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(54) DUAL-REFLECTOR ANTENNA AND CONTROL METHOD THEREFOR, AND COMMUNICATION SYSTEM

(57) Embodiments of this application provide a dual reflector antenna, a dual reflector antenna control method, and a communication system, and relate to the field of antenna technologies. The dual reflector antenna includes a primary reflector, a secondary reflector, a feed, a first driving structure, and a connecting piece. The secondary reflector is opposite to the primary reflector, and the feed is configured to radiate an electromagnetic wave to the secondary reflector. The first driving structure has a telescopic shaft. The connecting piece is connected to the secondary reflector. When the telescopic shaft is extended, the telescopic shaft abuts against the connecting piece, to drive the secondary reflector to restore to an initial position, where the initial position is a position in which a plane on which a diameter of the secondary reflector is located is parallel to a plane on which a diameter of the primary reflector is located.

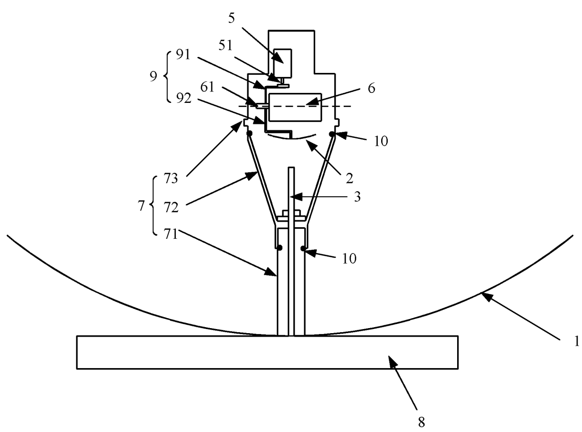

FIG. 10

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Description

TECHNICAL FIELD

[0001] This application relates to the field of antenna technologies, and in particular, to a dual reflector antenna, a dual reflector antenna control method, and a communication system.

BACKGROUND

[0002] With rapid development of wireless communication technologies, especially a sharp increase in base station data traffic in the era of the 5th generation (5th generation, 5G), a transmission capacity requirement for point-to-point microwave communication (Point-To-Point Microwave Communication) is increasingly high.

[0003] An E-band (E-band) ranges from 71 GHz to 76 GHz and from 81 GHz to 86 GHz. Due to a wide operating frequency band and a large capacity, the E-band gradually becomes a main frequency band for 5G transmission. However, rain fade of electromagnetic waves in the E-band is particularly serious. The "rain fade" herein refers to fade caused when an electric wave enters a rain layer. The "rain fade" limits a transmission distance of the E-band. Therefore, a high-gain E-band antenna is required to increase the transmission distance of the E-band antenna.

[0004] However, the high-gain E-band antenna has a problem that a half-power angle of a radiation pattern is small. For example, in a radiation pattern of an E-band antenna with a diameter of 0.6 m or a diameter of more than 0.6 m shown in FIG. 1, in FIG. 1, a horizontal coordinate indicates an angle, and a vertical coordinate indicates a gain. It can be learned from FIG. 1 that a half-power angle of the antenna is only approximately 0.5°.

[0005] In actual application, an antenna is usually installed on a tower, and the tower and the antenna may shake and deflect under the influence of wind. To prevent a receive frequency of a link on which the antenna is located from greatly decreasing when the antenna shakes, an antenna beam needs to be adjusted in most cases, to ensure stability of signal transmission of the link on which the antenna is located.

[0006] However, when the antenna beam is adjusted, a fault may occur. As a result, the antenna is located at a position within an adjustable range or the antenna is outside the adjustable range. In this way, stability of signal transmission of the link on which the antenna is located deteriorates, and even use of the antenna is limited.

SUMMARY

[0007] Embodiments of this application provide a dual reflector antenna, a dual reflector antenna control method, and a communication system, to provide a dual reflector antenna that can restore the antenna to an initial position and be used as a common antenna when an antenna beam direction cannot be adjusted.

[0008] To achieve the foregoing objective, the following technical solutions are used in embodiments of this application.

[0009] According to a first aspect, this application provides a dual reflector antenna. The dual reflector antenna includes a primary reflector, a secondary reflector, a feed, a first driving structure, and a connecting piece. The secondary reflector is opposite to the primary reflector, and the feed is configured to radiate an electromagnetic wave to the secondary reflector. The first driving structure has a telescopic shaft. The connecting piece is connected to the secondary reflector. When the telescopic shaft is extended, the telescopic shaft abuts against the connecting piece, to drive the secondary reflector to restore to an initial position. The initial position is a position in which a plane on which a diameter of the secondary reflector is located is parallel to a plane on which a diameter of the primary reflector is located.

[0010] The dual reflector antenna provided in this embodiment of this application includes the first driving structure that has the telescopic shaft and the connecting piece that is connected to the secondary reflector, the telescopic shaft can abut against the connecting piece when the telescopic shaft is extended, and the secondary reflector is driven by using the connecting piece to restore to the initial position. In this way, when the dual reflector antenna cannot adjust a beam direction, the telescopic shaft of the first driving structure may be extended and abut against the connecting piece, and the secondary reflector is rotated to the initial position by pushing the connecting piece. Compared with that the secondary reflector deviates from the initial position, the dual reflector antenna can be used as a common antenna to ensure basic performance of the antenna.

[0011] In addition, for example, a size and a weight of the primary reflector are far greater than a size and a weight of the secondary reflector. In this embodiment of this application, the first driving structure drives the secondary reflector with a smaller size and weight to rotate. In this way, compared with driving the primary reflector, power consumption of the first driving structure is reduced.

[0012] In a possible implementation of the first aspect, the dual reflector antenna further includes a second driving structure. The second driving structure has a rotating shaft. The rotating shaft is configured to drive the secondary reflector to rotate along a pitch axis relative to the primary reflector, to adjust the beam direction of the dual reflector antenna. The pitch axis is parallel to the plane on which the diameter of the primary reflector is located.

[0013] In other words, the primary reflector is fastened, and the secondary reflector is rotatable under the drive of the rotating shaft of the second driving structure. In this way, after the dual reflector antenna is installed on a tower, when the tower and the dual reflector antenna shake under the influence of wind, the rotating shaft may drive the secondary reflector to rotate around the pitch axis relative to the primary reflector, to adjust the beam direction of the antenna. In addition, even if the antenna shakes at a large angle under the drive of the tower, a gain of the antenna does not decrease sharply, thereby avoiding interruption of a link on which the antenna is located.

[0014] In a possible implementation of the first aspect, the connecting piece includes a first connecting piece and a second connecting piece. One end of the first connecting piece is connected to the rotating shaft, and the other end of the first connecting piece abuts against the telescopic shaft when the telescopic shaft is extended. One end of the second connecting piece is connected to the rotating shaft, and the other end of the second connecting piece is connected to the secondary reflector.

[0015] Power consumption of the first driving structure and the second driving structure can be further reduced by using the first connecting piece and the second connecting piece that are connected to the rotating shaft.

[0016] In a possible implementation of the first aspect, the dual reflector antenna further includes a support. The first driving structure is disposed close to the secondary reflector. One end of the support is fastened relative to the first driving structure, and the other end of the support is fastened relative to the primary reflector.

[0017] In other words, the support is used to support the first driving structure that is close to the secondary reflector and that is suspended in the air.

[0018] In a possible implementation of the first aspect, a part that is of the support, that is located between the primary reflector and the secondary reflector, and that is at least close to the secondary reflector is made of a dielectric material.

[0019] In this way, after the electromagnetic wave radiated by the feed to the secondary reflector is reflected for a first time, the reflected electromagnetic wave radiates to the primary reflector after completely passing through the dielectric material. In this way, performance of the gain and a pattern of the antenna are not deteriorated.

[0020] In a possible implementation of the first aspect, a radial size of a part that is of the support and that is located between the secondary reflector and the primary reflector gradually decreases along a direction from the secondary reflector to the primary reflector, to form a conical structure.

[0021] The conical structure may be used to further reduce influence on the gain and the pattern.

[0022] In a possible implementation of the first aspect, an included angle between a busbar and an axis of the conical structure is 10° to 30°.

[0023] Defining the conical structure may prevent the gain and the pattern from being affected by a wall thickness.

[0024] In a possible implementation of the first aspect, the wall thickness h of the part that is of the support and that is located between the primary reflector and the secondary reflector is: $h = N \times \frac{c}{2f\sqrt{Er}}$. C is a speed of light, f is an operating frequency of the dual reflector antenna, Er is a relative dielectric constant of the dielectric material, and N is a positive integer greater than or equal to 1.

[0025] Defining the wall thickness of the support may prevent the gain and the pattern from being affected by the wall thickness.

[0026] In a possible implementation of the first aspect, a sealed cavity is formed in the support, and the first driving structure and the secondary reflector are disposed in the sealed cavity.

[0027] The first driving structure and the secondary reflector are disposed in the sealed cavity to prevent rainwater from entering and damaging the first driving structure and the secondary reflector.

[0028] In a possible implementation of the first aspect, the support includes a first support, a second support, and a third support. The first support is fastened relative to the primary reflector, and the feed is disposed in the first support. The second support is fastened relative to the first support, and the second support is made of the dielectric material. The third support is fastened relative to the second support, and the first driving structure is fastened in the third support.

[0029] In a possible implementation of the first aspect, the dual reflector antenna further includes an underpan, both the primary reflector and the feed are fastened relative to the underpan, and the feed passes through the primary reflector and faces the secondary reflector.

[0030] According to a second aspect, this application further provides a communication system, including the dual reflector antenna in any implementation of the first aspect and a first controller. The first controller is configured to detect whether a secondary reflector can adjust a beam direction of the dual reflector antenna, and when it is determined that the secondary reflector cannot adjust the beam direction, the first controller controls a telescopic shaft to extend and abut against a connecting piece, to drive the secondary reflector to restore to an initial position.

[0031] In the communication system of this application, when determining that the secondary reflector cannot adjust the beam direction, the first controller controls a first driving structure. The first driving structure starts and extends the telescopic shaft to drive the secondary reflector to rotate to the initial position, to ensure that the dual reflector antenna is a common antenna and has a basic function of the antenna.

