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(54) Title: SYSTEM WITH ANTI-CABLE TWISTING MECHANISM AND METHOD THEREOF

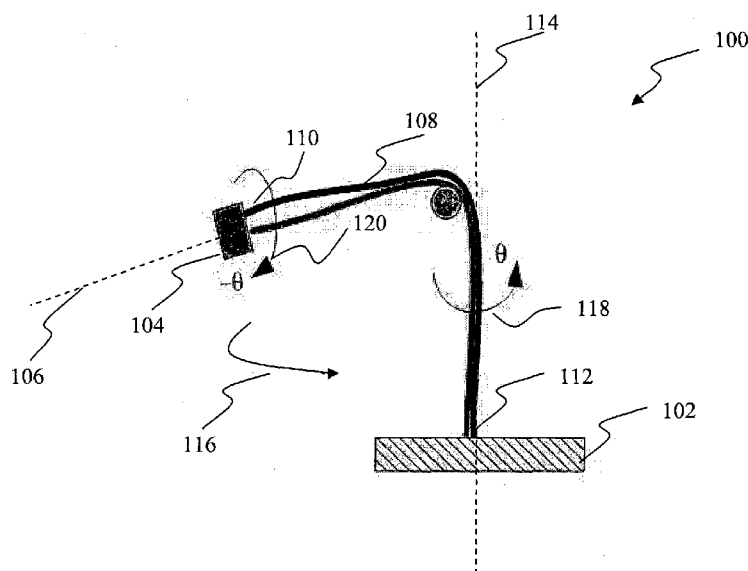


FIG. 1

(57) Abstract: A system is provided comprising a base; and a movable member affixed with respect to the base, the movable member having a first axis, wherein at least one cable is connectable to the movable member and the base such that a length of said cable exists therebetween, and wherein the system is configured such that rotating the movable member about a second axis is accompanied with a corresponding rotation of the movable member about the first axis in an opposite direction so as to minimise twisting of said cable about its length when said cable is connected to the movable member and the base. There is also provided a method of orientating a movable member in a system for tracking a target.

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SYSTEM WITH ANTI-CABLE TWISTING MECHANISM AND METHOD THEREOF

FIELD OF INVENTION

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The invention broadly relates to a system with an anti-cable twisting mechanism and a method thereof, and in particular, an antenna system and a method of orientating an antenna for tracking a target such as a satellite.

BACKGROUND

A cable twisting problem will be explained with respect to a conventional antenna system. However, it will be apparent to a person skilled in the art that such a problem will also exist in other types of systems.

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In a conventional antenna system having an antenna structure with unlimited azimuth rotation with respect to a fixed structure, there exists a problem where cables (e.g., RF (for radio frequency) cable) for relaying signals between the antenna structure and the fixed structure are caused to twist as the antenna structure is rotated about the azimuth axis. As a result, if the antenna structure is continuously rotated in the same azimuth direction, the cables can be twisted to such an extent that the cables will ultimately fail.

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Typically, to avoid such a cable twisting problem, it is known to employ a rotary joint (e.g., RF rotary joint) to relay signals between the antenna structure and the fixed structure. A rotary joint is known in the art and thus will not be described in detail herein. Although employing a rotary joint may avoid such twisting of cables, it introduces other problems. For example, the use of a rotary joint introduces noise to the signals received for processing. This may be a significant problem when sensitive or weak signals are being measured by the antenna and transmitted to electronic components on the fixed structure for processing. In addition, each rotary joint has a bandwidth limit which will restrict the transmission frequency of the antenna signal and has a limit to the number of channels it can accommodate. Furthermore, rotary joints typically have a short lifespan

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due to constant wear through friction between rotating parts and are relatively costly to replace.

It is against this background that the present invention has been developed.

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SUMMARY

The present invention seeks to overcome, or at least ameliorate, one or more of the deficiencies of the prior art mentioned above.

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According to a first broad aspect of the present invention, there is provided a system comprising:

a base; and

a movable member affixed with respect to the base, the movable member

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having a first axis,

wherein at least one cable is connectable to the movable member and the base such that a length of said cable exists therebetween, and

wherein the system is configured such that rotating the movable member about a second axis is accompanied with a corresponding rotation of the movable member about the first axis in an opposite direction so as to minimise twisting of said cable about its length when said cable is connected to the movable member and the base.

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Preferably, the system further comprises a rotatable member affixed to the base and extending along the second axis, wherein the movable member is coupled to the rotatable member such that the movable member is caused to rotate about the second axis when the rotatable member is rotated.

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Preferably, the system further comprises a mechanical assembly for coupling the movable member to the rotatable member for driving said corresponding rotation of the movable member about its first axis in the opposite direction when the rotatable member is rotated.

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Preferably, the mechanical assembly comprises a series of interlocking gears configured such that rotation of the rotatable member about the second axis is translated to proportional rotation of the movable member about the first axis in the opposite direction.

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Preferably, the series of interlocking gears are configured such that rotation of the rotatable member about the second axis is translated to equal rotation of the movable member about the first axis in the opposite direction.

10 Preferably, the series of interlocking gears include bevel gears.

Preferably, the system further comprises an actuator disposed on the movable member operable to generate a driving force for driving said corresponding rotation of the movable member about the first axis in the opposite direction.

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Preferably, the system further comprises a belt and pulley mechanism coupled to a shaft of the actuator and a shaft of the movable member such that the driving force generated by the actuator can be translated to the shaft of the movable member for rotating the movable member about the first axis.

20

Preferably, the actuator has said cable connectable thereto for receiving a control signal for controlling the driving force generated by the actuator.

25 Preferably, the control signal is determined such that a degree of rotation of the movable member about the first axis is proportional to a degree of the rotation of the movable member about the second axis.

Preferably, the degree of rotation of the movable member about the first axis is equal to the degree of the rotation of the movable member about the second axis.

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Preferably, the movable member is an antenna plate, the first axis is a boresight axis of the antenna plate and the second axis is an azimuth axis.

Preferably, the system further comprises an actuator for driving the antenna plate in the azimuth direction.

5 Preferably, the system further comprises an actuator for driving the antenna plate in an elevation direction.

Preferably, the system further comprises a receiver disposed on the antenna plate for receiving a signal, wherein the receiver has said cable connectable thereto.

10 Preferably, the system further comprises an electronic component disposed on the base for receiving and processing the signal from the receiver via said cable connectable thereo.

15 According to a second broad aspect of the present invention, there is provided a method of orientating a movable member in a system for tracking a target, the system comprising: a base; and a movable member affixed with respect to the base, the movable member having a first axis; wherein at least one cable is connectable to the movable member and the base such that a length of said cable exists therebetween, the method comprising:

20 rotating the movable member about the second axis for tracking the target, and

simultaneously rotating the movable member about its first axis in an opposite direction so as to minimise twisting of said cable about its length when said cable is connected to the movable member and the base.

