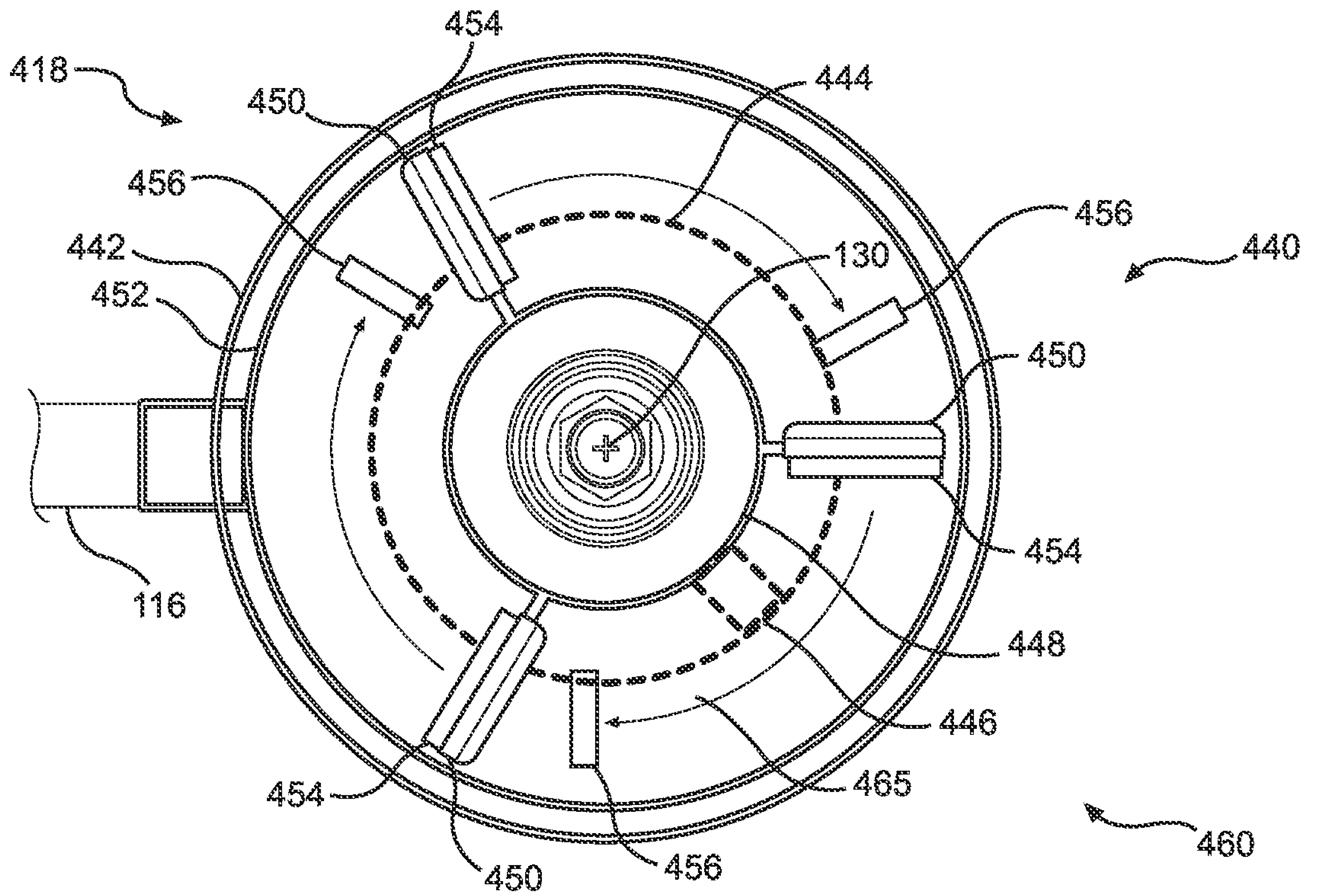
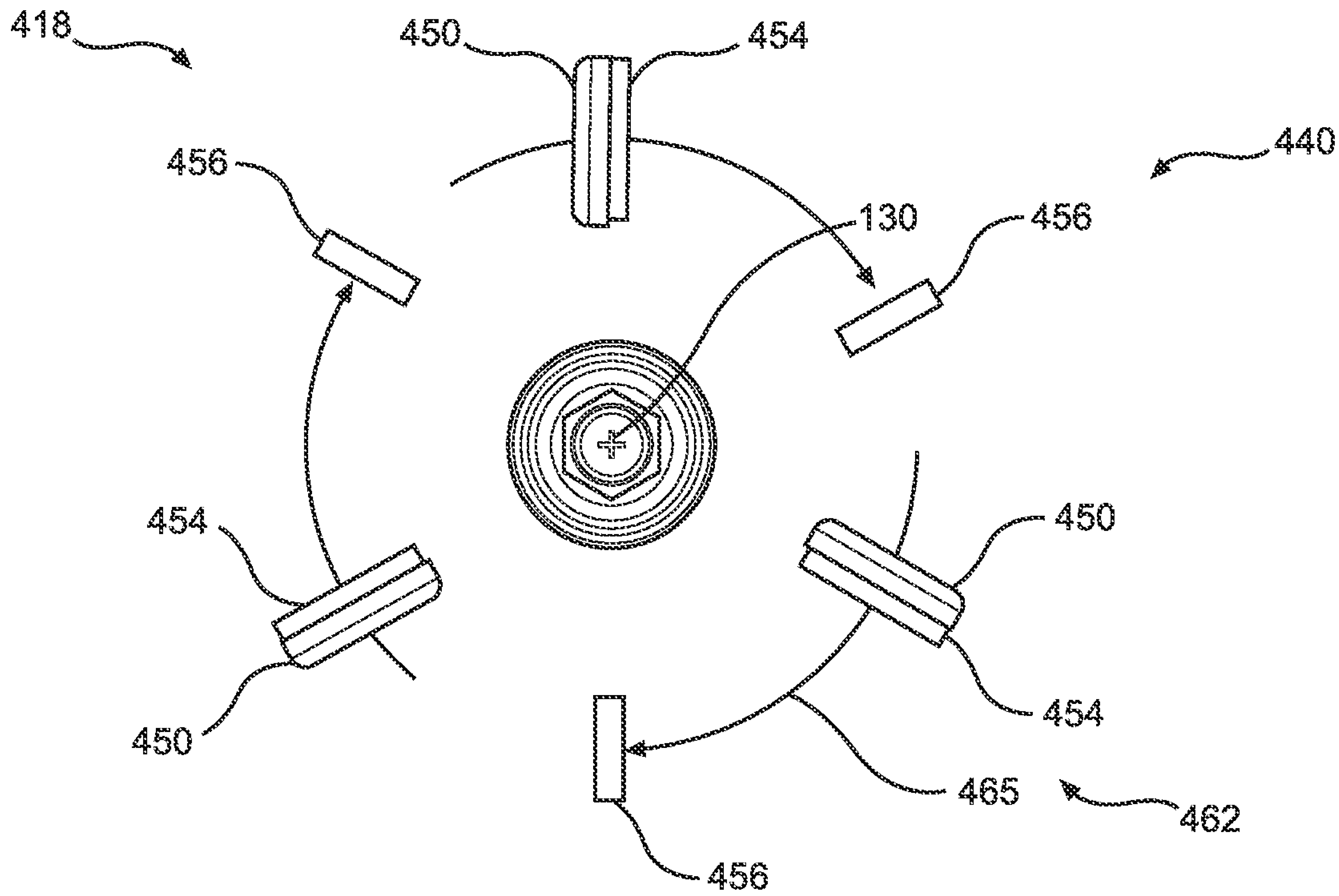

454
418
450
444
456
456
440
442
130
452
450
116
454
448
446
465
454
460
450
456

FIG. 13


418
450
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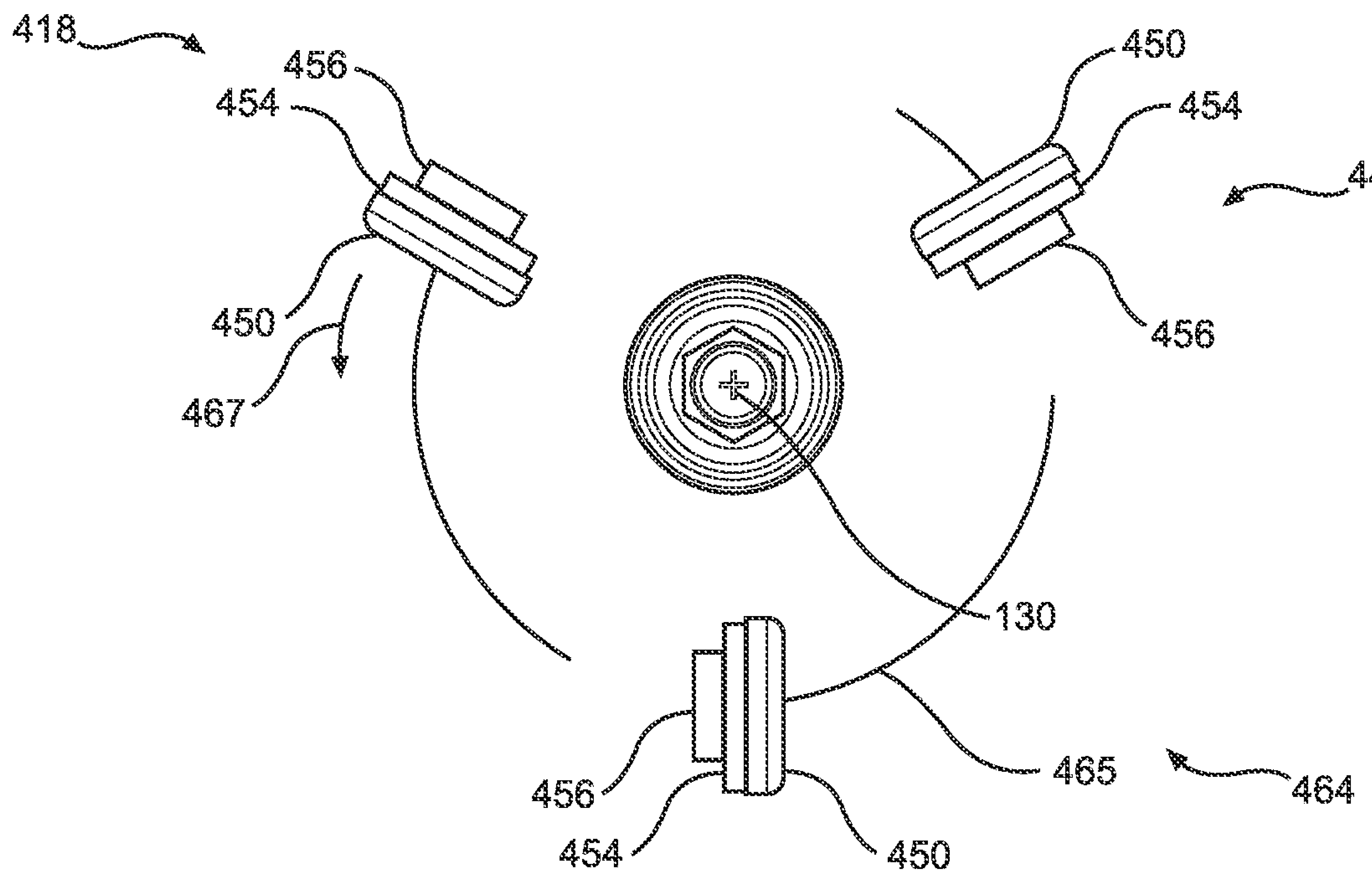
440
456
130
456
454
450
450
454
465
462
456