[0032] In a possible implementation of the second aspect, the dual reflector antenna further includes a second driving structure that has a rotating shaft, and the communication system further includes an angle detection element and a second controller. The angle detection element is configured to detect a deflection angle of a primary reflector. The second controller controls the rotating shaft to rotate based on the deflection angle, to drive the secondary reflector to rotate relative to the primary reflector, so as to adjust the beam direction of the dual reflector antenna.

[0033] The communication system further includes the angle detection element and the first controller. When the dual reflector antenna is disposed on a tower, and the tower and the dual reflector antenna shake under the influence of wind, the angle detection element may detect a deflection angle at which the dual reflector antenna shakes with the tower. In addition, after receiving a deflection angle signal, the second controller may output instructions that enable the secondary reflector to rotate, and then the second controller controls the second driving structure. In this way, the secondary reflector is driven by the rotating shaft of the second driving structure to adjust the beam direction of the antenna, so that a gain of the antenna basically remains unchanged, and a service of a link on which the antenna is located is maintained to run normally.

[0034] In a possible implementation of the second aspect, the dual reflector antenna further includes a power supply and an energy storage element. The power supply is configured to supply power to the first driving structure and the second driving structure. When the power supply cannot supply power to the first driving structure, the energy storage element is configured to supply power to the first driving structure.

[0035] The energy storage element is separately disposed to supply power to the first controller and the first driving structure. In this way, when the power supply of the dual reflector antenna fails, the energy storage element can be used to supply power to the first controller and the first driving structure, to ensure that the secondary reflector is restored to the initial position under action of the first controller and the first driving structure.

[0036] According to a third aspect, this application further provides a dual reflector antenna control method. A dual reflector antenna includes a first driving structure that has a telescopic shaft, and a connecting piece connected to a secondary reflector of the dual reflector antenna, and the control method includes:

determining that the secondary reflector of the dual reflector antenna cannot adjust a beam direction of the dual reflector antenna; and
controlling the telescopic shaft to extend and abut against the connecting piece, to drive the secondary reflector to restore to an initial position, where the initial position is a position in which a plane on which a diameter of the secondary reflector is located is parallel to a plane on which a diameter of a primary reflector of the dual reflector antenna is located.

[0037] In a possible implementation of the third aspect, the connecting piece includes a first connecting piece and a second connecting piece, and the dual reflector antenna further includes a second driving structure that has a rotating shaft. One end of the first connecting piece is connected to the rotating shaft. One end of the second connecting piece is connected to the rotating shaft, and the other end of the second connecting piece is connected to the secondary reflector.

[0038] Driving the secondary reflector to restore to an initial position includes:
controlling the telescopic shaft to extend and abut against the first connecting piece, and pushing the first connecting piece and the second connecting piece to rotate around the rotating shaft, to drive the secondary reflector to rotate to the initial position.

[0039] In a possible implementation of the third aspect, the dual reflector antenna further includes a second controller and an angle detection element.

[0040] The control method includes: determining at least one of the following:

determining that the rotating shaft has a rotation function;
determining that the second controller has a function of controlling the rotating shaft to rotate; and
determining that the angle detection element has a function of detecting a deflection angle of the primary reflector.

[0041] In this way, the first controller may detect the rotating shaft, and the second controller may detect the angle detection element, so as to detect any structure that affects rotation of the secondary reflector, thereby improving performance of the dual reflector antenna.

BRIEF DESCRIPTION OF DRAWINGS

[0042]

FIG. 1 is a curve diagram of a gain of a dual reflector antenna;
FIG. 2 is a schematic diagram of a structure of a dual reflector antenna;
FIG. 3 is a schematic diagram of a partial structure of a communication system according to an embodiment of this application;
FIG. 4 is a schematic diagram of a state in which a secondary reflector rotates relative to a primary reflector in a communication system according to an embodiment of this application;
FIG. 5 is a schematic diagram of a structure of a dual reflector antenna according to an embodiment of this application;
FIG. 6 is a schematic diagram of a structure of a dual reflector antenna according to an embodiment of this application;
FIG. 7 is a simulation diagram of beam scanning of a dual reflector antenna according to an embodiment of this application;
FIG. 8 is a block diagram of a control part of a dual reflector antenna according to an embodiment of this application;

FIG. 9 is a block diagram of a control part of a dual reflector antenna according to an embodiment of this application;

FIG. 10 is a schematic diagram of a structure of a dual reflector antenna according to an embodiment of this application;

FIG. 11 is a schematic diagram of a partial structure of FIG. 10;

FIG. 12 is a simulation diagram of electrical performance of a dual reflector antenna according to an embodiment of this application;

FIG. 13 is a flow block diagram of a dual reflector antenna control method according to an embodiment of this application;

FIG. 14 is a flow block diagram of a dual reflector antenna control method according to an embodiment of this application; and

FIG. 15 is a flow block diagram of a dual reflector antenna control method according to an embodiment of this application.

[0043] Reference numerals:
1: primary reflector; 2: secondary reflector; 3: feed; 4: support base; 5: first motor; 51: telescopic shaft; 6: second motor; 61: rotating shaft; 7: support; 71: first support; 72: second support; 73: third support; 8: underpan; 9: connecting piece; 91: first connecting piece; 92: second connecting piece; and 10: sealing strip.

DESCRIPTION OF EMBODIMENTS

[0044] To facilitate understanding of technical solutions, the following explains technical terms in this application.

[0045] A half-power angle is also referred to as 3 dB beamwidth or half-power beamwidth. In an antenna pattern, for example, each antenna has two or more lobes. A largest lobe is referred to as a main lobe, and the other lobes are referred to as side lobes. Radiation energy of the main lobe is the strongest. In the antenna pattern, in a plane containing a maximum radiation direction of the main lobe, an included angle between two points at which power flux density drops to half (or less than a maximum value 3 dB) of the power flux density relative to the maximum radiation direction is referred to as the half-power angle. A smaller half-power angle indicates better directivity and a stronger antiinterference capability of the antenna.

[0046] Antenna beam (antenna beam): For example, the antenna beam refers to the main lobe (also referred to as a main beam), and is an area in which antenna energy is most concentrated. For example, the antenna has only one main beam, and adjusting the antenna beam refers to adjusting the main beam of the antenna.

[0047] A direction of the antenna beam is a direction of the main beam of the antenna.

[0048] The following describes the technical solutions in embodiments in this application in detail with reference to accompanying drawings.

[0049] In the field of antenna, there is a dual reflector antenna. The dual reflector antenna (for example, a Cassegrain antenna or a Gregory antenna) is commonly used in microwave and millimeter wave bands, and is widely used in satellite communication, microwave communication, a radar, remote sensing, and other wireless communication systems.

[0050] FIG. 2 is a diagram of a structure of a dual reflector antenna. The dual reflector antenna includes a primary reflector 1, a secondary reflector 2, and a feed 3. An electromagnetic signal enters through the feed 3, radiates to the secondary reflector 2 and then is reflected for a first time. The reflected electromagnetic signal propagates to the primary reflector 1 and then is reflected for a second time, and the electromagnetic signal radiates to space after the second reflection. Black dashed lines with arrows in FIG. 2 indicate propagation paths of the electromagnetic signal. For example, in the dual reflector antenna, the primary reflector 1 uses a rotatable paraboloid, and the secondary reflector 2 uses a rotational hyperboloid.

[0051] Based on characteristics of a hyperboloid and a paraboloid, as shown in FIG. 2, wave paths of beams emitted by F1 of the feed 3 to an aperture S are equal, for example, F1A1+A1B1+B1CI=F1A2+A2B2+B2C2. In this case, a spherical wave of the feed whose phase center is at F1 is bound to become a plane wave on a diameter of the primary reflector 1, that is, the S plane is an equal-phase plane, so that the dual reflector antenna has performance of a high gain, a sharp beam, and a small half-power angle.

[0052] When designing the primary reflector 1, a focal-length-to-diameter ratio F/D of the primary reflector 1 is a key parameter. As shown in FIG. 2, in the focal-length-to-diameter ratio F/D of the primary reflector 1, F is a focal length of the primary reflector 1, and D is the diameter of the primary reflector 1. When focal-length-to-diameter ratios F/D are different, gain rollback values obtained when beams are deflected by a same angle are also different. For example, a value range of the focal-length-to-diameter ratio F/D is 0.25 to 0.4. In this embodiment of this application, a primary reflector 1 whose F/D is 0.357 may be selected.

[0053] For example, a diameter of the secondary reflector 2 is approximately one tenth of the diameter of the primary reflector 1, and performance of a secondary reflector whose diameter is 60 mm to 100 mm is better. In this application, a secondary reflector 2 whose diameter is 80 mm may be used.

[0054] The feed 3 may select an open-circular waveguide. To reduce waveguide losses caused by the open-circular waveguide, a diameter of the open-circular waveguide is generally 3 mm to 4 mm. In this application, an open-circular waveguide with a diameter of 3.56 mm may be selected.

[0055] In some implementations, for example, in a communication system, as shown in FIG. 3, the dual reflector antenna is installed on a support base 4 (which may also be referred to as a tower). In this way, the dual reflector antenna shakes with the support base 4 under action of wind force or the like. In FIG. 3, black solid lines indicate structures of the support base 4 and the dual reflector antenna when the support base 4 and the dual reflector antenna do not deflect, and black dashed lines indicate structures of the support base 4 and the dual reflector antenna after deflection. As long as shaking angles of the tower and the dual reflector antenna are greater than a half-power angle of the dual reflector antenna, a gain and a pattern of the antenna are deteriorated, and a received signal level of a link on which the dual reflector antenna is located is greatly reduced, causing interruption of the link including the dual reflector antenna. Therefore, a beam direction of the dual reflector antenna that shakes with the tower needs to be adj usted.

[0056] In some implementations, the primary reflector 1 is fastened relative to the support base 4. In this case, to adjust the beam direction of the antenna, with reference to FIG. 4, the secondary reflector 2 may rotate around a pitch axis L relative to the primary reflector 1. In this way, after an electromagnetic wave radiated by the feed radiates to the secondary reflector 2, a transmission direction of the electromagnetic wave reflected by the secondary reflector 2 changes. Then, the electromagnetic wave is transmitted to the primary reflector 1, and a transmission direction of the electromagnetic wave reflected by the primary reflector 1 also changes. Therefore, beam scanning is implemented, to adjust the beam direction of the antenna and prevent gain deterioration.