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BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example
30 only, and in conjunction with the drawings, in which:

Figure 1 depicts a schematic diagram broadly illustrating an exemplary system according to an embodiment of the present invention;

Figure 2 depicts a schematic diagram illustrating an exemplary antenna system according to an embodiment of the present invention;

5 Figure 3 depicts a simplified diagram illustrating the two degrees of freedom of the antenna system shown in Figure 2;

Figure 4 depicts a simplified diagram of the antenna system 200 shown in Figure 2 for illustrating a differential motion principle;

10 Figure 5 depicts a schematic diagram of a top view of an antenna system according to an embodiment of the present invention;

Figure 6 depicts a schematic diagram of a side view of an antenna system according to another embodiment of the present invention;

15 Figure 7 depicts a gear chain diagram illustrating the mechanical interactions between the bevel gears of the antenna system shown in Figure 6;

20 Figure 8 depicts a flow diagram of a method of orientating a movable member in a system for tracking a target according to an embodiment of the present invention.

DETAILED DESCRIPTION

25 Figure 1 is a schematic diagram broadly illustrating an exemplary system 100 according to an embodiment of the present invention with an anti-cable twisting mechanism. The system 100 comprises a base 102, and a movable member 104 having a first axis 106 and affixed (not shown) with respect to the base 102. At least one cable 108 is connectable to the movable member 104 and the base 102 such that a length of the cable exists therebetween. For example, when connected, the cable 108 has one
30 part 110 connected to the movable member 104 and another part 112 connected to the base 102. In particular, the system 100 is configured such that rotating the movable member 104 about a second axis 114 is accompanied with a corresponding rotation of the movable member 104 about its first axis 106 in an opposite or reverse direction so as to substantially prevent, or at least minimise,

twisting of the cable about its length. For example, when the movable member 104 is rotated about the second axis 114 in a clockwise direction (e.g., when looking into the second axis 114 from the top of Figure 1), the opposite or reverse direction which the movable member 104 is rotated about its first axis 106 is an anticlockwise direction (e.g., when looking into the first axis 106 from the left of Figure 1) and vice versa.

For ease of understanding, systems according to embodiments of the present invention are hereinafter described with cables 108 connected to the movable member 104 and the base 102. However, as described above, it will be apparent to a person skilled in the art that the systems described hereinafter do not necessarily need to have cables 108 already connected to the movable member 104 and the base 102. Instead, the systems may be manufactured and/or sold without such cables 108 and the cables 108 may be connected in the systems thereafter.

Referring to Figure 1, since the cables 108 each has one part 110 connected to the movable member 104 and another part 112 connected to the base 102, the cables will begin twisting as the movable body 104 is rotated about the second axis 114 (e.g., an azimuth axis). As a result, if the movable body 104 is continuously rotated in the same azimuth direction, e.g., anti-clockwise as denoted by arrow 116, the cables 108 will continue to twist as denoted by arrow 118 and to such an extent that the cables 108 may ultimately fail.

According to embodiments of the present invention, in order to substantially avoid, or at least minimise, such twisting of the cables 108, the movable member 104 is configured to rotate or turn about its own axis 106 in an opposite or reverse direction (e.g., clockwise as denoted by arrow 120). Advantageously, such a rotation of the movable member 104 about its own axis 106 acts to release the twist of the cables 108 created by the rotation of the movable member 104 about the second axis 114. In this regard, two equal but reverse torsional forces on the cables 108 will result in the net torsion on the cables 108 being zero. Therefore, in contrast to the prior art, the cable twisting problem is minimised or substantially avoided without having to employ a rotary joint.

For example, the first axis 106 is an axis generally perpendicular to a plane of the movable member 104. Alternatively, or in addition to, the first axis 106 is generally along a direction which the cables 108 generally extend from the movable member 104. For example, in the case where the system 100 is an antenna system, the first axis 106 is preferably a boresight axis 106 and the second axis 114 is an azimuth axis.

It will be appreciated by a person skilled in the art that the embodiment of Figure 1 can be applied to any type of system that may suffer from the above-described cable twisting problem. Furthermore, it is apparent to a person skilled in the art that there are various ways to configure the system 100 to achieve the above-mentioned technical function (i.e., such that rotating the movable member 104 about the second axis 114 is accompanied with a corresponding rotation of the movable member 104 about its first axis 106 in an opposite direction). By way of examples only, the present invention will later be described with respect to two possible configurations of an antenna system for achieving the above-mentioned technical function. However, it will be appreciated to a person skilled in the art that the present invention is not limited to the specific configurations described hereinafter and other configurations and types of system are within the scope of the present invention so long as they are configured to achieve the same or equivalent technical function.

Figure 2 illustrates a side view of an exemplary antenna system 200 according to an embodiment of the present invention. The antenna system 200 comprises a base 202, a movable member 204 having a first axis 206 and affixed with respect to the base 202, and one or more cables 208 each having one part 210 connected to the movable member 204 (e.g., connected to electrical device(s) or component(s) 211 on the movable member 204) and another part 212 connected to the base 202 (e.g., connected to electrical device(s) or component(s) on the base 202) such that a length of cable exists therebetween. Hereinafter, for ease of understanding, the movable member 204 will be referred to as (but not limited to) an antenna plate, the first axis 206 will be referred to as (but not limited to) a boresight axis and the second axis 214 will be referred to as (but not limited to) an azimuth axis. Due to the orientation of the antenna plate 204 in Figure 2, the boresight axis 206 is shown to be coaxial with the azimuth axis 214. However, it is apparent to a person skilled in the art that in other positions or orientations, the boresight axis 206 is not coaxial

with the azimuth axis 214 (e.g., see Figure 3) since the boresight axis 206 is perpendicular to a plane of the antenna plate 204.

The antenna system 200 as shown in Figure 2 has an azimuth-elevation configuration. That is, the antenna plate 204 is rotatable about the azimuth axis 214 and the elevation axis 216 resulting in two degrees of freedom (DOFs). As illustrated in Figure 3, the antenna plate 204 is rotatable 360 degrees (i.e., unlimited rotation) about the azimuth axis 214 as denoted by arrow 215 and for example about 140 degrees about the elevation axis 216 as denoted by arrow 217. In other embodiments, depending on the requirements, the antenna plate 204 may be rotatable up to about 230 degrees so that the antenna plate 204 can have a tracking coverage of greater than a hemisphere.

The antenna system 200 comprises an actuator 220 (e.g., a motor such as a stepper motor) for driving the antenna plate 204 about the azimuth axis 206 (hereinafter referred to as an azimuth motor 220) and another actuator 222 (e.g., a motor such as a stepper motor) for driving the antenna plate 204 about the elevation axis 216 (hereinafter referred to as an elevation motor 222).