FIG. 14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440
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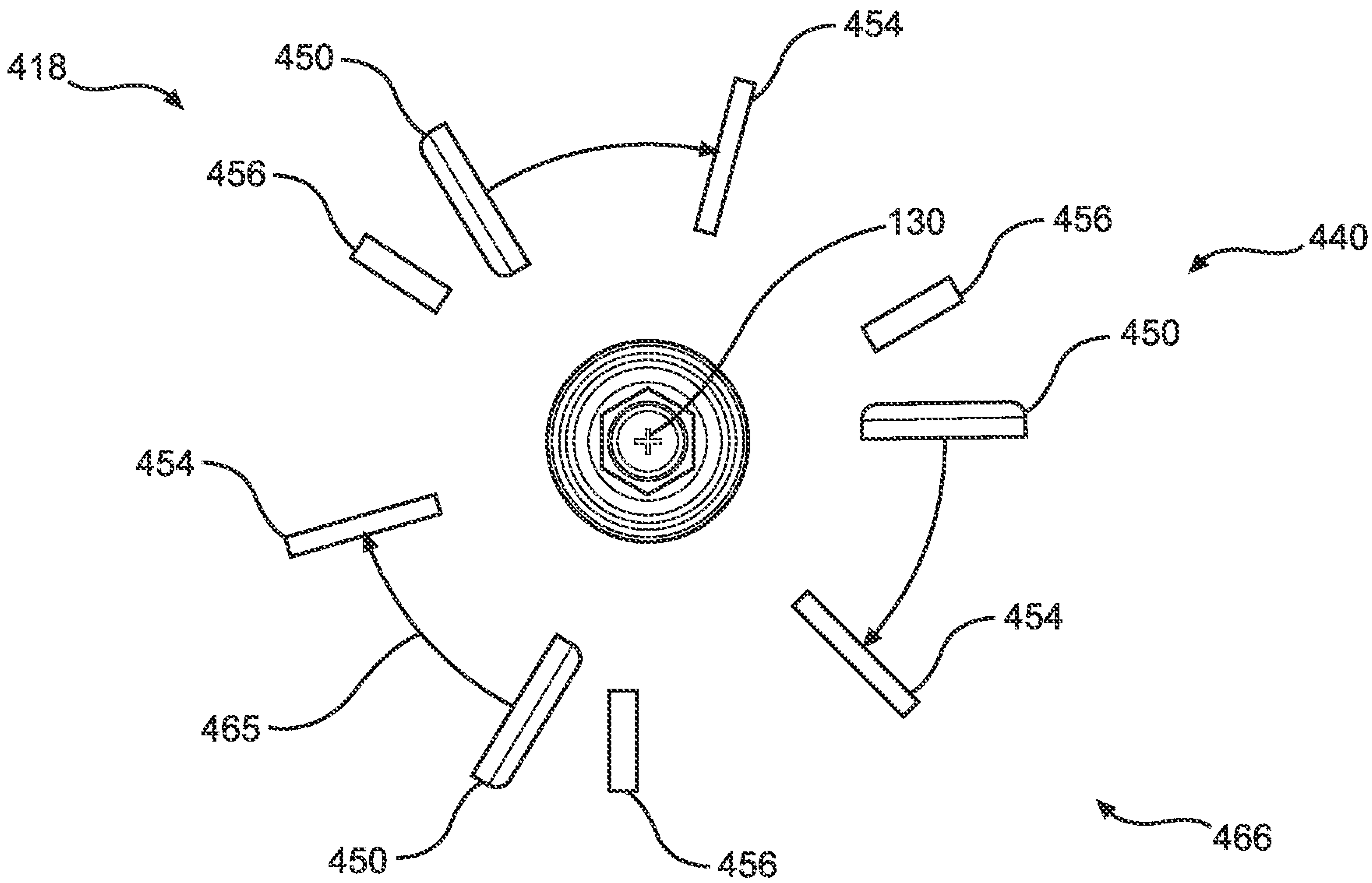
467
130
465
464
456
454
450

FIG. 15


418
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456
130
456
440
450
454
454
465
450
456
466

FIG. 16

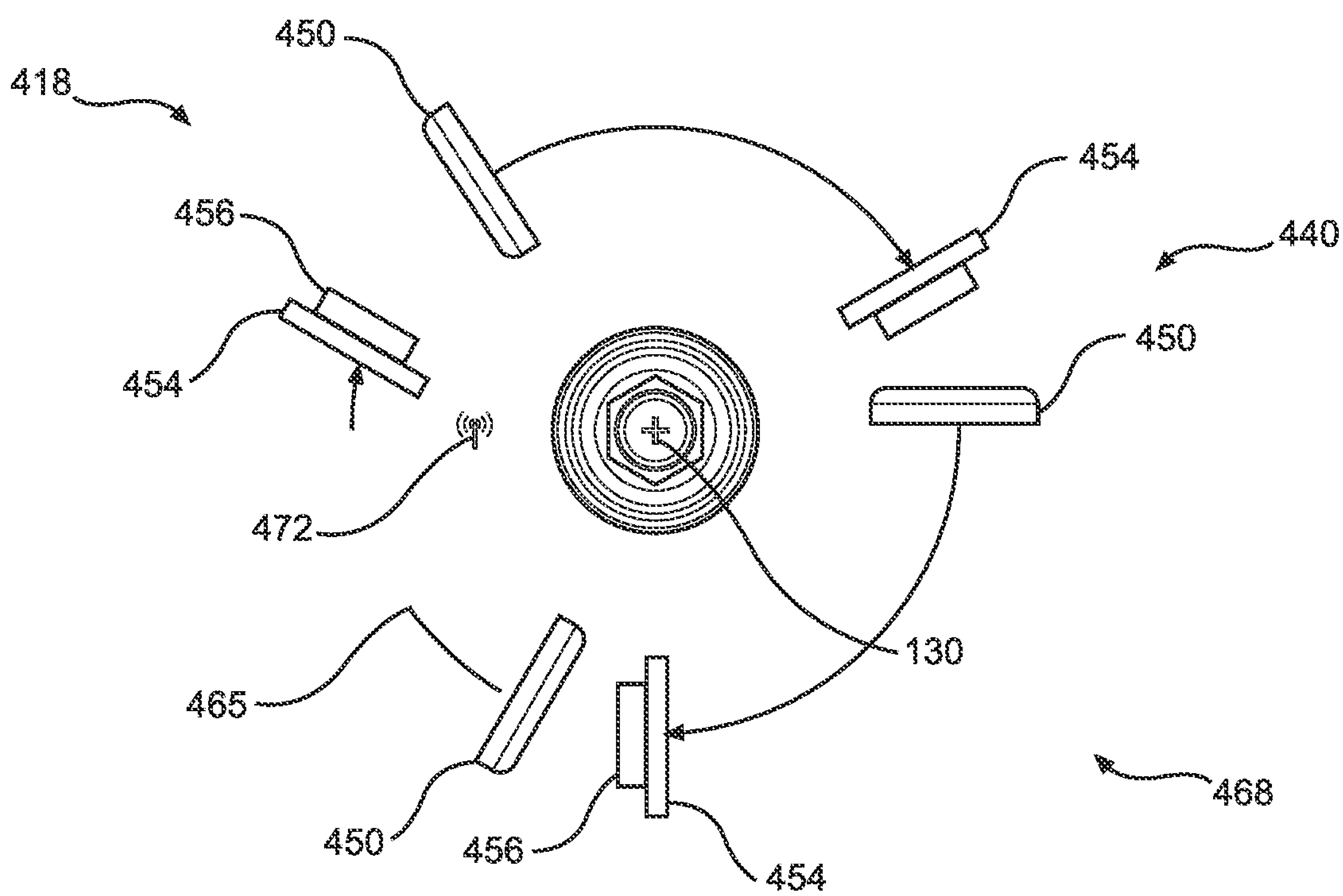
450
418
454
456
440
450
454
472
130
465
450
456
454
468

FIG. 17

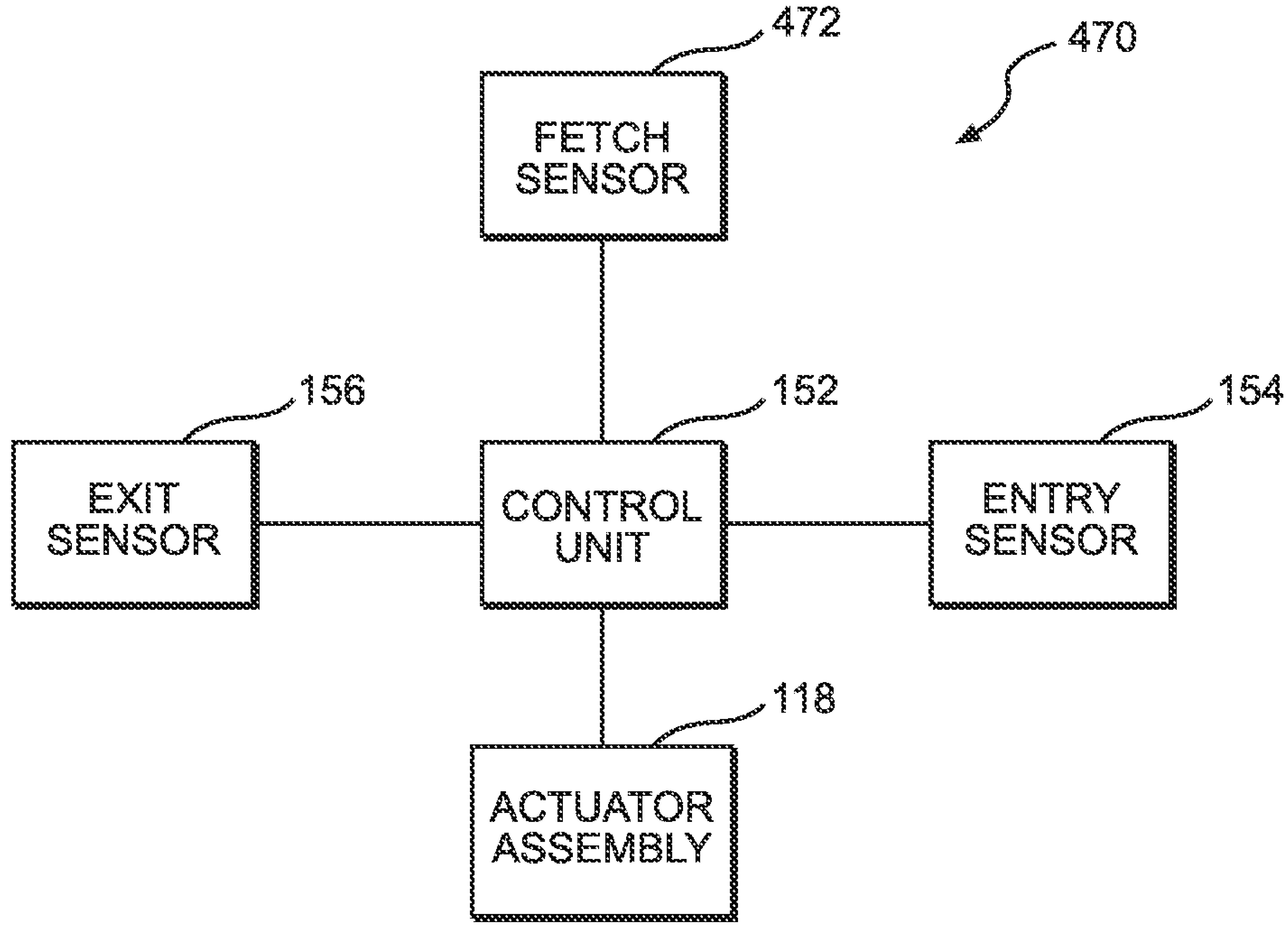
472
470
FETCH SENSOR
156
152
154
EXIT SENSOR
CONTROL UNIT
ENTRY SENSOR
118
ACTUATOR ASSEMBLY

FIG. 18

VEHICLE BARRIER GATE SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

Not applicable to this application.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable to this application.

BACKGROUND

The described example embodiments in general relate to vehicle barrier gate systems which are positioned above a roadway and which selectively allow (or prevent) vehicles to pass. Vehicle barrier gates are commonly used to control ingress and egress to or from various parking areas such as parking lots, parking ramps, and the like (e.g. parking lot gates). Various designs of vehicle barrier gates have been around for some time, and there are many design variations to overcome issues such as low ceiling heights or constricted spaces.

For example, FIG. **1** shows a prior art barrier system **10** for selectively allowing a vehicle **12** to travel on a travel surface **11** (e.g. roadway, parking garage, etc.). The barrier system **10** includes a main support **14** (e.g. post, bollard, etc.) projecting upwardly from the travel surface **11**, and a barrier arm **16** attached to the main support **14** by an actuator assembly **18**. The actuator assembly **18** is configured to pivot (or rotate) the barrier arm **16** between a lowered position **20** and a raised position **22**. The barrier arm **16** has a length L, and as the actuator assembly **18** rotates the barrier arm **16** about a rotation axis **30**, the barrier arm **16** moves from the lowered position **20** through an arc of rotation **24** to the raised position **22**.

More specifically, in the lowered position **20**, the barrier arm **16** extends substantially horizontally across a travel path **15** of the vehicle **12**, with a distal end of the barrier arm **16** being an initial height H_0 above the travel surface **11**. In the raised position **22**, the barrier arm **16** is moved out of the travel path **15** of the vehicle **12** by the actuator assembly **18** to allow passage of the vehicle **12** along the travel path **15**, with the distal end of the barrier arm **16** being raised to a raised height H_1 above the travel surface **11**. As further shown in FIG. **1**, if a cartesian coordinate system is aligned such that the travel path **15** of the vehicle **12** is substantially along a z axis, the arc of rotation **24** defined by the movement of the barrier arm **16** lies within the x-y plane, which is substantially vertical with respect to the travel path **15**. After the vehicle **12** safely passes the barrier system **10** along the travel path **15**, the actuator assembly **18** lowers the barrier arm **16** through the arc of rotation **24**, returning the barrier arm **16** to the lowered position **20**.

Unfortunately, with at least some prior art barrier systems, the driving experience may be slowed due to poor visibility of the barrier arm **16**, which may be blocked from view by a front portion of the vehicle **12** when in the lowered position **20**, or may be blocked from view by a ceiling or other support structures (e.g. pillars) as the barrier arm **16** moves into the raised position **22**. In some cases, the driver must awkwardly visually monitor the raising of the barrier arm **16** until they are comfortable to pass through, also requiring height comparison with the vehicle **12**. Such mental exercises may add to a driver's burden, and may cause stress due to the possibility of hitting the barrier arm

16 if the vehicle **12** is moved forward along the travel path **15** too early, or due to the possibility that the barrier arm **16** may unexpectedly come down onto the vehicle **12** if not pulling through the barrier system **10** fast enough.