[0057] However, when the secondary reflector 2 rotates relative to the primary reflector 1 to adjust the beam direction of the antenna, some abnormal phenomena may occur. As a result, the secondary reflector 2 cannot rotate relative to the primary reflector 1, and the secondary reflector 2 is at a specific position within an adjustable range. Alternatively, a rotation range of the secondary reflector 2 is beyond the adjustable range. For example, the secondary reflector needs to rotate between -15° to 15°, but the secondary reflector cannot continue to rotate when the secondary reflector rotates to 13°, or the secondary reflector rotates to 18°. When the foregoing cases occur, stability of signal transmission of the link on which the antenna is located deteriorates or even is interrupted.

[0058] To find out in time whether the antenna can perform beam direction adjustment, and ensure stability of signal transmission of the link on which the antenna is located, the dual reflector antenna provided in this embodiment of this application further includes a first driving structure and a connecting piece. The connecting piece is connected to the secondary reflector, and the first driving structure has a telescopic shaft. When the secondary reflector cannot adjust the beam direction of the dual reflector antenna, the telescopic shaft of the first driving structure extends and abuts against the connecting piece, and the connecting piece drives the secondary reflector 2 to restore to an initial position. The initial position herein is a position in which a plane on which the diameter of the secondary reflector 2 is located is parallel to a plane on which the diameter of the primary reflector 1 is located, in other words, the diameter of the secondary reflector 2 is aligned with the diameter of the primary reflector 1.

[0059] When the secondary reflector 2 is directly aligned with the primary reflector 1, the dual reflector antenna in this state cannot implement beam scanning or change the beam direction. However, compared with an antenna whose secondary reflector is at another position, the antenna may further be used as a common antenna and has a basic function of the antenna. The common antenna herein is the antenna in which the diameter of the secondary reflector 2 is aligned with the diameter of the primary reflector 1.

[0060] FIG. 5 shows that the first driving structure may be a first motor 5, and an output shaft of the first motor may move along an axial direction. For example, the output shaft of the first motor 5 is a telescopic shaft 51, and the telescopic shaft 51 of the first motor may move to a connecting piece 9 that is connected to the secondary reflector 2. Force is applied to the connecting piece 9 to push the secondary reflector 2 to rotate around the pitch axis L shown in FIG. 4 relative to the primary reflector 1.

[0061] In addition, the first driving structure may alternatively be a telescopic cylinder, a telescopic oil cylinder, or the like, and telescopic rods in the telescopic cylinder and the telescopic oil cylinder each are the telescopic shaft in this application. The first driving structure is not specifically limited in this application, and may alternatively be another driving structure that has a telescopic shaft.

[0062] To control extension of the telescopic shaft of the first driving structure, optionally, the dual reflector antenna further includes a first controller. The first controller is configured to determine whether the secondary reflector can adjust the beam direction of the dual reflector antenna. When it is determined that the secondary reflector cannot adjust the beam direction, the first controller controls the telescopic shaft of the first driving structure to extend and abut against the connecting piece, to drive the secondary reflector to restore to the initial position.

[0063] This application further provides a structure configured to rotate the secondary reflector relative to the primary reflector, to adjust a beam of the antenna. For example, the dual reflector antenna further includes a second driving structure, and the second driving structure has a rotating shaft. The rotating shaft is parallel to the plane on which the diameter of the primary reflector 1 is located, and the secondary reflector 2 is driven to rotate by using the rotating shaft. In other words, the second driving structure provides rotation power to the secondary reflector 2, to prompt the secondary reflector 2 to rotate.

[0064] Optionally, this application further provides the second driving structure configured to drive the secondary reflector 2 to rotate. Compared with the primary reflector 1, the secondary reflector 2 has a smaller volume and a lighter weight. Therefore, compared with driving the primary reflector 1 to rotate, power consumption of the second driving structure is reduced, and power consumption of the entire dual reflector antenna is reduced. In addition, the second driving structure with the light weight and the small volume may be selected, so that a weight and a volume of the entire antenna are reduced.

[0065] The second driving structure that drives the secondary reflector 2 to rotate may have a plurality of structures. For example, the second driving structure may be a motor whose output shaft can rotate, and the output shaft of the motor is directly connected to the secondary reflector, to drive the secondary reflector to rotate. For another example, the second driving structure may alternatively be a motor with a telescopic output shaft, and the output shaft of the motor is connected to a transmission structure. The transmission structure herein can convert a linear motion into a rotational motion, for example, a spiral transmission structure. Then, the transmission structure is connected to the secondary reflector. In other words, the output shaft of the motor moves linearly, and the secondary reflector rotates through conversion of the transmission structure. The second driving structure is not specifically limited in this application, and may alternatively be another driving structure that has a rotation function.

[0066] FIG. 6 shows that the second driving structure is a second motor 6, and an output shaft of the second motor 6 is a rotating shaft 61. Herein, the rotating shaft 61 is disposed in parallel to the pitch axis L, and the rotating shaft 61 is connected to the secondary reflector 2. After the second motor 6 is started, the rotating shaft 61 of the second motor rotates, to drive the secondary reflector 2 to rotate around the rotating shaft 61 that is of the second motor and that is parallel to the pitch axis.

[0067] FIG. 7 is a simulation diagram in which the second driving structure is used to drive the secondary reflector to perform beam scanning. The figure shows a corresponding range of an antenna beam scanning angle when the second driving structure drives the secondary reflector to rotate in a range of -15° to 0°. In FIG. 7, a horizontal coordinate is a beam scanning angle, and a vertical coordinate is a gain. It can be learned from this figure that, when the second driving structure drives the secondary reflector to rotate in the range of -15° to 0°, a range of the antenna beam scanning angle is close to -2° to 0°. In addition, it can be learned from FIG. 7 that, when the antenna beam scanning angle is close to 0°, the gain is close to 53.6 dB, and when the antenna beam scanning angle is close to -2°, the gain is close to 50.5 dB. Therefore, when the antenna beam is scanned to a range of -2° to 0°, the gain is only approximately 3 dB lower than that when no scanning is performed, and antenna performance is excellent.

[0068] To adjust the beam direction of the antenna in real time and improve the antenna performance, with reference to FIG. 8, the dual reflector antenna may further include an angle detection element and a second controller. The angle detection element is configured to detect a deflection angle of the primary reflector, for example, an angle at which the primary reflector is deflected when driven by the tower. The second controller controls the rotating shaft of the second driving structure to rotate based on the deflection angle detected by the angle detection element, to drive the secondary reflector 2 to rotate relative to the primary reflector 1.

[0069] In other words, the angle detection element detects that the primary reflector is deflected, and transmits a deflection angle signal to the second controller. After performing corresponding processing, the second controller outputs an angle control signal, and controls the rotating shaft 61 of the second motor to rotate, so that the secondary reflector 2 rotates to a corresponding angle.

[0070] The angle detection element herein has a plurality of embodiments. For example, a gyroscope may be used for detection, an angle detection sensor may be used, or another structure used for angle detection may be used.

[0071] The angle detection element may be installed on the primary reflector 1 or on the tower.

[0072] The angle detection element and the second controller may be installed in a control box, and the control box is electrically connected to the second motor through a cable.

[0073] The dual reflector antenna provided in this embodiment of this application further includes a power supply, and the power supply may supply power to the first driving structure and the second driving structure. For example, the power supply is disposed in the control box, and is connected to the first driving structure and the second driving structure through the cable.

[0074] It should be noted that the first controller and the second controller may be different microcontroller units (Microcontroller Units, MCUs), or a same MCU.

[0075] When the dual reflector antenna includes the first driving structure, the second driving structure, the angle detection element, and the power supply, a condition for triggering the first controller to control the telescopic shaft of the first driving structure to extend to drive the secondary reflector to restore to the initial position may include at least one of the following. As shown in FIG. 9, for example, the first controller determines that the rotating shaft of the second driving structure can rotate to drive the secondary reflector to rotate. For another example, the first controller determines whether the second controller has a function of controlling the rotating shaft of the second driving structure to rotate. For another example, the first controller determines whether the angle detection element has a function of detecting the deflection angle of the primary reflector, in other words, whether the angle detection element can detect the deflection angle of the primary reflector. For another example, the first controller determines whether the power supply can supply power to the first driving structure and the second driving structure.

[0076] It can be understood that, when detecting that any of the foregoing structures cannot work normally, the first controller triggers extension of the telescopic shaft of the first driving structure, to make the secondary reflector return to zero. Returning to zero herein is to restore the secondary reflector to the initial position.

[0077] When the power supply cannot supply power to the first driving structure and the second driving structure, the first driving structure cannot drive the secondary reflector to restore to the initial position. Therefore, the dual reflector antenna in this embodiment of this application further includes an energy storage element. When the power supply cannot supply power to the first driving structure, the energy storage element supplies power to the first controller and the first driving structure, to restore the secondary reflector to the initial position.

[0078] The energy storage element may be a large-capacity battery, a rechargeable battery, a large-capacity capacitor, or the like.

[0079] When the dual reflector antenna has both the first driving structure and the second driving structure, this application provides a structure that can make a connection structure compact and reduce power consumption. For example, with reference to FIG. 10, the connecting piece 9 includes a first connecting piece 91 and a second connecting piece 92. One end of the first connecting piece 91 is connected to the rotating shaft 61, and the other end of the first connecting piece 91 abuts against the telescopic shaft 51 when the telescopic shaft 51 is extended. One end of the second connecting piece 92 is connected to the rotating shaft 61, and the other end of the second connecting piece 92 is connected to the secondary reflector 2.