An exemplary mechanism for driving the antenna plate 204 about the azimuth axis 206 using the azimuth motor 220 and about the elevation axis 216 using the elevation motor 222 will now be described. As described hereinbefore, the antenna plate 204 is affixed with respect to the base 202. In this regard, the antenna system 200 includes a carrier shaft or a first rotary shaft 230 extending vertically along the azimuth axis 214. The azimuth motor 220 is fixed on the base 202 and the carrier shaft 230 is affixed to (and rotatable with respect to) the base 202. A bottom end 232 of the carrier shaft 230 is coupled with a shaft 234 of the azimuth motor 220 via a belt and pulley mechanism 236 thereby enabling the driving force of the azimuth motor 220 to be translated to the carrier shaft 230 for rotating the carrier shaft 230 about the azimuth axis 214. A top end 238 of the carrier shaft 230 has a slot 240 for receiving a second rotary shaft or elevation shaft 242 therein such that the elevation shaft 242 extends along the elevation axis 248 and perpendicular to the carrier shaft 230 (i.e., azimuth axis 214). An antenna plate bracket 244 is affixed to the elevation shaft 242 and provides an arm structure for projecting or extending the antenna

plate 204 away from the top end 238 of the carrier shaft 230. With this mechanism, when the carrier shaft 230 is rotated about the azimuth axis 214 by the azimuth motor 250, the elevation shaft 242, the antenna plate bracket 244 and thus the antenna plate 204 affixed to the antenna plate bracket 244 would also be rotated about the azimuth axis 214.

In order for the elevation motor 222 to drive the antenna plate 204 about the elevation axis 216, a third rotary shaft 248 is affixed to the base 202 and extends vertically along the azimuth axis 214 and coaxial with the carrier shaft 230. A first bevel gear 246 fixed to a top end of the third rotary shaft 248 is arranged to interlock with a second bevel gear 250 fixed to an end of the elevation shaft 242 at right angle. The elevation motor 222 is fixed on the base 202 of the antenna system 200 and a shaft 252 of the elevation motor 222 is coupled with a bottom end 254 of the third rotary shaft 248 via a belt and pulley mechanism 256. With this mechanism, when the third rotary shaft 248 is rotated about the azimuth axis 214 by the elevation motor 222, the elevation shaft 242 will rotate about the elevation axis 216 through the second bevel gear 250 interacting with the first bevel gear 246. As a result, the antenna plate 204 affixed to the elevation shaft 242 would also rotate about the elevation axis 216.

As shown in Figure 2, the carrier shaft 230 is hollow along its length for allowing cable(s) 208 to pass through from the base 202 to the antenna plate 204. The third rotary shaft 248 is also hollow along its length thereby allowing the carrier shaft 230 to extend coaxially therein. Furthermore, bearings 258 are provided between structures as illustrated in Figure 2 for allowing one structure to rotate relative to another structure.

Therefore, with the above-described mechanism, the two DOFs rotary motions of the antenna plate 204 are realised through bevel gear differential motion. Figure 4 depicts a simplified diagram of the antenna system 200 shown in Figure 2 for illustrating the differential motion principle resulting in the two DOFs rotary motions of the antenna plate 204. The elevation shaft 242 is capable of making a compound rotary motion that includes a rotation about the azimuth axis 214 and a rotation about the elevation axis 216. If the angular speeds of the motor 1 and the motor 2 are ω_1 and ω_2 , respectively,

then the rotational speed of the antenna plate 204 affixed to the elevation shaft 242 in terms of the component of the azimuth axis (ω_z) and the component of the elevation axis (ω_E) can be determined by:

$$\omega_E = N_1/N_2(\omega_2 - \omega_1) \quad \text{equation (i)}$$

$$\omega_z = \omega_2 \quad \text{equation (ii)}$$

where N_1 and N_2 are the number of teeth of the first bevel gear and the second bevel gear, respectively. Therefore, the desired azimuth rotation and elevation rotation of the antenna plate 204 can be obtained through controlling the driving force or rotation speed of the azimuth motor 220 and the elevation motor 222 based on equations (i) and (ii).

For example, the antenna system 200 may be an antenna mount installed on a mobile vehicle 218 (e.g., a boat 218 as shown in Figure 3). Therefore, as the mobile vehicle 218 moves and turns in different directions, the antenna system 200 will preferably need unlimited rotation about the azimuth axis 214 in order to continuously track a target such as a satellite. As explained with reference to Figure 1, without an anti-cable twisting mechanism, the cable (e.g., a RF cable) 208 having one part 210 connected to an electrical device or component (e.g., a RF sensor) 211 on the antenna plate 204 and another part 212 connected to an electrical device or component 213 (e.g., RF signal processor) on the base 202, the cable 208 will begin twisting as the antenna plate 204 is rotated about the azimuth axis 214. Therefore, over a period of time, such twisting of the cable can build up to an extent that the cable 208 may ultimately fail. In order to substantially avoid, or at least minimise, such twisting of the cable 208, as described hereinbefore, the antenna plate 204 is configured such that rotating the antenna plate 204 the azimuth axis 214 is accompanied with a corresponding rotation of the antenna plate 204 about its boresight axis 106 in an opposite or reverse direction.

By way of examples only, two possible configurations of the antenna system 200 for achieving the above-mentioned technical function will now be described according to two embodiments of the present invention. However, as explained hereinbefore, it

will be appreciated to a person skilled in the art that the present invention is not limited to the specific configurations described hereinafter and other configurations and types of systems are within the scope of the present invention so long as they are configured to achieve the same or equivalent technical function.

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Figure 5 depicts a schematic diagram of a top view of an antenna system 500 configured such that rotating the antenna plate 204 about the azimuth axis 214 is accompanied with a corresponding rotation of the antenna plate 204 about its boresight axis 206 in an opposite direction. The main difference between the
10 antenna system 500 shown in Figure 5 and the antenna system 200 shown in Figure 2 is the incorporation of an actuator 502 and related mechanisms or configurations for correspondingly rotating the antenna plate 204 about its boresight axis 206. Hereinafter, for ease of understanding, the actuator 502 will be referred to as (but not limited to) a motor 502. The components of the antenna system 500
15 which are the same or equivalent to those of the antenna system 200 described hereinbefore will be denoted with the same reference numerals and detailed description will therefore be omitted for conciseness.

In the embodiment, the motor 502 is disposed on the antenna plate 204 and coupled
20 to a mechanism 504 for translating the driving force of the motor 502 to rotate the antenna plate 204 about its boresight axis 206. In particular, the motor 502 is disposed on a front surface (i.e., outward facing surface) 506 of the antenna plate 204 and has a shaft 508 which extends through an opening 510 and beyond a back surface (i.e., inward facing surface) 512 of the antenna plate 204. As shown, the
25 opening 510 formed on the antenna plate 204 is offset with respect to the boresight axis 206 for allowing the motor shaft 508 to pass through. The antenna plate 204 also has a hollow shaft 514 extending from the back surface 512 about the boresight axis 206. Therefore, by coupling the motor shaft 508 and the hollow shaft 514 of the antenna plate 204 with a belt and pulley mechanism 504, the antenna plate 204 can
30 be rotated about its boresight axis 206 by the driving force of the motor 502. For example, a bearing mechanism 515 is coupled between the hollow shaft 514 of the antenna plate 512 and a hollow shaft 516 of the antenna plate bracket 244 for allowing the antenna plate 204 to be rotatable about its boresight axis 206.