In addition, typical barrier arms **16** may become damaged upon collision with a vehicle **12**. This can lead to a period of inoperability, as well as time and expenses associated with repairing the barrier system **10** and obtaining compensation from the driver. Thus, although desirable results have been achieved using prior art barrier systems, there is room for improvement.

SUMMARY

Some of the various embodiments of the present disclosure relate to vehicle barrier systems that can selectively move a barrier arm between a first position that prevents a vehicle from passing along a travel path, or a second position that allows the vehicle to pass along the travel path, wherein the barrier arm moves through an arc of movement that extends both upwardly away from the travel path and laterally along the travel path in a direction away from the vehicle. It will be appreciated that because the barrier arm is moved both upwardly away from the travel path and laterally along the travel path in a direction away from the vehicle, an improved view of the movement of the barrier arm may be provided to a driver of the vehicle, while simultaneously "leading" the driver of the vehicle through the barrier system in a sweeping or leading movement by the barrier arm.

In further embodiments, a barrier system includes an actuator assembly that can selectively move a barrier arm between a first position that prevents a vehicle from passing along a travel path, or a second position that allows the vehicle to pass along the travel path, wherein the actuator assembly includes a breakaway assembly coupled to the barrier arm. The breakaway assembly may include one or more drive magnets that are magnetically coupled to one or more magnetically-attractive elements, the one or more drive magnets being configured to remain magnetically engaged to the one or more magnetically-attractive elements as the actuator assembly is actuated to move the barrier arm between the first position to the second position. In the event that an abnormal force applied to the barrier arm exceeds a predetermined threshold, however, the one or more drive magnets disengage from the one or more magnetically-attractive elements to prevent damage to the barrier system.

There has thus been outlined, rather broadly, some of the embodiments of the present disclosure in order that the detailed description thereof may be better understood, and in order that the present contribution to the art may be better appreciated. There are additional embodiments that will be described hereinafter and that will form the subject matter of the claims appended hereto. In this respect, before explaining at least one embodiment in detail, it is to be understood that the various embodiments are not limited in its application to the details of construction or to the arrangements of the components set forth in the following description or illustrated in the drawings. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of the description and should not be regarded as limiting.

To better understand the nature and advantages of the present disclosure, reference should be made to the following description and the accompanying figures. It is to be understood, however, that each of the figures is provided for the purpose of illustration only and is not intended as a definition of the limits of the scope of the present disclosure. Also, as a general rule, and unless it is evidence to the contrary from the description, where elements in different figures use identical reference numbers, the elements are generally either identical or at least similar in function or purpose.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a vehicle barrier system in accordance with the prior art.

FIG. **2** is a perspective view of a vehicle barrier system in accordance with an example embodiment.

FIG. **3** is a front elevational view of the vehicle barrier system of FIG. **2** in a lowered position as viewed along a z axis in accordance with an example embodiment.

FIG. **4** is a side elevational view of the vehicle barrier system of FIG. **2** in the lowered position as viewed along a negative x axis in accordance with an example embodiment.

FIG. **5** is a front elevational view of the vehicle barrier system of FIG. **2** in a raised position as viewed along the z axis in accordance with an example embodiment.

FIG. **6** is a side elevational view of the vehicle barrier system of FIG. **2** in the raised position as viewed along the negative x axis in accordance with an example embodiment.

FIG. **7** is another perspective view of the vehicle barrier system of FIG. **2** with the barrier arm in a series of positions from the lowered position to the raised position in accordance with an example embodiment.

FIG. **8** is a schematic diagram of a control system of the vehicle barrier system of FIG. **7** in accordance with an example embodiment.

FIG. **9** is a schematic diagram of a control system of the vehicle barrier system of FIG. **7** in accordance with another example embodiment.

FIG. **10** is a perspective view of a vehicle barrier system having a vertical support structure in accordance with another example embodiment.

FIG. **11** is a perspective view of a vehicle barrier system having a support structure projecting downwardly from a ceiling in accordance with another example embodiment.

FIG. **12** is a perspective view of a vehicle barrier system having a breakaway assembly in accordance with an example embodiment.

FIG. **13** is a partially cutaway view of an actuator assembly that includes a breakaway assembly viewed from above along an axis of rotation in accordance with an example embodiment.

FIG. **14** is a partially cutaway view of the actuator assembly and the breakaway assembly of FIG. **13** in a second position in accordance with an example embodiment.

FIG. **15** is a partially cutaway view of the actuator assembly and the breakaway assembly of FIG. **13** in a third position in accordance with an example embodiment.

FIG. **16** is a partially cutaway view of the actuator assembly and the breakaway assembly of FIG. **13** in a fourth position in accordance with an example embodiment.

FIG. **17** is a partially cutaway view of the actuator assembly and the breakaway assembly of FIG. **13** in a fifth position in accordance with an example embodiment.

FIG. **18** is a schematic diagram of a control system of the vehicle barrier system of FIG. **12** in accordance with an example embodiment.

DETAILED DESCRIPTION

A. Overview

Some of the various embodiments of the present disclosure relate to a vehicle barrier system configured to move the barrier arm between a lowered position and a raised position (and vice versa) in a novel way that provides an improved driving experience to the driver of the vehicle. More specifically, in at least some embodiments, a barrier system in accordance with the present disclosure may advantageously improve the visibility of the barrier arm to a driver of a vehicle during movement of the barrier arm between the lowered position and the raised position, reducing distraction and possible stress on the driver as the driver operates the vehicle through the vehicle barrier system.

For example, in some of the various embodiments of the present disclosure, a barrier system may include a barrier arm **116** having a proximal end **126** and a distal end **128** opposite from the proximal end **128**, and a main support **114** configured to attach to a support surface **111**. An actuator assembly **118** is coupled between the main support **114** and the proximal end **126** of the barrier arm **116**. The actuator assembly **128** is configured to selectively move the barrier arm **116** between a lowered position **120** wherein the barrier arm **116** is positioned at least partially in a travel path **15** of a vehicle **12** to prevent passage of the vehicle **12** along the travel path **15**, and a raised position **122** wherein the barrier arm **116** is positioned out of the travel path **15** to allow passage of the vehicle **12** along the travel path **15**, the actuator assembly **118** being configured to move the distal end **128** of the barrier arm **116** from the lowered position **120** to the raised position **122** such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124** that extends both upwardly away from the travel path **15** and laterally along the travel path **15** in a direction away from the vehicle **12**.

In addition, in some embodiments, the main support **114** comprises a bollard **114** that projects upwardly from the support surface **111** at a tilt angle α (with respect to vertical) such that the bollard **114** is tilted in a direction opposite from the travel path **12**. In such embodiments, the actuator assembly **218** may be configured to move the barrier arm **116** such that the arc of movement **124** lies within a movement plane **132**, the movement plane **132** being sloped upwardly with respect to the travel path **15**.

In further embodiments, the actuator assembly **418** includes a drive bracket **448** rotatably coupled to the main support **114** and an arm bracket **452** coupled to the proximal end **126** of the barrier arm **116**, the drive bracket **448** being coupled to the arm bracket **452** by a breakaway assembly **440**. The drive bracket **448** and the arm bracket **452** are rotatable about an axis of rotation **130** as the barrier arm **116** is moved from the lowered position **120** to the raised position **122**. In some embodiments, the breakaway assembly **440** includes at least one magnetically-attractive element **454** coupled to the arm bracket **452** and radially spaced apart from the axis of rotation **130**, and at least one drive magnet **450** coupled to the drive bracket **446** and radially spaced apart from the axis of rotation **130** and aligned with the at least one magnetically-attractive element **454** when the drive bracket **446** is engaged with the arm bracket **452**. The at least one drive magnet **450** remains magnetically engaged to the at least one magnetically-attractive element **454** as the actuator assembly **418** is actuated to move the barrier arm **116** between the lowered position **120** to the raised position **122**, and disengages from the at least one magnetically-attractive element **454** in response to an abnormal force **415** applied to the barrier arm **116** to disengage the drive bracket **448** from the arm bracket **452** when the abnormal force **415** exceeds a pre-determined threshold.

These and other aspects of various embodiments of barrier systems in accordance with the present disclosure are described in further detail below with reference to the accompanying figures.

B. Exemplary Embodiments

FIGS. **2-9** show a barrier system **110** for selectively allowing a vehicle **12** to travel on a travel surface **11** (e.g. roadway, parking garage, etc.) in accordance with the present disclosure. In some embodiments, the barrier system **110** includes a main support **114** (e.g. post, bollard, etc.) projecting upwardly away from the travel surface **11**, and a barrier arm **116** having a proximal end **126** and a distal end **128**. It may be noted that in the embodiment shown in FIGS. **2-9**, the main support **114** is tilted with respect to vertical by a tilt angle α. The barrier arm **116** is attached to the main support **114** by an actuator assembly **118**. The actuator assembly **118** is coupled to the proximal end **126** of the barrier arm **116**, and is configured to move the barrier arm **116** between a lowered position **120** and a raised position **122**. More specifically, in some embodiments, the barrier arm **116** has a length L, and the actuator assembly **118** rotates the barrier arm **116** about a rotation axis **130**, moving the barrier arm **116** from the lowered position **120** to the raised position **122** such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124**.

More specifically, as best shown in FIGS. **2** and **3**, in the lowered position **120**, the barrier arm **116** extends substantially horizontally across a travel path **15** of the vehicle **12**, with the distal end **128** of the barrier arm **116** being an initial height H_0 above the travel surface **11**. In the raised position **122** (FIGS. **2** and **5-6**), the barrier arm **116** is moved out of the travel path **15** of the vehicle **12** by the actuator assembly **118** to allow passage of the vehicle **12** along the travel path **15**, with the distal end **128** of the barrier arm **116** being raised to a raised height H_2 above the travel surface **11**.

In some embodiments, as best shown in FIG. **6**, the actuator assembly **118** is configured to rotate the barrier arm **116** into the raised position **122** such that the barrier arm **116** extends at a slope angle β with respect to the travel surface **11** (or with respect to the travel path **15** of the vehicle **12**). Moreover, in some embodiments, the slope angle β of the barrier arm **116** may be equal to (or approximately equal to) the tilt angle α of the main support **114**. As shown in FIG. **5**, in the raised position **122**, the distal end **128** extends to the raised height H_2 above the travel surface **11**.

As further shown in FIGS. **2-7**, in some embodiments, if a cartesian coordinate system is aligned such that the travel path **15** of the vehicle **12** is substantially along a z axis, the arc of rotation **124** defined by the movement of the distal end **128** of the barrier arm **116** lies within a plane of movement that is sloped upwardly (i.e. non-vertically) with respect to the travel path **15** of the vehicle (which lies within an x-z plane of the cartesian coordinate system). In other words, the actuator assembly **118** is configured to move the barrier arm **116** from the lowered position **120** to the raised position **122** such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124** that extends both upwardly away from the travel path **15** and laterally along the travel path **15** in a direction away from the vehicle **12**. After the vehicle **12** safely passes the barrier system **10** along the travel path **15**, the actuator assembly **118** lowers the barrier arm **116** through the arc of rotation **124**, returning the barrier arm **116** to the lowered position **120**.

It will be appreciated that because the barrier arm **116** is moved by the actuator assembly **118** both upwardly away from the travel path **15** and laterally along the travel path **15** in a direction away from the vehicle **12**, the movement of the barrier arm **116** may be maintained within view of the driver of the vehicle, while simultaneously "leading" the driver of the vehicle **12** through the barrier system **110** in a sweeping or leading movement by the barrier arm **116**. In some embodiments, the barrier arm **116** still appears as a standard barrier arm **16** in accordance with the prior art (see FIG. **1**) as the vehicle **12** approaches, maintain existing familiarity. Accordingly, the barrier system **110** in accordance with the teachings of the present disclosure may advantageously provide improved visibility, and an overall improved driving experience, to the driver of the vehicle **12**.

In addition, because the barrier arm **116** extends upwardly by the slope angle β when moved to the raised position **122**, for a given length L, the raised height H_2 above the travel surface **11** is substantially less than the raised height H_1 of the conventional barrier arm **16** (for the same length L) of the prior art barrier system **10** (see FIG. **1**). Therefore, with an appropriate slope angle β, the barrier arm **116** having an appropriate length L that is suitable to obstruct movement of the vehicle **12** when placed in the lowered position **120**, will require considerably less height when moved into the raised position **122**, and can still be below a ceiling when moved into the raised position **122**. Accordingly, the barrier system **110** in accordance with the teachings of the present disclosure may advantageously provide improve fit or improved performance within covered or confined areas in comparison with conventional barrier systems.

a. Barrier Arm

As noted above, in at least some embodiments, the vehicle barrier system **110** includes a barrier arm **116**. In some implementations, the barrier arm **116** is an elongated bar or beam member that extends at least partially across the travel path **15** of the vehicle **12**. As shown in the accompanying figures, the barrier arm **116** may generally comprise an elongated member such as a pole, rod, post, beam, or the like, and may be a solid or hollow structure. In some embodiments, the barrier arm **116** is supported in a cantilevered configuration, extending outwardly from the main support **114**.