[0080] A working process of the structure shown in FIG. 10 is as follows: When the secondary reflector 2 rotates relative to the primary reflector 1 to adjust the beam direction, the telescopic shaft 51 is in a retracted state, is separated from the first connecting piece 91 without contacting, and the rotating shaft 61 rotates. The second connecting piece 92 drives the secondary reflector to rotate relative to the primary reflector 1, to adjust the beam direction. When it is determined that the secondary reflector 2 cannot rotate relative to the primary reflector 1, the beam direction of the dual reflector antenna cannot be adjusted. In this case, the telescopic shaft 51 is extended and abuts against the first connecting piece 91, and applies pushing force to the first connecting piece 91, so that the first connecting piece 91 and the second connecting piece 92 rotate around the rotating shaft 61. Because the rotating shaft 61 is parallel to the pitch axis, the secondary reflector 2 is driven to restore to the initial position.

[0081] In other words, in FIG. 10, the telescopic shaft 51 and the rotating shaft 61 are matched by using the first connecting piece 91 and the second connecting piece 92. In this way, when the secondary reflector 2 rotates by a same angle, power consumption of the first driving structure and the second driving structure can be correspondingly reduced. In addition, in this application, the pushing force is applied to the first connecting piece 91 to push the rotating shaft 61 to rotate, so as to enable the secondary reflector to be restored to the initial position. In this way, when the dual reflector antenna cannot perform beam direction adjustment, the telescopic shaft keeps pushing the rotating shaft, so that the secondary reflector is in a stable state and does not shake, and stability of the gain and the pattern when the dual reflector antenna is used as a common antenna is ensured.

[0082] In some implementations, with reference to FIG. 10, the primary reflector 1 is fastened relative to an underpan 8, and the secondary reflector 2, the first motor 5, and the second motor 6 are located on a side that is of the primary reflector 1 and that is away from the underpan 8. In this case, the dual reflector antenna further includes a support 7. The first motor 5 and the second motor 6 are fastened relative to the support 7, and the other end of the support 7 is fastened relative to the primary reflector 1, or is fastened relative to the underpan 8 through the primary reflector 1, that is, the first motor 5 and second motor 6 suspended in the air are fastened by using the support 7. The support 7 may be in a regular shape such as a cone, a cylinder, or a rectangle, or may be in an irregular shape.

[0083] A part of the support 7 is on a propagation path of the electromagnetic signal. Therefore, in order to prevent the support 7 from blocking propagation of the electromagnetic signal, a part that is of the support 7 and that is between the primary reflector 1 and the secondary reflector 2 is made of a dielectric material. The dielectric material has a relative dielectric constant less than 4.5. For example, the dielectric material includes a material such as polyphenylene oxide (Polyphenylene Oxide, PPO) or polycarbonate (Polycarbonate, PC). In this way, an electromagnetic wave signal reflected from the secondary reflector 2 radiates to the primary reflector 1 after completely passing through the support 7, and the antenna performance is not affected compared with a support made of metal.

[0084] The closer a part of the support 7 is to the primary reflector 1, the fewer electromagnetic signals passing through the part. Therefore, the part that is of the support 7, that is located between the primary reflector 1 and the secondary reflector 2, and that is close to the secondary reflector 2 can be made of the dielectric material. The rest may be made of a dielectric electrical material or another material (for example, a metal material) with higher strength. In this way, the antenna performance is not affected on the premise that high strength and good stability of an entire structure is ensured.

[0085] Selection of a shape and a wall thickness of the part that is of the support 7 and that is between the primary reflector 1 and the secondary reflector 2 also affects the antenna performance.

[0086] With reference to FIG. 11, a radial size (size of

D in the figure) of the support 7 gradually decreases along a direction from the secondary reflector 2 to the primary reflector 1, and it can be understood that the support 7 is of a conical structure. In addition, an included angle θ between a busbar and an axis of the conical structure is between 10° and 30°, or between 12° and 30°. In the dual reflector antenna in this application, θ may be selected as 20°.

[0087] With reference to FIG. 11, the wall thickness h of the part that is of the support 7 and that is between the primary reflector 1 and the secondary reflector 2 is: $h = N \times \frac{C}{2f\sqrt{Er}}$. C is a speed of light, f is a center frequency of the dual reflector antenna, Er is the relative dielectric constant of the dielectric material, and N is a positive integer greater than or equal to 1. For example, when an operating frequency range of the dual reflector antenna is 71 GHz to 86 GHz, the center frequency f is 78.5 GHz. When the relative dielectric constant Er of the dielectric material is selected as 2.55, h may be selected as 1.2 mm, 2.4 mm, 3.6 mm, 4.8 mm, or the like. h may alternatively be selected to be close to 1.2 mm, 2.4 mm, 3.6 mm, or 4.8 mm, for example, a tolerance is approximately 5% or 10%.

[0088] In some implementations, with reference to FIG. 10, the feed 3 is installed in a first support 71, the first motor 5 and the second motor 6 are installed in a third support 73, and the support 7 further includes a second support 72. The first support 71, the second support 72, and the third support 73 may be assembled into the support 7 described above.

[0089] When the dual reflector antenna is installed on site, after the primary reflector 1 and the first support 71 mounted with the feed 3 are fastened relative to the underpan 8, the second support 72 and the third support 73 mounted with the first motor 5 and the second motor 6 are assembled, and relative positions of the primary reflector 1 and the secondary reflector 2 are adjusted.

[0090] Optionally, in order to make the first motor 5, the second motor 6, and the secondary reflector 2 locate in an environment with good air tightness, a sealed cavity is formed in the support 7. The first motor 5, the second motor 6, and the secondary reflector 2 are located in the sealed cavity to prevent rainwater from entering the cavity formed by the supports and influencing performance of the first motor and the second motor. Therefore, when the second support 72 is installed with the first support 71 and the third support 73, sealing strips 10 are disposed at a joint between the second support 72 and the first support 71 and a joint between the second support 72 and the third support 73, so that the first motor, the second motor, and the secondary reflector are in a closed environment.

[0091] Because the second support 72 is located between the primary reflector 1 and the secondary reflector 2, the second support 72 is made of the dielectric material, and the first support 71 is close to the primary reflector 1, and has little impact on transmission of the electromagnetic signal. Therefore, the first support 71 may be made of the metal material, to ensure strength of the entire structure. The third support 73 may also be made of the metal material.

[0092] FIG. 12 is a simulation diagram of electrical performance of the dual reflector antenna in this application when h of the second support 72 is selected as 3.6 mm and θ is 20°, and a simulation diagram of electrical performance of a dual reflector antenna that is not provided with a second support. In FIG. 12, a horizontal coordinate is an angle, a vertical coordinate is a gain, a curve 1 is a gain curve of the dual reflector antenna that is not provided with the second support 72, and a curve 2 is a gain curve of the dual reflector antenna provided with the second support 72. It can be learned from results that the two curves basically coincide, and this proves that the second support made of the dielectric material in the present invention had little deterioration effect on the performance of the gain and the pattern of the antenna.

[0093] For the dual reflector antenna, this application further provides a dual reflector antenna control method. The control method includes a control method for returning the secondary reflector to zero, and a control method for adjusting the beam direction.

[0094] With reference to FIG. 13, a control method for returning a secondary reflector to zero includes the following steps.

[0095] S11: Determine that the secondary reflector cannot adjust a beam direction of a dual reflector antenna.

[0096] S12: Control a telescopic shaft to extend and abut against a connecting piece, to drive the secondary reflector to restore to an initial position, where the initial position is a position in which a plane on which a diameter of the secondary reflector is located is parallel to a plane on which a diameter of a primary reflector of the dual reflector antenna is located. That is, the secondary reflector is returned to zero.

[0097] When a structure of the dual reflector antenna is shown in FIG. 10, to be specific, when the dual reflector antenna includes a first connecting piece 91 and a second connecting piece 92, driving the secondary reflector to restore to an initial position specifically includes: controlling a telescopic shaft 51 to extend and abut against the first connecting piece 91, and pushing the first connecting piece 91 and the second connecting piece 92 to rotate around a rotating shaft 61, to drive the secondary reflector 2 to rotate to the initial position.

[0098] In step S11, a condition for determining that the secondary reflector cannot adjust the beam direction of the dual reflector antenna is described above, and details are not described herein again.

[0099] With reference to FIG. 14, a control method for adjusting a beam direction includes the following steps.

[0100] S21: Detect a deflection angle of a primary reflector.

[0101] When a dual reflector antenna including the primary reflector and a secondary reflector shakes with a tower, a deflection angle of the primary reflector or a deflection angle of the tower may be detected.

[0102] S22: Control a rotating shaft based on the deflection angle, where the rotating shaft drives the secondary reflector to rotate along a pitch axis relative to the primary reflector, to adjust the beam direction of the dual reflector antenna.

[0103] For example, when it is detected that the deflection angle of the primary reflector is -15°, the rotating shaft drives the secondary reflector to rotate -1.5° relative to the primary reflector. This is only an example description, and does not mean that in practice, when the deflection angle of the primary reflector is -15°, a rotation angle of the secondary reflector needs to be -1.5°.

[0104] It should be noted that: when a plane on which a diameter of the secondary reflector is located is parallel to a plane on which a diameter of the primary reflector is located, an angle at which the secondary reflector rotates relative to the primary reflector is 0°; when the secondary reflector rotates relative to the primary reflector in a first direction, the rotation angle is greater than 0°; and when the secondary reflector rotates relative to the primary reflector in a second direction opposite to the first direction, the rotation angle is less than 0°.

[0105] In a beam direction adjustment process, whether the secondary reflector can adjust the beam direction may be detected in real time, or may be detected periodically.

[0106] During specific implementation, if it is detected that the secondary reflector cannot adjust the beam direction, the secondary reflector is returned to zero, and a fault alarm may be activated to prompt replacement or maintenance of a device.

[0107] Before the beam direction adjustment is performed, self-check may further be performed on the dual reflector antenna, to ensure that the beam direction adjustment can be performed. In this case, before the secondary reflector rotates relative to the primary reflector, the control method further includes: detecting whether the secondary reflector can adjust the beam direction of the dual reflector antenna. When it is detected that the secondary reflector can adjust the beam direction, the rotating shaft drives the secondary reflector to rotate; and when it is detected that the secondary reflector cannot adjust the beam direction, the fault alarm is activated to prompt replacement or maintenance of the device.