The motor 502 is configured to receive a control signal for controlling the amount of driving force generated for driving the antenna plate 204 about its boresight axis 206. As shown in Figure 5, a cable 208 is connected to the motor 502 for transmitting the control signal to control the motor 502 generated from an electrical component fixed on the base 202. The antenna plate 204 has an opening 517 form therein preferably about the boresight axis 206 for allowing cables 208 connected to the base 202 to pass through to connect to any electrical device(s) or component(s) on the front surface 506 of the antenna plate 204.

In an embodiment, the motor 502 is controlled to generate a driving force such that the degree of rotation of the antenna plate 204 about its boresight axis 206 is proportional to the degree of the rotation of the antenna plate 204 about the azimuth axis 214 but in an opposite direction. In this case, the control signal for controlling the motor 502 is generated to be the proportional but opposite in polarity to a control signal for controlling the azimuth motor 220. Preferably, the degree of rotation of the antenna plate 204 about the boresight axis 206 is substantially equal to the degree of the rotation of the antenna plate 204 about the azimuth axis 214. In this case, the control signal for controlling the motor 502 is generated to be the same but opposite in polarity to a control signal for controlling the azimuth motor 220.

As a result, twisting of the cables 208 can be advantageously minimised or substantially avoided without requiring a rotary joint. For example, the motor 502 can be a commercially available low cost motor. It is apparent to a person skilled in the art that various modifications can be made to the antenna system 500 while achieving the same technical result or effect and thus are within the scope of the present invention. For example, instead of receiving a control signal from a cable 208 generated by an electrical component on the base 202, a sensor 518 capable of detecting an angular velocity of the antenna plate 204 in the azimuth direction can be disposed on the antenna plate 204. Therefore, the sensed signal containing angular velocity data in the azimuth direction can be used for controlling the motor 502 to drive the antenna plate 204 about its boresight axis 206 in the manner as hereinbefore described.

Figure 6 depicts a schematic diagram of a side view of an antenna system 600 illustrating another configuration according to an embodiment of the present

invention for simultaneously rotating the antenna plate 204 about its boresight axis 206 in an opposite direction when the antenna plate 204 is rotated about the azimuth axis 214. In particular, instead of using the motor 502 as described in the embodiment of Figure 5, a mechanical assembly 601 is provided for coupling the antenna plate 204 and the carrier shaft 230 together such that rotating the antenna plate 204 about the azimuth axis 214 is accompanied with a corresponding rotation of the antenna plate 204 about its boresight axis 206 in an opposite direction so as to substantially prevent, or at least minimise, twisting of said one or more cables about its length. The components of the antenna system 600 which are the same or equivalent to those of the antenna systems 200, 500 described hereinbefore will be denoted with the same reference numerals and detailed description will therefore be omitted for conciseness.

In one configuration, the mechanical assembly 601 comprises a series of interlocking gears configured such that rotation of the carrier shaft 230 about the azimuth axis 214 is translated to proportional rotation of the antenna plate 204 about its boresight axis 206 but in the opposite direction. Preferably, the degree of rotation of the antenna plate 204 about the boresight axis 206 is substantially equal to the degree of the rotation of the antenna plate 204 about the azimuth axis 214. The mechanical assembly 601 comprises a first bevel gear 602, a second bevel gear 604, a third bevel gear 606 and a fourth bevel gear 608. The first bevel gear 602 is stationary and rigidly fixed to the base 202 via a shaft 303 (i.e., non-rotatable). The second bevel gear 604 and the third bevel gear 606 are fixed to a common shaft 605 therebetween such that they rotate together. The common shaft 605 is arranged within the slot 240 of the carrier shaft 230 such that it extends along the elevation axis 216 and is perpendicular to the carrier shaft 230. The common shaft 605 is hollow to allow the elevation shaft 242 to extend coaxially therein. The fourth bevel gear 608 and the antenna plate 204 are fixed to a common shaft 610 therebetween such that they rotate together. The second bevel gear 604 is engaged with the first bevel gear 602 at right angle and the third bevel gear 606 is engaged with the fourth bevel gear 608 at right angle in the manner as shown in Figure 6.

With this configuration, rotating the carrier shaft 230 about the azimuth axis 214 using the azimuth motor 220 will cause the shaft 605 connecting the second and

third bevel gears 604, 606 to rotate about the azimuth axis 214. As a result, since the second bevel gear 604 is engaged at right angle to the non-rotatable first bevel gear 602, the second bevel gear 304 will be caused to rotate about the elevation axis 216 in an opposite direction. Furthermore, since the third bevel gear 606 is connected to the second bevel gear 604 via the common shaft 605, the third bevel gear 606 will also be caused to rotate in the same direction as the second bevel gear 604. Therefore, as the fourth bevel gear 608 is engaged with the third bevel gear 606 at right angle, the fourth bevel gear 608 will also rotate thereby rotating the antenna plate 204 about its boresight axis. The above-described mechanical interactions between the first to the fourth bevel gears 602, 604, 606, 608 are schematically illustrated in a gear chain diagram shown in Figure 7. According to the gear chain diagram, assuming that the numbers of teeth of the first to fourth bevel gears are the same, it can be deduced that the rotation speed (ω_s) of the antenna plate 204 about the boresight axis 206 has the following relationship:

$$\omega_s = -\omega_z \quad \text{equation (iii)}$$

Accordingly, the mechanical assembly 601 is capable of coupling the antenna plate 204 and the carrier shaft 230 such that rotating the antenna plate 204 about the azimuth axis 214 is accompanied with a corresponding rotation of the antenna plate 204 about its boresight axis 206 in an opposite direction. As a result, twisting of the cables 208 can be advantageously minimised or substantially avoided without requiring a rotary joint. It is apparent to a person skilled in the art that various modifications can be made to the antenna system 600 while achieving the same technical result or effect and thus are within the scope of the present invention.

It is understood that the number of teeth of the bevel gears is chosen to achieve a desired proportion of rotation of one bevel gear with respect to another bevel gear. For example, in a preferred embodiment, the first bevel gear 602 and the second bevel gear 604 have the same number of teeth and the third bevel gear 604 and the fourth bevel gear have the same number of teeth such that the antenna plate 204 will rotate by the same amount as the carrier shaft 230 (but in an opposite direction).

The number of teeth of the bevel gears can be adjusted to achieve different rotation proportion.

According to an embodiment of the present invention, there is provided a method of orientating a movable member 204 for tracking a target such as a satellite (not shown) as shown in Figure 8. The method comprises a step 802 of rotating the movable member (e.g. the antenna plate) 204 about the second axis (e.g., the azimuth axis) 214 for tracking the target, and a step 804 of simultaneously rotating the movable member 204 about its first axis (e.g., the boresight axis) 206 in an opposite direction so as to minimise twisting of one or more cables 208 about its length.

Accordingly, embodiments of the present invention provide mechanisms / configurations that substantially avoid or at least minimise twisting of cable(s) 208 during continuous rotation of the antenna plate 204 about the azimuth axis 214 without relying on a costly rotary joint. The azimuth motor 250 and the elevation motor 252 that drive angular motions of antenna plate 204 about the azimuth axis 214 and the elevation axis 216 are mounted on the base 202, thus providing a faster response in terms of the antenna's tracking capability. Embodiments of the present invention advantageously provide low-cost, large tracking coverage and compact systems with an anti-cable twisting mechanism.