The barrier arm **116** may be constructed with a traditional method (e.g. wood, metal, etc.) or may include more advanced light weight materials, such as composite materials including carbon fiber-containing materials or fiber glass. A light weight material may have the benefit of reducing the structural strength required for the actuator assembly **118** and overall mounting (e.g. main support **114**), but is not essential.

It will be appreciated that the barrier arm **116** may be configured in a variety of suitable ways, and is not limited to the particular embodiments shown in the accompanying figures. In other embodiments, for example, the barrier arm **116** may include supports or other additional structures that assist in positioning and supporting the functionalities of the barrier arm **116**. More specifically, in some embodiments, the barrier arm **116** may include other structures, such as a gate or other framework, and may also include a sign (e.g. "Stop" sign), placard, light, reflector, or other visual indicators.

b. Main Support

In at least some embodiments, the vehicle barrier system **110** includes a main support **114** that supports the actuator assembly **118** and the barrier arm **116**. The main support **114** may be a pole, post, bollard, or other similar structure that projects upwardly away from a travel surface **11**. In some embodiments, as shown in FIGS. **4**-**7**, the main support **114** may be attached to a support surface **111** (e.g. curb, median, etc.) that is positioned proximate to the travel surface **11**, however, it will be appreciated that in other embodiments, the support surface **111** may simply be a portion of the travel surface **11**. In the embodiment shown in FIGS. **3**-**6**, the support surface **111** is parallel with, and slightly raised above, the travel surface **11**.

As best shown in FIGS. **4** and **6**, in some embodiments, the main support **114** is tilted by a tilt angle α. More specifically, the tilt angle α is the angle of the main support **114** with respect to a local normal to the travel surface **11** (which for a horizontal travel surface **11** is the vertical direction). The main support **114** projects away from the travel surface **11** in a non-normal (or non-vertical) direction, and tilts in a direction opposite to the travel path **15** of the vehicle **12** at the tilt angle α (with respect to normal). In some embodiments, the actuator assembly **118** is attached to the main support **114** and is configured such that the axis of rotation **130** extends along an axis of the main support **114**, and therefore, the axis of rotation **130** also tilts at the tilt angle α (FIGS. **4**, **6**, and **7**).

It will be appreciated that the main support **114** may be configured in a variety of suitable ways, and is not limited to the particular embodiments shown in the accompanying figures. For example, although the main support **114** is shown as being located on the right side of the travel path **15** of the vehicle **12**, in some embodiments, the main support **114** may be located on the left side of the travel path **15**. In addition, the main support **114** may be tilted in a forward direction along the travel path **15** (rather than in a direction opposite from the travel path **15** as shown in FIGS. **2**-**7**). In some other embodiments, the barrier system **110** may be wall-mounted such that the main support **116** projects outwardly from a nearby wall, or the barrier system **110** may even be ceiling-mounted (or other overhead support structure) such that the main support **116** projects downwardly from a ceiling (or other overhead support structure) disposed above the travel surface **11**.

c. Actuator Assembly

As noted above, the vehicle barrier system **110** includes an actuator assembly **118** coupled to the main support **114** and to the proximal end **126** of the barrier arm **116**. In some embodiments, the actuator assembly **118** is coupled to a top portion of the main support **114**, and is configured to selectively move the barrier arm **116** from the lowered position **120** to the raised position **122** such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124** that extends both upwardly away from the travel path **15** and laterally along the travel path **15** in a direction away from the vehicle **12**.

Generally, the actuator assembly **118** may be configured in a wide variety of suitable configurations using known components, including one or more of electrical motors, gears, bearings, linear actuators, drive belts, pulleys, solenoids, pistons, switches, transceivers, or other suitable components. In some embodiments, the actuator assembly **118** may generally be configured to selectively move the barrier arm **116** between the lowered position **120** and the raised position **122** (and vice versa) in response to one or more command signals from a control unit **152** of a control system **150**.

For example, FIG. **8** shows a schematic diagram of a control system **150** that may be used to selectively control the actuator assembly **118** of the vehicle barrier system **110** of FIGS. **2**-**7**. In at least some embodiments, a control unit **152** is operatively coupled to, and provides control signals to, the actuator assembly **118**. An entry sensor **154** may be operatively coupled to the control unit **152**, and may configured to detect an arrival of the vehicle **12** at the vehicle barrier system **110**, and may transmit a signal to the control unit **152** to indicate that the vehicle **12** has arrived. In some embodiments, the entry sensor **154** may be configured to detect whether the vehicle **12** is authorized to pass through the vehicle barrier system **110**. In response, the control unit **152** may send a signal to the actuator assembly **118** to cause the actuator assembly **118** to move the barrier arm **116** from the lowered position **120** to the raised position **122**. Similarly, an exit sensor **156** may be operatively coupled to the control unit **152**, and may transmit a signal to the control unit **152** indicating that the vehicle **12** has passed the vehicle barrier system **110**. In response, the control unit **152** may send a signal to the actuator assembly **118** to cause the actuator assembly **118** to move the barrier arm **116** from the raised position **122** to the lowered position **120**.

As best shown in FIG. **6**, in some embodiments, the actuator assembly **118** is configured to rotate the barrier arm **116** into the raised position **122** such that the barrier arm **116** extends at a slope angle β with respect to the travel surface **11** (or the travel path **15** of the vehicle **12**). Moreover, in some embodiments, the slope angle β of the barrier arm **116** in the raised position **122** may be equal to (or approximately equal to) the tilt angle α of the main support **114**.

In other words, as best shown in FIG. **7**, the actuator assembly **118** may be configured to rotate the distal end **128** of the barrier arm **116** from the lowered position **120** through the arc of movement **124** to the raised position **122**, wherein the arc of movement **124** lies within a movement plane **132** (indicated by dotted line **132** in FIG. **7**) that is sloped upwardly with respect to the travel surface **11** by the slope angle β. In some exemplary embodiments, the slope angle of the movement plane **132** that contains the arc of movement **124** of the barrier arm **116** is equal to (or at least approximately equal to) the tilt angle α of the main support **114**.

Of course, in alternate embodiments, the actuator assembly **118** may be configured such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124**, but wherein the arc of movement **124** is not confined within a movement plane **132**, or wherein the arc of movement **124** is confined within the movement plane **132**, but the slope angle β is not equal to the tilt angle α.

To further facilitate an understanding of the movement of the barrier arm **116** of the vehicle barrier system **110**, a cartesian coordinate system is depicted in FIGS. **2**-**7**. In at least some embodiments, if the travel path **15** is aligned with (or parallel to) a z axis of the cartesian coordinate system, the actuator assembly **118** may be operable to rotate the barrier arm **116** about the axis of rotation **130** that lies in a y-z plane of the cartesian coordinate system, wherein the axis of rotation **130** is tilted in a direction opposite from the travel path and forming the tilt angle α with a y axis of the cartesian coordinate system. In some embodiments, the actuator assembly **118** is configured to move the barrier arm **116** such that the arc of movement **124** of the distal end **128** of the barrier arm **116** lies within the movement plane **132** that is angled upwardly by the slope angle β with respect to the travel path **15**.

d. Control Unit

As best shown in FIGS. **7-9**, the control unit **152** may be utilized to control the actuator assembly **118** and thus control the position of the barrier arm **116**. The control unit **152** is generally in communication with the actuator assembly **118** so as to control the actuator assembly **118**. In some embodiments, the control unit **152** may be disposed within the main support **114**, while in other embodiments, the control unit **152** may be integrated with the actuator assembly **118**, may be directly connected to the actuator assembly **118** (e.g., through the use of cables, wires, leads, etc.), or may be remotely connected to the actuator assembly **118** (e.g., through the use of wireless communications such as radio frequency waves, Wi-Fi, and the like).

The control unit **152** may comprise a computing device such as a computer, microcontroller, programmable logic circuit, integrated circuit, or the like. The control unit **152** may be positioned off-site or may be positioned on-site with the other components of the vehicle barrier system **110**. As noted above, in various embodiments, the control unit **152** may be in contact or integral with the actuator assembly **118**, or may be distally positioned away from the actuator assembly **118**. In embodiments utilizing multiple vehicle barrier systems **110** and multiple barrier arms **116**, a single control unit **152** may control all of the actuator assemblies **118**, or each actuator assembly **118** may have its own control unit **152**.

In another exemplary embodiment, the control unit **152** may be integrated with or in communication with (e.g., communicatively interconnected with) an authorization system **162** that provides authority for vehicles to pass, that may include an interface such as a user terminal **166**, either directly or via a greater system. For example, as shown in FIG. **9**, in some embodiments, a control system **160** includes an authorization system **162** operatively coupled to the control unit **152**, and a user terminal **166** is operatively coupled to the authorization system **162**. The authorization system **162** may be integrated into the user terminal **166** or stand alone. In some embodiments, the authorization system **162** may comprise a computing device or system including a processor and memory capable of processing data from interconnected sensors, which may include one or more of entry and exit sensors **154**, **156**, a license plate recognition sensor **168**, the user terminals **166**, or other suitable sensors (e.g. a device that senses a user's mobile device **165**). In some embodiments, the authorization system **162** may receive information from one or more of the sensors (e.g. identification information, payment confirmation, etc.) of the control system **160**, and then access a database **164** to determine whether the vehicle **12** is authorized to pass through the vehicle barrier system **110**.

In response to a signal from the authorization system **162** indicating that the vehicle **12** is authorized to pass through the vehicle barrier system **110**, the control unit **152** may send a signal to the actuator assembly **118** to cause the actuator assembly **118** to move the barrier arm **116** from the lowered position **120** to the raised position **122**. Similarly, in response to a signal from the exit sensor **156** indicating that the vehicle **12** has passed the vehicle barrier system **110**, the control unit **152** may send a signal to the actuator assembly **118** to cause the actuator assembly **118** to move the barrier arm **116** from the raised position **122** to the lowered position **120**.

As shown in FIG. **9**, a license plate recognition device **168** may be utilized in which the authorization system **162** is adapted to authorize passage, and thus direct the barrier system **110** to open, upon detection of an authorized license plate or other identifying feature on the vehicle **12** approaching the barrier system **110**. Generally, the license plate recognition device **168** may be configured in a wide variety of suitable configurations using known components, including one or more of cameras, programmable devices, integrated circuits, or other suitable circuitry and components configured to perform detection and recognition functionalities. In some embodiments, the license plate recognition device **168** may be integrated with the entry sensor **154**.

Additionally or alternatively, the user terminal **166** may be utilized as previously discussed, in which a user may enter information (e.g., an access code), provide payment (e.g., through use of a credit card or mobile device **165**), show evidence of authorization (e.g., through use of an RFID card or badge), or the like. The user terminal **166** may comprise various types of scanners or readers known in the art to control access to an area, such as but not limited to a card reader. For example, the user terminal **166** may comprise a free-standing structure including a scanner configured to read a payment card (e.g., a or debit card), an RFID access card or badge, a touch screen user interface panel (e.g., through which a user may enter an access code), and the like. In some embodiments, a user's mobile device **165** (e.g. cell phone, computing device, personal assistant device, etc.) may be used, such as, for example, by scanning a driver's mobile device **165** with the user terminal **166**, or by receiving a signal from the mobile device **165** located within the vehicle **12**, or by other suitable means.

With continued to reference FIG. **9**, it can be seen that the database **164** may be in communication with the authorization system **162**. The database **164** may be integrated with the authorization system **162**, or the authorization may be in communication with a remote database **164** (e.g., through the cloud). The database **164** may store various information needed for use by the authorization system **162** such as, for example, a listing of license plates that are authorized to pass through the barrier system **110**.

When the authorization system **162** successfully verifies a payment, an entered access code, or other methods of authorization/verification, the authorization system **162** directs the control unit **152** to activate the actuator assembly **118** to raise the barrier arm **116** into the raised position **122**. Upon an indication that the vehicle **12** has departed (e.g., if the vehicle **12** has been sensed by the exit sensor **156** as having passed through), or alternately, after a certain amount of time, the control unit **152** may again activate the actuator assembly **118** to lower the barrier arm **116** back into the lowered position **120**.

In some embodiments, a user may use a mobile device **165** such as a smart phone, smart watch, tablet, computer, or the like, to transmit a signal to the control unit **152** (directly or indirectly via the authorization system **162**) to prove authorization of their vehicle **12** to pass. In other embodiments, the user may be directed to enter their license plate information, either via a user terminal **166** or via the user's mobile device **165**.

e. Sensors

As noted above, in some exemplary embodiments such as shown in FIGS. **7-9**, one or more sensors **154**, **156**, **168** may be utilized to automatically detect a vehicle **12** approaching or departing the barrier system **110**. Any such sensors **154**, **156**, **168** will generally be in communication with the control unit **152** through either a direct connection or an indirect connection. Such sensors **154**, **156**, **168** may aid the control unit **152** with operational timing of the barrier arm **116** in the case of an external authorization input (e.g., use of a user terminal **168**). However, in certain embodiments or situations, external authorization may not be required at all. In such cases, the control unit **152** may direct the barrier arm **116** to be opened upon the entry sensor **154** detecting a vehicle **12** approaching without the need for any specific authorization. In such embodiments, the authorization system **162** and other components of the control system **160** (e.g. license plate recognition device **168**) may be omitted or disabled as-needed.