[0108] In addition to detection before and in a rotation process of the secondary reflector, in some scenarios, a first controller may also control a telescopic shaft of a first driving structure to extend, to drive the secondary reflector to restore to the initial position. For example, the dual reflector antenna needs to be maintained, an angle detection element indicates long-term shaking beyond an allowable range, the first controller and the first driving structure need to be checked periodically, and the like.

[0109] FIG. 15 is a flow block diagram of specific use of a dual reflector antenna. After a dual reflector antenna system is initialized, when it is determined that a secondary reflector can adjust a beam direction of the dual reflector antenna, the beam direction of the dual reflector antenna is adjusted. A method for adjusting the beam direction of the dual reflector antenna is described above. The beam direction of the dual reflector antenna is adjusted, and fault detection is performed. When it is determined that the beam direction of the dual reflector antenna cannot be adjusted, a telescopic shaft is controlled to extend and abut against a connecting piece, to drive the secondary reflector to restore to an initial position.

[0110] In the descriptions of this specification, specific features, structures, materials, or characteristics may be combined in a proper manner in any one or more of embodiments or examples.

[0111] The foregoing descriptions are merely specific implementations of this application, but are not intended to limit the protection scope of this application. Any variation or replacement readily figured out by a person skilled in the art within the technical scope disclosed in this application shall fall within the protection scope of this application. Therefore, the protection scope of this application shall be subject to the protection scope of the claims.

Claims

1. A dual reflector antenna, comprising:

   a primary reflector, a secondary reflector, and a feed, wherein the primary reflector is opposite to the secondary reflector, and the feed is configured to radiate an electromagnetic wave to the secondary reflector;
   a first driving structure, having a telescopic shaft; and
   a connecting piece, connected to the secondary reflector, wherein
   when the telescopic shaft is extended, the telescopic shaft abuts against the connecting piece, to drive the secondary reflector to restore to an initial position, wherein the initial position is a position in which a plane on which a diameter of the secondary reflector is located is parallel to a plane on which a diameter of the primary reflector is located.

2. The dual reflector antenna according to claim 1, wherein the dual reflector antenna further comprises:

   a second driving structure, having a rotating shaft, wherein
   the rotating shaft is configured to drive the secondary reflector to rotate relative to the primary reflector along a pitch axis, to adjust a beam direction of the dual reflector antenna, wherein

the pitch axis is parallel to the plane on which the diameter of the primary reflector is located.

3. The dual reflector antenna according to claim 2, wherein the connecting piece comprises a first connecting piece and a second connecting piece;

one end of the first connecting piece is connected to the rotating shaft, and when the telescopic shaft is extended, the other end of the first connecting piece abuts against the telescopic shaft; and
one end of the second connecting piece is connected to the rotating shaft, and the other end of the second connecting piece is connected to the secondary reflector.

4. The dual reflector antenna according to any one of claims 1 to 3, wherein the dual reflector antenna further comprises:
a support, wherein the first driving structure is disposed close to the secondary reflector, one end of the support is fastened relative to the first driving structure, and the other end of the support is fastened relative to the primary reflector.

5. The dual reflector antenna according to claim 4, wherein a part that is of the support, that is located between the primary reflector and the secondary reflector, and that is at least close to the secondary reflector is made of a dielectric material.

6. The dual reflector antenna according to claim 4 or 5, wherein a radial size of a part that is of the support and that is located between the secondary reflector and the primary reflector gradually decreases along a direction from the secondary reflector to the primary reflector, to form a conical structure.

7. The dual reflector antenna according to claim 6, wherein an included angle between a busbar and an axis of the conical structure is 10° to 30°.

8. The dual reflector antenna according to any one of claims 4 to 7, wherein a wall thickness h of the part that is of the support and that is located between the secondary reflector and the primary reflector is: $\mathrm{h} = \mathrm{N} \times \frac{\mathrm{C}}{2\mathrm{f}\sqrt{\mathrm{Er}}}$, wherein
C is a speed of light, f is a center frequency of the dual reflector antenna, Er is a relative dielectric constant of the dielectric material, and N is a positive integer greater than or equal to 1.

9. The dual reflector antenna according to any one of claims 4 to 8, wherein a sealed cavity is formed in the support, and the first driving structure and the secondary reflector are disposed in the sealed cavity.

10. The dual reflector antenna according to any one of claims 4 to 9, wherein the support comprises:

a first support, wherein the first support is fastened relative to the primary reflector, and the feed is disposed in the first support;
a second support, wherein the second support is fastened relative to the first support, and the second support is made of a dielectric material; and
a third support, wherein the third support is fastened relative to the second support, and the first driving structure is fastened in the third support.

11. A communication system, comprising:

the dual reflector antenna according to any one of claims 1 to 10; and
a first controller, wherein the first controller is configured to detect whether a secondary reflector can adjust a beam direction of the dual reflector antenna, and when it is determined that the secondary reflector cannot adjust the beam direction, the first controller controls a telescopic shaft to extend and abut against a connecting piece, to drive the secondary reflector to restore to an initial position.

12. The communication system according to claim 11, wherein the dual reflector antenna further comprises a second driving structure that has a rotating shaft, and the communication system further comprises:

an angle detection element, configured to detect a deflection angle of a primary reflector; and
a second controller, configured to control, based on the deflection angle, the rotating shaft to rotate, to drive the secondary reflector to rotate relative to the primary reflector, so as to adjust the beam direction of the dual reflector antenna.

13. A dual reflector antenna control method, wherein a dual reflector antenna comprises a first driving structure that has a telescopic shaft and a connecting piece that is connected to a secondary reflector of the dual reflector antenna, and the control method comprises:

determining that the secondary reflector of the dual reflector antenna cannot adjust a beam direction of the dual reflector antenna; and
controlling the telescopic shaft to extend and abut against the connecting piece, to drive the secondary reflector to restore to an initial posi-

tion, wherein the initial position is a position in which a plane on which a diameter of the secondary reflector is located is parallel to a plane on which a diameter of a primary reflector of the dual reflector antenna is located.

14. The dual reflector antenna control method according to claim 13, wherein the connecting piece comprises a first connecting piece and a second connecting piece, the dual reflector antenna further comprises a second driving structure that has a rotating shaft, one end of the first connecting piece is connected to the rotating shaft, one end of the second connecting piece is connected to the rotating shaft, and the other end of the second connecting piece is connected to the secondary reflector; and
driving the secondary reflector to restore to an initial position comprises:
controlling the telescopic shaft to extend and abut against the first connecting piece, and pushing the first connecting piece and the second connecting piece to rotate around the rotating shaft, to drive the secondary reflector to rotate to the initial position.

15. The dual reflector antenna control method according to claim 14, wherein the dual reflector antenna further comprises a second controller and an angle detection element; and
the control method comprises: determining at least one of the following:

determining that the rotating shaft has a rotation function;
determining that the second controller has a function of controlling the rotating shaft to rotate; and
determining that the angle detection element has a function of detecting a deflection angle of the primary reflector.

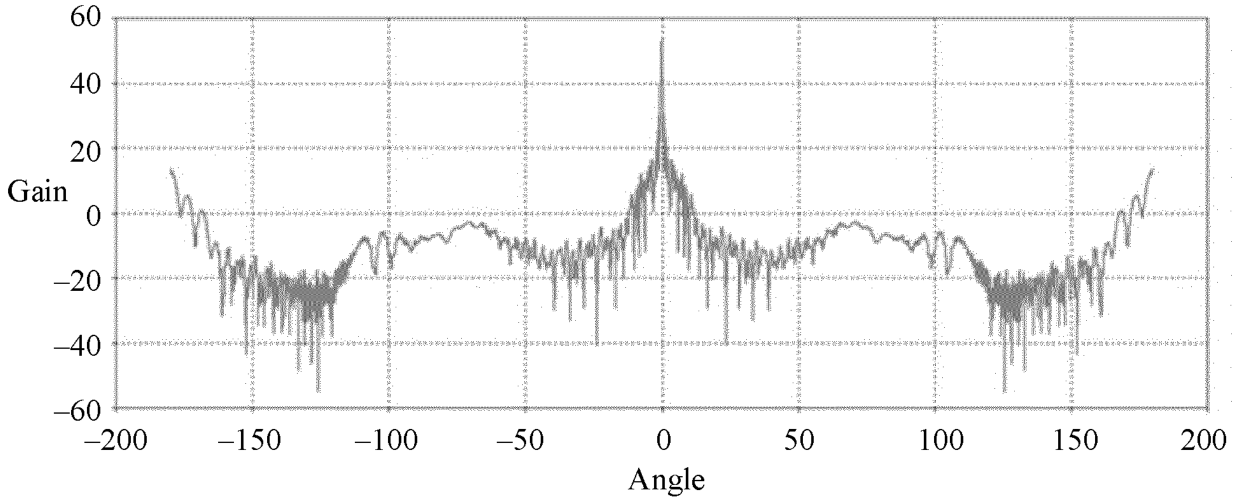
60
40
20
Gain
0
−20
−40
−60
−200
−150
−100
−50
0
50
100
150
200
Angle

