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(54) DEPLOYABLE REFLECTARRAY ANTENNA STRUCTURE

ENTFALTBARE REFLEKTIONSARRAY-ANTENNENSTRUKTUR

STRUCTURE D'ANTENNE RÉSEAU À RÉFLEXION DÉPLOYABLE

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Description

FIELD OF THE INVENTION

[0001] The invention relates to a deployable antenna structure and, more specifically, to a deployable reflectarray antenna structure.

BACKGROUND OF THE INVENTION

[0002] In applications requiring a high-gain antenna, there are at least three types of antennas that are typically employed, namely, a parabolic antenna, phased-array antenna, and a reflectarray antenna. The basic parabolic antenna includes a parabolic shaped reflector and a feed antenna located at the focus of the paraboloid and directed towards the reflector. The phased-array antenna includes multiple antennas with a feed network that provides a common signal to each of the antennas but with the relative phase of the common signal being fed to each of the antennas established such that the collective radiation pattern produced by the array of antennas is reinforced in one direction and suppressed in other directions, i.e., the beam is highly directional. In many applications, the phased-array antenna is preferred to the parabolic antenna because a phased-array antenna can be realized with a lower height profile relative to the parabolic antenna. However, the phased-array antenna typically requires a complicated and/or expensive feed network and amplifier structures. The basic reflectarray antenna includes a reflectarray that is flat or somewhat curved and a feed antenna directed towards the reflectarray. The reflectarray includes an array of radiating elements that each receive a signal from the feed antenna and reradiate the signal. Each of the radiating elements has a phase delay such that the collective reradiated signal produced by the array of radiating elements is in a desired direction. Importantly, the radiating elements are fed by the feed antenna. As such, relative to the phased-arrayed antenna, the reflectarray avoids the need for a feed network to provide a signal to each of the radiating elements.

[0003] An application that frequently requires a high-gain antenna is a space-related application in which the antenna is associated with a spacecraft, e.g., a communication satellite. Such space-related applications typically impose an additional requirement of deployability on the design of a high-gain antenna, i.e., the antenna needs to be able to transition from a stowed/undeployed state in which the antenna is inoperable or marginally operable to unstowed/deployed state in which the antenna is operable. As such, the high-gain antenna in these applications is coupled with a deployment mechanism that is used to transition the antenna from the stowed/undeployed state to the unstowed/deployed state. Characteristic of many space-related applications for such antennas is that the antenna and deployment mechanism occupy a small volume in the undeployed state relative to the volume occupied by the antenna and deployment

mechanism in the deployed state.

[0004] One approach for realizing a deployable high-gain antenna suitable for use on a spacecraft is a parabolic antenna structure that includes a wire mesh reflector, a feed antenna, and a deployment mechanism. The deployment mechanism operates to transition: (a) the wire mesh reflector from a stowed state in which the reflector is folded to an unstowed state in which the reflector is supported in a paraboloid-like shape by a frame associated with the deployment mechanism and (b) the wire mesh reflector and the feed antenna from an inoperable stowed state in which the wire mesh reflector and feed antenna are not operably positioned relative to one another to an unstowed state in which the wire mesh reflector and feed antenna are operatively positioned relative to one another. Characteristic of such deployable parabolic antenna structures is a high part count and the need for a relatively large volume to accommodate the stowed wire mesh reflector, feed antenna, and deployment mechanism. Document US 2014/0263844 A1 describes such a deployable reflectarray antenna.

[0005] A second approach for realizing a deployable high-gain antenna suitable for use on a spacecraft is a reflectarray antenna structure that includes a two-layer reflectarray membrane, a feed antenna, and an inflatable deployment mechanism. The inflatable deployment mechanism operates to transition: (a) the reflectarray membrane from a stowed state in which the membrane is folded to an unstowed state in which the inflated deployment mechanism forms a frame that is used in tensioning the reflectarray membrane into a flat shape, similar to trampoline and (b) the reflectarray membrane and the feed antenna from an inoperable stowed state in which the reflectarray membrane and feed antenna are not operably positioned with respect to one another to an unstowed state in which the reflectarray membrane and the feed antenna are operably positioned relative to one another. Characteristic of such a deployable reflectarray are difficulties in understanding the deployment kinematics and reliability challenges, particularly in space-based applications.

SUMMARY OF THE INVENTION

[0006] A deployable reflectarray antenna structure is provided that is suitable for use in applications in which elements that are used to form the reflectarray antenna structure need to transition from an undeployed state in which the elements conform to a particular volume in which the elements are not situated so as to function in a reflectarray antenna structure to a deployed state in which the elements are situated so as to function in a reflectarray antenna structure. One such application for a deployable reflectarray antenna structure is as part of a space vehicle, (e.g., a communication satellite) in which elements of the structure typically need to conform to a compact or dimensionally constrained volume for at least a portion of the launch of the space vehicle and then be

deployed from the compact or dimensionally constrained space so as to form a reflectarray antenna structure that typically occupies a considerably greater volume.

[0007] In one embodiment, the deployable reflectarray antenna structure includes a pair of electrical elements and a deployment mechanism for transitioning the pair of electrical elements from an undeployed state in which the electrical elements are not positioned relative to one another to function in a reflectarray antenna towards a deployed state in which the electrical elements are positioned relative to one another to function in a reflectarray antenna. To facilitate the transition of the electrical elements from the undeployed state towards the deployed state, a tape is employed in which one end of the tape is operatively connected to one of the electrical elements. In operation, the tape transitions from undeployed state in which the ends of the tape are relatively close to one another to a deployed state in which the ends of the tape are farther from one another than in the undeployed state. In performing this transition, the end of the tape that is operatively connected to one of the pair of electrical elements facilitates the positioning of the electrical element for use in a reflectarray antenna. To control the transition of the tape between the undeployed and deployed states, the deployment mechanism employs a damper. In a particular embodiment, one of the pair of electrical elements and the deployment mechanism cooperate to establish a reflectarray in a deployed Cassegrain/Gregorian-type reflectarray antenna structure. The other of the pair of electrical elements and the deployment mechanism cooperate to establish a subreflector in the deployed Cassegrain/Gregorian-type reflectarray antenna structure.

[0008] In another embodiment, the deployable reflectarray antenna structure includes a pair of electrical elements and a deployment mechanism that employs multiple tapes in transitioning the two electrical elements from an undeployed state towards a deployed state. In the undeployed state, neither of the two electrical elements functions as an element of a reflectarray antenna system. In the deployed state, the two electrical elements and the deployment mechanism cooperate to form two elements of a reflectarray antenna structure. Further, the deployment mechanism functions in the deployed state to establish the necessary positional relationships of the two elements for functioning in a reflectarray antenna structure.

[0009] In one embodiment, multiple tapes in the deployed state cooperate with one of the pair of electrical elements to form an element of a reflectarray antenna structure. In this regard, the multiple deployed tapes define a solid shape. In a particular embodiment, the first ends of four tapes define one base of a frustum of a pyramid-like structure, the second ends of the four tapes define the other base of the frustum of a pyramid-like structure, and the substantial portions of the four tapes that are linearly disposed between the first and second ends define the edges of the frustum of a pyramid-like structure.

[0010] In another embodiment, multiple tapes in the deployed state form support structures. In a particular embodiment, the first ends of three tapes define one base of a frustum of a tetrahedron-like structure (i.e., a particular type of pyramid), the second ends of the three tapes define the other base of the frustum of a tetrahedron-like structure, and the substantial portions of the three tapes that are linearly disposed between the first and second ends define the edges of the frustum of the tetrahedron-like structure. In yet another embodiment, four tapes in the deployed state define a portion of a queen post like truss. In this regard, two of the deployed tapes form a substantial portion of the tie beam of the queen post like truss and the other two of the deployed tapes form the queen posts of the queen post like truss.

[0011] Yet another embodiment of the deployable reflectarray antenna structure includes a pair of flexible electrical elements, a feed antenna, and a deployment mechanism that includes a deployable frame structure. The deployable reflectarray antenna structure also includes a canister that defines an enclosed space for storing the flexible electrical elements, feed antenna, and deployment mechanism, when each such component of the structure is in an undeployed state. The canister includes a door or hatch that, when opened, allows the flexible electrical elements, feed antenna, and deployment mechanism to operate so that the deployable frame structure and pair of flexible electrical elements cooperate to produce a reflectarray and a subreflector of a Cassegrain/Gregorian-type reflectarray antenna with the reflectarray and subreflector appropriately positioned relative to the feed antenna for a Cassegrain/Gregorian-type reflectarray antenna. When the pair of flexible elements, feed antenna, and deployment mechanism are undeployed and situated within the canister, the deployable frame mechanism is located between the pair of flexible electrical elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 illustrates an embodiment of the deployable reflectarray antenna structure in an undeployed state;

FIG. 2 is a cross-sectional view of the deployable reflectarray antenna structure shown in FIG. 1 in the undeployed state;

FIG. 3 is an exploded view of the deployable reflectarray antenna structure shown in FIG. 1 in the undeployed state;

FIGS. 4A and 4B respectively are a perspective view and side view of the reflectarray of the deployable reflectarray antenna shown in FIG. 1;

FIG. 5 is a perspective view of the subreflector of the deployable reflectarray antenna shown in FIG. 1;

FIG. 6 is a perspective view of the primary tape dispenser for transitioning a flexible membrane from an

undeployed state towards a deployed state in which the flexible membrane is configured for use as the reflectarray illustrated in Figs. 4A and 4B; FIG. 7 is a perspective view of the motor and transmission system associated with the primary tape dispenser shown in FIG. 6; FIG. 8 is a perspective view of the motor and drive train associated with the primary tape dispenser shown in FIGS. 6 and 7; FIG. 9 is a perspective view of the secondary tape dispenser for transitioning a flexible membrane from an undeployed state towards a deployed state in which the flexible membrane is configured for use as the subreflector shown in FIG. 5; FIG. 10 is a perspective view of the motor and transmission system associated with the secondary tape dispenser shown in FIG. 9; FIG. 11 is a perspective view of the motor and drive train associated with the secondary tape dispenser shown in FIGS. 9 and 10; FIG. 12 is a perspective view of a tape cartridge or dispenser used in the secondary tape dispenser shown in FIGS. 9-11; FIG. 13 is an exploded view of the tape dispenser shown in FIG. 12; FIG. 14 is a cross-sectional view of the tape dispenser shown in FIG. 12; FIG. 15 illustrates the tape associated with the tape dispenser shown in FIG. 12 in its deployed state; FIG. 16 illustrates the connection structure used to establish a connection between a membrane, a pair of lanyards, and a tape; FIGS. 17A-17C illustrate the method of folding the first flexible electrical element to place in the element in an undeployed state; and FIGS. 18A-18D illustrate the transition of the deployable reflectarray antenna structure shown in the foregoing figures from the undeployed state to the deployed state.

DETAILED DESCRIPTION

[0013] With reference to Figs. 1-5 and 18A-18D, an embodiment of a deployable reflectarray antenna structure 20 (hereinafter referred to as "the deployable reflectarray 20") is described. The deployable reflectarray 20 conforms to the CubeSat design specification. More specifically, the deployable reflectarray 20 conforms to a 1U CubeSat design specification, which requires the deployable reflectarray 20 be embodied within a cube that is 10 cm on a side and has a mass of no more than 1.33 kg. Although the deployable reflectarray 20 conforms to the CubeSat 1U design specification, it should be appreciated that adaptation to other form factors and mass requirements is feasible.

[0014] The deployable reflectarray 20 includes a canister 22, a feed antenna 24, a first flexible electrical element 26, a second flexible electrical element 28, and a

deployment mechanism 30. Generally, the canister 22 stores the feed antenna 24, first and second flexible electrical elements 26, 28 and the deployment mechanism 30 in an undeployed state and provides a base for supporting the feed antenna 24, first and second flexible elements 26, 28 and the deployment mechanism 30 in the deployed state. In the undeployed state, the feed antenna 24 is disposed within a particular volume within the canister 22. Additionally, the first and second flexible electrical elements 26, 28 are folded so as to conform to particular volumes within the canister 22. In the deployed state, the feed antenna 24 and the first and second flexible electrical elements 26, 28 are supported in a centered Cassegrain/Cregorian-style reflectarray antenna configuration. More specifically, the deployment mechanism 30 respectively supports the first flexible electrical element 26 so as to form a primary reflectarray 40 and the second flexible electrical element 28 so as to form a secondary reflectarray 42 (reflectarray subreflector) in the configuration. Further, the deployment mechanism 30 positions the feed antenna 24, primary reflectarray 40, and secondary reflectarray 42 relative to one another to realize the noted configuration. In this regard, the feed antenna 24, primary reflectarray 40, and secondary reflectarray 42 are disposed along a center-line 44.

[0015] With reference to Figs. 1 and 2, the canister 22 generally is comprised of a tubular side surface 50, a bottom surface 52 that extends across one end of the tubular side surface 50, and door structure 54 that extends across the other end of the tubular side surface 50. The tubular side surface 50 includes four planar side surfaces 56A-56D and four inside corner surfaces 58A-58D that each engages the lateral edges of two adjacent planar side surfaces. Each of the inside corner surfaces accommodates a square rod (not shown) that is part of the CubeSat design specification. The bottom surface 52 is planar and defines at least one hole or passageway 60 that accommodates a coaxial cable (not shown) which allows electrical signals to be communicated to and/or from the feed antenna 24. The door structure 54 includes a first hinged door 62 that is spring-biased towards an open position and a second hinged door 64 that is also spring-biased towards an open position. Associated with the door structure 54 is a latch mechanism 66 that holds the first and second hinged doors 62, 64 in a closed/undeployed state and can be released so as to allow the first and second hinged doors 62, 64 to each rotate towards an open or deployed position. In the illustrated embodiment, the latch mechanism 66 includes a melttable pin 68 that engages the second hinged door 64 to hold the doors in the closed/undeployed state. Associated with the canister 22 is a control board 70 that is used to apply an electrical current to the melttable pin 68 via wires (not shown) that causes the pin to melt so that the first and second hinged doors 62, 64 can each rotate towards the open/deployed position.

[0016] The feed antenna 24 is an antenna that is capable of feeding the secondary reflectarray 42 when the

deployable reflectarray antenna structure 20 is in the deployed state. In the illustrated embodiment, the feed antenna 24 is a low-profile phased array antenna. In other embodiments, a horn antenna is employed for the feed antenna.

[0017] With reference to Figs. 4A and 4B, the first flexible electrical element 26 is comprised of (a) a first flexible membrane 80 that supports an array of reflectarray elements and (b) a second flexible membrane 82 that serves as a ground plane in the deployed state. A compressible and flexible dielectric structure is located between the first and second flexible membranes and operates to maintain a desired spacing between the first and second flexible membranes when the first flexible electrical element 26 is deployed as the primary reflectarray 40. Generally, the first flexible electrical element 26 has an outer edge 86 that defines a substantially square shape with catenary-shaped edges when the element is in the deployed state. The flexible element 26 also has an inner edge 88 that defines a hole which accommodates a portion of the deployment mechanism 30. The flexible characteristics of the first and second flexible membranes 80, 82 and the compressible and flexible nature of the dielectric structure allow the first flexible electrical element 26 to be folded so as to fit within a specified volume within the canister 22 when the element is in the undeployed state. When the first flexible electrical element 26 is in the deployed state, i.e., forming the primary reflectarray 40, the first flexible electrical element 26 generally defines a frustum of a pyramid in which the outer edge 86 defines a substantially square base of a pyramid-like structure and the inner edge defines a flattened apex of the pyramid-like structure. In other embodiments, the first flexible electrical element in the deployed state is in the form of: a substantially flat square. It should be appreciated that the first flexible electrical element is not limited to having an outer edge that takes on a square shape when the element is in the deployed state. For example, other polygon shapes (e.g., triangles), curved shapes (e.g., circles), and shapes comprised of curved and straight sections are feasible. In the case of the deployable reflectarray 20, the square characteristic of the outer edge 86 of the first flexible electrical element 26 substantially conforms to the square/cubic nature of the canister 22. Other applications may more naturally lend themselves to a first flexible electrical element having a different deployed shape. For instance, a cylindrical volume for storing a first flexible electrical element may suggest an element with an outer edge that is circular in the deployed state.