In a first exemplary embodiment, a single sensor may be utilized for both detecting arriving and departing vehicles **12**. In other exemplary embodiments, an entry sensor **154** may be utilized for detecting arriving vehicles **12** and an exit sensor **156** may be utilized for detecting departing vehicles **12**.

The one or more sensors **154**, **156**, **168** will generally be positioned above the roadway **16** in an overhead position such as shown in FIG. **7**. Previously, such sensors **154**, **156**, **168** have instead been positioned on the travel surface **11**, or next to the travel surface **11**. By positioning the sensors **154**, **156**, **168** in an overhead position, inadvertent damage may be avoided, such as in the case of vehicles **12** crashing into sensors **154**, **156**, **168** which are positioned on or near the travel surface **11**. In some alternate embodiments, however, the one or more of the sensors may be embedded within the travel surface **11**, such as to detect a pressure caused by the weight of approaching or departing vehicle **12**.

Generally, one or more of the sensors **154**, **156**, **168** may be connected to a ceiling **17** above the travel surface **11**, or to a wall proximate the travel surface **11**, or any other suitable location. In some embodiments, one or more of the sensors **154**, **156**, **168** may be connected to the main support **114**, or to some other pole, support stand, overhead support structure, or other dedicated support means. The sensors **154**, **156**, **168** will generally be in communication with (e.g., communicatively interconnected with) the control unit **152** so as to communicate to the control unit **152** when a vehicle **12** is detected approaching or departing the barrier system **110**.

The positioning and orientation of the sensors **154**, **156**, **168** may vary in different embodiments. In some embodiments, the sensors **154**, **156**, **168** may be oriented downwardly (e.g., vertically). In other embodiments, the sensors **154**, **156**, **168** may be oriented at a downward angle (e.g., diagonally). The sensors **154**, **156**, **168** may be positioned adjacent to the main support **114** or be connected to the main support **114**, or other structures/devices of the barrier system **110**.

The sensors **154**, **156**, **168** may in other embodiments be distally positioned away from the barrier system **110**, such as on a ceiling or on an overhead support structure. In the embodiment shown in FIG. **7**, it can be seen that the entry sensor **154** (and license plate recognition sensor **168**) may be positioned above the travel surface **11** on a first side of the barrier arm **116** and that the exit sensor **156** is positioned above the travel surface **11** on a second side of the barrier arm **116**. Various other positioning of the sensors **154**, **156**, **168** may be utilized.

While the figures illustrate discrete entry and exit sensors **154**, **156**, **168**, it will be appreciated that in some embodiments, a single sensor may be utilized to perform the required functions. Such a single sensor would be oriented to cover both the travel surface **11** approaching the barrier system **110** and the travel surface **11** departing the barrier system **110**.

Various types of sensors **154**, **156**, **168** may be utilized to achieve the sensing objectives, including binary sensors, "shape" sensors configured to detect shapes resembling vehicles, ranging sensors, and the like. In some embodiments, LIDAR sensors may be utilized.

Binary sensors may simply trigger an on or off output (to the control unit **152**) when a corresponding or tuned element is within the sensitivity range of the specific sensor (e.g. entry and exit sensors **154**, **156**). A non-limiting example of a binary sensor may comprise an induction loop that sets an output when the vehicle **12** has approached the induction loop. Other binary sensors could include reflected light or magnetic-based proximity sensors, as well as broken light beam type sensors, (e.g. photodiodes, photodetectors, etc.).

"Shape" sensors may be configured to recognize the shape of objects within the scope of the sensor. For example, in some embodiments, a camera with appropriate image processing may be used to recognize objects as such a "shape" sensor. Other technologies with comparable outcomes may include radar imaging or point cloud imaging, which use multiple distance readings to form an image for further processing. All such "shape" sensors, either individually or used in conjunction with other sensing elements, may be utilized to achieve the sensing objectives of an exemplary embodiment of the vehicle barrier system **110**. Such sensors may also provide the added functionality of detecting or recognizing obstructions to the barrier arm **116** (e.g., if a person was in the path of the barrier arm **116**).

Ranging sensors may utilize distance measurements and provide an output to the control unit **152** that reflects that distance. Such ranging sensors may include, without limitation, ultrasonic or light-based sensors (e.g., infrared, LIDAR, and the like). A singular ranging sensor, mounted overhead oriented on an angle down on the travel path **15** of vehicle **12** could be used to detect the vehicle **12** position based on a simple calculation of distance readings and the known position of the barrier arm **116** relative to the location of the sensor. Other embodiments could utilize a pair of ranging sensors (e.g., LIDAR-based sensors), in a more vertical orientation, with the entry sensor **154** positioned before the barrier arm **116** and the exit sensor **156** positioned after the barrier arm **116**.

In some embodiments, the entry sensor **154** (and possibly the exit sensor **156**) may be configured to perform license plate recognition in addition to the role of aiding operation and control of the barrier arm **116**. Thus, as noted above, in some embodiments, the license plate recognition sensor **168** may be integrated with the entry sensor **154**. Such license plate recognition may be integrated into one or more of the sensors **154**, **156**, or may utilize one or more separate, stand-alone sensors. An exemplary embodiment of one or more sensors **154**, **156** which allow for license plate recognition is shown and described in U.S. Patent Publication No. 2021/0264779, covering a "Vehicle Identification System", the entire disclosure of which, except for any definitions, disclaimers, disavowals, and inconsistencies, is incorporated herein by reference.

In such embodiments, one or more of the sensors **154**, **156** may comprise imaging devices such as cameras or the like which are adapted to detect not only the vehicle, but to also detect and identify the license plate (or other identifying characteristics) or each vehicle **12** approaching the barrier arm **116**. If the one or more of the sensors **154**, **156** detects a license plate or other identifying characteristic that confirms authorization of the vehicle **12** to pass, the control unit **152** will direct the actuator assembly **118** to raise the barrier arm **116** so that the vehicle **12** may pass.

In certain embodiments, separate authorization (e.g., through license plate recognition sensor **168** or the like) may be omitted or disabled. In such embodiments, any vehicle **12** approaching the barrier arm **116** may be permitted to pass without any separate authorization or payment. For example, the entry sensor **154** may simply function to raise the barrier arm **116** when the vehicle **12** approaches, and the exit sensor **156** may function to lower the barrier arm **116** when the vehicle **12** departs (or after a set period of time). In other embodiments, the barrier arm **116** may function without the need for sensors **154**, **156** at all. In such embodiments, a push button, such as incorporated into the user terminal **166**, may be utilized to raise the barrier arm **116**, with the barrier arm **116** lowering itself after a preset amount of time sufficient to allow the vehicle **12** to pass.

f. Alternate Embodiments

FIGS. **10-18** illustrate various alternate embodiments of the vehicle barrier systems in accordance with the present disclosure. For example, FIGS. **10** and **11** show vehicle barrier systems having different embodiments of main supports in accordance with the present disclosure. In addition, FIGS. **12-18** show a vehicle barrier system having a breakaway assembly in accordance with the present disclosure.

In the following discussion of alternate embodiments, the vehicle barrier systems may include many of the same (or substantially similar) components as described above. Therefore, the same reference numerals may be used to refer to the same (or substantially similar) components. For the sake of brevity, in the following discussion of alternate embodiments, the discussion will focus primarily on different features or aspects between such alternate embodiments and the previously-described embodiments. Components that are the same as (or substantially similar to) those described above will not be described in detail again.

FIG. **10** is a perspective view of a barrier system **210** in accordance with another example embodiment. In this embodiment, the barrier system **210** includes a main support **214** that projects downwardly from a ceiling (or other overhead support structure) **222**. An actuator assembly **218** is attached to the main support **214** that movably supports the barrier arm **116**. More specifically, the actuator assembly **218** is coupled to the proximal end **126** of the barrier arm **116**, and is configured to rotate the barrier arm **116** about an axis of rotation **230**, moving the barrier arm **116** from the lowered position **120** to the raised position **122** such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124**. The axis of rotation **230** of the actuator assembly **218** is tilted with respect to vertical (or local normal to the travel surface **11**) by a tilt angle α.

It will be appreciated that, although the main support **214** projects downwardly, the actuator assembly **218** is configured such that the axis of rotation **230** is tilted with respect to vertical (or local normal to the travel surface **11**) by the tilt angle α. In some embodiments, as shown in FIG. **10**, the axis of rotation **230** is tilted in a direction along the travel path. More specifically, in some embodiments, the axis of rotation **230** lies in the y-z plane of a cartesian coordinate system, and is angled with respect to the y axis of the cartesian coordinate system by the tilt angle α.

As shown in FIG. **10**, the actuator assembly **218** is coupled to a lower end portion of the main support **214**, and is configured to selectively move the barrier arm **116** from the lowered position **120** to the raised position **122** in a "leading" movement such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124** that extends both upwardly away from the travel path **15** and laterally along the travel path **15** in a direction away from the vehicle **12**. In some embodiments, the arc of movement **124** lies within the movement plane **132** that slopes with respect to the travel path **15** of the vehicle **12** (or the travel surface **11**) by the slope angle β. Moreover, in some embodiments, the slope angle β of the movement plane **132** may be equal to (or approximately equal to) the tilt angle α of the axis of rotation **230**.

To illustrate that the entry sensor **154** (and license plate recognition device **168**) may be positioned in other suitable locations, in the embodiment shown in FIG. **10**, the entry sensor **154** (and license plate recognition device **168**) are shown as being integrated into a single device and attached to the main support **214** of the barrier system **210**. Similarly, to illustrate that the control unit **152** may be positioned in other suitable locations, in the embodiment shown in FIG. **10**, the control unit **152** is located within the actuator assembly **218**.

It will be appreciated that embodiments of barrier systems **210** as depicted in FIG. **10** may provide the above-noted advantages of "leading" the driver of the vehicle **12** through the barrier system **210** in a sweeping or leading movement by the barrier arm **116**, while using a main support **214** that projects downwardly from a ceiling (or support structure) **222**. In other words, the ceiling **222** has become a support surface for the main support **214**. Such embodiments may be desirable in certain environments, such as covered or enclosed areas, thereby providing the above-described advantages of improved fit of the barrier arm **116** within a covered area, improved visibility of the barrier arm **116** during movement between the lowered and raised positions **120**, **122**, and an overall improved driving experience to the driver of the vehicle **12**.

FIG. **11** is a perspective view of a vehicle barrier system **310** in accordance with another example embodiment. In this embodiment, the barrier system **310** includes a main support **314** (e.g. post, bollard, etc.) that projects vertically upwardly away from the support surface **111**, and an actuator assembly **318** attached to the main support **314** that movably supports the barrier arm **116**. More specifically, the actuator assembly **318** is coupled to the proximal end **126** of the barrier arm **116**, and is configured to rotate the barrier arm **116** about an axis of rotation **330**, moving the barrier arm **116** from the lowered position **120** to the raised position **122** such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124**. In some embodiments, the exit sensor **156** may be attached to a ceiling (or overhead support structure) **322**.

It will be appreciated that, even though the main support **314** extends vertically upwardly from the support surface **111**, the axis of rotation **330** of the actuator assembly **318** is tilted with respect to vertical by a tilt angle α. Such a configuration may be achieved in various ways, such as by angularly mounting of the actuator assembly **318** onto the main support **314** to achieve the desired tilt angle α, or by other suitable methods.

Thus, although the main support **314** projects vertically upwardly, the actuator assembly **318** may be configured such that the axis of rotation **330** is tilted with respect to vertical by a tilt angle α. In other words, in some embodiments, the axis of rotation **330** of the actuator assembly **318** is not aligned with a longitudinal axis of the main support **314**. In some embodiments, the axis of rotation **330** is tilted in a direction opposite from the travel path. In some embodiments, the axis of rotation **330** lies in the y-z plane of the cartesian coordinate system, and is angled with respect to the y axis of the cartesian coordinate system by the tilt angle α.

As shown in FIG. **11**, the actuator assembly **318** is coupled to a top portion of the main support **314**, and is configured to selectively move the barrier arm **116** from the lowered position **120** to the raised position **122** such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124** that extends both upwardly away from the travel path **15** and laterally along the travel path **15** in a direction away from the vehicle **12**. In some embodiments, the arc of movement **124** lies within the movement plane **132** that slopes with respect to the travel path **15** of the vehicle **12** (or the travel surface **11**) by the slope angle β. Moreover, in some embodiments, the slope angle β of the movement plane **132** may be equal to (or approximately equal to) the tilt angle α of the axis of rotation **330**.