FIG. 1

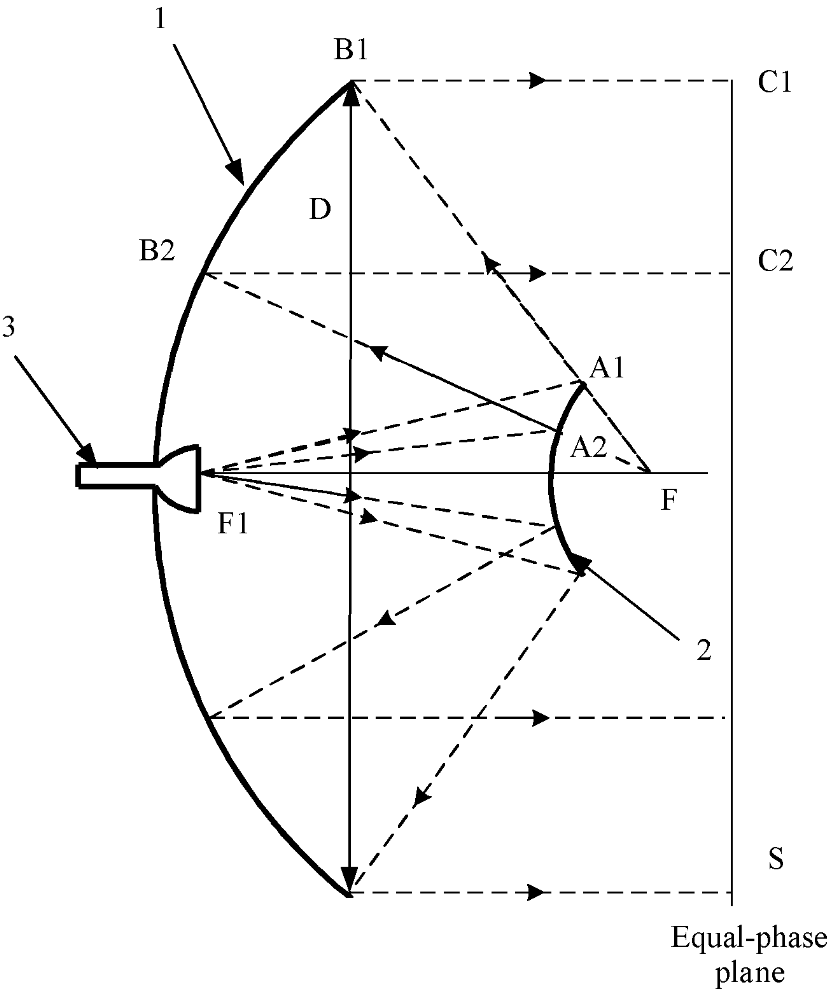
1
B1
C1
D
B2
C2
3
A1
A2
F1
F
2
S
Equal-phase plane

FIG. 2

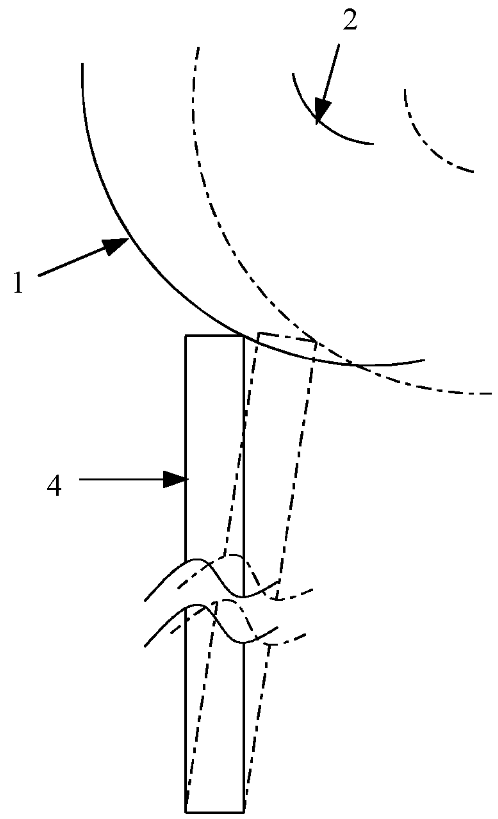

FIG. 3

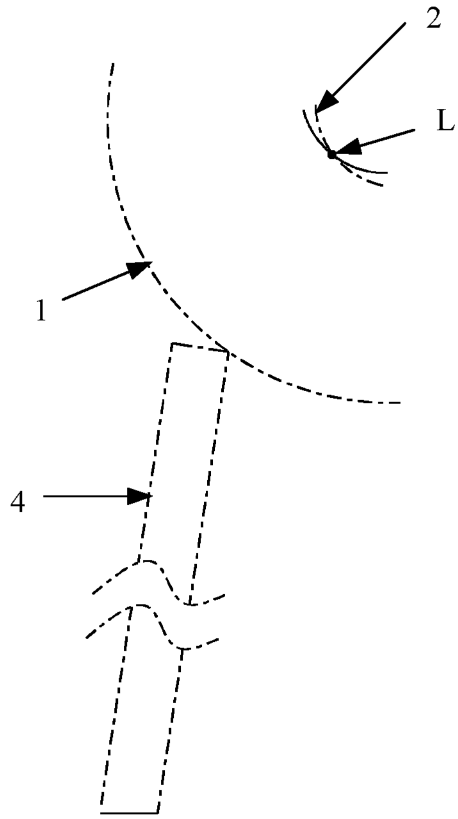

FIG. 4

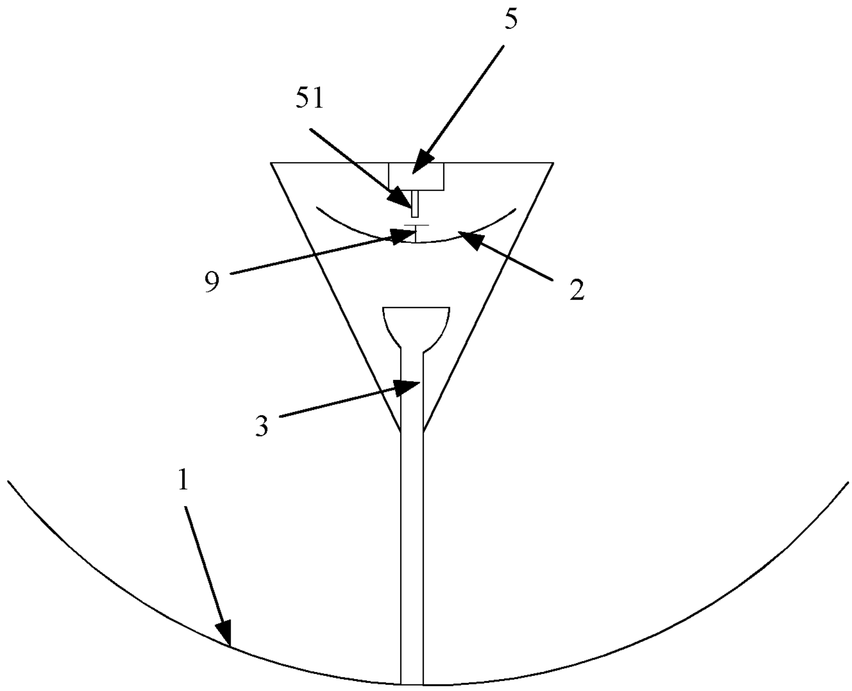

FIG. 5

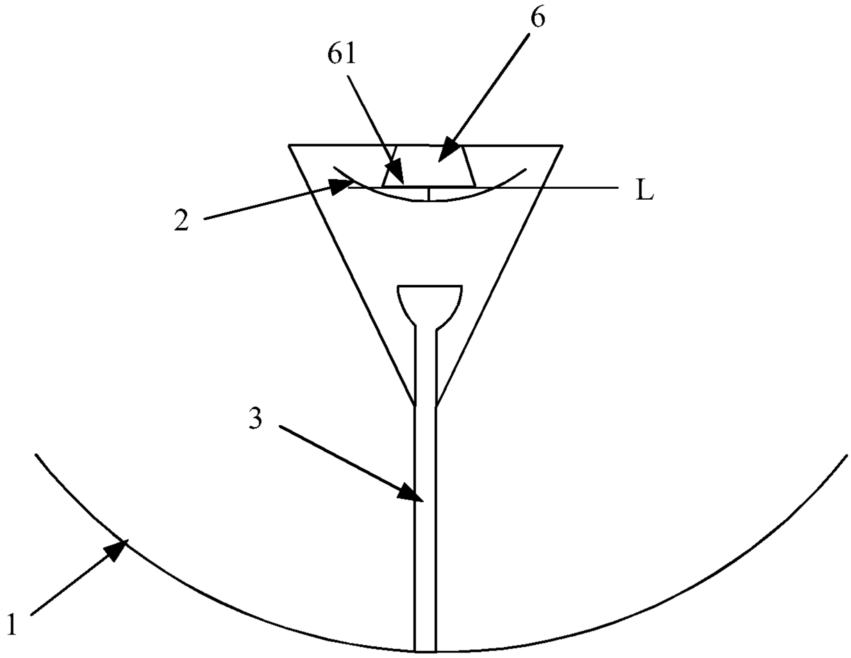

FIG. 6

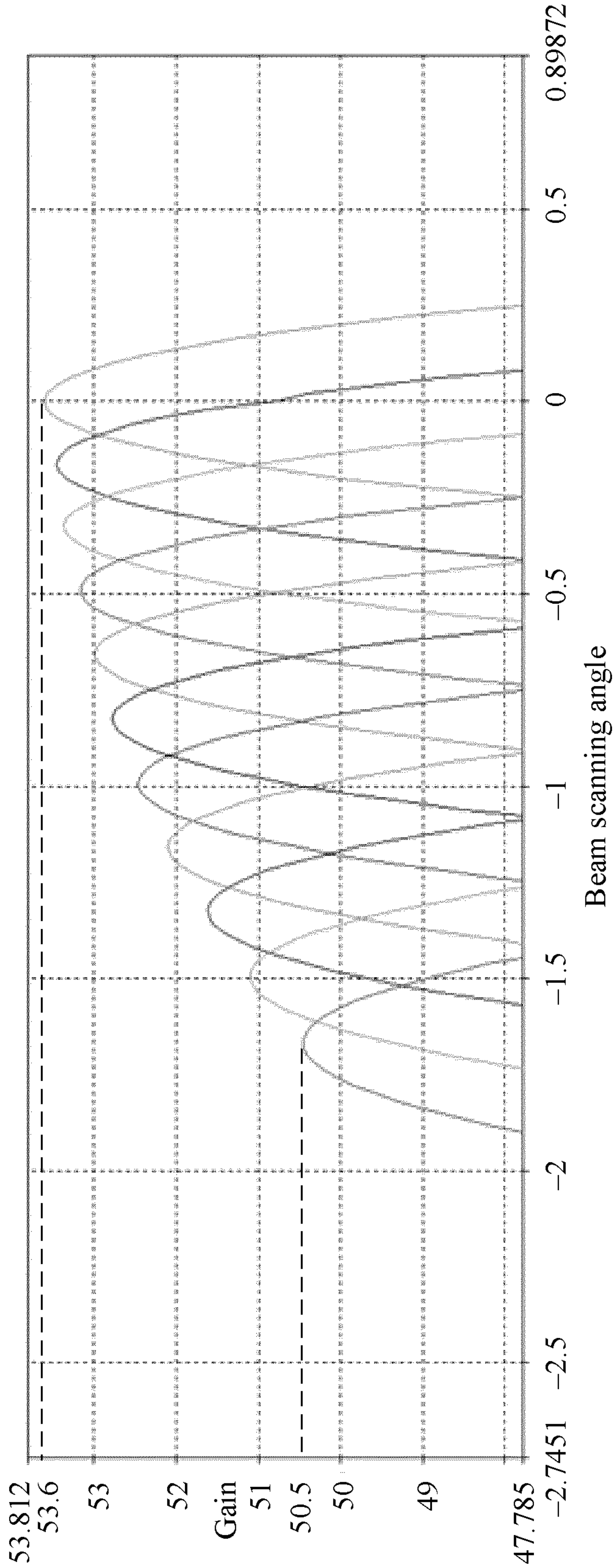
Gain
53.812
53.6
53
52
51
50.5
50
49
47.785
−2.7451
−2.5
−2
−1.5
−1
−0.5
0
0.5
0.89872
Beam scanning angle