[0018] With reference to Fig. 5, the second flexible electrical element 28 is comprised of (a) a first flexible membrane 90 that supports an array of reflectarray elements and (b) a second flexible membrane 92 that serves as a ground plane in the deployed state. A compressible and flexible dielectric structure is located between the first and second flexible membranes and operates to maintain a desired spacing between the first and second

flexible membranes when the second flexible electrical element 28 is deployed as the secondary reflectarray 42. Generally, the second flexible electrical element 28 has an outer edge 96 that defines a substantially square shape with catenary-shaped edges when the element is in the deployed state. The flexible element 28 also has an inner edge 98 that defines a hole. The flexible characteristics of the first and second flexible membranes 90, 92 and the compressible and flexible nature of the dielectric structure allow the second flexible electrical element 28 to be folded so as to fit within a specified volume of the canister 22 when the element is in the undeployed state. When the second flexible electrical element 28 is in the deployed state, i.e., forming the secondary reflectarray 42, the second flexible electrical element 28 is generally planar and the outer edge 96 generally defines a square. It should be appreciated that the second flexible electrical element is not limited to having an outer edge that takes on a square shape when the element is in the deployed state. For example, other polygon shapes (e.g., triangles), curved shapes (e.g., circles), and shapes comprised of curved and straight sections are feasible. Additionally, in other embodiments, the second flexible electrical element can be a reflector or polarizer, as opposed to a reflectarray subreflector.

[0019] With reference to Figs. 2 and 3, the deployment mechanism 30 operates to transition the deployable reflectarray 20 between an undeployed state and a deployed state. In the undeployed state, the feed antenna 24, first flexible electrical element 26, second flexible electrical element 28, and the deployment mechanism 30 are disposed within the enclosed space defined by the canister 22 when the first and second hinged doors 62, 64 are closed. In the deployed state, the first and second flexible electrical elements 26, 28 are supported so as to respectively form the primary and secondary reflectarrays 40, 42 in a center-fed Cassegrain/Gregorian-style reflectarray antenna. Further, the feed antenna 24, primary reflectarray 40, and secondary reflectarray 42 are located with respect to one another so as to implement a center-fed Cassegrain/Cregorian-style reflectarray antenna.

[0020] The deployment mechanism 30 transitions the deployable reflectarray 20 between the undeployed and deployed states in two phases. In the first phase, the first and second flexible electrical elements 26, 28, which are in folded in the undeployed state, are positioned so that the elements can be unfolded and deployed so as to establish the primary and secondary reflectarrays 40, 42 and the necessary positional relationships with one another and the feed antenna 24 to establish the center-fed Cassegrain/Gregorian-style reflectarray antenna. The second phase involves the deployment of the first and second electrical elements 26, 28 so as to establish the primary and secondary reflectarrays 40, 42 and the positioning of the reflectarrays relative to the feed antenna 24 to establish the reflectarray antenna.

[0021] Generally, the deployment mechanism 30 in-

cludes a guide tube structure 110, a spring 112, a limit lanyard system 114, a primary housing 116, a base plate 118, a tape dispenser 120, and a secondary housing 122.

[0022] The guide tube structure 110 serves a number of purposes. To elaborate, the guide tube structure 110 directs the displacement of the primary housing 116 with the undeployed first flexible electrical element 26 supported by the housing, the base plate 118, the tape dispenser 120, the feed antenna 24, the secondary housing 122 with the undeployed second flexible electrical element 28 during the first phase of the transition of the deployable reflectarray 20 between the undeployed and deployed states. The guide tube structure 110 also operates so as to prevent the base plate 118, tape dispenser 120, feed antenna 24, and secondary housing 122 from rotating relative to the canister 122 during the transition and thereafter. Additionally, the guide tube structure 110 provides an axle about which the primary housing 116 can rotate during the second phase of the transition. The guide tube structure 110 also defines a portion of the passageway 60 that accommodates the coaxial cable or other signal transmission structure that is capable of providing electrical signals to and/or from the feed antenna 24.

[0023] The guide tube structure 110 includes a ridged cylindrical guide tube 130 with a first end 132 fixedly attached to the bottom surface 52 of the canister 22 and a free end 134. Additionally, the ridged cylindrical guide tube 130 defines a longitudinally extending ridge 136.

[0024] The guide tube structure also includes a slotted cylindrical guide tube 140 with a first end 142 fixedly attached to the base plate 118, a free end 144, and a slot 146 that is dimensioned to engage the ridge 136 associated with ridged cylindrical guide tube 130. The inner diameter of the slotted guide tube 140 (excluding the ridge 146) is slightly greater than the outer diameter of the ridged cylindrical guide tube 130. As such, the slotted guide tube 140 is capable of sliding over the ridged guide tube 130 when the tubes are oriented so that the slot 146 engages the ridge 136. In the first phase of the transition between the undeployed and deployed states, the slotted guide tube 140 can be extended away from the ridged guide tube 130 to direct the primary housing 116 and other elements outside of the canister 22. The "keying" of the slot 146 and the ridge 136 prevents rotation of the base plate 118 and other elements supported by the base plate during the transition and thereafter.

[0025] The spring 112 provides the energy for moving the primary housing 116 with the undeployed first flexible electrical element 26 supported by the primary housing, the base plate 118, the tape dispenser 120, the feed antenna 24, the second housing 122 with the undeployed second flexible electrical element 28 during the first phase of the transition of the deployable reflectarray 20 between the undeployed and deployed states. The spring 112 extends between the interior side of the bottom surface 52 of the canister and the primary housing 116. When the deployable reflectarray 20 is in the undeployed

state with the first and second doors 62, 64 of the canister 22 closed, the spring 112 is compressed. After the first and second doors 62, 64 are opened, the potential energy stored in the spring 112 is released and a force is applied to the primary housing 116 with the undeployed first flexible electrical element 26 supported by the housing, the base plate 118, the tape dispenser 120, the feed antenna 24, the second housing 122 with the undeployed second flexible electrical element 28 as directed by the guide tube structure 110 so that these elements are positioned for the second phase of the transition between the undeployed and deployed states. In the illustrated embodiment, the spring 112 provides sufficient energy so that the primary housing 116 and the first flexible electrical element 26 and the secondary housing 122 and the second flexible electrical element 28 are sufficiently exposed for the second phase of the transition between the undeployed and deployed state. In this regard, the spring 112 provides sufficient energy to position the bottom of the primary housing 116 at or slightly above the edge of the canister 22 that is exposed following the opening of the first and second doors 62, 64.

[0026] The limit lanyard system 114 operates to limit the extent to which the spring 112 moves the primary housing 116 with the undeployed first flexible electrical element 26 supported by the housing, the base plate 118, the tape dispenser 120, the feed antenna 24, the second housing 122 with the undeployed second flexible electrical element 28 along the guide tube structure 110 during the first phase of the transition between the undeployed and deployed states. To elaborate, the spring 112 is designed to provide sufficient energy to move the noted elements to a desired position for the second phase of the transition. To ensure that the elements reach the desired position, the spring 112 is designed so as to be capable of providing more energy than is needed to position the elements at the desired position. As such, the spring 112 is potentially capable of moving the elements beyond the desired position. The limit lanyard system 114 prevents the spring 112 from moving the elements beyond the desired position. The limit lanyard system includes lanyards 150A-150D, each with one end connected to the bottom surface 52 of the canister 22 and the other end connect to the base plate 118. The length of each of the lanyards 150A-150D is chosen so that when the lanyard is fully extended due to the force being provided by the spring 112, the elements are at the desired position for the second phase of the transition.

[0027] The primary housing 116 serves to define, in combination with a portion of the canister 22, the space within which the first flexible electrical element 26 resides when in the undeployed state. The primary housing 116 also operates so as to rotate about the slotted cylindrical guide tube 140 during the second phase of the transition of the first flexible electrical element 26 between the undeployed and deployed states. The need for the primary housing 116 and the first flexible electrical element 26 to rotate during the second phase of the transition is neces-

sitated by the manner in which the first flexible electrical element 26 is folded when in the undeployed state. The primary housing 116 also serves to provide a portion of the forces that are used to shape the first flexible electrical element 26 in the manner needed to realize the primary reflectarray 40.

[0028] The primary housing 116 includes a reel-like structure 160 that includes a lower wall 162, an upper wall 164 that is substantially parallel to the lower wall 162, and a hollow cylindrical core 166 that extends between the lower wall 162 and the upper wall 164. The upper wall 164 has an outer edge with four scalloped sections 168A-168D that are portions of channels that allow mechanical connections to be established between the tapes associated with the tape dispenser 120 and the first flexible electrical element 26 and lanyards that extend between the first and second electrical elements 26, 28. The hollow cylindrical core 166 has an inner diameter sufficient to receive the slotted cylindrical guide tube 140. The hollow cylindrical core 166 also defines upper and lower bearing seats 170A, 170B that respectively support roller bearings 172A, 172B. The bearings 172A, 172B extend between the hollow cylindrical core 166 and the slotted cylindrical guide tube 140 and facilitate the rotation of the housing 116 about slotted cylindrical guide tube 140 when the first flexible electrical element 26 is transitioned from the deployed state during the second phase of the transition. Clearance between the bearing 172A and the base plate 118 prevents the base plate 118 from inhibiting rotation of the primary housing 116. Also associated with the primary housing 116 are a series of tapped holes that are respectively engaged by screws 176A-176D that pass through holes in the first flexible electrical element 26 and are used to connect the primary housing 116 to the first flexible electrical element 26.

[0029] The base plate 118 serves as a support for the tape dispenser 120, feed antenna 24, secondary housing 122, and second flexible electrical element 28. The base plate 118 has an outer edge with four scalloped sections 180A-180D that correspond with the four scalloped sections 168A-168D to provide pathways for mechanical connections to be established between the tapes associated with the tape dispenser 120 and the first flexible electrical element 26 and lanyards that extend between the first and second electrical elements 26, 28. The base plate 118 also has an inner edge that defines a hole 182 that forms a portion of the pathway that accommodates a coaxial cable used to send electrical signals to and/or from the feed antenna 24.

[0030] The tape dispenser 120 provides a plurality of tapes (frequently referred to as carpenter tapes) that are used to: (a) deploy the first flexible electrical element 26 so as to establish the primary reflectarray 40, (b) deploy the second flexible electrical element 28 so as to establish the secondary reflectarray 42, and (c) position the primary and secondary reflectarrays 40, 42 relative to one another and to the feed antenna 24 in a center-fed

Cassegrain/Gregorian-style reflectarray antenna configuration.

[0031] The tape dispenser 120 is comprised of a primary tape dispenser 190 that is used to dispense tapes that are used to deploy the first flexible electrical element 26 and a secondary tape dispenser 192 that is used to dispense tapes that are used to deploy the second flexible electrical element 28.

[0032] With reference to Figs. 6-8, the primary tape dispenser 190 operates to dispense four tapes that each engages the first flexible electrical element 26 at a point adjacent to one of the corners of the outer edge 86 of the element. The four tapes, when dispensed or deployed, cooperate with the screws 176A-176D that each engage the element at a point adjacent to the inner edge 88 to hold the flexible electrical element 26 in the pyramid-like shape of the primary reflectarray 40.

[0033] The primary tape dispenser 190 includes: (a) four individual tape dispensers or cartridges 200A-200D that respectively have tape axles 202A-202D that are each adapted to support a roll of tape with a first terminal end of the tape operatively connected to the axle and the other or second terminal end operatively connected to the first flexible electrical element 26, (b) an electric motor 204 for providing the force needed to drive the axles 202A-202D and thereby dispense the tapes from the dispensers, and (c) a transmission system 206 for transmitting force from the motor 204 to each of the axles 202A-202D to dispense the tapes and to dispense the tapes at substantially the same time and at substantially the same rate. When the tape is rolled a first terminal end of the tape is located a first distance, dictated by the diameter of the axle and depth of coiled tape, from the second terminal end of the tape. In the deployed state, the first terminal end is located a second distance from the second terminal end that is greater than the first distance and a substantial portion of the tape located between the first and second terminal ends is substantially linear.

[0034] The transmission system 206 includes a motor gear 210 that is connected to the axle of the electric motor 204, a gearhead 212 with a first gearhead gear 214 that engages the motor gear 210 and a second gearhead gear 216 that the gearhead 212 causes to rotate at multiple times the rate at which first gearhead gear 214 is caused to rotate by the electric motor 204, a drive train 218 that is comprised of a number of gears that transfer the force produced by the second gearhead gear 216 to tape axle 202A, and a miter gear system that transfers the rotational force imparted to tape axle 202A to axles 202B-202D. The miter gear system includes a first pair of miter gears 222A, 222B associated with the axle 202A; a second pair of miter gears 224A, 224B associated with the axle 202B; a third pair of miter gears 226A, 226B associated with axle 202C; and a fourth pair of miter gears 228A, 228B associated with the axle 202D.

[0035] With reference to Figs. 9-11, the secondary tape dispenser 192 operates to dispense four tapes that each engages the second flexible electrical element 28 at a

point adjacent to one of the corners of the outer edge 96 of the element to hold the second flexible electrical element 28 in the flat shape of the secondary reflectarray 42.

[0036] The secondary tape dispenser 192 includes: (a) four individual tape dispensers or cartridges 240A-240D that respectively have tape axles 242A-242D that are each adapted to support a roll of tape with one end of the tape operatively connected to the axle and the other end operatively connected to the second flexible electrical element 28, (b) a motor 244 for providing the force needed to drive the axles 242A-242D and thereby dispense the tapes from the dispensers, and (c) a transmission system 246 for transmitting force from the motor 244 to each of the axles 242A-242D to dispense the tapes and to dispense the tapes at substantially the same time and at substantially the same rate.

[0037] The transmission system 246 includes a motor gear 250 that is connected to the axle of the electric motor 244, a gearhead 252 with a first gearhead gear 254 that engages the motor gear 250 and a second gearhead gear 256 that the gearhead 252 causes to rotate at many times the rate at which first gearhead gear 254 is caused to rotate by the electric motor 244, a drive train 258 that is comprised of a number of gears that transfer the force produced by the second gearhead gear 256 to a connecting rod system 260 that, in turn, transfers the rotational force to axles 242A-242D. The connecting rod system 260 includes connecting rods 262A-262D, a first pair of U-joints 264A, 264B associated with connecting rod 262A and respectively engaging axles 242A, 242B, a second pair of U-joints 266A, 266B associated with connecting rod 262B and respectively engaging axles 242B, 242C, a third pair of U-joints 268A, 268B associated with connecting rod 262C and respectively engaging axles 242C, 242D, and a fourth pair of U-joints 270A, 270B associated with connecting rod 262D and respectively engaging axles 242D, 242A. The connecting rod system 260 operates to transfer the rotational force imparted by the drive train 258 to the connecting rod 262A to each of the axles 242A-242D.

[0038] With reference to Figs. 12-15 tape dispenser or tape cartridge 240A of the secondary tape dispenser 192 is described with the understanding that tape dispensers 240B-240D are substantially identical. Further, the tape dispensers 200A-200D of the primary tape dispenser 190 are also substantially identical to the tape dispenser 240A with two exceptions, namely, (a) the tape dispensers 200A-200D dispense tape in a different direction than tape dispenser 240A and (b) the tape dispensers 200A-200D dispense a different length of tape than tape dispenser 240A. The tape dispenser 240A includes a bi-stable composite tape 280, the tape axle 242A, and housing 284. The bi-stable composite tape 280 has two stable states, namely, (1) a first state in which the tape has a coiled cylindrical shape and (2) a second state in which the tape extends in a linear fashion with a lateral cross-section that has an arc. The bi-stable composite tape 280 extends from a first end 286A to a second end 286B. The

first end 286A defines a pair of holes 288A, 288B that are used to engage the tape to the tape axle 242A with a pair of screws 290A, 290B. The second end 286B defines a hole 292 that is used to engage a fastener 294 which is used in connecting the tape 280 to the second flexible electrical element 28. The housing 284 includes a main housing 296 and side panels 298A, 298B that engage the main housing. A substantial portion of the main housing 296 and the side panel 298A, 298B define a chamber 300 for holding, prior to deployment, the bulk of the tape 280 in the first state, i.e., in the coiled cylindrical shape. The housing 284 also includes a transition portion 302 that supports a short section of the tape 280 in a manner that transitions the short section of tape from the first state to the second state. The side panels 298A, 298B respectively define holes 304A, 304B that receive bearings 306A, 306B. The bearings 306A, 306B facilitate the rotation of the tape axle 242A within the main housing 296. Each of the bearings 306A, 306B also engages one half of a U-joint.