It will be appreciated that embodiments of the present invention advantageously enable low-cost manufacture without sacrificing the large tracking coverage required for mobile vehicle communication, such as in cars or ships. The antenna system according to embodiments of the present invention provides an effective mechanism for preventing cables such as an RF cable from twisting under continuous tracking motion without requiring the use of an expensive rotary joint. Furthermore, the antenna systems according to embodiments of the present invention are configured without a pole or discontinuity in the upper hemisphere, thereby avoiding limitations suffered by certain conventional 2-axis antenna systems. Compared to conventional 3-axis gimbaled antenna system, the antenna systems according to embodiments of the present invention are structurally less complex, and therefore cheaper to manufacture.

Those skilled in the art will understand that the embodiments described in the foregoing can be modified, without going beyond the scope of the invention, for applications in diverse fields such as communications and sustainable energy harvesting. For example, mobile vehicles and vessels can be equipped with the antenna system according to
5 embodiments of the present invention for satellite communications. In another application, solar panel systems having solar panels configured to track the position of the sun can be equipped with the anti-cable twisting mechanism according to embodiments of the present invention described herein.

CLAIMS

1. A system comprising:
a base; and
5 a movable member affixed with respect to the base, the movable member having a first axis,
wherein at least one cable is connectable to the movable member and the base such that a length of said cable exists therebetween, and
wherein the system is configured such that rotating the movable member
10 about a second axis is accompanied with a corresponding rotation of the movable member about the first axis in an opposite direction so as to minimise twisting of said cable about its length when said cable is connected to the movable member and the base.
- 15 2. The system according to claim 1, further comprising a rotatable member affixed to the base and extending along the second axis, wherein the movable member is coupled to the rotatable member such that the movable member is caused to rotate about the second axis when the rotatable member is rotated.
- 20 3. The system according to claim 2, further comprising a mechanical assembly for coupling the movable member to the rotatable member for driving said corresponding rotation of the movable member about its first axis in the opposite direction when the rotatable member is rotated.
- 25 4. The system according to claim 3, wherein the mechanical assembly comprises a series of interlocking gears configured such that rotation of the rotatable member about the second axis is translated to proportional rotation of the movable member about the first axis in the opposite direction.
- 30 5. The system according to claim 4, wherein the series of interlocking gears are configured such that rotation of the rotatable member about the second axis is translated to equal rotation of the movable member about the first axis in the opposite direction.

6. The system according to claim 4, wherein the series of interlocking gears include bevel gears.

5 7. The system according to claim 1, further comprising an actuator disposed on the movable member operable to generate a driving force for driving said corresponding rotation of the movable member about the first axis in the opposite direction.

10 8. The system according to claim 7, further comprising a belt and pulley mechanism coupled to a shaft of the actuator and a shaft of the movable member such that the driving force generated by the actuator can be translated to the shaft of the movable member for rotating the movable member about the first axis.

15 9. The system according to claim 7, wherein the actuator has said cable connectable thereto for receiving a control signal for controlling the driving force generated by the actuator.

20 10. The system according to claim 9, wherein the control signal is determined such that a degree of rotation of the movable member about the first axis is proportional to a degree of the rotation of the movable member about the second axis.

25 11. The system according to claim 10, wherein the degree of rotation of the movable member about the first axis is equal to the degree of the rotation of the movable member about the second axis.

30 12. The system according to claim 1, wherein the movable member is an antenna plate, the first axis is a boresight axis of the antenna plate and the second axis is an azimuth axis.

13. The system according to claim 12, further comprising an actuator for driving the antenna plate in the azimuth direction.

14. The system according to claim 12, further comprising an actuator for driving the antenna plate in an elevation direction.

5 15. The system according to claim 12, further comprising a receiver disposed on the antenna plate for receiving a signal, wherein the receiver has said cable connectable thereto.

10 16. The system according to claim 15, further comprising an electronic component disposed on the base for receiving and processing the signal from the receiver via said cable connectable thereo.

15 17. A method of orientating a movable member in a system for tracking a target, the system comprising: a base; and a movable member affixed with respect to the base, the movable member having a first axis; wherein at least one cable is connectable to the movable member and the base such that a length of said cable exists therebetween, the method comprising:

rotating the movable member about the second axis for tracking the target, and

20 simultaneously rotating the movable member about its first axis in an opposite direction so as to minimise twisting of said cable about its length when said cable is connected to the movable member and the base.