FIG. 7

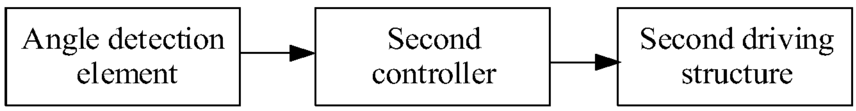
Angle detection element
Second controller
Second driving structure

FIG. 8

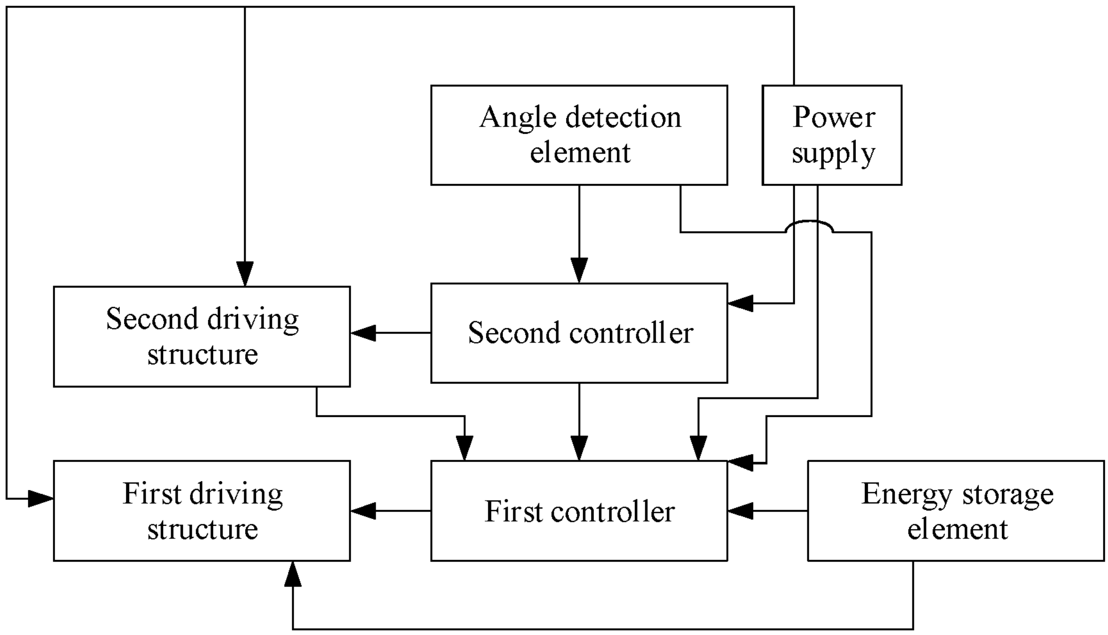
Angle detection element
Power supply
Second driving structure
Second controller
First driving structure
First controller
Energy storage element

FIG. 9

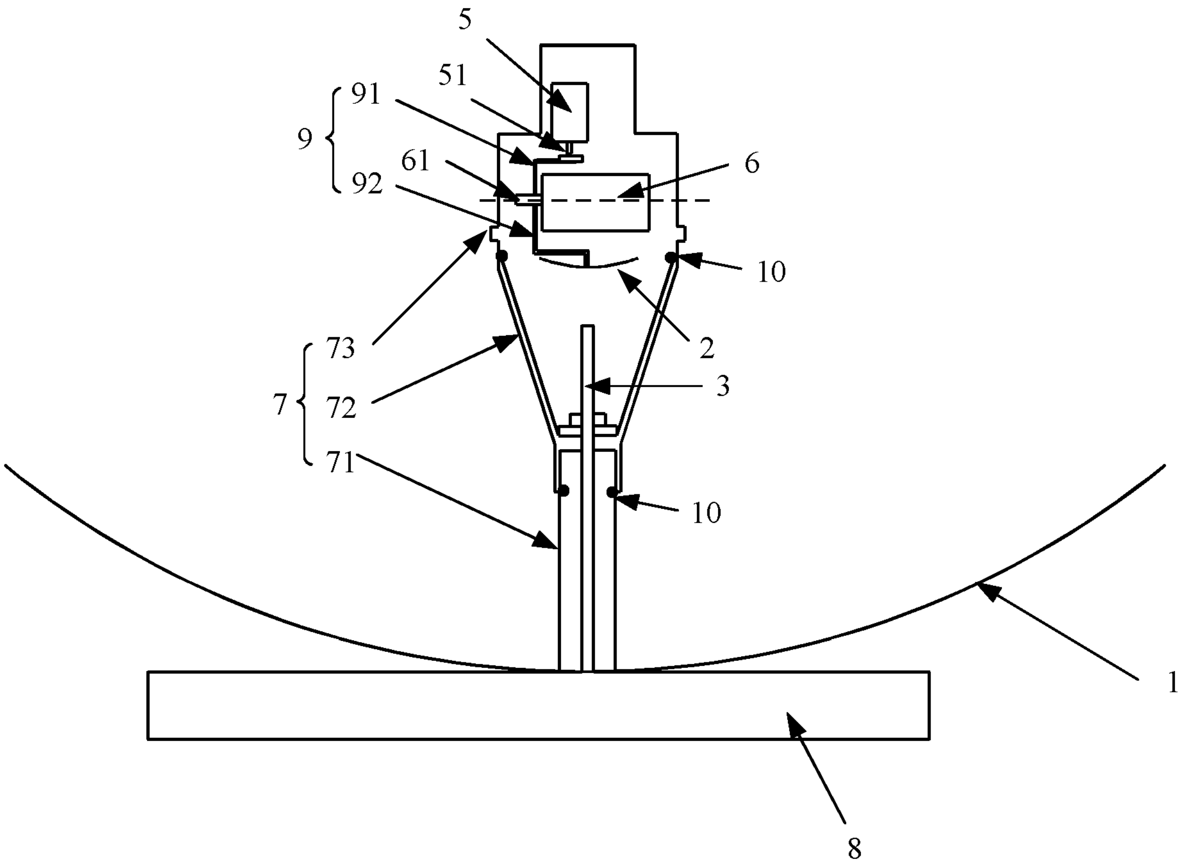

FIG. 10

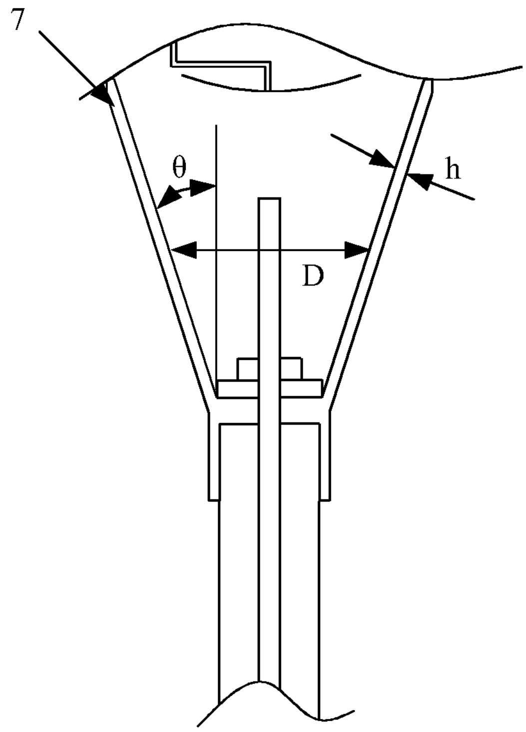

FIG. 11

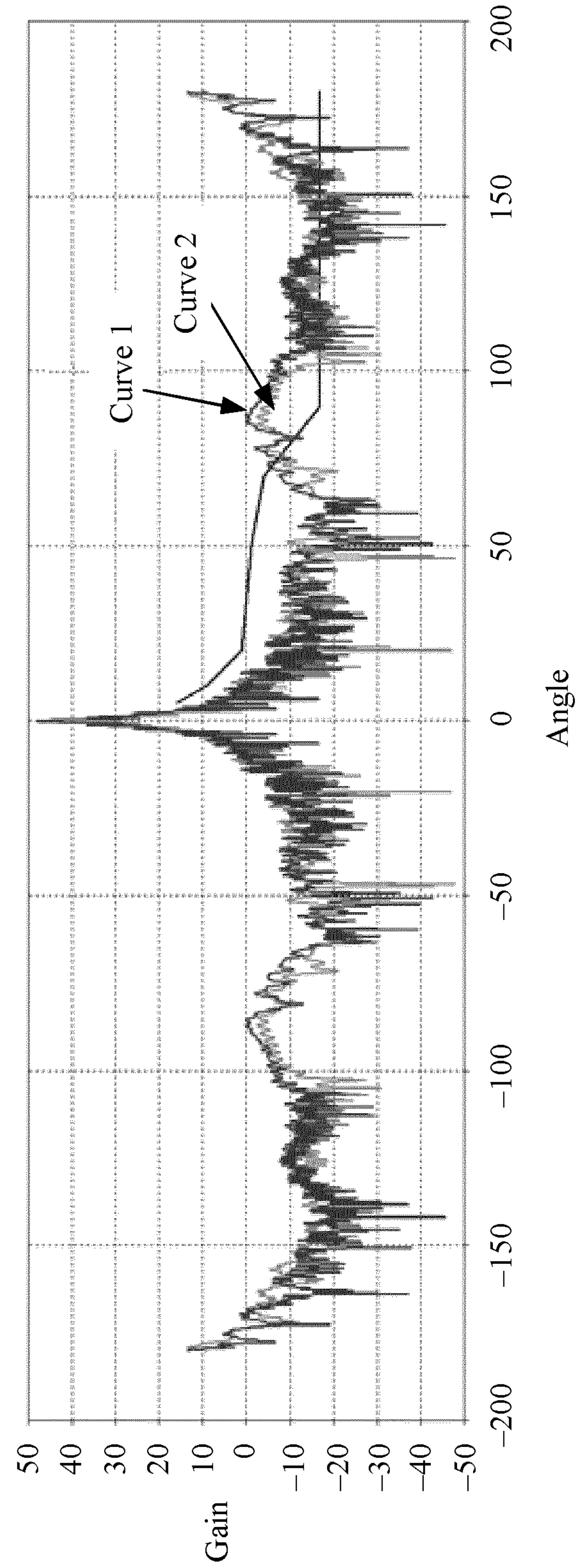
Curve 1
Curve 2
Gain
Angle
50
40
30
20
10
0
−10
−20
−30
−40
−50
−200
−150
−100
−50
0
50
100
150
200