[0039] With reference to FIG. 18D, the primary tape dispenser 190 operates to synchronously dispense four tapes 320A-320D and the secondary tape dispenser 192 operates to synchronously dispense four tapes 322A-322D. Associated with the tapes 320A-320D and 322A-322D are lanyards 324A-324H with each lanyard extending between an end of one of the tapes 320A-320D and an end of one of the tapes 322A-322D. Each of the lanyards 324A-324D cooperates with the two tapes that it directly engages to facilitate the establishment of a truss structure that supports the primary and second reflectarrays 40, 42.

[0040] With reference to FIG. 16, a connection structure 330 is described that interconnects the first flexible electrical element 26, tape 320A, and lanyards 324A, 324B. The connection structure 330 is substantially identical to the connection structure associated with each of the tapes 320B-320D with the exception that each of these tapes engages a different pair of lanyards. Further, the connection structure 330 is substantially identical to the connection structure associated with each of the tapes 322A-322D with the exception that the connection structure associated with each of these tapes engages the second flexible electrical element 28, a different pair of lanyards, and does not include a spring. The connection structure 330 includes a first mount 332, second mount 334, and spring 336. The first mount 332 is operatively engaged to the first and second flexible membranes 80, 82 of the first flexible electrical element 26, one end of the lanyard 324A, one end of lanyard 324B, and one end of the spring 336. The second mount 334 operatively engages one end of the tape 320A and the other end of the spring 336. In operation, the spring 336 operates to keep forces applied to the first flexible electrical element 26 and the tape 320A relatively constant and thereby prevent the application of forces that could adversely affect the functionality of one or both of the element and the tape.

[0041] Before describing the operation of the deployable reflectarray 20, the manner in which the first flexible electrical element 26 is folded so as to be accommodated in the spaced defined by the primary housing 116 and a portion of the canister 22 when the deployable reflectarray 20 is in the undeployed state is described. With reference to FIG. 17A, the first flexible electrical element 26 initially is flat and the outer edge 96 substantially defines a square. Within the outer edge 96 folding lines are defined with the solid folding lines representing "ridges" and the dashed folding lines representing "valleys." This particular pattern of folding is known as a "leaf-in" folding pattern. With reference to FIG. 17B, folding the first flexible electrical element 26 according to the leaf-in pattern produces a four-branch structure 340 with arms 342A-342D that each extend away from the inner edge 88 of the first flexible electrical element 26. With reference to FIG. 17C, the folding of the first flexible electrical element 26 is completed by swirling the arms 342A-342D around the inner edge 88 so as to form a multi-arm spiral pattern that, as the radius of the spirals decreases, ultimately has the overall shape of a hollow cylinder.

[0042] With reference to FIGS. 18A-18D, the operation of the deployable reflectarray 20 is described. Initially and as shown in FIG. 18A, the deployable reflectarray 20 is in an undeployed state with the door structure 54 of the canister 22 closed and the meltable pin 68 intact. The feed antenna 24, first flexible electrical element 26, second flexible electrical element 28, and deployment mechanism 30 are enclosed within the canister 22.

[0043] With reference to FIGS. 18B and 18C, the first phase of the deployment commences with an electrical signal being applied to the meltable pin 68 to cause the pin 68 to fail and the spring biased doors 62, 64 to open. Once the doors 62, 64 are sufficiently open the spring 112 can apply a force to the overlying components, namely, the feed antenna 24, first flexible electrical element 26, second flexible electrical element 28, primary housing 116, base plate 118, tape dispenser 120, and secondary housing 122 to move these components to a location from which the first and second flexible electrical elements 26, 28 can be deployed to realize the primary and secondary reflectarrays 40, 42 and to position the primary and secondary reflectarrays relative to one another and to the feed antenna 24 so as to realize a centered Cassegrain/Crregorian-style reflectarray antenna structure. In this regard, the spring 112 applies sufficient force to position the overlying components outside of the canister 22 and such that the lower wall 162 of the primary housing 116 extends slightly above the upper edge of the canister 22. The limit lanyards 150A-150D prevent the spring 112 from moving the overlying components beyond this point.

[0044] With reference to FIG. 18D, the second phase of the deployment of the first and second electrical elements 26, 28 is accomplished by applying electrical power to the electric motor 204 of the primary tape dispenser 190 and to the electric motor 244 of the secondary tape

dispenser 192. Electric power can be simultaneously applied to the electric motors 204, 244. Alternatively, electric power can be sequentially applied to the electric motors 204, 244, i.e., electrical power being initially applied to electric motor 204 and subsequently applied to electric motor 244 or being initially applied to electric motor 244 and subsequently applied to electric motor 204. The source of the electrical power for the motors is typically a battery or solar array that is located outside of the deployable reflectarray 20. The electrical power is conveyed to the electrical motors 204, 244 via conductors disposed within the passageway 60.

[0045] Regardless of the manner in which electrical power is applied to the electrical motors 204, 244, the electric motor 204 and transmission 206 operate to simultaneously deploy tapes 320A-320D from the primary tape dispensers 200A-200D and in so doing establish the primary reflectarray 40. Due to the spiral folding of the first flexible electrical element 26, the dispensing of the primary tapes 320A-320D causes the primary housing 116 to rotate about the cylindrical guide tube 140. The electric motor 244 and transmission 246 also operate to simultaneously deploy tapes 322A-322D from the secondary tape dispenser 240A-240D and in so doing establish the secondary reflectarray 42. The deployment of the tapes 320A-320D and 322A-322D also deploys the lanyards 324A-324H. It should be appreciated that the electric motors 204, 244 are capable of being used so as to control the rate at which the tapes 320A-320D and 322A-322D are deployed. As such, the electric motors 204, 244 each function, at least in part, as dampers to control the transition of the tape between the undeployed and deployed states.. Note that the motors can be controlled so that not all of the tape beyond the fixed first terminal end is extended from its cartridge. Some tape may be retained on the axle to facilitate damping.

[0046] There are a number of features to note about the tapes 320A-320D and 322A-322D and/or the lanyards 324A-324H in the deployed state. First, each of the tapes is substantially located between the first flexible electrical element 26 and a plane defined by the second flexible electrical element 28. However, because the tapes are made of a composite material (e.g., fiberglass and an epoxy), the tapes act as a dielectric and have little, if any, effect on the electromagnetic waves that travel between the primary and secondary reflectarrays 40, 42 during operation of the antenna. Second, the deployed tapes 320A-320D apply sufficient force to the first flexible electrical element 26 so that a catenary is established between each of the corners of the outer edge 86. This, in turn, results in the first flexible electrical element 26 being deployed so as to have a relatively smooth surface that is substantially free of wrinkles that could adversely affect the performance of the deployed element. Third, the deployed tapes 320A-320D cause the first flexible electrical element 26 to have a shape that is pyramid-like and, more specifically, a frustum of a pyramid-like structure with the corners of the edge 86 of the element de-

fining the base of the pyramid-like structure, the inner edge 88 of the element defining flattened apex of the pyramid-like structure, and the seams between the corners of the edge 86 and the inner edge 88 defining the edges of the pyramid-like structure. It is believed that the pyramid-like structure of the deployed first flexible electrical element 26 improves the bandwidth of the antenna. Fourth, the deployed tapes 320A-320D also define a solid shape such as a pyramid-like shape with the outer ends 286B of the tapes defining the base of the pyramid-like structure, the inner ends 286A of the tapes defining the flattened apex of the pyramid-like structure, and the tapes defining the edges of the pyramid-like structure. However, in certain embodiments the deployed tapes 320A-320D lie substantially in a plane and define a flat shape. Fifth, each of the deployed tapes 320A-320D is in compression due to the force applied to the first end 286A of the tape by the tape axle to which the tape is connected and the force applied to the second end 286B of the tape by one of the connection structure 330, two of the lanyards, and the first flexible electrical element 26. Sixth, the two lanyards and the first flexible electrical element 26 also cooperate to substantially limit any bending moment being applied to each of the deployed tapes 320A-320D. Seventh, the deployed tapes 322A-322D and the lanyards 324A-324H apply sufficient force to the second flexible electrical element 28 so that a catenary is established between each of the corners of the outer edge 96. This, in turn, results in the second flexible electrical element 28 being deployed so as to have a relatively smooth surface that is substantially free of wrinkles that could adversely affect the performance of the deployed element. Eighth, the deployed tapes 322A-322D and the lanyards 324A-324H also apply sufficient force to the second flexible electrical element 28 so that the element is substantially planar. Ninth, the deployed tapes 322A-322D also define a solid shape such as a pyramid-like shape with the outer ends 286B of the tapes defining the base of the pyramid-like structure, the inner ends 286A of the tapes defining the flattened apex of the pyramid-like structure, and the tapes defining the edges of the pyramid-like structure. In certain embodiment, the deployed tapes 322A-322D can be substantially parallel to one another. In this case, the deployed tapes 322A-322D define a column-like structure with a polygonal cross-section. Tenth, four combinations of: (a) the deployed tapes 320A-320D, (b) the deployed tapes 322A-322D, and (c) the lanyards 324A-324H each form a first tetrahedron truss structure. For example, the combination of the deployed tape 320A, deployed tapes 322A and 322B, and lanyards 324A and 324B define one of the four first tetrahedron truss structures. Eleventh, four combinations of: (a) the deployed tapes 320A-320D, (b) the deployed tapes 322A-322D, and (c) the lanyards 324A-324H each form a second tetrahedron truss structure. For example, the combination of the deployed tapes 320A and 320B, deployed tape 322B, and lanyards 324B and 324C define one of the four second tetrahedron truss structures.

Twelfth, four combinations of: (a) the deployed tapes 320A-320D, (b) the deployed tapes 322A-322D, and (c) the lanyards 324A-324H each substantially form a queens post-like truss structure. For example, the deployed tapes 320A and 320C with the base plate 118 define a tie beam of a queens post-like truss structure, deployed tapes 322B and 322C each define a queens post of a queens post-like truss structure, lanyards 324B and 324E each define a principle of a queens post-like truss structure, and the second flexible electrical element 28 defines the strain beam of a queens post-like truss structure.

[0047] While the deployable reflectarray 20 operates to implement a center-fed Cassegrain/Gregorian-like reflectarray antenna (i.e., a dual-reflector configuration), it should be appreciated that a deployable single-reflector configuration comprised of a reflectarray and a feed antenna is also feasible. In such a configuration, there would be no second flexible electrical element to deploy. Rather, the secondary tape dispenser would be adapted to deploy a feed antenna (that is the secondary electrical element is the feed antenna in such an implementation) at a specific distance from a primary reflectarray (which, in such an embodiment, is the only reflectarray in the antenna). It should also be appreciated that tape deployment of one or more reflectarray antenna elements can be implemented for offset-fed Cassegrain/Gregorian-like reflectarray antennas, i.e., dual-reflector configurations in which the feed antenna, reflectarray, and subreflector are not aligned. Similarly, tape deployment of one or more reflectarray antenna elements can be implemented for an offset single-reflector configuration in which the feed antenna and reflectarray are not aligned, i.e., a normal to the surface of the reflectarray or the boresight of the reflectarray is not aligned with the boresight of the feed antenna. In such a configuration one or more tapes could be on other side of the electrical elements, and not located between the first electrical element and the second electrical element as in the illustrated embodiments.

[0048] The foregoing description of the invention is intended to explain the best mode known of practicing the invention and to enable others skilled in the art to utilize the invention in various embodiments and with the various modifications required by their particular applications or uses of the invention.

[0049] In one option there is provided a deployable reflectarray antenna structure comprising: a first electrical element for use in a reflectarray antenna; a second electrical element for use in a reflectarray antenna; and a deployment mechanism for transitioning the first electrical element and the second electrical element from an undeployed state in which the first and second electrical elements are not positioned relative to one another for use in a reflectarray antenna towards a deployed state in which the first and second electrical elements are positioned relative to one another for use in a reflectarray antenna; wherein the deployment mechanism includes a tape that extends from a first terminal end to a second

terminal end; wherein, in the undeployed state, the first terminal end of the tape is located a first distance from the second terminal end of the tape; wherein in the deployed state, the first terminal end of the tape is located a second distance from the second terminal end of the tape that is greater than the first distance and a substantial portion of the tape located between the first and second terminal ends is substantially linear; wherein at least one of the first and second electrical elements is operatively engaged to the tape at a location adjacent to the second terminal end of the tape; wherein the deployment mechanism includes a damper that operatively engages the tape and operates during the transition of the tape from the undeployed state towards the deployed tape state.

[0050] In such a deployable reflectarray antenna structure, when the tape is in the deployed tape state, the substantial portion of the tape located between the first and second terminal ends that is substantially linear is at least one of: (a) in compression and (b) substantially not subject to a bending moment.

[0051] In such a deployable reflectarray antenna structure, when the tape is in the deployed tape state, the substantial portion of the tape located between the first and second terminal ends that is substantially linear is substantially located between the first electrical element and the second electrical element.

[0052] In such a deployable reflectarray antenna structure when the first electrical element is in the deployed state, the first electrical element is a reflectarray of a reflectarray antenna. Similarly when the second electrical element is in the deployed state, the second electrical element is a subreflector of a reflectarray antenna. Each of the electrical elements is flexible; and folded in the undeployed state; and unfolded in the deployed state relative to the undeployed state.

[0053] Optionally the subreflector is a reflectarray subreflector.

[0054] Optionally the second electrical element is a feed antenna.

[0055] In such a deployable reflectarray antenna structure the first electrical element is in the deployed state, the first electrical element has one of: (a) a substantially flat shape and (b) a pyramid-like shape.

[0056] Optionally the deployable reflectarray antenna structure further comprises

a canister that defines an enclosed space for storing each of the first electrical element, second electrical element, feed antenna and tape in an undeployed state;

wherein the canister has a closed end, an openable end, and a side that extends between the closed end and the openable end;

wherein, when the tape, first electrical element, and second electrical element are stored in the canister, the tape is located between the first electrical element and the second electrical element.

[0057] In another aspect there is provided a deployable reflectarray antenna structure comprising:

a first flexible electrical element for use in a reflectarray antenna;

a second flexible electrical element for use in a reflectarray antenna;

a feed antenna for use in a reflectarray; and

a deployment mechanism for transitioning the first and second flexible electrical elements from a an undeployed state in which the first and second flexible electrical elements are folded towards a deployed state in which: (a) the first and second flexible electrical elements are unfolded relative to the undeployed state and (b) positioned relative to one another and to the feed antenna in a reflectarray antenna configuration;

wherein the deployment mechanism comprises a deployable frame structure;

a canister that defines an enclosed space for storing the first flexible element, second flexible element, feed antenna, and deployable frame structure in the undeployed state;

wherein the canister has a closed end, an openable end, and a side that extends between the closed end and the openable end;

wherein, in the undeployed state, the deployable frame structure is located between the first foldable element and the second foldable element.

[0058] In such a deployable reflectarray antenna structure, the first flexible element is folded in a leaf-in pattern in the undeployed state with at least three "leaves" which are spirally folded about an axis.

[0059] In such a deployable reflectarray antenna structure the deployable frame structure comprises a plurality of tapes, optionally composite tapes that are optionally bistable.

[0060] In such a deployable reflectarray antenna structure, the deployable frame structure comprises a plurality of lanyards with each lanyard extending between a pair of composite tapes in the plurality of tapes.

Claims

1. A deployable reflectarray antenna structure (20) comprising:

a first electrical element (26) for use in a reflectarray antenna;

a second electrical element (28) for use in a reflectarray antenna; and

a deployment mechanism (30) for transitioning the first electrical element and the second electrical element from an undeployed state in which the first and second electrical elements are not positioned relative to one another for use in a reflectarray towards a deployed state in which the first and second electrical elements are positioned relative to one another for use in a re-

flectarray antenna;
 wherein the deployment mechanism includes a plurality of tapes (320, 322) for transitioning the first and second electrical elements from the unde-
 5 deployed state towards the deployed state;
 wherein each tape of the plurality of tapes:

extends from a first terminal end (286A) to a second terminal end (286B);
 wherein, in the undeployed state, the first terminal end is located a first distance from the second terminal end;
 wherein, in the deployed state, the first terminal end is located a second distance from the second terminal end that is greater than the first distance and a substantial portion of the tape located between the first and second terminal ends is substantially linear;
 wherein each of the plurality of tapes engages one of the first and second electrical elements at a location adjacent to the second terminal end of the tape;

wherein the deployment mechanism includes a damper (204, 244) that operatively engages the plurality of tapes during the transition of the first and second electrical elements from the unde-
 25 ployed state towards the deployed state.

- 2. A deployable reflectarray antenna structure, as claimed in claim 1, wherein:

when the first electrical element (26) is in the deployed state, the first electrical element is part of a reflectarray antenna; and
 35 the second terminal ends of at least two tapes (320) of the plurality of tapes are operatively connected to the first electrical element.