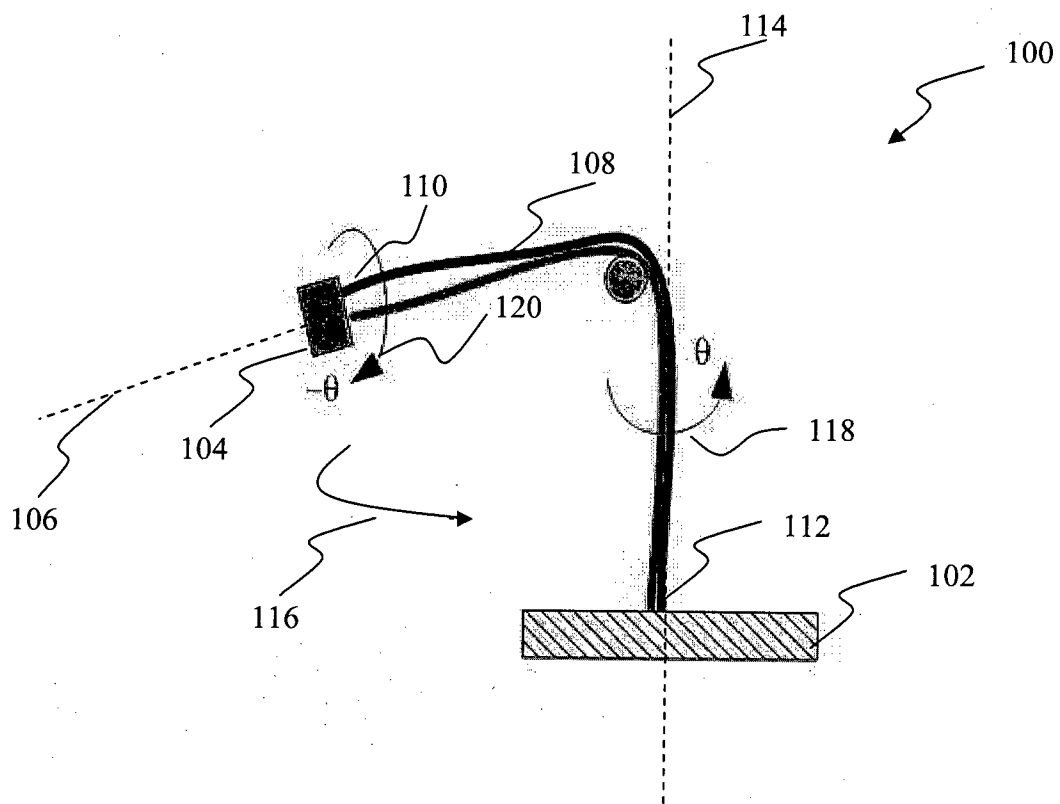


FIG. 1

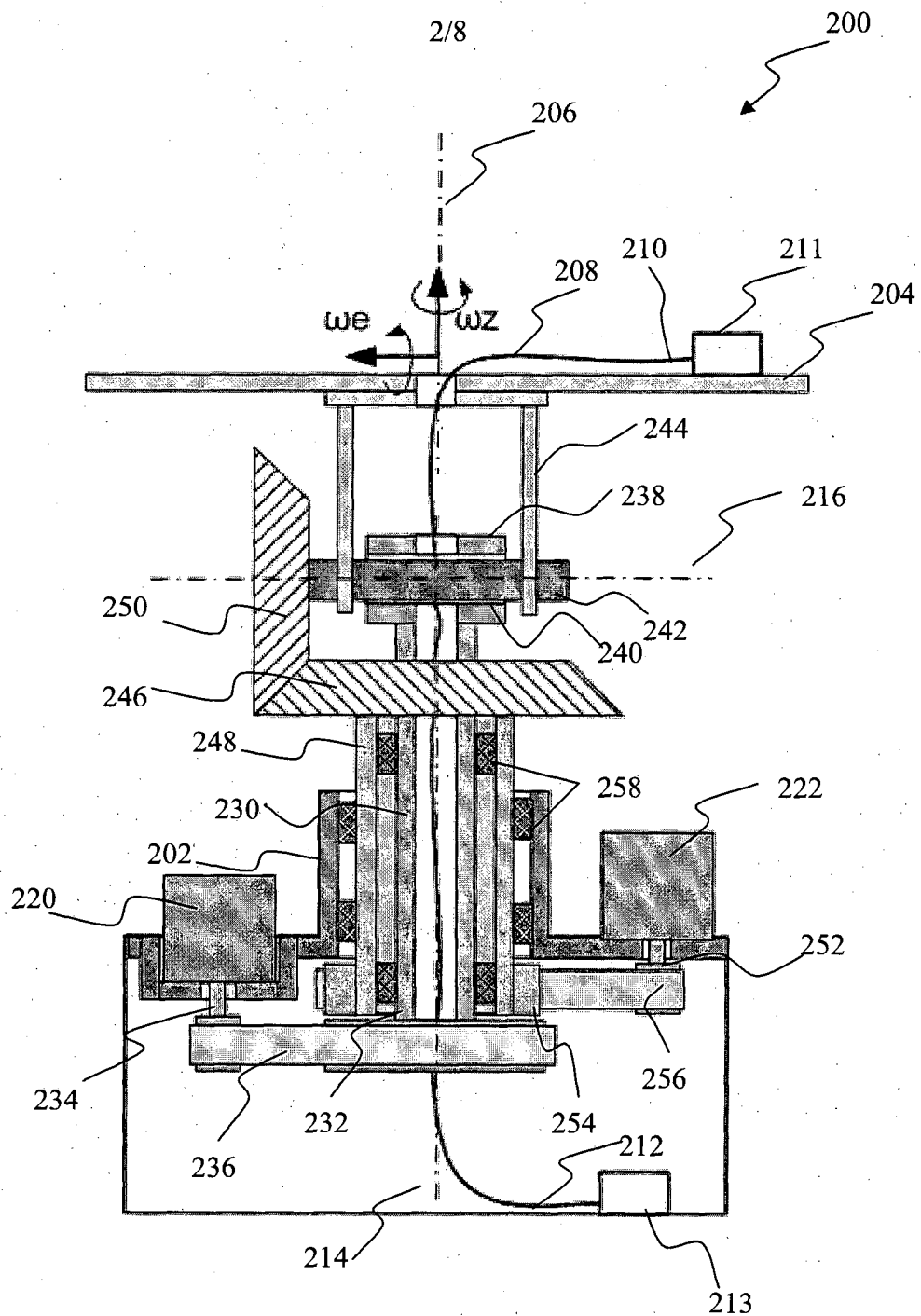


FIG. 2

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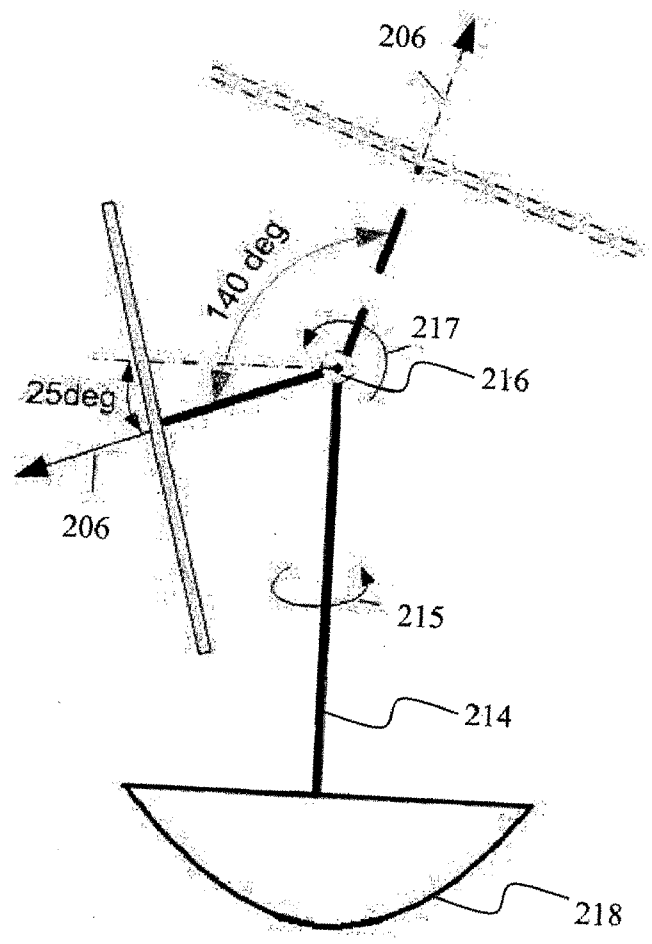