FIG. 12

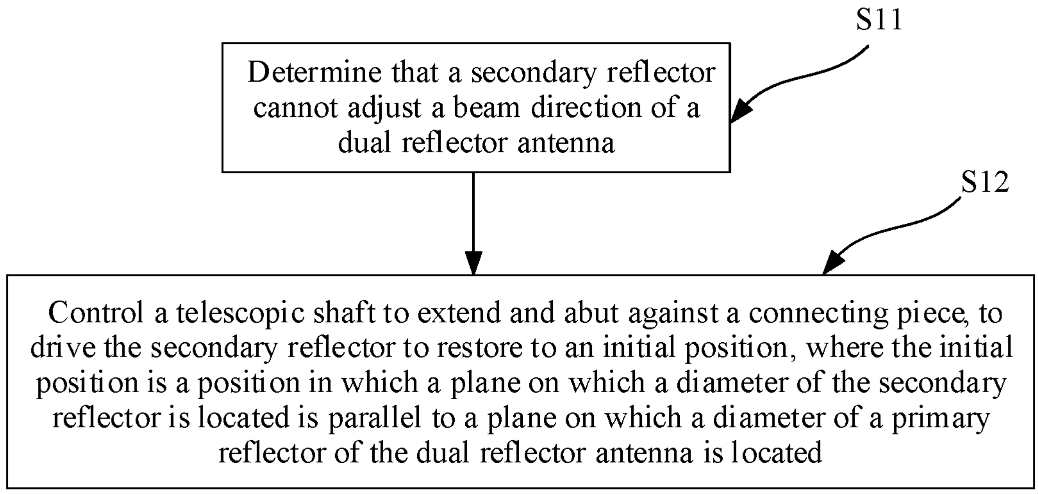
S11
Determine that a secondary reflector cannot adjust a beam direction of a dual reflector antenna
S12
Control a telescopic shaft to extend and abut against a connecting piece, to drive the secondary reflector to restore to an initial position, where the initial position is a position in which a plane on which a diameter of the secondary reflector is located is parallel to a plane on which a diameter of a primary reflector of the dual reflector antenna is located

FIG. 13

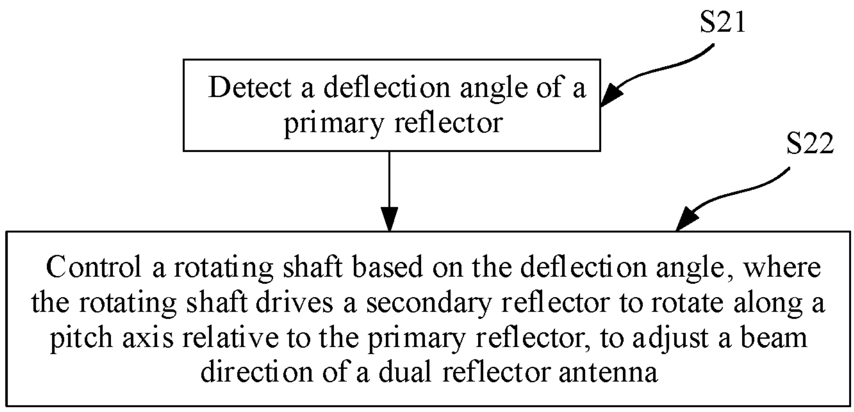
S21
Detect a deflection angle of a primary reflector
S22
Control a rotating shaft based on the deflection angle, where the rotating shaft drives a secondary reflector to rotate along a pitch axis relative to the primary reflector, to adjust a beam direction of a dual reflector antenna

FIG. 14

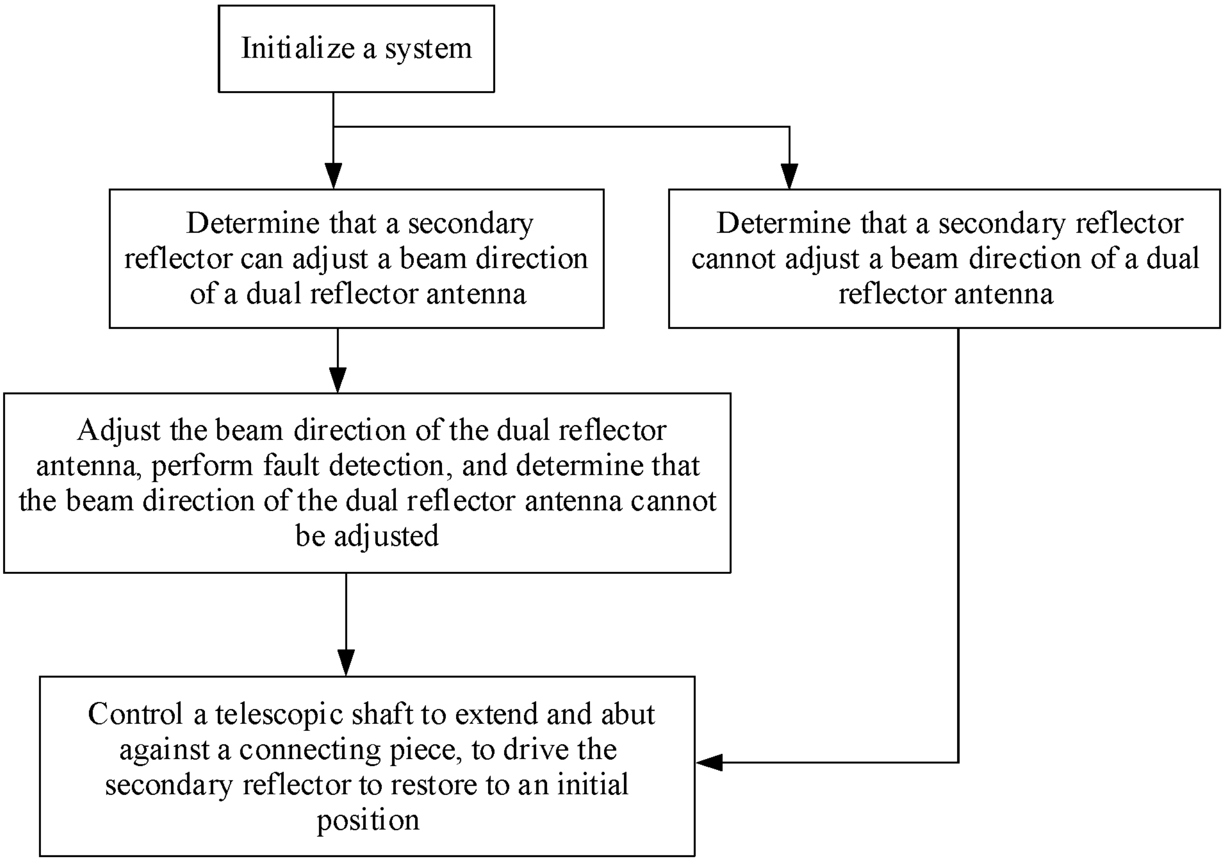
Initialize a system
Determine that a secondary reflector can adjust a beam direction of a dual reflector antenna
Determine that a secondary reflector cannot adjust a beam direction of a dual reflector antenna
Adjust the beam direction of the dual reflector antenna, perform fault detection, and determine that the beam direction of the dual reflector antenna cannot be adjusted
Control a telescopic shaft to extend and abut against a connecting piece, to drive the secondary reflector to restore to an initial position

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No. **PCT/CN2021/070184**

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 15/14(2006.01)i； H01Q 19/18(2006.01)i； H01Q 3/20(2006.01)i； H01Q 1/12(2006.01)i

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)

H01Q

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)

EPTXT; USTXT; VEN; WOTXT; CNABS; CNTXT: 天线, 伸缩, 连接件, 波束, 平行, 初始, 位置, 双反射器, antenna, aerial, retract+, extent+, extend+, parallel+, telescope, double, reflector, beam, initializ+, location

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 105591206 A (INSTITUTE OF APPLIED ELECTRONICS, CHINA ACADEMY OF ENGINEERING PHYSICS) 18 May 2016 (2016-05-18) description, paragraphs 0006-0022, and figures 1-6	1-15
A	CN 106058479 A (SHANGHAI NORMAL UNIVERSITY) 26 October 2016 (2016-10-26) entire document	1-15
A	CN 103904430 A (BEIJING INSTITUTE OF TECHNOLOGY) 02 July 2014 (2014-07-02) entire document	1-15
A	US 2012242539 A1 (MIZZONI ROBERTO et al.) 27 September 2012 (2012-09-27) entire document	1-15
A	US 2014354501 A1 (THALES SA.) 04 December 2014 (2014-12-04) entire document	1-15

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
17 September 2021	**26 September 2021**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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