- 3. A deployable reflectarray antenna structure, as claimed in claim 2, wherein:

the second terminal ends of at least three tapes (320) of the plurality of tapes are operatively connected to the first electrical element;
 45 when each of the at least three tapes of the plurality of tapes is in the deployed tape state, the at least three tapes of the plurality of tapes define one of : (a) a first solid shape with the first terminal ends of the at least three tapes defining a first planar base of the first solid shape, with the second terminal ends of the at least three tapes defining a second planar base of the first solid shape, and with the portion of a tape located between the first and second terminal ends of each of the at least three tapes defining an edge of the first solid shape and (b) a substantially flat shape.

- 4. A deployable reflectarray antenna structure, as claimed in claim 3, wherein:

the first solid shape is a frustum of a pyramid, and the at least three tapes in the deployed state are non-parallel to one another.

- 5. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein:

when the second electrical element (28) is in the deployed state, the second electrical element is part of one of (a) a subreflector; and (b) a feed antenna (24)
 15 the second terminal ends of at least two of the plurality of tapes (322) are operatively connected to the second electrical element.

- 6. A deployable reflectarray antenna structure, as claimed in claim 5, wherein:

the second terminal ends of at least three tapes (322) of the plurality of tapes are operatively connected to the second electrical element (28);
 25 when each of the at least three tapes of the plurality of tapes is in the deployed tape state, the at least three tapes of the plurality of tapes define a second solid shape with the second terminal ends of the at least three tapes defining a first planar base of the second solid shape, with the first terminal ends of the at least three tapes defining a second planar base of the second solid shape, and with the portion of a tape located between the first and second terminal ends of each of the at least three tapes defining an edge of the second solid shape.

- 7. A deployable reflectarray antenna structure, as claimed in claim 6, wherein:

the second solid shape is one of: (a) a column with a polygonal cross-section, the at least three tapes in the deployed state being substantially parallel to one another and (b) a frustum of a pyramid, the at least three tapes in the deployed state being non-parallel to one another.

- 8. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein:

when the first electrical element is in the deployed state, the first electrical element is a reflectarray in a reflectarray antenna;
 when the second electrical element is in the deployed state, the second electrical element is a subreflector in a reflectarray antenna; and
 the second terminal end of each of the plurality of tapes is operatively connected to one of: (a)

the first electrical element and (b) the second electrical element.

- 9. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein: 5

the first terminal ends of the plurality of tapes are substantially fixed;
 the second terminal ends of at least two of the tapes move farther from one another in the transition of the plurality of tapes from the undeployed state to the deployed state.

- 10. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein: 15

the deployment mechanism (30) includes at least one lanyard (324) extending between the second terminal ends of two of the plurality of tapes. 20

- 11. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein: 25

the second terminal ends of three tapes of the plurality of tapes are operatively connected to the first and second electrical elements;
 two of the three tapes of the plurality of tapes are operatively connected to one of the first and second electrical elements;
 the other of the three tapes of the plurality of tapes is operatively connected to the other one of the first and second electrical elements;
 when the three tapes of the plurality of tapes are in the deployed state, the second ends of the three tapes define a base of a tetrahedron-like structure and the first ends of the three tapes define an apex of the tetrahedron-like structure. 30 35

- 12. A deployable reflectarray antenna structure, as claimed in claim 11, further comprising: 40

a first lanyard (324A) extending between the first and second of the three tapes of the plurality of tapes;
 a second lanyard extending between the first and a third of the three tapes of the plurality of tapes. 45

- 13. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein: 50

the first terminal ends of four tapes of the plurality of tapes are operatively connected to the first and second electrical elements;
 the first tape (320A) and the second tape (320C) of the four tapes of the plurality of tapes are op-

eratively connected to the first electrical element (26) and the third tape (322B) and the fourth tape (322C) of the four tapes of the plurality of tapes are operatively connected to the second electrical element (28);
 when the four tapes of the plurality of tapes are in the deployed state, the four tapes define a portion of a queens post like truss.

- 14. A deployable reflectarray antenna structure, as claimed in claim 13, wherein: 55

a first lanyard (324B) operatively engages the second terminal ends of the first (320A) and third (322B) tapes of the four tapes of the plurality of tapes; and
 a second lanyard (324E) operatively engages the second terminal ends of the second (320C) and fourth (322C) tape of the four tapes of the plurality of tapes.

- 15. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein: 60

at least one of the first and second electrical elements is flexible, folded in the undeployed state, and unfolded in the deployed state relative to the undeployed state.

- 16. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein: 65

in the deployed state, the first electrical element (26) has a border that substantially defines a plane and an inner section that is spaced from the plane.

- 17. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein: 70

in the deployed state, a subset of the plurality of tapes is located between the first electrical element and the second electrical element.

- 18. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, further comprising: 75

a canister (22) that defines an enclosed space for storing each of the first electrical element (26), second electrical element (28), a feed antenna (24) and plurality of tapes in an undeployed state;
 wherein the canister has a closed end, an openable end, and a side that extends between the closed end and the openable end;
 wherein, when the plurality of tapes, first electrical element, and second electrical element are

stored in the canister, the plurality of tapes is located between the first electrical element and the second electrical element.

19. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein the first electrical element is flexible, and when the first electrical element is in the undeployed state, the first electrical element is folded in a "leaf-in" pattern that has at least three "leaves". 5
20. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein: 10
- the deployment mechanism (30) comprises a motor (204), a plurality of tape cartridges (240) each for housing one tape (280) of the plurality of tapes, and a transmission system comprising a first plurality of drive axles, a second plurality of drive axles with each axle of the second plurality of axles connected to two axles of the first plurality of axles, and one of the second plurality of axles operatively engaged to the motor, and each of the first plurality of axles supporting one of the plurality of tapes. 20
21. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein at least one said tape is a composite tape. 25
22. A deployable reflectarray antenna structure, as claimed in any one of the preceding claims, wherein at least one said tape is a bistable tape. 30

Patentansprüche

1. Einsetzbare Reflektarrayantennenstruktur (20), umfassend: 40
- ein erstes elektrisches Element (26) zur Verwendung in einer Reflektarrayantenne; ein zweites elektrisches Element (28) zur Verwendung in einer Reflektarrayantenne; und einen Einsatzmechanismus (30) zum Überführen des ersten elektrischen Elements und des zweiten elektrischen Elements von einem nicht eingesetzten Zustand, in dem das erste und zweite elektrische Element nicht relativ zueinander zur Verwendung in einem Reflektarray positioniert sind, hin zu einem eingesetzten Zustand, in dem das erste und zweite elektrische Element relativ zueinander zur Verwendung in einer Reflektarrayantenne positioniert sind; 50
- wobei der Einsatzmechanismus eine Vielzahl von Bändern (320, 322) zum Überführen des ersten und zweiten elektrischen Elements von

dem nicht eingesetzten Zustand hin zum eingesetzten Zustand beinhaltet; wobei jedes Band der Vielzahl von Bändern:

- sich von einem ersten Terminalende (286A) zu einem zweiten Terminalende (286B) erstreckt; wobei, in dem nicht eingesetzten Zustand, das erste Terminalende in einer ersten Entfernung von dem zweiten Terminalende angeordnet ist; wobei, in dem eingesetzten Zustand, das erste Terminalende in einer zweiten Entfernung von dem zweiten Terminalende angeordnet ist, die größer als die erste Entfernung ist, und ein wesentlicher Abschnitt des Bandes, das zwischen dem ersten und zweiten Terminalende angeordnet ist, im Wesentlichen linear ist; wobei jedes der Vielzahl von Bändern mit einem des ersten und zweiten elektrischen Elements an einer dem zweiten Terminalende benachbarten Position des Bandes in Eingriff steht; wobei der Einsatzmechanismus einen Dämpfer (204, 244) beinhaltet, der operativ mit der Vielzahl von Bändern, während der Überführung des ersten und zweiten elektrischen Elements von dem nicht eingesetzten Zustand hin zum eingesetzten Zustand, in Eingriff steht.

2. Einsetzbare Reflektarrayantennenstruktur nach Anspruch 1, wobei:

wenn sich das erste elektrische Element (26) in dem eingesetzten Zustand befindet, das erste elektrische Element Teil einer Reflektarrayantenne ist; und die zweiten Terminalenden von mindestens zwei Bändern (320) der Vielzahl von Bändern operativ mit dem ersten elektrischen Element verbunden sind.

3. Einsetzbare Reflektarrayantennenstruktur nach Anspruch 2, wobei:

die zweiten Terminalenden von mindestens drei Bändern (320) der Vielzahl von Bändern operativ mit dem ersten elektrischen Element verbunden sind; wenn jedes der mindestens drei Bänder der Vielzahl von Bändern sich in dem eingesetzten Bandzustand befindet, die mindestens drei Bänder der Vielzahl von Bändern eines definieren aus Folgendem: (a) einer ersten festen Form, wobei die ersten Terminalenden der mindestens drei Bänder eine erste ebene Basis der ersten

- festen Form definieren, wobei die zweiten Terminalenden der mindestens drei Bänder eine zweite ebene Basis der ersten festen Form definieren, und wobei der Abschnitt eines Bandes, das zwischen den ersten und zweiten Terminalenden jedes der mindestens drei Bänder angeordnet ist, eine Kante der ersten festen Form definiert und (b) einer im Wesentlichen flachen Form.
- 5
4. Einsetzbare Reflektarrayantennenstruktur nach Anspruch 3, wobei:
- 10 die erste feste Form ein Pyramidenstumpf ist, und die mindestens drei Bänder in dem eingesetzten Zustand nicht zueinander parallel sind.
- 15
5. Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei:
- 20 wenn das zweite elektrische Element (28) sich in dem eingesetzten Zustand befindet, das zweite elektrische Element Teil von einem ist aus (a) einem Subreflektor; und (b) einer Feedantenne (24)
- 25 die zweiten Terminalenden von mindestens zwei der Vielzahl von Bändern (322) operativ mit dem zweiten elektrischen Element verbunden sind.
- 30
6. Einsetzbare Reflektarrayantennenstruktur nach Anspruch 5, wobei:
- 35 die zweiten Terminalenden von mindestens drei Bändern (322) der Vielzahl von Bändern operativ mit dem zweiten elektrischen Element (28) verbunden sind;
- 40 wenn sich jedes der mindestens drei Bänder der Vielzahl von Bändern in dem eingesetzten Bandzustand befindet, die mindestens drei Bänder der Vielzahl von Bändern eine zweite feste Form definieren, wobei die zweiten Terminalenden der mindestens drei Bänder eine erste ebene Basis der zweiten festen Form definieren, wobei die ersten Terminalenden der mindestens drei Bänder eine zweite ebene Basis der zweiten festen Form definieren, und wobei der Abschnitt eines Bandes, das zwischen den ersten und zweiten Terminalenden jedes der mindestens drei Bänder angeordnet ist, eine Kante der zweiten festen Form definiert.
- 45
- 50
7. Einsetzbare Reflektarrayantennenstruktur nach Anspruch 6, wobei:
- 55 die zweite feste Form eines ist aus Folgendem: (a) einer Säule mit einem polygonalen Querschnitt, wobei die mindestens drei Bänder in dem eingesetzten Zustand im Wesentlichen parallel zueinander sind und (b) einem Pyramidenstumpf, wobei die mindestens drei Bänder in dem eingesetzten Zustand nicht parallel zueinander sind.
8. Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei:
- wenn das erste elektrische Element sich in dem eingesetzten Zustand befindet, das erste elektrische Element ein Reflektarray in einer Reflektarrayantenne ist;
- wenn das zweite elektrische Element sich in dem eingesetzten Zustand befindet, das zweite elektrische Element ein Subreflektor in einer Reflektarrayantenne ist; und
- das zweite Terminalende jedes der Vielzahl von Bändern operativ verbunden ist mit einem aus: (a) dem ersten elektrischen Element und (b) dem zweiten elektrischen Element.
9. Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei:
- die ersten Terminalenden der Vielzahl von Bändern im Wesentlichen fixiert sind;
- die zweiten Terminalenden von mindestens zwei der Bänder sich weiter voneinander weg bewegen bei dem Übergang der Vielzahl von Bändern von dem nicht eingesetzten Zustand in den eingesetzten Zustand.
10. Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei:
- der Einsatzmechanismus (30) mindestens ein Halteseil (324) beinhaltet, das sich zwischen den zweiten Terminalenden von zwei der Vielzahl von Bändern erstreckt.
11. Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei:
- die zweiten Terminalenden von drei Bändern der Vielzahl von Bändern operativ mit den ersten und zweiten elektrischen Elementen verbunden sind;
- zwei der drei Bänder der Vielzahl von Bändern operativ mit einem des ersten und zweiten elektrischen Elements verbunden sind;
- das andere der drei Bänder der Vielzahl von Bändern operativ mit dem anderen einen des ersten und zweiten elektrischen Elements verbunden ist;
- wenn die drei Bänder der Vielzahl von Bändern sich in dem eingesetzten Zustand befinden, die zweiten Enden der drei Bänder eine Basis einer

- tetraederartigen Struktur definieren und die ersten Enden der drei Bänder einen Apex der tetraederartigen Struktur definieren.
- 12.** Einsetzbare Reflektarrayantennenstruktur nach Anspruch 11, weiter umfassend:
- ein erstes Halteseil (324A), das sich zwischen dem ersten und zweiten der drei Bänder der Vielzahl von Bändern erstreckt;
- ein zweites Halteseil, das sich zwischen dem ersten und einem dritten der drei Bänder der Vielzahl von Bändern erstreckt.
- 13.** Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei:
- die ersten Terminalenden von vier Bändern der Vielzahl von Bändern operativ mit dem ersten und zweiten elektrischen Element verbunden sind;
- das erste Band (320A) und das zweite Band (320C) der vier Bänder der Vielzahl von Bändern operativ mit dem ersten elektrischen Element (26) verbunden sind und das dritte Band (322B) und das vierte Band (322C) der vier Bänder der Vielzahl von Bändern operativ mit dem zweiten elektrischen Element (28) verbunden sind;
- wenn die vier Bänder der Vielzahl von Bändern sich in dem eingesetzten Zustand befinden, die vier Bänder einen Abschnitt eines dachbalkengefügeähnlichen Dachstuhls definieren.
- 14.** Einsetzbare Reflektarrayantennenstruktur nach Anspruch 13, wobei:
- ein erstes Halteseil (324B) operativ mit den zweiten Terminalenden der ersten (320A) und dritten (322B) Bänder der vier Bänder der Vielzahl von Bändern in Eingriff steht; und
- ein zweites Halteseil (324E) operativ mit den zweiten Terminalenden des zweiten (320C) und vierten (322C) Bandes der vier Bänder der Vielzahl von Bändern in Eingriff steht.
- 15.** Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei:
- mindestens eines des ersten und zweiten elektrischen Elements flexibel ist, gefaltet in dem nicht eingesetzten Zustand und entfaltet in dem eingesetzten Zustand, relativ zu dem nicht eingesetzten Zustand.
- 16.** Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei:
- in dem eingesetzten Zustand das erste elektri-
- sche Element (26) eine Grenze aufweist, die im Wesentlichen eine Ebene definiert und einen Innenbereich, der von der Ebene beabstandet ist.
- 17.** Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei:
- in dem eingesetzten Zustand eine Untermenge der Vielzahl von Bändern zwischen dem ersten elektrischen Element und dem zweiten elektrischen Element angeordnet ist.
- 18.** Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, weiter umfassend:
- einen Behälter (22), der einen abgeschlossenen Raum zum Verstauen jedes des ersten elektrischen Elements (26), des zweiten elektrischen Elements (28), einer Feedantenne (24) und einer Vielzahl von Bändern in einem nicht eingesetzten Zustand definiert;
- wobei der Behälter ein geschlossenes Ende, ein öffnungsfähiges Ende und eine Seite aufweist, die sich zwischen dem geschlossenen Ende und dem öffnungsfähigen Ende erstreckt;
- wobei, wenn die Vielzahl von Bändern, das erste elektrische Element und das zweite elektrische Element in dem Behälter verstaут sind, die Vielzahl von Bändern zwischen dem ersten elektrischen Element und dem zweiten elektrischen Element angeordnet ist.
- 19.** Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei das erste elektrische Element flexibel ist, und wenn das erste elektrische Element sich in dem nicht eingesetzten Zustand befindet, das erste elektrische Element in einem "Blatt-in"-Muster gefaltet ist, das mindestens drei "Blätter" aufweist.
- 20.** Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei:
- der Einsatzmechanismus (30) einen Motor (204), eine Vielzahl von Bänderhülsen (240), jede zum Beherbergen von einem Band (280) der Vielzahl von Bändern, und ein Übertragungssystem umfasst, das eine erste Vielzahl von Antriebsachsen, eine zweite Vielzahl von Antriebsachsen umfasst, wobei jede Achse der zweiten Vielzahl von Achsen mit zwei Achsen der ersten Vielzahl von Achsen verbunden ist, und wobei eine der zweiten Vielzahl von Achsen operativ mit dem Motor in Eingriff steht, und wobei jede der ersten Vielzahl von Achsen eines aus der Vielzahl der Bänder stützt.

21. Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei mindestens ein Band ein Kompositband ist.
22. Einsetzbare Reflektarrayantennenstruktur nach einem der vorstehenden Ansprüche, wobei mindestens ein Band ein bistabiles Band ist.

Revendications

1. Structure déployable d'antenne à réseau réfléchissant (20), comprenant :

un premier élément électrique (26) pour l'utilisation dans une antenne à réseau réfléchissant ; un second élément électrique (28) pour l'utilisation dans une antenne à réseau réfléchissant ; et un mécanisme de déploiement (30) pour la transition du premier élément électrique et du second élément électrique à partir d'un état non déployé dans lequel les premier et second éléments électriques ne sont pas positionnés l'un par rapport à l'autre pour l'utilisation dans un réseau réfléchissant, vers un état déployé, dans lequel les premier et second éléments électriques sont positionnés l'un par rapport à l'autre pour l'utilisation dans une antenne à réseau réfléchissant ; dans laquelle le mécanisme de déploiement inclut une pluralité de rubans (320, 322) pour la transition des premier et second éléments électriques à partir de l'état non déployé vers l'état déployé ; dans laquelle chaque ruban parmi la pluralité de rubans :

s'étend d'une première extrémité terminale (286A) à une seconde extrémité terminale (286B) ;

dans laquelle, dans l'état non déployé, la première extrémité terminale est située à une première distance de la seconde extrémité terminale ;

dans laquelle, dans l'état déployé, la première extrémité terminale est située à une seconde distance de la seconde extrémité terminale qui est supérieure à la première distance et une portion importante du ruban située entre les première et seconde extrémités terminales est sensiblement linéaire ; dans laquelle chacun parmi la pluralité de rubans entre en prise avec l'un parmi les premier et second éléments électriques à un emplacement adjacent à la seconde extrémité terminale du ruban ;

dans laquelle le mécanisme de déploiement inclut un amortisseur (204, 244) qui entre

fonctionnellement en prise avec la pluralité de rubans durant la transition des premier et second éléments électriques à partir de l'état non déployé vers l'état déployé.

2. Structure déployable d'antenne à réseau réfléchissant, selon la revendication 1, dans laquelle :

lorsque le premier élément électrique (26) est dans l'état déployé, le premier élément électrique fait partie d'une antenne à réseau réfléchissant ; et les secondes extrémités terminales d'au moins deux rubans (320) parmi la pluralité de rubans sont fonctionnellement raccordées au premier élément électrique.

3. Structure déployable d'antenne à réseau réfléchissant, selon la revendication 2, dans laquelle :

les secondes extrémités terminales d'au moins trois rubans (320) parmi la pluralité de rubans sont fonctionnellement raccordées au premier élément électrique ;

lorsque chacun des au moins trois rubans parmi la pluralité de rubans est dans l'état de ruban déployé, les au moins trois rubans parmi la pluralité de rubans définissent l'une parmi : (a) une première forme solide avec les premières extrémités terminales des au moins trois rubans définissant une première base plane de la première forme solide, avec les secondes extrémités terminales des au moins trois rubans définissant une seconde base plane de la première forme solide, et avec la portion d'un ruban située entre les première et seconde extrémités terminales de chacun des au moins trois rubans définissant un bord de la première forme solide et (b) une forme sensiblement plate.

4. Structure déployable d'antenne à réseau réfléchissant, selon la revendication 3, dans laquelle :

la première forme solide est un tronc d'une pyramide, et les au moins trois rubans dans l'état déployé ne sont pas parallèles les uns aux autres.

5. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle :

lorsque le second élément électrique (28) est dans l'état déployé, le second élément électrique est une partie de l'un parmi : (a) un sous-réflécteur ; et (b) une antenne d'alimentation (24)

les secondes extrémités terminales d'au moins

- deux parmi la pluralité de rubans (322) sont fonctionnellement raccordées au second élément électrique.
6. Structure déployable d'antenne à réseau réfléchissant, selon la revendication 5, dans laquelle :
- les secondes extrémités terminales d'au moins trois rubans (322) parmi la pluralité de rubans sont fonctionnellement raccordées au second élément électrique (28) ;
lorsque chacun des au moins trois rubans parmi la pluralité de rubans est dans l'état de ruban déployé, les au moins trois rubans parmi la pluralité de rubans définissent une seconde forme solide avec les secondes extrémités terminales des au moins trois rubans définissant une première base planaire de la seconde forme solide, avec les premières extrémités terminales des au moins trois rubans définissant une seconde base planaire de la seconde forme solide, et avec la portion d'un ruban située entre les première et seconde extrémités terminales de chacun des au moins trois rubans définissant un bord de la seconde forme solide.
7. Structure déployable d'antenne à réseau réfléchissant, selon la revendication 6, dans laquelle :
- la seconde forme solide est l'un parmi : (a) une colonne avec une section transversale polygonale, les au moins trois rubans dans l'état déployé étant sensiblement parallèles les uns aux autres et (b) un tronc d'une pyramide, les au moins trois rubans dans l'état déployé n'étant pas parallèles les uns aux autres.
8. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle :
- lorsque le premier élément électrique est dans l'état déployé, le premier élément électrique est un réseau réfléchissant dans une antenne à réseau réfléchissant ;
lorsque le second élément électrique est dans l'état déployé, le second élément électrique est un sous-réfecteur dans une antenne à réseau réfléchissant ; et
la seconde extrémité terminale de chacun parmi la pluralité de rubans est fonctionnellement raccordée à l'un parmi : (a) le premier élément électrique et (b) le second élément électrique.
9. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle :
- les premières extrémités terminales de la pluralité de rubans sont sensiblement fixes ;
les secondes extrémités terminales d'au moins deux des rubans se déplacent plus loin l'une de l'autre dans la transition de la pluralité de rubans de l'état non déployé à l'état déployé.
10. Structure déployable d'antenne à réseau réfléchissant selon l'une quelconque des revendications précédentes, dans laquelle :
- le mécanisme de déploiement (30) inclut au moins un cordon (324) s'étendant entre les secondes extrémités terminales de deux parmi la pluralité de rubans.
11. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle :
- les secondes extrémités terminales de trois rubans parmi la pluralité de rubans sont fonctionnellement raccordées aux premier et second éléments électriques ;
deux des trois rubans parmi la pluralité de rubans sont fonctionnellement raccordés à l'un parmi les premier et second éléments électriques ;
l'autre des trois rubans parmi la pluralité de rubans est fonctionnellement raccordé à l'autre des premier et second éléments électriques ;
lorsque les trois rubans parmi la pluralité de rubans sont dans l'état déployé, les secondes extrémités des trois rubans définissent une base d'une structure en forme de tétraèdre et les premières extrémités des trois rubans définissent un sommet de la structure en forme de tétraèdre.
12. Structure déployable d'antenne à réseau réfléchissant, selon la revendication 11, comprenant en outre :
- un premier cordon (324A) s'étendant entre les premier et deuxième des trois rubans parmi la pluralité de rubans ;
un second cordon s'étendant entre le premier et un troisième des trois rubans parmi la pluralité de rubans.
13. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle :
- les premières extrémités terminales de quatre rubans parmi la pluralité de rubans sont fonctionnellement raccordées aux premier et second éléments électriques ;
le premier ruban (320A) et le deuxième ruban

- (320C) des quatre rubans parmi la pluralité de rubans sont fonctionnellement raccordés au premier élément électrique (26) et le troisième ruban (322B) et le quatrième ruban (322C) des quatre rubans parmi la pluralité de rubans sont fonctionnellement raccordés au second élément électrique (28) ;
 lorsque les quatre rubans parmi la pluralité de rubans sont dans l'état déployé, les quatre rubans définissent une portion d'une ferme à deux poinçons.
14. Structure déployable d'antenne à réseau réfléchissant, selon la revendication 13, dans laquelle :
- un premier cordon (324B) entre fonctionnellement en prise avec les secondes extrémités terminales des premier (320A) et troisième (322B) rubans des quatre rubans parmi la pluralité de rubans ; et
 un second cordon (324E) entre fonctionnellement en prise avec les secondes extrémités terminales des second (320C) et quatrième (322C) rubans des quatre rubans parmi la pluralité de rubans.
15. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle :
- au moins l'un parmi les premier et second éléments électriques est flexible, plié dans l'état non déployé, et déplié dans l'état déployé par rapport à l'état non déployé.
16. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle :
- dans l'état déployé, le premier élément électrique (26) présente une bordure qui définit sensiblement un plan et une section intérieure qui est espacée du plan.
17. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle :
- dans l'état déployé, un sous-ensemble parmi la pluralité de rubans est situé entre le premier élément électrique et le second élément électrique.
18. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, comprenant en outre :
- un bidon (22) qui définit un espace renfermé pour stocker chacun parmi le premier élément électrique (26), le second élément électrique (28), une antenne d'alimentation (24) et une pluralité de rubans dans un état non déployé ; dans laquelle le bidon possède une extrémité fermée, une extrémité ouvrable, et un côté qui s'étend entre l'extrémité fermée et l'extrémité ouvrable ; dans laquelle, lorsque la pluralité de rubans, le premier élément électrique, et le second élément électrique sont stockés dans le bidon, la pluralité de rubans est située entre le premier élément électrique et le second élément électrique.
19. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle le premier élément électrique est flexible, et lorsque le premier élément électrique est dans l'état non déployé, le premier élément électrique est plié en un motif « feuilles vers l'intérieur » qui possède au moins trois « feuilles ».
20. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle :
- le mécanisme de déploiement (30) comprend un moteur (204), une pluralité de cartouches à ruban (240) chacune pour loger un ruban (280) parmi la pluralité de rubans, et un système de transmission comprenant une première pluralité d'axes d'entraînement, une seconde pluralité d'axes d'entraînement avec chaque axe parmi la seconde pluralité d'axes raccordé à deux axes parmi la première pluralité d'axes, et l'un parmi la seconde pluralité d'axes fonctionnellement en prise avec le moteur, et chacun parmi la première pluralité d'axes supportant l'un parmi la pluralité de rubans.
21. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle au moins un dit ruban est un ruban composite.
22. Structure déployable d'antenne à réseau réfléchissant, selon l'une quelconque des revendications précédentes, dans laquelle au moins un dit ruban est un ruban bistable.

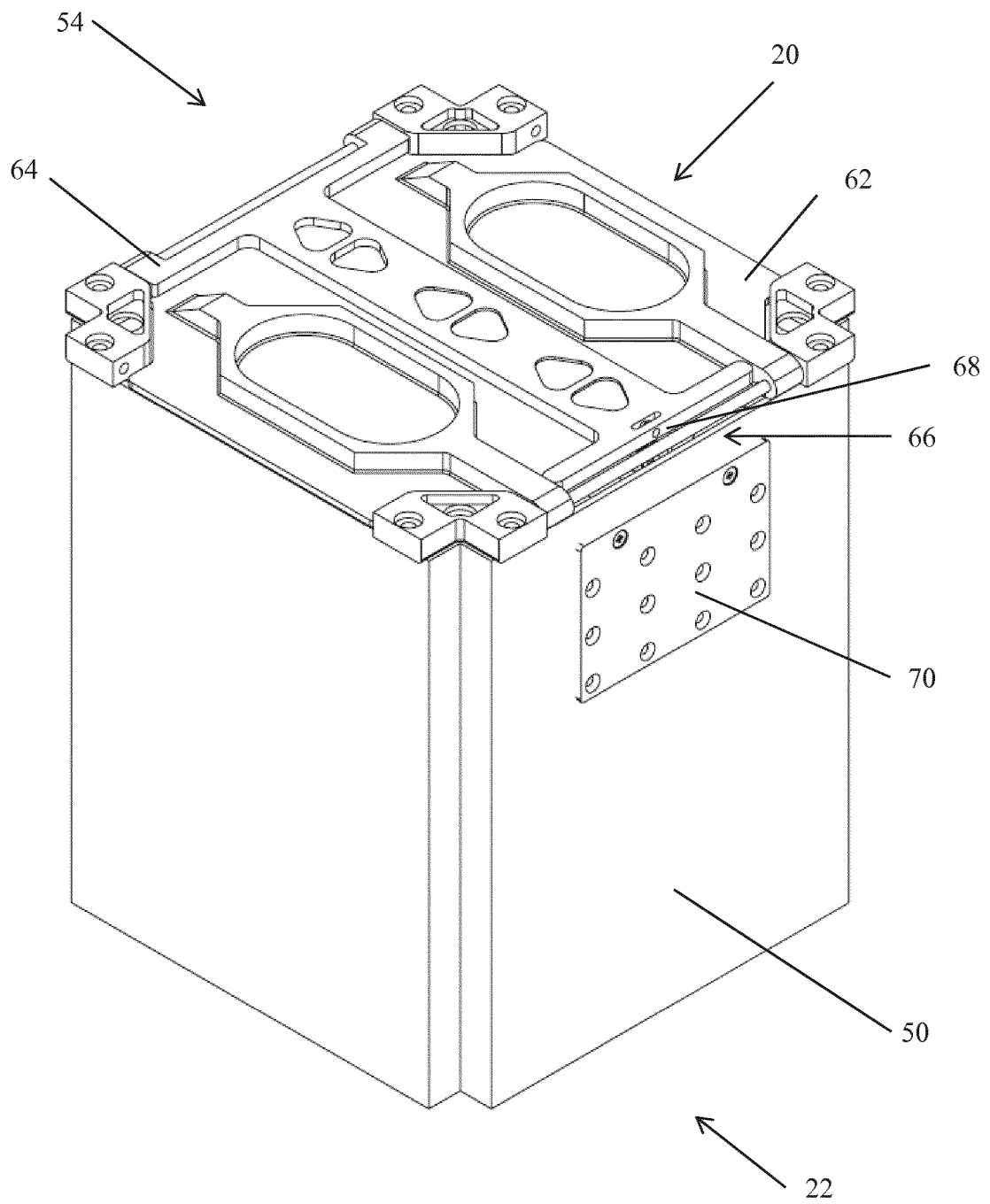
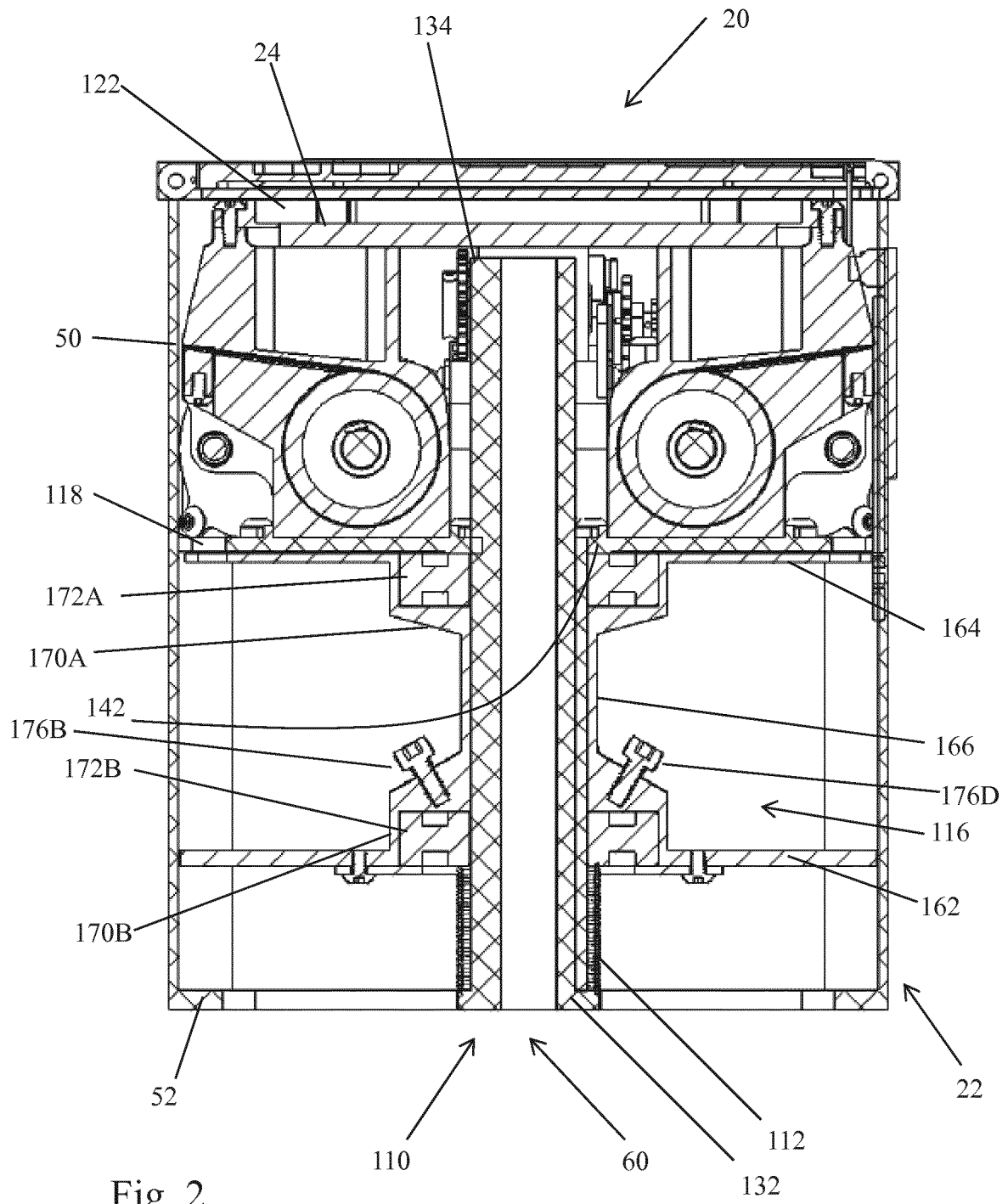