It will be appreciated that embodiments of barrier systems **310** as depicted in FIG. **11** may provide the above-noted advantages of "leading" the driver of the vehicle **12** through the barrier system **310** in a sweeping or leading movement by the barrier arm **116**, while also having a vertical main support **214**, such as may be encountered by an operator who wishes to modify or retrofit a conventional barrier system **10** (FIG. **1**). In such scenarios, a main support **14** that projects vertically may be retro-fitted with the actuator assembly **318** having an axis of rotation **330** that is tilted with respect to vertical by a tilt angle α, thereby providing the above-described advantages of improved visibility of the barrier arm **116** during movement between the lowered and raised positions **120**, **122**, improved fit of the barrier arm **116** within a covered area, and an overall improved driving experience to the driver of the vehicle **12**.

g. Embodiments Having a Breakaway Assembly

In some embodiments, vehicle barrier systems may be configured to include a breakaway assembly. With the barrier arm **116** subject to collisions with vehicles **12** due to bad drivers, or damage due to other possible causes (e.g. vandalism), in some embodiments, it may be advantageous for the barrier system **110** to include some form of breakaway assembly. It may also be desirable to allow an attendant to manually disengage a breakaway assembly to raise the barrier arm **116** to the raised position **122**, such as when the barrier system **110** is not needed or is out of service.

For example, FIG. **12** is a perspective view of a vehicle barrier system **410** having an actuator assembly **418** that includes a breakaway assembly **440** in accordance with an example embodiment. In some embodiments, in normal operations, the actuator assembly **418** moves the barrier arm **116** through an arc of movement **124** that extends both upwardly away from the travel path **15** and laterally along the travel path **15** as described above. If an abnormal force **415** is applied to the barrier arm **116** that exceeds a predetermined threshold, however, the breakaway assembly **440** may advantageously prevent damage to the barrier system **410**.

More specifically, in some embodiments, the barrier system **410** includes a main support **114** (e.g. post, bollard, etc.) that projects upwardly away from the support surface **111** (or travel surface **11**), and an actuator assembly **418** attached to the main support **114** that movably supports the barrier arm **116**. As described above, the actuator assembly **418** is coupled to the proximal end **126** of the barrier arm **116**, and may be configured to rotate the barrier arm **116** about an axis of rotation **130**, moving the barrier arm **116** from the lowered position **120** to the raised position **122** such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124**. In some embodiments, as shown FIG. **12**, the axis of rotation **130** of the actuator assembly **418** is tilted with respect to vertical by a tilt angle α.

Additional details of an exemplary embodiment of the breakaway assembly **440** are shown in FIGS. **13**-**18**. For example, FIG. **13** is a partially cutaway view (looking downwardly along the axis of rotation **130**) of the actuator assembly **418** that includes the breakaway assembly **440** in accordance with an example embodiment.

In some embodiments, the actuator assembly **418** includes an outer housing **442** that covers and protects internal components of the actuator assembly **418**, and a stationary frame **444** that couples the actuator assembly **418** (directly or indirectly) to the main support **114**. In FIG. **13**, portions of the outer housing **442** have been cutaway to show some of the internal components of the actuator assembly **418**. The actuator assembly **418** may further include a drive motor **446** (or other suitable actuation mechanism) that may be coupled to the stationary frame **444**, and a drive bracket **448** that is rotatably coupled to the stationary frame **444**. The actuator assembly **418** may further include an arm bracket **452** that attaches to the barrier arm **116**. The arm bracket **452** is operatively coupled to the drive bracket **448** by the breakaway assembly **440**, as described more fully below.

More specifically, the breakaway assembly **440** may be configured to remain engaged during normal operations as the actuator assembly **418** raises the barrier arm **116** from the lowered position **120** to the raised position **122** (FIG. **12**). In the event that the barrier arm **116** encounters an abnormal force **415** (e.g. a vehicle strike, vandalism, etc.) that exceeds a predetermined threshold, the breakaway assembly **440** may be configured to become disengaged such that the barrier arm **116** (and arm bracket **452**) swings freely through the arc of rotation **124** independently of some of the other components of the actuator assembly **418** (e.g. drive bracket **448**, motor **446**, etc.). In this way, the breakaway assembly **116** may reduce or prevent breakage of the barrier arm **116** or other components of the actuator assembly **418**.

With continued reference to FIG. **13**, in some embodiments, the breakaway assembly **440** of the actuator assembly **418** includes one or more drive magnets **450** disposed on the drive bracket **448**, and one or more magnetically-attractive elements **454** disposed on the arm bracket **452**. In the embodiment shown in FIG. **13**, the breakaway assembly **440** includes three drive magnets **450** that are distributed on the drive bracket **448** at three equally-spaced circumferential positions distributed about the axis of rotation **130**. Similarly, the breakaway assembly **440** shown in FIG. **13** includes three magnetically-attractive elements **454** coupled to the arm bracket **452**. It will be appreciated that in alternate embodiments, a different number of drive magnets **450** and magnetically-attractive elements **454** may be used, and that the spacing and locations of the drive magnets **450** and magnetically-attractive elements **454** may be different from the particular embodiment shown in FIGS. **13**-**17**.

In a first position **460** shown in FIG. **13**, each of the drive magnets **450** of the drive bracket **448** is aligned with and magnetically coupled to a corresponding one of the magnetically-attractive elements **454** disposed on the arm bracket **452**. In this way, the arm bracket **452** (and thus the barrier arm **116**) is magnetically coupled to the drive bracket

448 by the breakaway assembly **440**. In some embodiments, the arm bracket **452** can rotate freely of the motor **446** (or other suitable actuator device) about the axis of rotation **130** if allowed by the breakaway assembly **440** (i.e. if disengaged from the drive magnets **450** of the drive bracket **448**).

In at least some embodiments, the drive magnets **450** may be relatively strong magnets having a relatively strong attractive force with the magnetically-attractive elements **454** so that, during normal operations, the actuator assembly **418** can move the barrier arm **116** from the lowered position **120** to the raised position **122** without the breakaway assembly **440** becoming disengaged. In other words, during normal operations, the drive magnets **450** on the drive bracket **448** remain magnetically coupled to the magnetically-attractive elements **454** on the arm bracket **452** such that the arm bracket **452** (and barrier arm **116**) do not become disengaged from the drive bracket **448**.

The strength of the drive magnets **450** may vary from configuration to configuration depending upon a number of variables, such as the number of drive magnets **450**, and the predetermined threshold selected for the breakaway to occur. For example, in some embodiments, the predetermined threshold may be selected to avoid damage to the barrier system **410**, such that the predetermined threshold represents a value slightly lower than a force needed to break one or more components of the barrier system **410** (e.g. the barrier arm **116**, or the actuator assembly **418**, etc.). In other embodiments, other criteria may be used to select the predetermined threshold (e.g. to avoid damage to the vehicle **12**, to allow an attendant to easily manipulate the barrier arm **116** to manually disengage the breakaway assembly **440** to raise the barrier arm **116** to the raised position **122**, etc.). For example, if the barrier arm **116** needs to be raised manually (e.g. in the event of a power failure or other failure of the actuator assembly **418**), it may be desirable to allow an attendant to manually force the barrier arm **116** to pivot upwardly, overcoming the magnetic attraction between the drive magnets **450** and the magnetically-attractive elements **454** and raising the barrier arm **116** into the raised position **122**.

The drive magnets **450** may be formed of any suitable magnetic materials or selectively magnetic devices. For example, in some embodiments, the drive magnets **450** may be permanent magnets. In other embodiments the drive magnets **450** may be electromagnets that exhibit magnetic properties only when electrical power is provided. In still other embodiments, the drive magnets **450** may be any suitable combination of permanent magnets and electromagnets. Similarly, the magnetically-attractive elements **454** may be formed of any suitable materials that are magnetically attractive or suitably responsive to magnetic fields. For example, in some embodiments, the magnetically-attractive elements **454** may include iron or other ferrous-containing materials, or any other suitable magnetically-attractive material (e.g. nickel, rare earth metals, etc.).

As further shown in FIG. **13**, in some embodiments, the actuator assembly **418** may also include three stop magnets **456** that are attached to the stationary frame **444**. In the depicted embodiment, the stop magnets **456** are also distributed on the stationary frame **444** at three equally-spaced circumferential positions distributed about the axis of rotation **130**. It will be appreciated that in alternate embodiments, a different number of stop magnets **456** may be used, and that the spacing of the stop magnets **456** may be different from the particular configuration shown in FIGS. **13-17**.

It will be appreciated that the stop magnets **456** may be relatively weaker magnets, having a relatively weaker attractive force with the magnetically-attractive elements **454** than do the drive magnets **450**. More specifically, in some embodiments, the stop magnets **456** may be strong enough to magnetically hold the arm bracket **452** with the barrier arm **116** in the raised position **122**, however, the stop magnets **456** are relatively weaker than the drive magnets **450** such that the drive magnets **450** have a stronger magnetic attraction to the magnetically-attractive elements **454**, and may pull the magnetically-attractive elements **454** away from the stop magnets **456**, as described more fully below.

Similar to the drive magnets **450**, the stop magnets **456** may be formed of any suitable magnetic materials or selectively magnetic devices. For example, in some embodiments, the stop magnets **456** may be permanent magnets. In other embodiments the stop magnets **456** may be electromagnets that exhibit magnetic properties only when electrical power is provided. In still other embodiments, the stop magnets **456** may be any suitable combination of permanent magnets and electromagnets.

As noted above, in some embodiments, the actuator assembly **418** is configured to selectively move the barrier arm **116** during normal operations from the lowered position **120** to the raised position **122** in a "leading" movement such that the distal end **128** of the barrier arm **116** moves through an arc of movement **124** that extends both upwardly away from the travel path **15** and laterally along the travel path **15** in a direction away from the vehicle **12**, without the arm bracket **452** (and barrier arm **116**) becoming disengaged from the drive bracket **448**. In such embodiments, the axis of rotation **130** of the actuator assembly **418** may be tilted with respect to vertical by a tilt angle α.

In alternate embodiments, however, the actuator assembly **418** having the breakaway assembly **440** may be used in other suitable barrier systems in which the barrier arm **116** moves from a first (or closed/lowered) position into a second (or open/raised) position, wherein the barrier arm **116** remains approximately horizontal during movement. In such barrier systems, the axis of rotation **130** of the actuator assembly **418** shown in FIG. **13** may be a vertical axis (and not tilted by the tilt angle α). Thus, it will be appreciated that the breakaway assembly **440** of the present disclosure may be used in a variety of suitable barrier systems, and is not limited to the barrier systems (e.g. barrier system **110**) having an axis of rotation **130** that is tilted.

FIGS. **13-17** show the breakaway assembly **440** of the actuator assembly **418** in a series of different positions to facilitate an understanding of the operation of the breakaway assembly **440**. For the sake of clarity, however, FIGS. **14-17** primarily show the components of the breakaway assembly **440**, while some of the other components of the actuator assembly **418** are intentionally omitted, so that an improved understanding of the operation of the breakaway assembly **440** may be realized.

For example, FIG. **13** shows the actuator assembly **418** in a first position **460**, which may correspond to the barrier arm **116** being positioned in the lowered position **120** (FIG. **12**). In the first position **460**, the breakaway assembly **440** is fully engaged such that the drive magnets **450** on the drive bracket **448** are magnetically coupled with the magnetically-attractive elements **454** on the arm bracket **452**. When the motor **446** of the actuator assembly **418** is actuated (e.g. by the control unit **152**), the motor **446** begins rotating the drive bracket **448** and the arm bracket **452** in a clockwise direction **465** about the axis of rotation **130**, which begins raising the barrier arm **116** through the arc of rotation **124** (FIG. **12**).

FIG. **14** shows the actuator assembly **418** in a second position **462**. In the second position **462**, the drive bracket **448** has continued to rotate the arm bracket **452** in the clockwise direction **465** about the axis of rotation **130**, which has continued to raise the barrier arm **116** through the arc of rotation **124**. In some embodiments, the second position **462** may correspond to the barrier arm **116** being raised to approximately a midpoint of the arc of rotation **124** between the lowered position **120** and the raised position **124** (FIG. **12**). In the second position **462**, the breakaway assembly **440** remains fully engaged such that the drive magnets **450** on the drive bracket **448** are magnetically coupled with the magnetically-attractive elements **454** on the arm bracket **452**. As the motor **446** continues rotating the drive bracket **448** and the arm bracket **452** in the clockwise direction **465** about the axis of rotation **130**, the barrier arm **116** continues to be raised through the arc of rotation **124** (FIG. **12**).

FIG. **15** shows the actuator assembly **418** in a third position **464**. In the third position **464**, the drive bracket **448** (and motor **446**) has continued to rotate the arm bracket **452** in the clockwise direction **465** about the axis of rotation **130** until the magnetically-attractive elements **454** on the arm bracket **452** have reached the stop magnets **456**. In some embodiments, the third position **464** may correspond to the barrier arm **116** being raised to the raised position **124** (FIG. **12**). In the third position **464**, the breakaway assembly **440** remains fully engaged such that the drive magnets **450** on the drive bracket **448** remain magnetically coupled with the magnetically-attractive elements **454** on the arm bracket **452**. Also, in the third position **464**, the magnetically-attractive elements **454** may become magnetically engaged with the stop magnets **456** on the stationary frame **444**, and the motor **446** may be stopped. The stop magnets **456** may thereby assist in holding the barrier arm **116** in the raised position **122**.