FIG. 3

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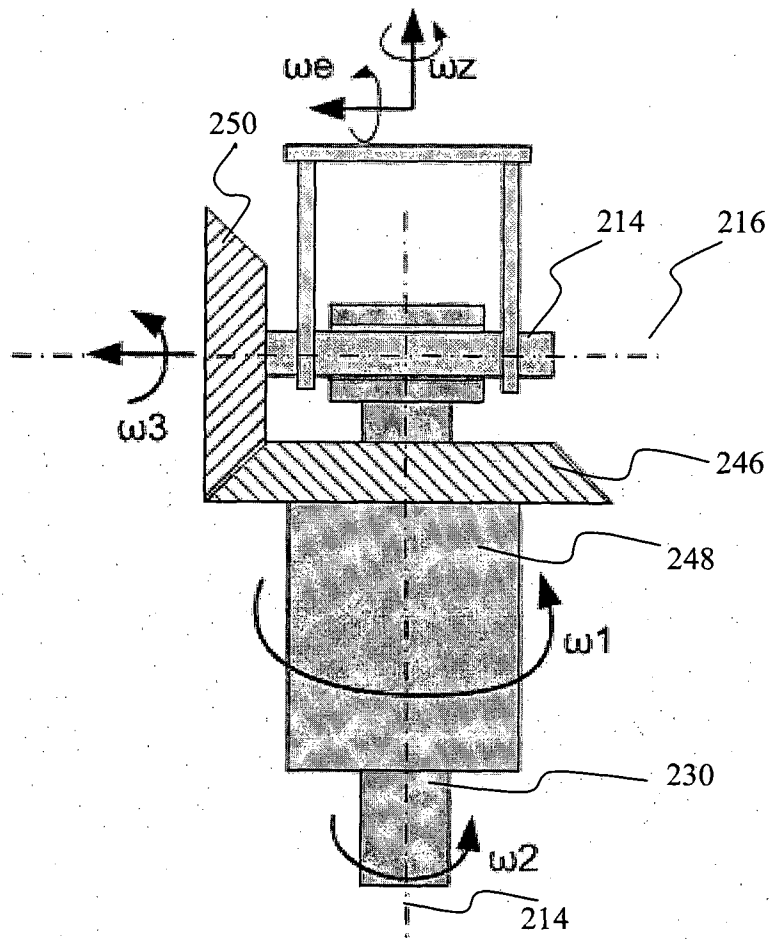


FIG. 4

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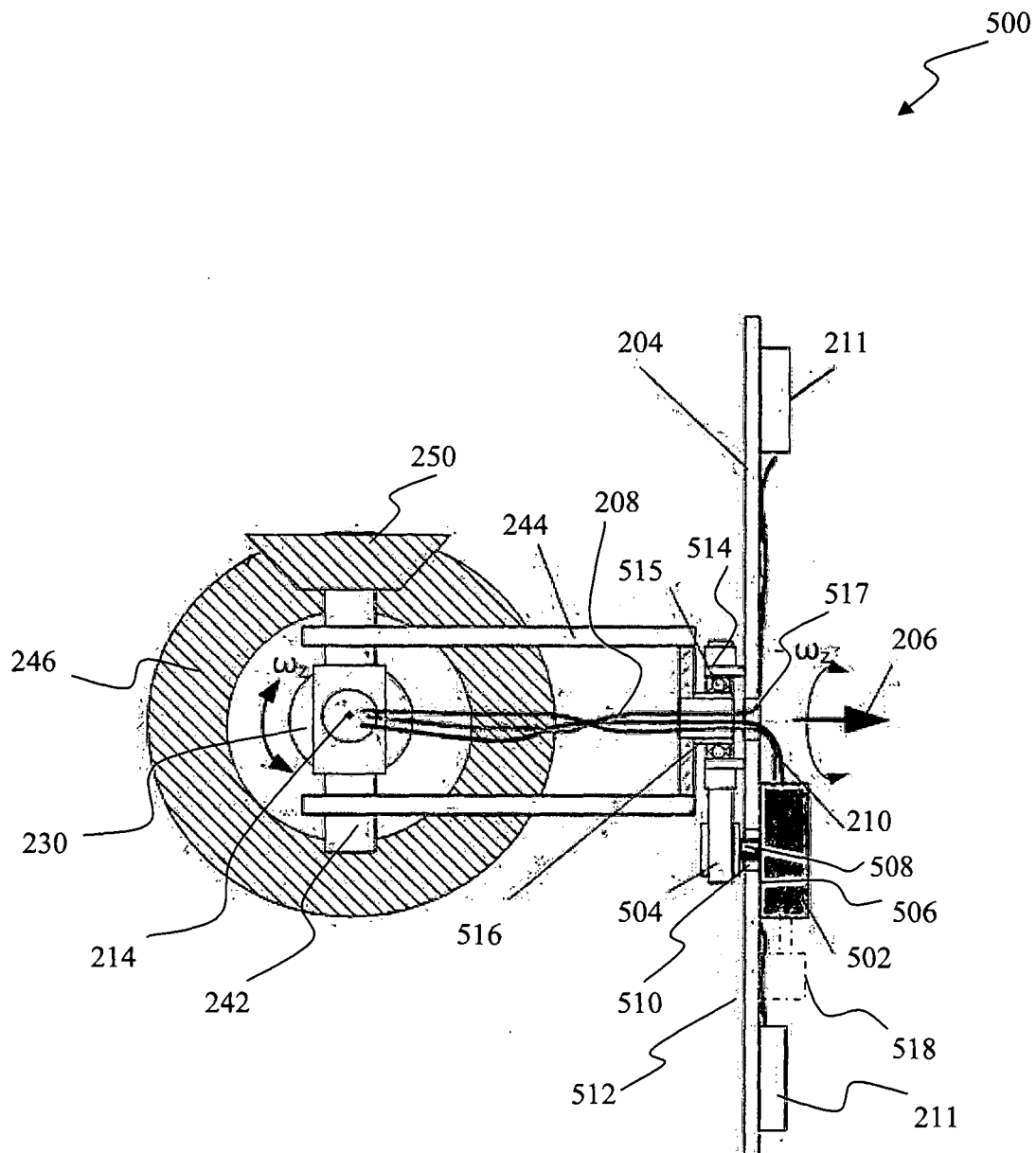