Fig. 1



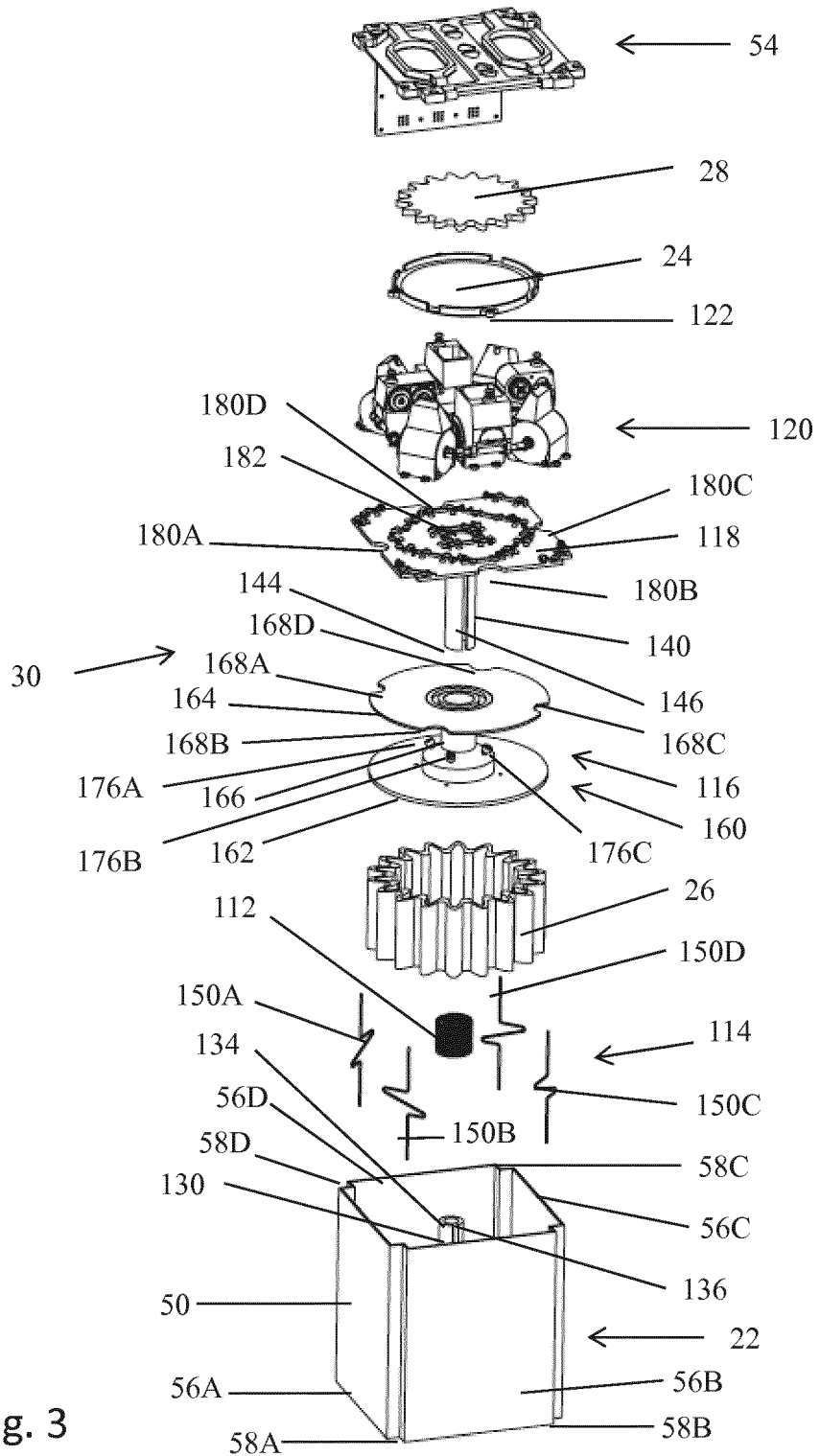


Fig. 3

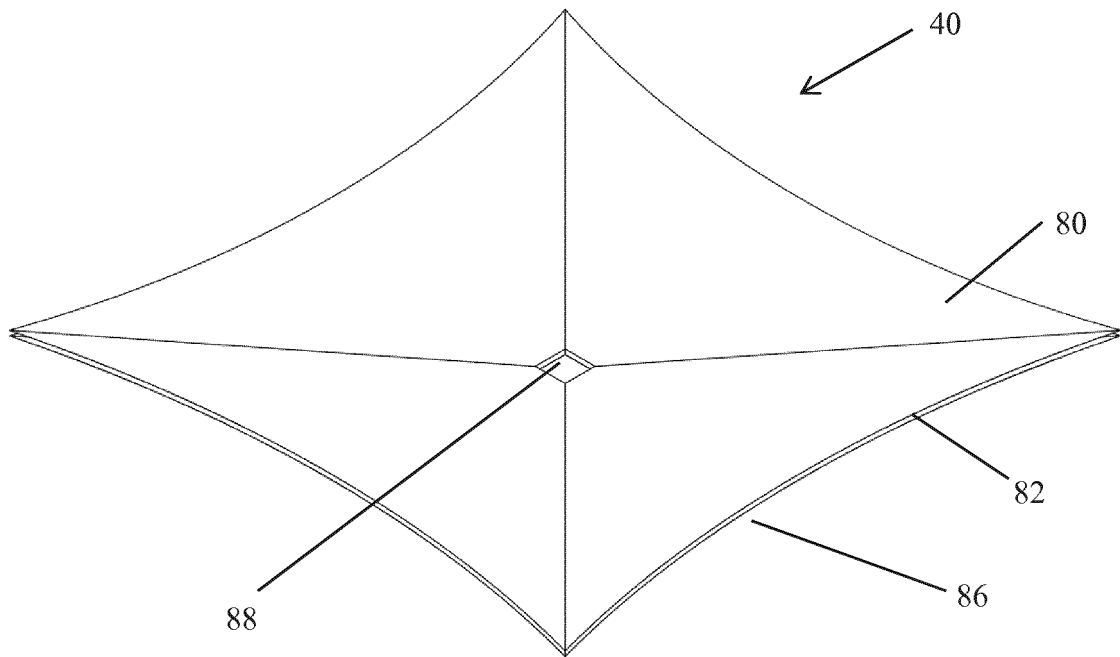


Fig. 4A

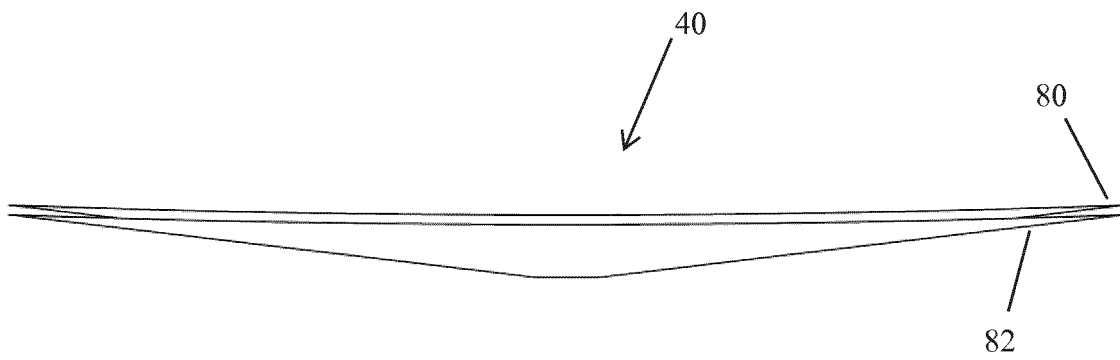


Fig. 4B

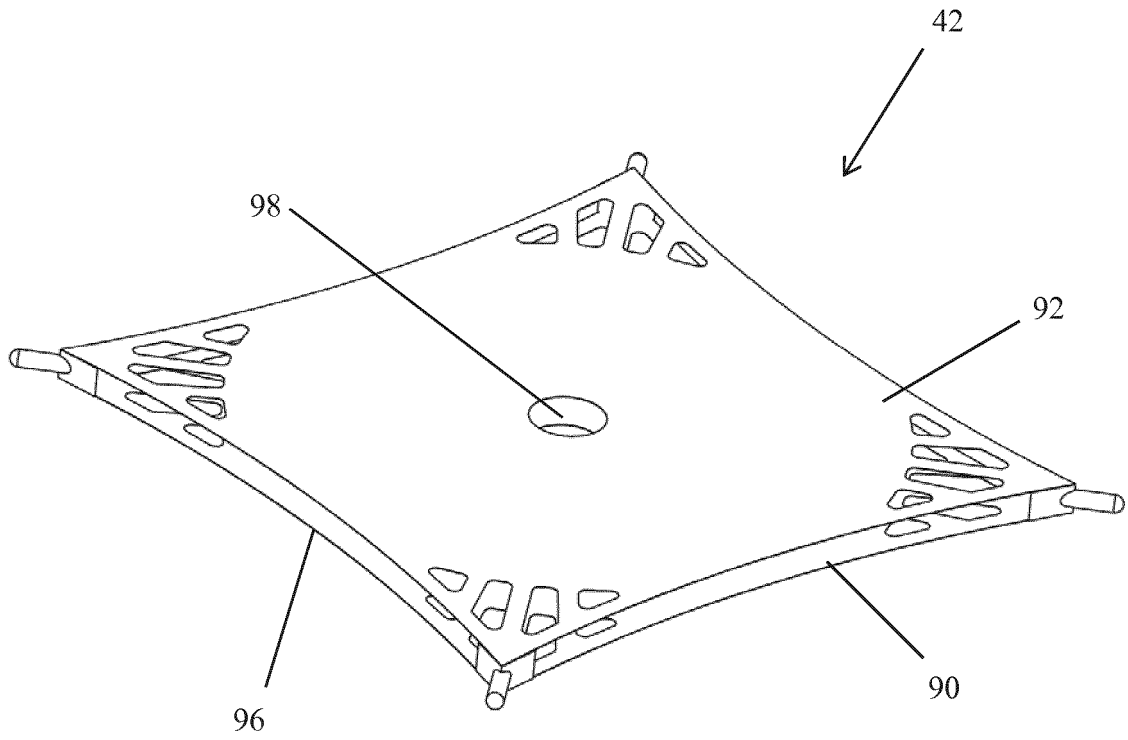


Fig. 5

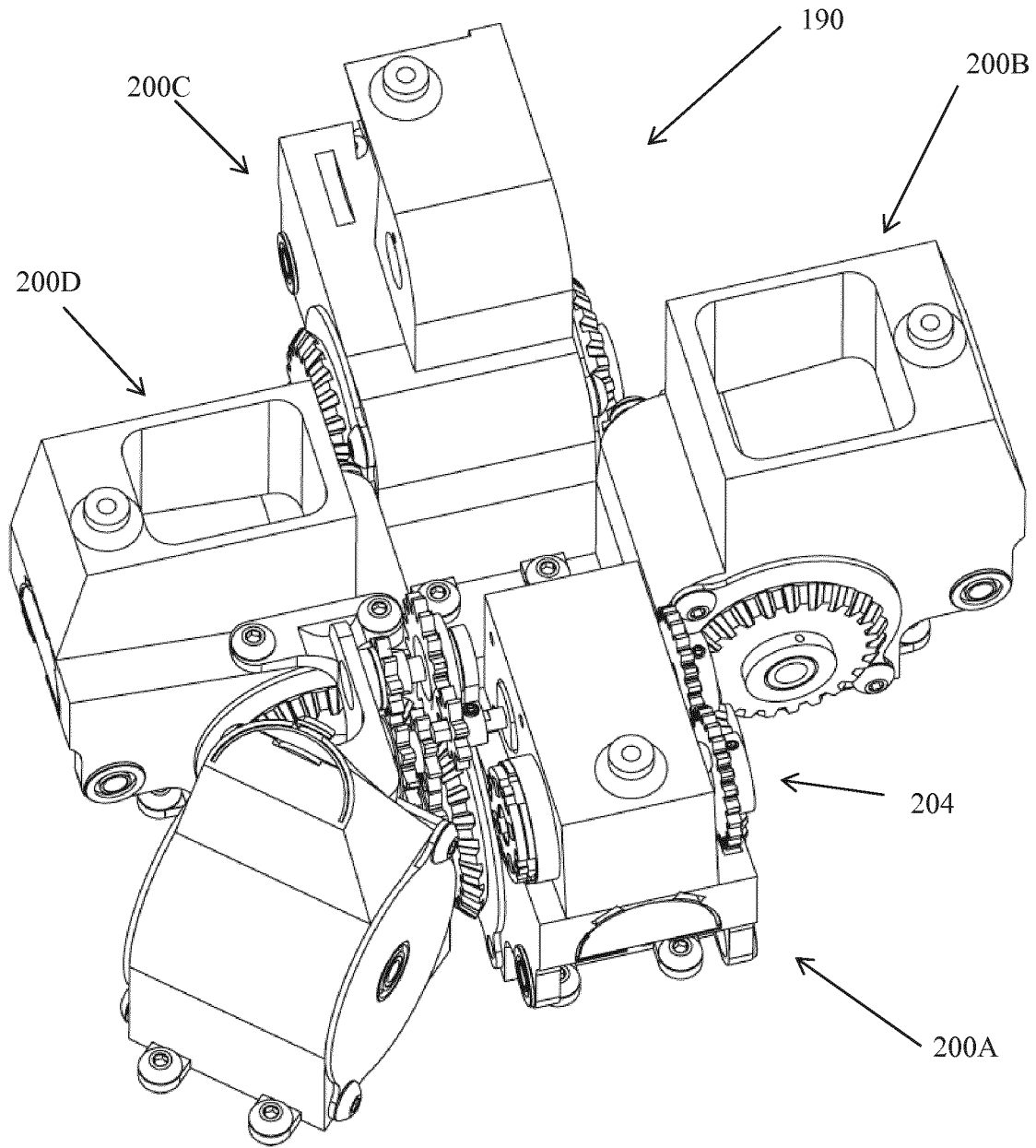