After the vehicle **12** successfully passes the barrier system **410**, the motor **446** of the actuator assembly **418** may be actuated (e.g. by the control unit **152**) to rotate the drive bracket **448** (and the arm bracket **452**) in a counter-clockwise direction **467** about the axis of rotation **130**. It will be appreciated that because the drive magnets **450** are relatively stronger than the stop magnets **456**, the magnetic attraction of the drive magnets **450** with the magnetically-attractive elements **454** is stronger than the weaker magnetic attraction between the stop magnets **456** and the magnetically-attractive elements **454**. Accordingly, as the drive bracket **448** is rotated in the counter-clockwise direction **467**, the drive magnets **450** are able to exert a greater magnetic force on the magnetically-attractive elements **454** and pull the magnetically-attractive elements **454** away from the stop magnets **456**. The motor **446** is therefore free to continue rotating the drive bracket **448** and the arm bracket **452** in the counter-clockwise direction **467** to the first position (FIG. **13**), lowering the barrier arm **116** to the lowered position **120** (FIG. **12**). Therefore, FIGS. **13-15** show the operation of the breakaway assembly **440**, and that the breakaway assembly **440** remains fully engaged as the actuator assembly **418** is actuated (e.g. by control unit **152**) to raise the barrier arm **116** during normal operations from the lowered position **120** to the raised position **122**, and remains engaged as the actuator assembly **418** is actuated to lower the barrier arm **116** during normal operations from the raised position **122** to the lowered position **120**.

FIG. **16** shows the actuator assembly **418** (and breakaway assembly **440**) in a fourth position **466** such as may occur in response to application of the abnormal force **415** on the barrier arm **116** as depicted in FIG. **12**. In some embodiments, the abnormal force **415** applied on the barrier arm **116** may be caused by the vehicle **12** pushing on or striking the barrier arm **116**, or by a variety of other causes. As shown in FIG. **12**, the abnormal force **415** may be aligned with the travel path **15** of the vehicle **12**, however, in other embodiments, other abnormal forces may be encountered.

With reference to FIG. **16**, in the fourth position **466**, the abnormal force **415** applied to the barrier arm **116** has exceeded the predetermined threshold and has caused the breakaway assembly **440** to become disengaged. More specifically, the abnormal force **415** has overcome the magnetic attractive force between the magnetically-attractive elements **454** on the arm bracket **452** and the drive magnets **450** on the drive bracket **448** (FIG. **13**), causing the magnetically-attractive elements **454** to disengage from the drive magnets **450**. Also, in the fourth position **466**, the abnormal force **415** has caused the arm bracket **452** to rotate in the clockwise direction **465** about the axis of rotation **130** so that the magnetically-attractive elements **454** are circumferentially spaced apart from the drive magnets **450** in the clockwise direction **465**. The disengagement of the breakaway assembly **440** permits the arm bracket **452** to rotate independently from the drive bracket **448**, thereby permitting the barrier arm **116** to be pushed by the abnormal force **415** along the arc of rotation **124** (FIG. **12**). Accordingly, in the fourth position **466**, the breakaway assembly **440** has disengaged the arm bracket **452** (and the barrier arm **116**) from other components of the actuator assembly **418** (i.e. disengaged from the drive bracket **448**) in response to the abnormal force **415** acting on the barrier arm **116**, allowing the arm bracket **452** to rotate freely of the motor **446** about the axis of rotation **130**.

Although the abnormal force **415** is depicted in FIG. **12** as being applied to the barrier arm **116** when the barrier arm **116** is in the lowered position **120**, it will be appreciated that the abnormal force **415** may be applied to the barrier arm **116** at any other location of the barrier arm **116** along the arc of movement **124** between the lowered position **120** and the raised position **122** (not including the raised position **122**). Therefore, the disengagement (or "breakaway") of the breakaway assembly **440** may occur during any position of the barrier arm **116** prior to reaching the raised position **122** (or third position **464** of FIG. **15**).

With continued reference to FIG. **16**, the components of the breakaway assembly **440** are shown in the fourth position **466** which, in some embodiments, may correspond to the barrier arm **116** being pushed by the abnormal force **415** to approximately a midpoint of the arc of movement **124** (FIG. **12**). If the abnormal force **415** were released, in some embodiments having the axis of rotation **130** tilted away from vertical by the tilt angle α, the barrier arm **116** may freely rotate in the counter-clockwise direction **467** back down to the first position **460** (FIG. **13**) due to gravitational force operating on the barrier arm **116**. Upon returning to the first position **460**, the breakaway assembly **440** may become re-engaged, with the magnetically-attractive elements **454** on the arm bracket **452** magnetically coupling with the drive magnets **450** on the drive bracket **448** (FIG. **13**), allowing the actuator assembly **418** to resume normal operations. The breakaway assembly **440** may become automatically re-engaged by gravitational force in this manner from positions along the arc of movement **124** that the barrier arm **116** may be displaced by the abnormal force **415** (other than positions proximate to the raised position **122** in which the magnetically-attractive elements **454** become magnetically engaged with the stop magnets **456**).

FIG. **17** shows the actuator assembly **418** (and breakaway assembly **440**) in a fifth position **468** such as may occur when the abnormal force **415** has disengaged the breakaway assembly **440** and has continued to raise the barrier arm **116**. More specifically, in the fifth position **468**, following disengagement of the breakaway assembly **440**, the abnormal force **415** applied to the barrier arm **116** has rotated the arm bracket **452** in the clockwise direction **465** about the axis of rotation **130** until the magnetically-attractive elements **454** have become magnetically engaged with the stop magnets **456**. In some embodiments, the fourth position **468** corresponds with the barrier arm **116** being raised into the raised position **122** (FIG. **12**).

In some embodiments, after the abnormal force **415** is removed from the barrier arm **116**, the stop magnets **456** may continue to magnetically engage with the magnetically-attractive elements **454** of the arm bracket **452** with sufficient strength to overcome the gravitational force on the barrier arm **116**, such that the barrier arm **116** remains held in the raised position **122** by the stop magnets **456**. Alternately, in other embodiments, the stop magnets **456** may be eliminated, or if present, may not have sufficient strength to overcome the gravitational force operating on the barrier arm **116**, and the barrier arm **116** may automatically return to the first position **460** (FIG. **13**) under the operation of gravitational force as described above.

Referring again to FIG. **17**, in some embodiments, when the stop magnets **456** have sufficient strength to maintain magnetic engagement with the magnetically-attractive elements **454** to hold the actuator assembly **418** (and breakaway assembly **440**) in the fifth position **468**, the barrier arm **116** may remain in the raised position **122** until further intervention occurs. In some embodiments, the intervention may take the form of an attendant or other suitable person manually disengaging the magnetically-attractive elements **454** from the stop magnets **456** by pulling down on the barrier arm **116**, returning the barrier arm **116** to the lowered position **120** and the actuator assembly **418** to the first position **460** shown in FIG. **13**, thus re-engaging the breakaway assembly **440** and returning to normal operations.

Alternately, in some embodiments, the actuator assembly **418** may remain in the fifth position **468** until a control system (e.g. control system **150**) initiates a fetching operation to return the actuator assembly **418** to normal operations. For example, in some embodiments, the control system **150** may be configured to determine that the actuator assembly **418** has reached the fifth position **468** and in response, may initiate a fetching operation to return the actuator assembly **418** to normal operations. In other embodiments, an attendant or other suitable person may observe that the barrier system **410** needs to be reset, and may command the control system to initiate the fetching operation to return the actuator assembly **418** to normal operations (e.g. by pushing a reset button, etc.)

More specifically, in some embodiments, the fetching operation may include the motor **446** being actuated to rotate the drive bracket **448** in the clockwise direction **465**, causing the drive magnets **450** on the drive bracket **448** to move into engagement with the magnetically-attractive elements **454** of the arm bracket **452**, re-engaging the breakaway assembly **440** and returning the actuator assembly **418** to the third position **464** shown in FIG. **15**. Once the actuator assembly **418** reaches the third position **464** and the breakaway assembly **440** has become re-engaged, the motor **446** may reverse direction and rotate the drive bracket **448** in the counter-clockwise direction **467** (FIG. **15**) to pull the magnetically-attractive elements **454** away from the stop magnets **456**. The motor **446** may then continue to rotate the drive bracket **448** and the arm bracket **452** in the counter-clockwise direction **467**, returning the actuator assembly **418** to the first position **460** (FIG. **13**) and returning the barrier arm **116** to the lowered position **120** (FIG. **12**).

FIG. **18** shows a schematic diagram of a control system **470** that may be used to control the actuator assembly **418** of the vehicle barrier system **410** of FIGS. **12**-**17**. In some embodiments, the control system **470** may include several of the components as described above with respect to the control systems **150**, **160** shown in FIGS. **8** and **9** (e.g. a control unit **152**, entry sensor **154**, exit sensor **156**, authorization system **162**, etc.), and may perform the same functionalities as described above. In the embodiment shown in FIG. **18**, however, the control system **470** also includes a fetch sensor **472**. In some embodiments, the fetch sensor **472** may be positioned within the actuator assembly **418** (see FIG. **17**), and may be operatively coupled to the control unit **152**. The fetch sensor **472** may detect when the actuator assembly **418** has been placed in the fifth position **468** (FIG. **17**) and requires re-setting to re-engage the breakaway assembly **440** and return the actuator assembly **418** to normal operations.

More specifically, the fetch sensor **472** may detect that the breakaway assembly **440** is disengaged and that the magnetically-attractive elements **454** have become magnetically engaged with the stop magnets **456**. Upon detecting the actuator assembly **418** in the fifth position **468** (FIG. **17**), the fetch sensor **472** may transmit a signal to the control unit **152** to initiate the fetching operation. In response, the control unit **152** may perform the above-described fetching operations, causing the actuator assembly **418** to re-engage the breakaway assembly **440** and to retrieve the barrier arm **116** from the raised position **122** and to move the barrier arm **116** to the lowered position **120** to return to (or commence) normal operations.

In some embodiments, if no fetch sensor **472** is present, then the barrier system **410** may simply rely on the next opening cycle of the actuator assembly to reset the barrier arm **116** position to what it should be (e.g. the lowered position **120**, closed position, etc.). In this way, even without a fetch sensor **472** or fetching operations, successful recover of the barrier arm to normal operations may be achieved without external intervention.

Barrier systems that have a breakaway assembly in accordance with the present disclosure may provide considerable advantages over prior art barrier systems. Because the breakaway assembly releases the barrier arm from other components of the actuator assembly under the application of an abnormal force that exceeds a pre-determined threshold, the barrier system may be advantageously protected from damage. More specifically, upon application of the abnormal force **415**, such as might be experienced from a vehicle **12** pushing or striking the barrier arm **116**, instead of breaking the barrier arm **116** or the actuator assembly **418** (or both), the breakaway assembly **440** allows the arm bracket **452** to become disengaged from the drive bracket **448** so that the arm bracket **452** and the barrier arm **116** can move along the arc of movement **124** until the abnormal force **415** abates. In this way, damages to the barrier system may be reduced or eliminated, and the costs associated with repairing such damages may be mitigated or avoided. In addition, in some embodiments, the actuator assembly **418** having the breakaway assembly **440** may be quickly and efficiently returned to normal operational service, either by manually returning the barrier arm **116** to the lowered position **120** (or closed position) so that the breakaway assembly **440** becomes re-engaged, or by the barrier arm **116** automatically returning to the lowered position **120** by operation of gravitational forces, or by the control system performing a fetching operation to re-engage the breakaway assembly **440** and return the barrier system **410** to normal operations. Therefore, barrier systems having a breakaway assembly in accordance with the present disclosure may advantageously be returned to normal operations quickly and in a cost-efficient manner.

It will be appreciated that alternate embodiments may be readily conceived, and that embodiments of barrier systems in accordance with the present disclosure are not limited to the particular embodiments described above and shown in the accompanying figures. For example, although the actuator assembly **418** described above and shown in FIGS. **13-17** has a breakaway assembly **440** that includes three drive magnets **450** (and correspondingly three magnetically-attractive elements **454** and three stop magnets **456**), it will be appreciated that in alternate embodiments, other suitable numbers of these components (**450**, **454**, **456**) could be employed. For example, alternate embodiments of actuator assemblies may be provided with a breakaway assembly having only one drive magnet **450** (and one magnetically-attractive element **454**, and one stop magnet **456**), or having only two drive magnets **450** (and two magnetically-attractive elements **454**, and two stop magnets **456**), or having four drive magnets **450** (and four magnetically-attractive elements **454**, and four stop magnets **456**), or any other suitable numbers of these components. In addition, as noted above, in some alternate embodiments, the stop magnets **456** may be eliminated. Generally speaking, in some embodiments, although an actuator assembly may have an equal number of drive magnets **450** and magnetically-attractive elements **454**, there may be a fewer (or greater) number of stop magnets **456** depending upon the relative strengths of the magnets **450**, **456**.

Furthermore, although the breakaway assembly **440** shown in FIGS. **13-17** includes drive magnets **450** (and corresponding magnetically-attractive elements **454** and stop magnets **456**) that are circumferentially spaced apart by equal distances around the axis of rotation **130**, it should be appreciated that in alternate embodiments, these elements need not be spaced apart by equal distances. For example, in alternate embodiments of breakaway assemblies, the drive magnets **450** (and magnetically-attractive elements **454**, and stop magnets **456**) need not be equally spaced, and may instead be non-equally spaced about the axis of rotation **130**. In still further embodiments, the drive magnets **450** (and magnetically-attractive elements **454**, and stop magnets **456**) need not be placed around the entire circumference of the axis of rotation **130**, but rather, may be positioned within only a portion or region of the circumference (e.g. within a third of the circumference, half of the circumference, etc.).