FIG. 5

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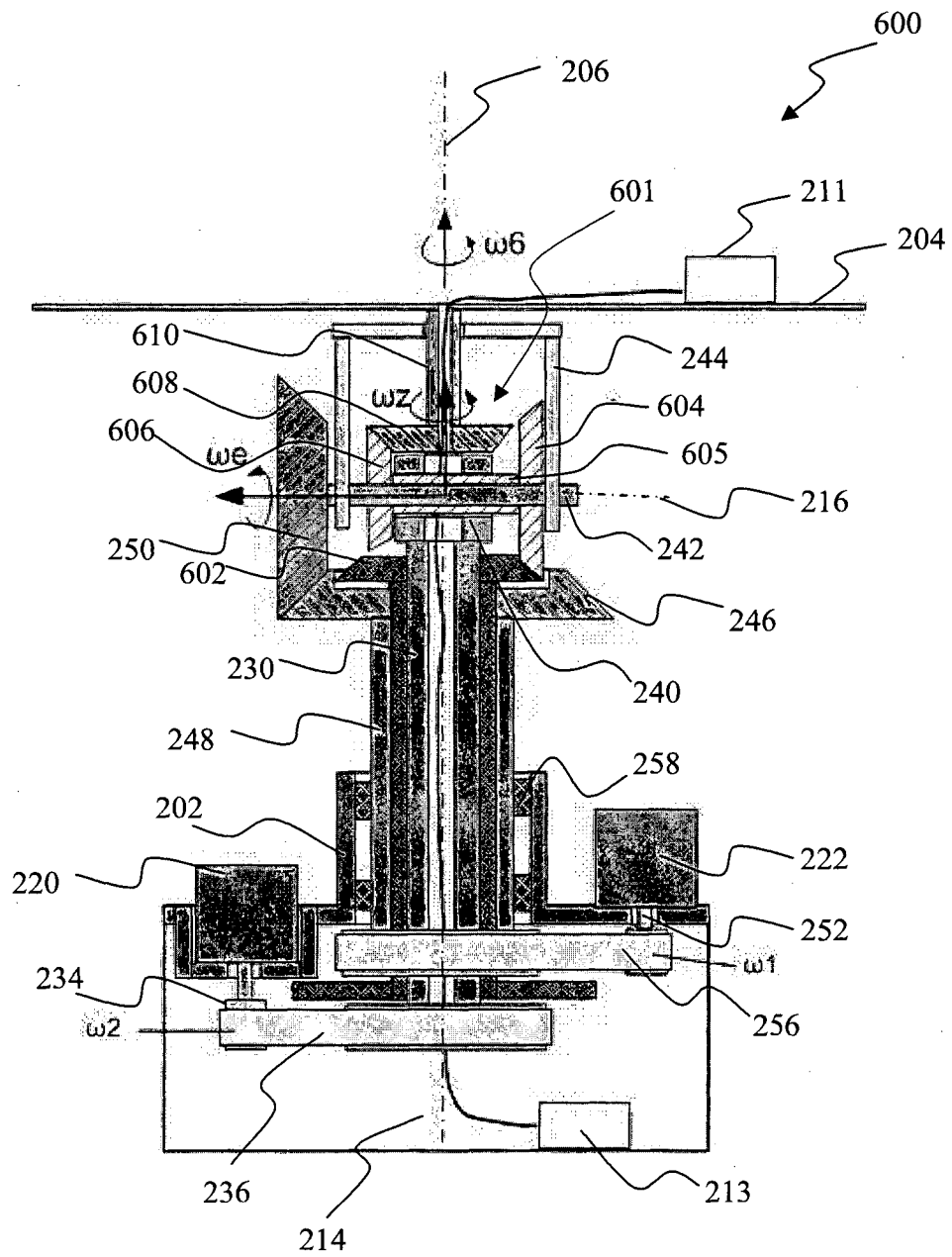


FIG. 6

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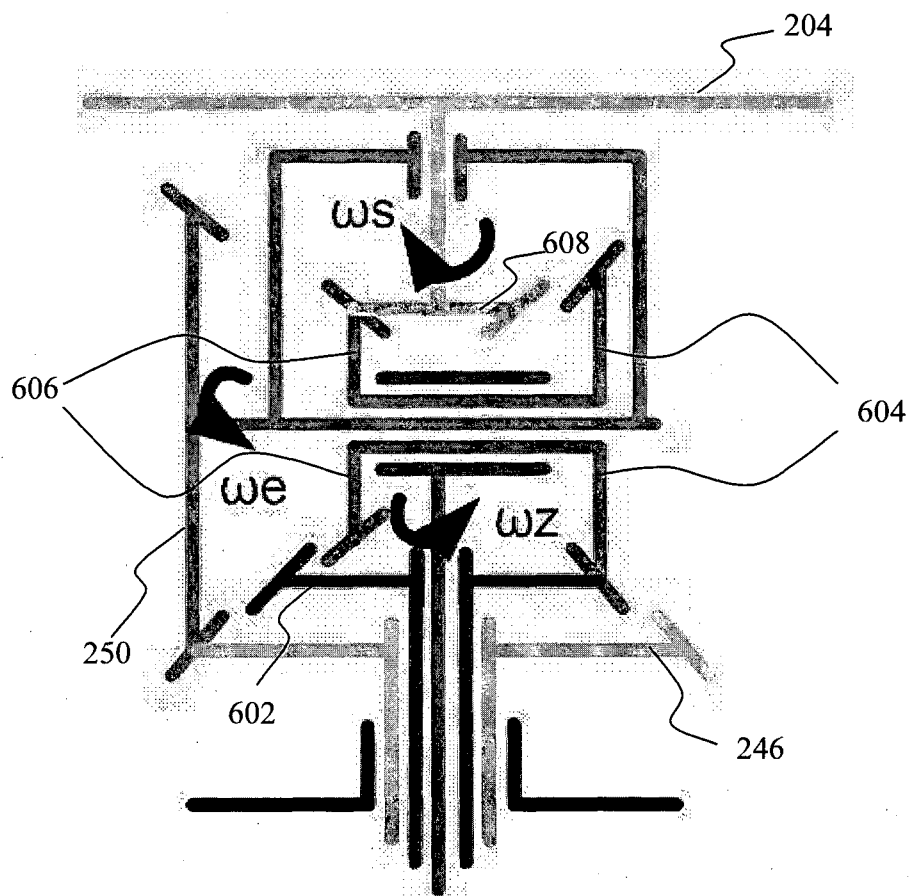


FIG. 7

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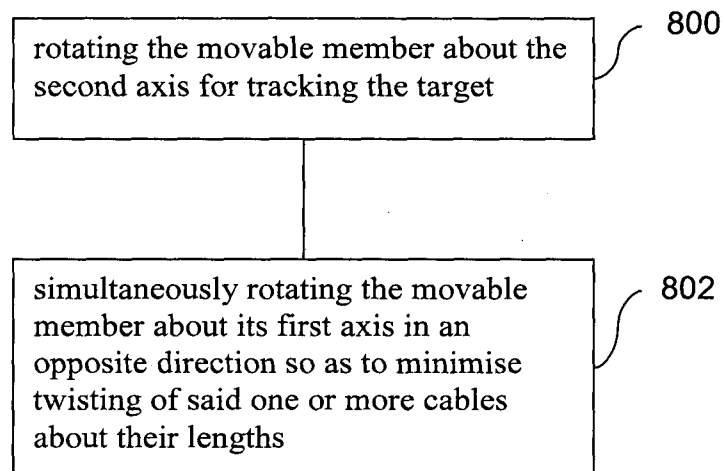


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2012/000276

A. CLASSIFICATION OF SUBJECT MATTER

H01P 1/12 (2006.01) H01Q 1/14 (2006.01) H01Q 3/08 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI: IPCs-H01P1, H01Q1, H01P5, H01Q3; keywords-cable, twist, prevent, opposite, rotation, target, antenna, gear and like words.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
03 September 2012Date of mailing of the international search report
13 September 2012

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INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/SG2012/000276
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2003-249808 A (MITSUBISHI ELECTRIC CORP) 05 September 2003 Abstract, fig.1-3, para.[0009], [0011], [0013]	1-2, 7-17
X	US 4739337 A (ANDERSON) 19 April 1988 Abstract, fig.2, col.1 lines 28-33, col.5 lines 36-42	1-3, 7, 12, 13, 15-17
A	US 6188300 B1 (RODEFFER) 13 February 2001 Fig.11	14

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2012/000276

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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		JP 3699050 B2	28 Sep 2005
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		US 6188300 B1	13 Feb 2001
		WO 9837591 A1	27 Aug 1998

End of Annex