Fig. 6

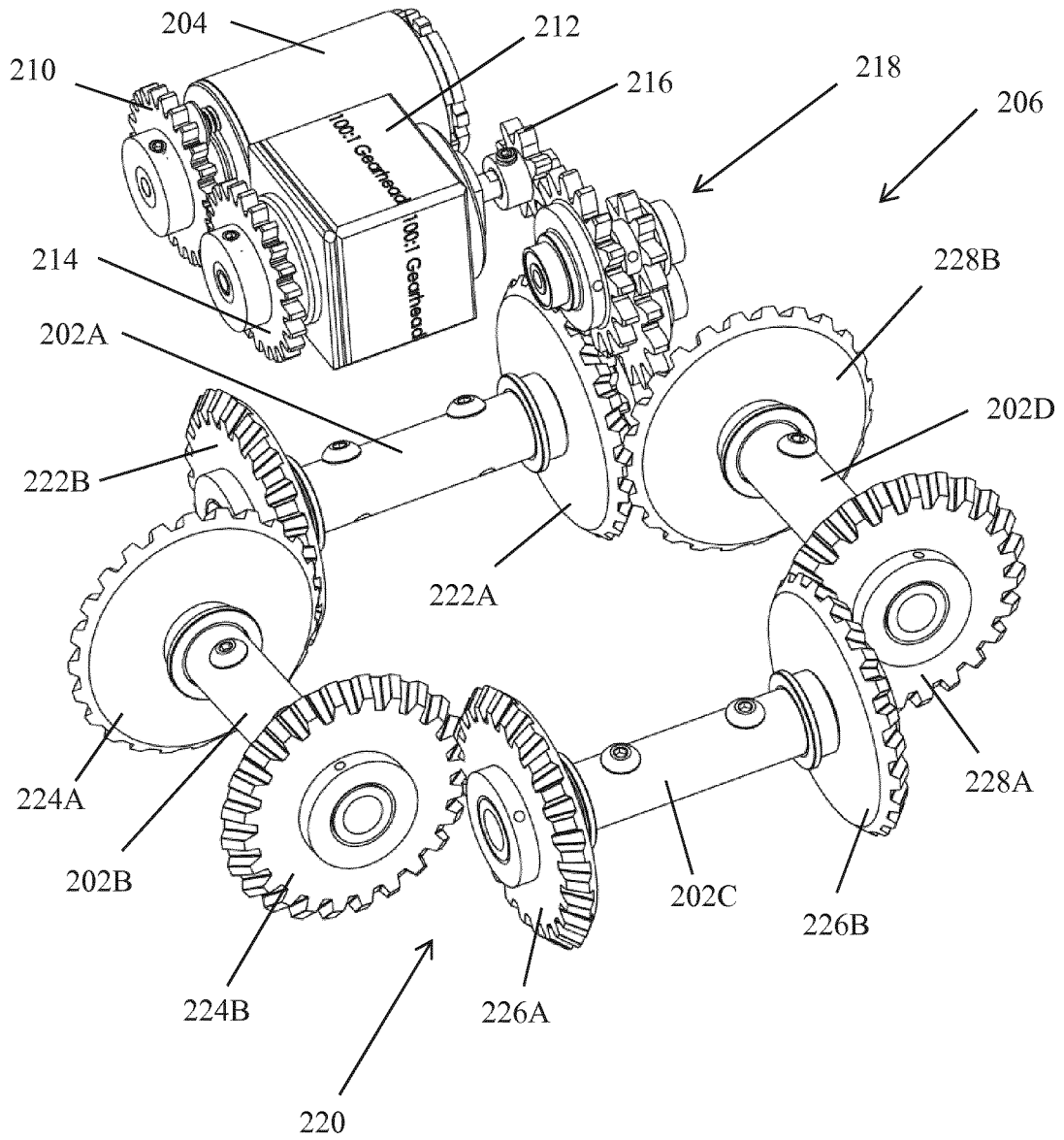


Fig. 7

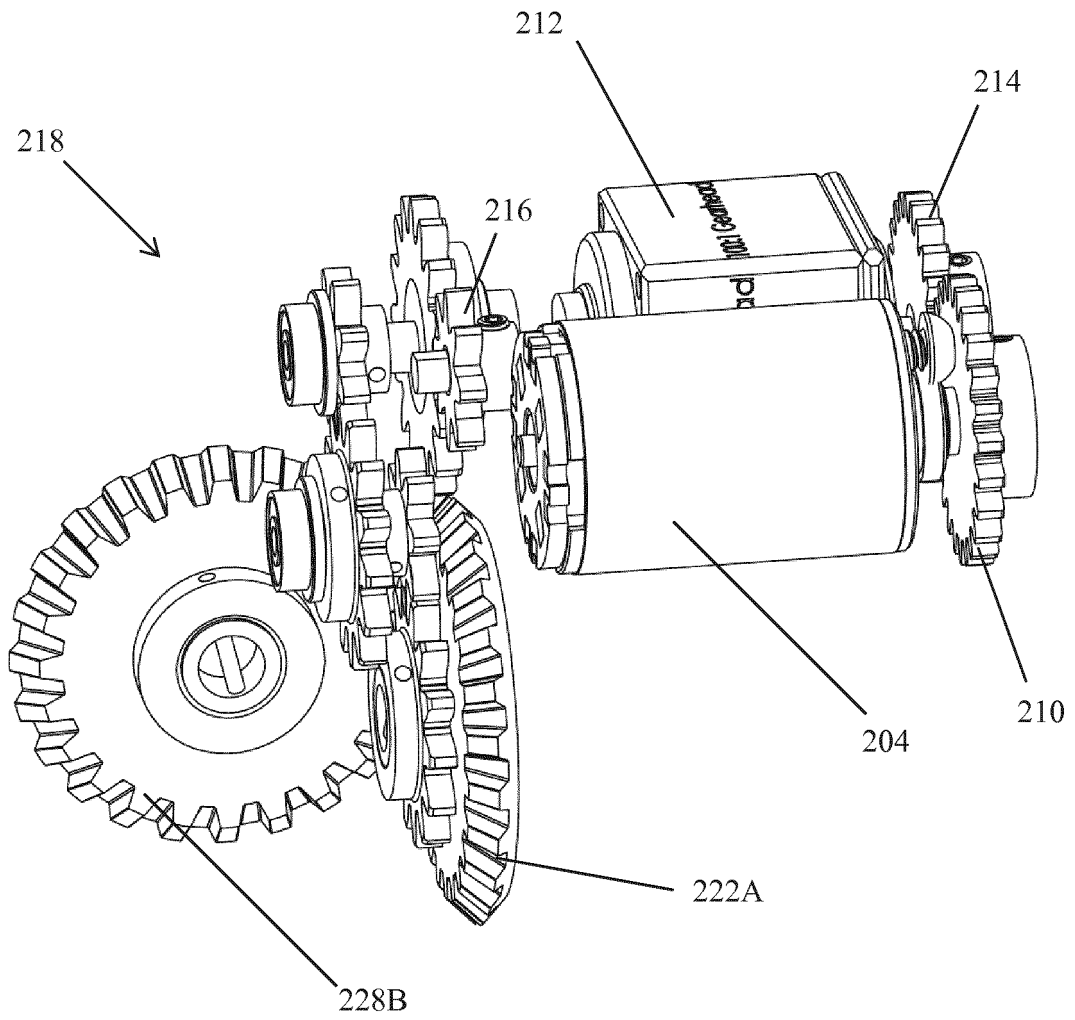


Fig. 8

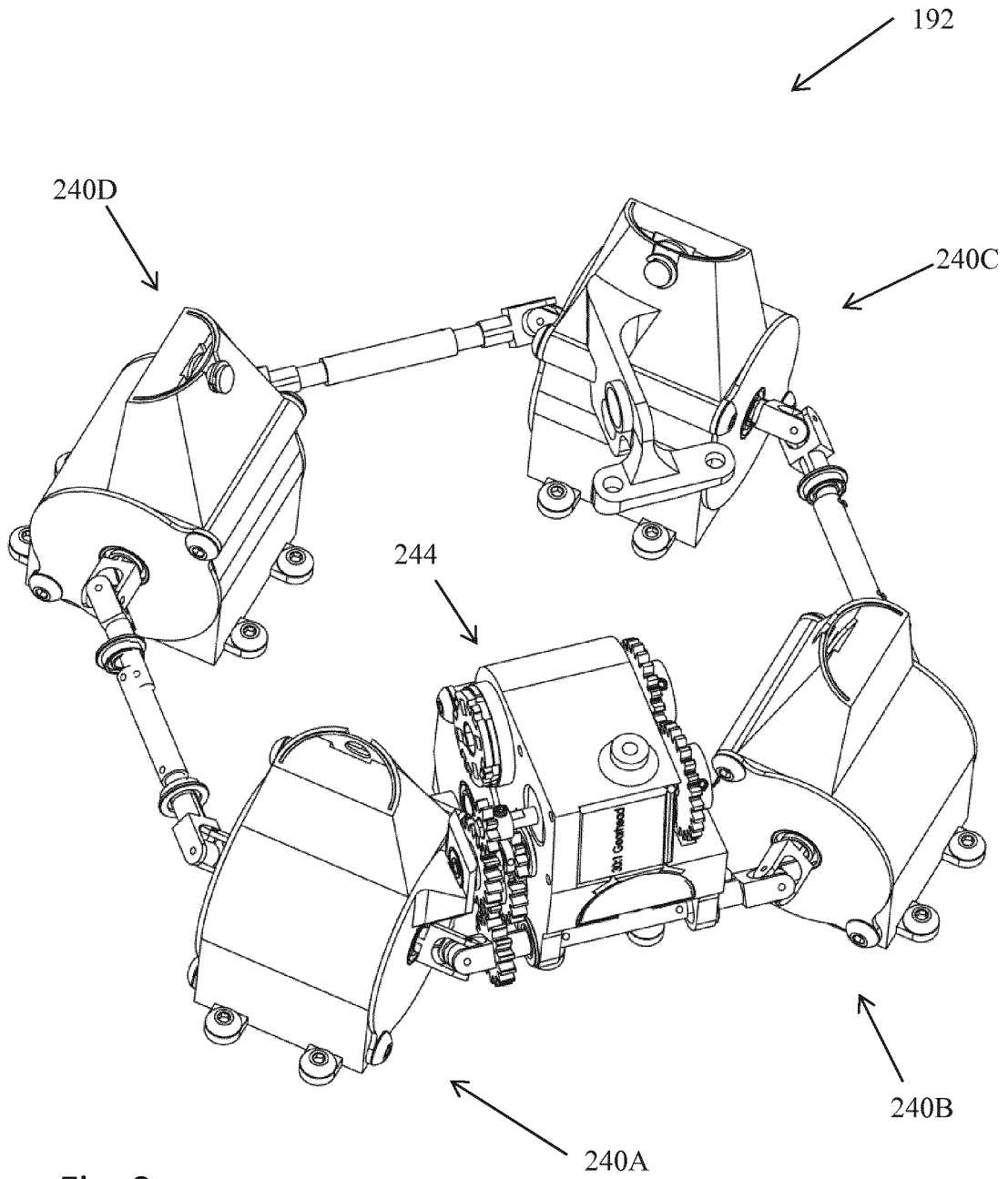


Fig. 9

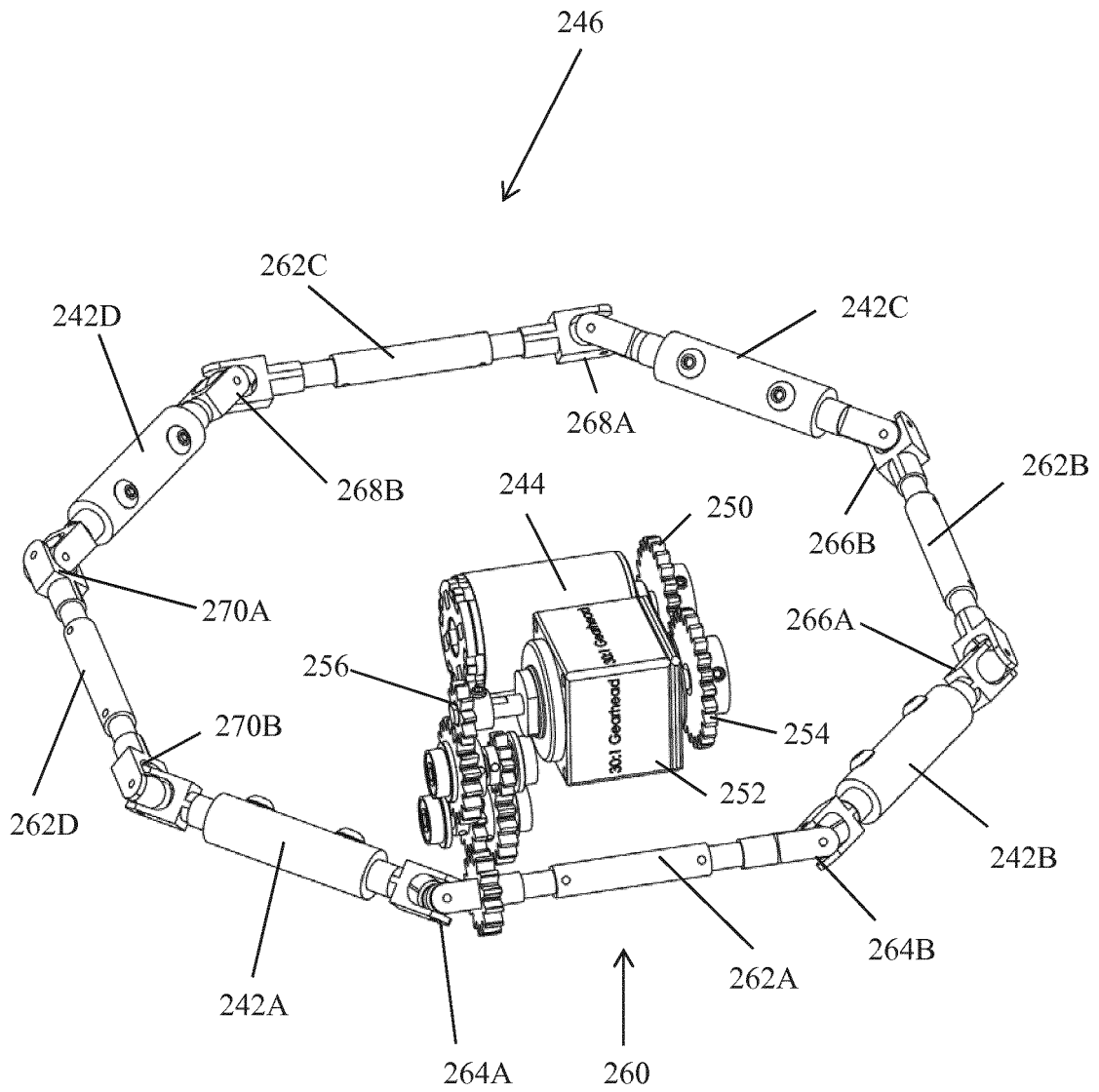


Fig. 10