In addition, it will be appreciated that, in alternate embodiments, the breakaway assembly **440** of FIGS. **13-17** may be implemented in an actuator assembly (such as actuator assembly **418**) wherein the axis of rotation is oriented in a vertical direction. In such embodiments, the actuator assembly may selectively move the barrier arm between a closed position (that prohibits movement of the vehicle through the barrier system) and an open position (that allows the vehicle to pass through the barrier system), with the arc of movement of the barrier arm being confined within a horizontal plane of movement. Thus, in alternate embodiments wherein the axis of rotation is vertical, when the breakaway assembly **440** disengages as shown in FIG. **16**, the gravitational force operating on the barrier arm may not automatically return the actuator assembly to the first position **460** (FIG. **13**) after the abnormal force **415** is removed from the barrier arm. In some embodiments, when the breakaway assembly **440** is disengaged by the abnormal force **415** and the axis of rotation is vertical, then the actuator assembly **418** may need to be reset manually by an attendant, or by the actuator assembly **418** performing a fetching operation, such as the fetching operation described above.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar to or equivalent to those described herein can be used in the practice or testing of the various embodiments of the present disclosure, suitable methods and materials are described above. All patent applications, patents, and printed publications cited herein are incorporated herein by reference in their entireties, except for any definitions, subject matter disclaimers or disavowals, and except to the extent that the incorporated material is inconsistent with the express disclosure herein, in which case the language in this disclosure controls. The various embodiments of the present disclosure may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and it is therefore desired that the various embodiments in the present disclosure be considered in all respects as illustrative and not restrictive. Any headings utilized within the description are for convenience only and have no legal or limiting effect.

What is claimed is:

1. A barrier system, comprising:

a barrier arm having a proximal end and a distal end opposite from the proximal end;

a main support configured to attach to a support surface; and

an actuator assembly coupled between the main support and the proximal end of the barrier arm, the actuator assembly being configured to selectively rotatably drive the barrier arm between a lowered position wherein the barrier arm is positioned at least partially across a travel path of a vehicle to prevent passage of the vehicle along the travel path, and a raised position wherein the barrier arm is positioned out of the travel path to allow passage of the vehicle along the travel path;

the actuator assembly being configured to rotatably drive the barrier arm from the lowered position to the raised position such that the distal end of the barrier arm moves through an arc of movement that extends both upwardly away from the travel path and laterally along the travel path in a direction away from the vehicle; and

a breakaway assembly that is engageable with the actuator assembly, wherein the breakaway assembly is:

engageable with the actuator assembly to rotate the barrier arm through the arc of movement; and

disengageable from the actuator assembly, responsive to an abnormal force that exceeds a pre-determined force threshold applied to the barrier arm, wherein the barrier arm rotates freely through the arc of movement while the breakaway assembly is disengaged from the actuator assembly.

2. The barrier system of claim **1**, wherein the actuator assembly is configured to rotatably drive the barrier arm such that the arc of movement lies within a movement plane, the movement plane being sloped upwardly with respect to the travel path by a slope angle.

3. The barrier system of claim 1, wherein the main support comprises a bollard that projects upwardly from the support surface at a tilt angle such that the bollard is tilted at least partially opposite to a direction of travel of the vehicle along the travel path, the actuator assembly being configured to rotatably drive the barrier arm such that the arc of movement lies within a movement plane, the movement plane being sloped upwardly with respect to the travel path by a slope angle.

4. The barrier system of claim 3, wherein the slope angle of the movement plane is equal to the tilt angle of the bollard.

5. The barrier system of claim 1, wherein the main support comprises a bollard that projects downwardly from the support surface at a tilt angle such that the bollard is tilted at least partially along a direction of travel of the vehicle along the travel path, the actuator assembly being configured to rotatably drive the barrier arm such that the arc of movement lies within a movement plane, the movement plane being sloped upwardly with respect to the travel path by a slope angle.

6. The barrier system of claim 1, wherein the travel path is aligned with a z axis of a cartesian coordinate system, and wherein the actuator assembly rotatably drives the barrier arm about an axis of rotation that lies in a y-z plane of the cartesian coordinate system, the axis of rotation being tilted at least partially opposite to a direction of travel of the vehicle along the travel path and forming a tilt angle with a y axis of the cartesian coordinate system, the actuator assembly being configured to rotatably drive the barrier arm such that the arc of movement lies within a movement plane that is sloped upwardly with respect to the travel path by a slope angle.

7. The barrier system of claim 1, wherein the actuator assembly includes a drive bracket that is driven by the motor and that is rotatably coupled to the main support and an arm bracket coupled to the proximal end of the barrier arm, the drive bracket being coupled to the arm bracket by the breakaway assembly, the drive bracket and the arm bracket being rotatable about an axis of rotation as the barrier arm is rotated from the lowered position to the raised position, the breakaway assembly including:

at least one magnetically-attractive element coupled to the arm bracket and radially spaced apart from the axis of rotation, and

at least one drive magnet coupled to the drive bracket and radially spaced apart from the axis of rotation and aligned with the at least one magnetically-attractive element when the drive bracket is engaged with the arm bracket, the at least one drive magnet being configured such that:

the at least one drive magnet remains magnetically engaged to the at least one magnetically-attractive element as the motor of the actuator assembly is operated to rotate the barrier arm between the lowered position to the raised position, and

the at least one drive magnet disengages from the at least one magnetically-attractive element in response to an abnormal force applied to the barrier arm to disengage the drive bracket from the arm bracket when the abnormal force exceeds a pre-determined threshold.

8. The barrier system of claim 7, wherein the arm bracket is configured to rotate freely about the axis of rotation such that the barrier arm rotates freely between the lowered position and the raised position when the at least one drive magnet disengages from the at least one magnetically-attractive element in response to the abnormal force applied to the barrier arm.

9. The barrier system of claim 7, wherein the at least one magnetically-attractive element comprises at least two magnetically-attractive elements circumferentially disposed around the axis of rotation, and wherein the at least one drive magnet comprises at least two drive magnets circumferentially disposed around the axis of rotation, each of the at least two drive magnets being aligned with a corresponding one of the at least two magnetically-attractive elements when the drive bracket is engaged with the arm bracket.

10. The barrier system of claim 7, wherein the at least one magnetically-attractive element comprises at least three magnetically-attractive elements circumferentially disposed and equally spaced apart around the axis of rotation, and wherein the at least one drive magnet comprises at least three drive magnets circumferentially disposed and equally spaced apart around the axis of rotation, each of the at least three drive magnets being aligned with a corresponding one of the at least three magnetically-attractive elements when the drive bracket is engaged with the arm bracket.

11. The barrier system of claim 1, wherein the actuator assembly further includes at least one stop magnet coupled to the main support, the at least one stop magnet being radially spaced apart from the axis of rotation and aligned with at least one magnetically-attractive element when the barrier arm is in the raised position, and wherein

the at least one stop magnet is strong enough to magnetically retain the barrier arm in the raised position against a gravitational force operating on the barrier arm when the arm bracket is disengaged from the drive bracket, and

the at least one stop magnet is relatively weaker than the at least one drive magnet such that the at least one drive magnet may pull the at least one magnetically-attractive element away from the at least one stop magnet when the motor of the actuator assembly is operated to rotate the barrier arm from the raised position to the lowered position.

12. The barrier system of claim 11, further comprising a control system operatively coupled to the actuator assembly and configured to detect that the barrier arm is being magnetically retained in the raised position by the at least one stop magnet, and to actuate the actuator assembly to rotate the drive bracket to magnetically engage the at least one drive magnet with the at least one magnetically-attractive element, and to actuate the actuator assembly to rotate the drive bracket to move the barrier arm from the raised position to the lowered position.

13. The barrier system of claim 1, wherein the breakaway assembly is re-engageable with the actuator assembly to rotatably drive the barrier arm.

14. The barrier system of claim 1, wherein the barrier arm is rotated about a singular tilted axis.

15. A barrier system, comprising:

a barrier arm having a proximal end and a distal end opposite from the proximal end;

a main support configured to attach to a support surface and to project away from the support surface; and

an actuator assembly coupled between the main support and the proximal end of the barrier arm, the actuator assembly being configured to selectively rotatably drive the barrier arm about an axis of rotation that is oriented at a tilt angle with respect to vertical, and to rotate the barrier arm between a lowered position wherein the barrier arm is positioned at least partially across a travel path of a vehicle to prevent passage of the vehicle along the travel path, and a raised position wherein the barrier arm is positioned out of the travel path to allow passage of the vehicle along the travel path,

the actuator assembly being configured to rotatably drive the barrier arm from the lowered position to the raised position such that the distal end of the barrier arm rotates through an arc of movement that extends both upwardly away from the travel path and laterally along the travel path in a direction away from the vehicle, the arc of movement being sloped upwardly with respect to the travel path by a slope angle; and

a breakaway assembly that is engageable with the actuator assembly, wherein the breakaway assembly is:

engageable with the actuator assembly to rotate the barrier arm through the arc of movement; and

disengageable from the actuator assembly responsive to an abnormal force that exceeds a pre-determined force threshold applied to the barrier arm, wherein the barrier arm rotates freely through the arc of movement while the breakaway assembly is disengaged from the actuator assembly.

16. The barrier system of claim **15**, wherein the arc of movement of the distal end of the barrier arm lies within a movement plane, the movement plane being sloped upwardly with respect to the travel path by the slope angle.

17. The barrier system of claim **16**, wherein the slope angle of the movement plane is equal to the tilt angle of the axis of rotation.

18. A barrier system, comprising:

a barrier arm having a proximal end and a distal end opposite from the proximal end;

a main support configured to attach to a support surface and to project away from the support surface; and

an actuator assembly coupled between the main support and the proximal end of the barrier arm, the actuator assembly being configured to selectively rotatably drive the barrier arm about an axis of rotation to rotate the barrier arm between a closed position wherein the barrier arm is positioned at least partially across a travel path of a vehicle to prevent passage of the vehicle along the travel path, and an open position wherein the barrier arm is positioned out of the travel path to allow passage of the vehicle along the travel path,

wherein the actuator assembly includes a motor-driven drive bracket rotatably coupled to the main support and an arm bracket coupled to the proximal end of the barrier arm, the drive bracket being coupled to the arm bracket by a breakaway assembly, the motor-driven drive bracket and the arm bracket being rotatable about the axis of rotation as the barrier arm is rotated from the closed position to the open position, the breakaway assembly including:

at least one magnetically-attractive element coupled to the arm bracket and radially spaced apart from the axis of rotation, and

at least one drive magnet coupled to the motor-driven drive bracket and radially spaced apart from the axis of rotation and aligned with the at least one magnetically-attractive element when the motor-driven drive bracket is engaged with the arm bracket, the at least one drive magnet being configured such that:

the at least one drive magnet remains magnetically engaged to the at least one magnetically-attractive element as a motor of the actuator assembly is operated to rotatably drive the barrier arm between the closed position to the open position, and

the at least one drive magnet disengages from the at least one magnetically-attractive element in response to an abnormal force applied to the barrier arm to disengage the motor-driven drive bracket from the arm bracket when the abnormal force exceeds a pre-determined threshold, wherein the barrier arm rotates freely between an open position and a closed position while the breakaway assembly is disengaged from the actuator assembly.

19. The barrier system of claim **18**, wherein the arm bracket is configured to rotate freely about the axis of rotation such that the barrier arm rotates freely between the closed position and the open position when the at least one drive magnet is disengaged from the at least one magnetically-attractive element in response to the abnormal force applied to the barrier arm.

20. The barrier system of claim **18**, wherein the at least one magnetically-attractive element comprises at least two magnetically-attractive elements circumferentially disposed around the axis of rotation, and wherein the at least one drive magnet comprises at least two drive magnets circumferentially disposed around the axis of rotation, each of the at least two drive magnets being aligned with a corresponding one of the at least two magnetically-attractive elements when the motor-driven drive bracket is engaged with the arm bracket.

21. The barrier system of claim **18**, wherein the actuator assembly further includes at least one stop magnet coupled to the main support, the at least one stop magnet being radially spaced apart from the axis of rotation and aligned with the at least one magnetically-attractive element when the barrier arm is in the open position, and wherein

the at least one stop magnet is strong enough to magnetically retain the barrier arm in the open position against a gravitational force operating on the barrier arm when the arm bracket is disengaged from the motor-driven drive bracket, and

the at least one stop magnet is relatively weaker than the at least one drive magnet such that the at least one drive magnet may pull the at least one magnetically-attractive element away from the at least one stop magnet when the motor of the actuator assembly is operated to rotate the barrier arm from the open position to the closed position.

22. The barrier system of claim **21**, further comprising a control system operatively coupled to the actuator assembly and configured to detect that the barrier arm is being magnetically retained in the second position by the at least one stop magnet, and to operate the motor of the actuator assembly to rotate the drive bracket to magnetically engage the at least one drive magnet with the at least one magnetically-attractive element, and to operate the motor of the actuator assembly to rotate the drive bracket to rotate the barrier arm from the open position to the closed position.

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