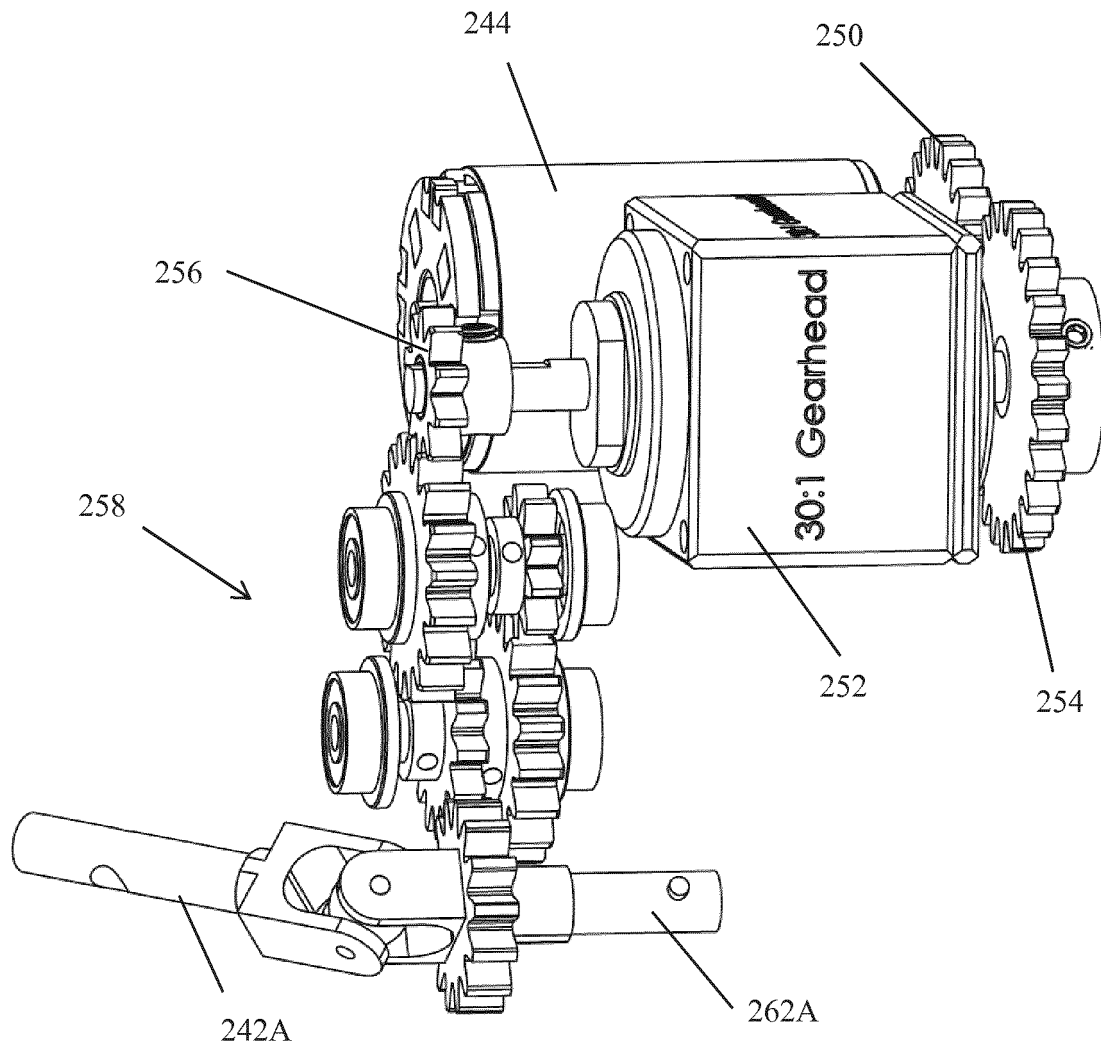


Fig. 11

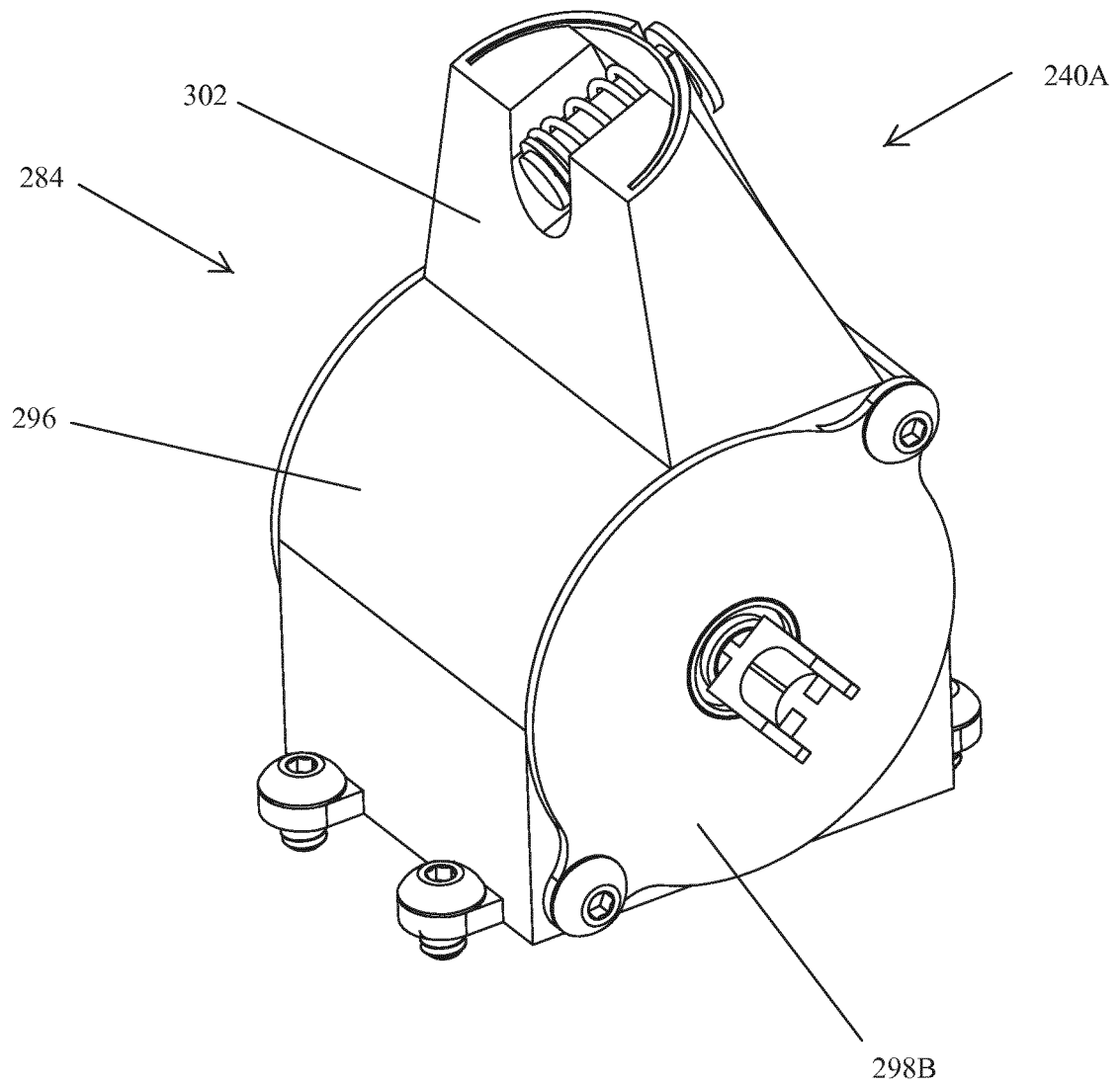


Fig. 12

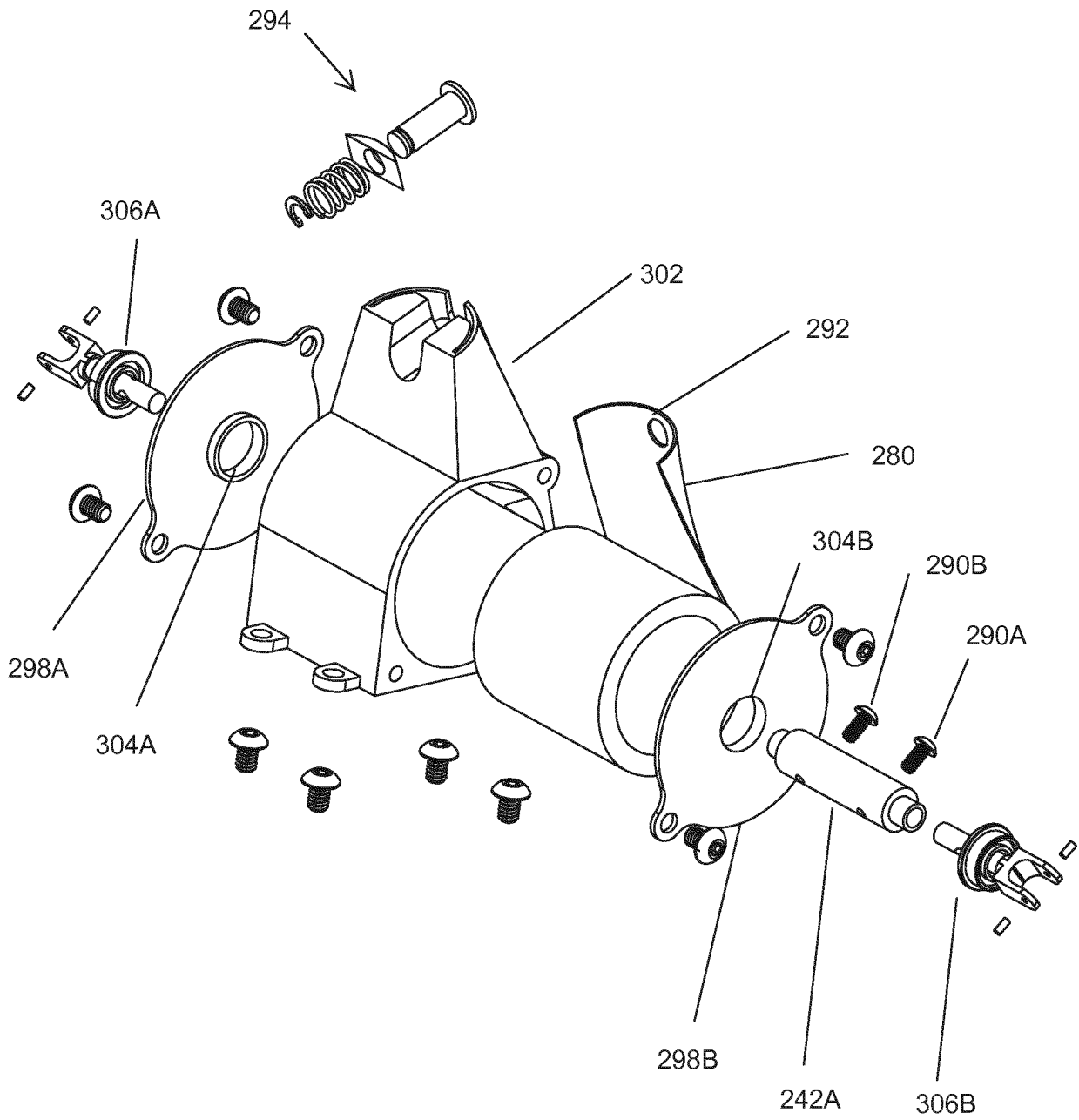


Fig. 13

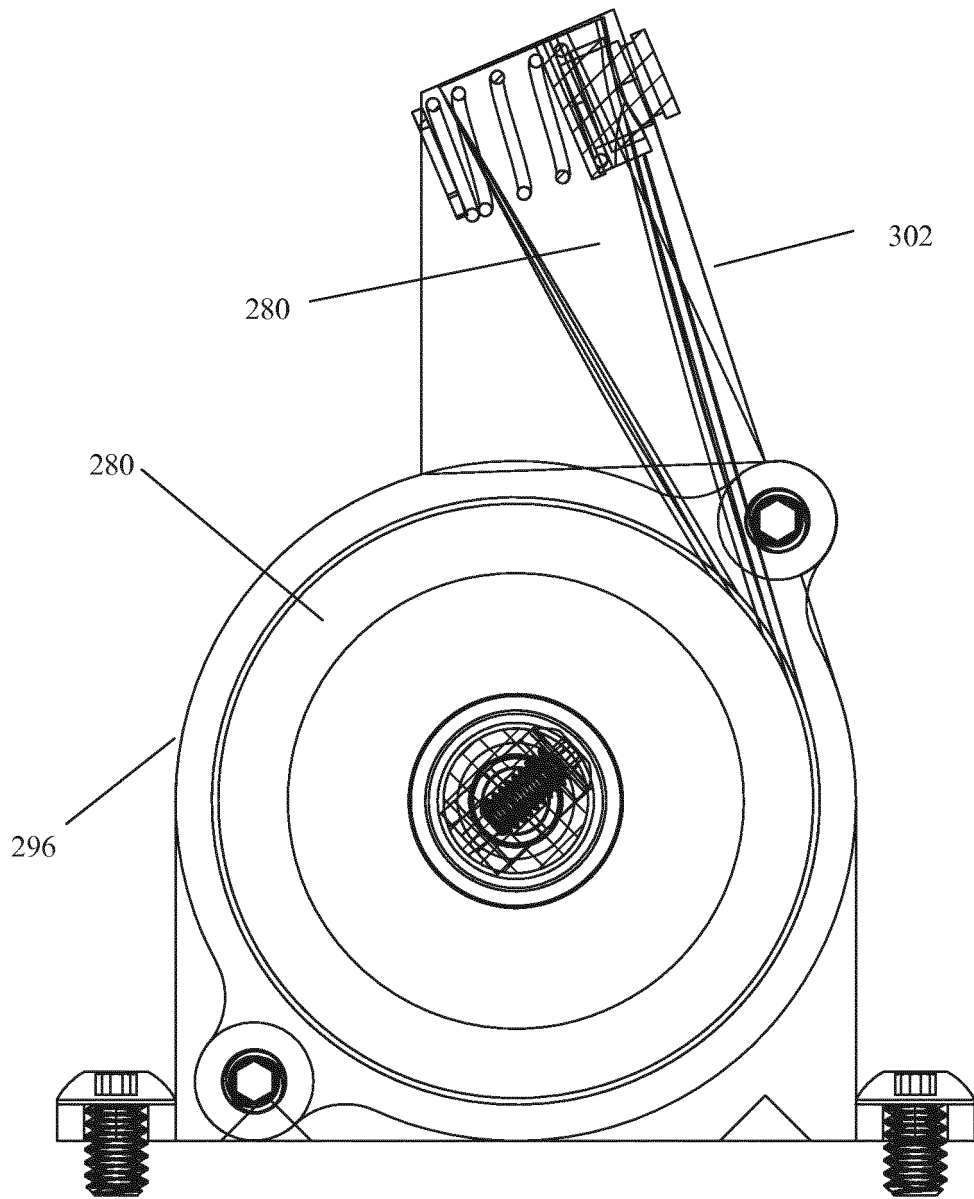


Fig. 14

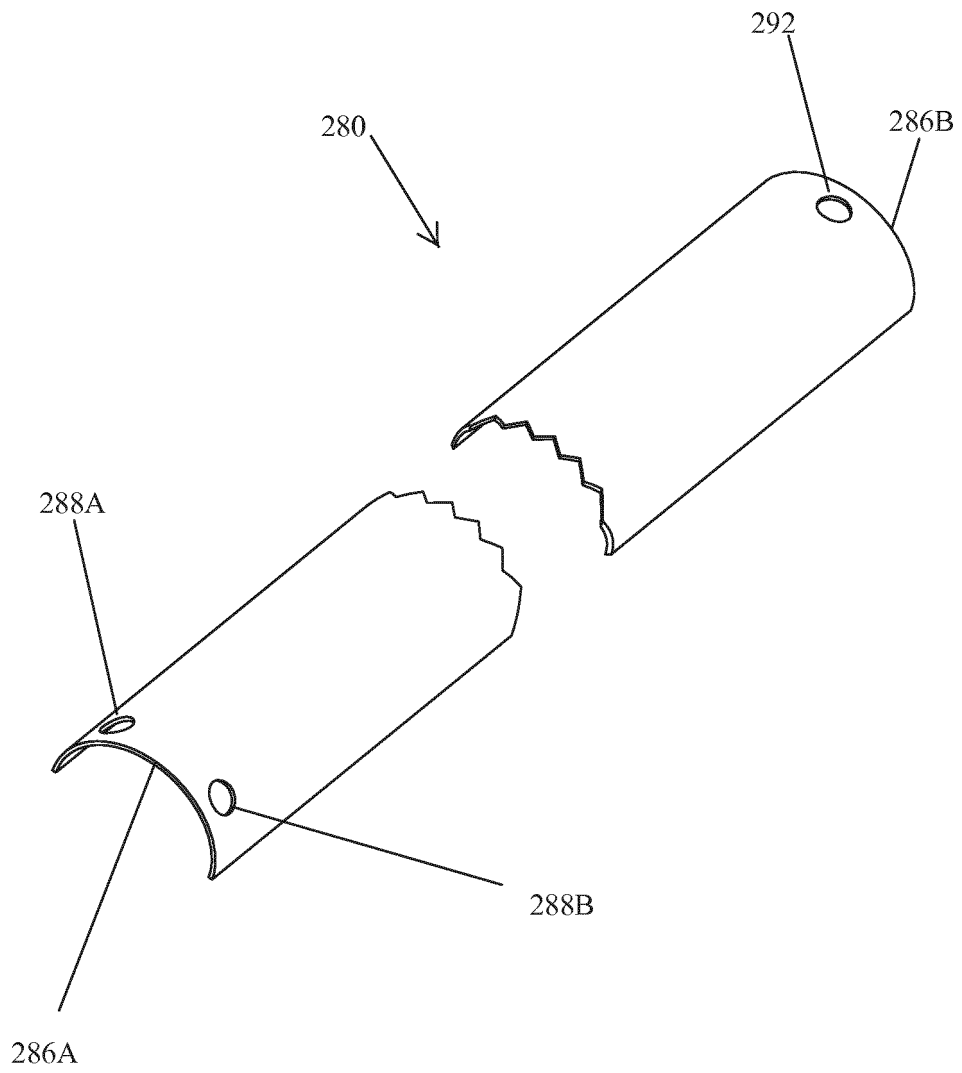


Fig. 15

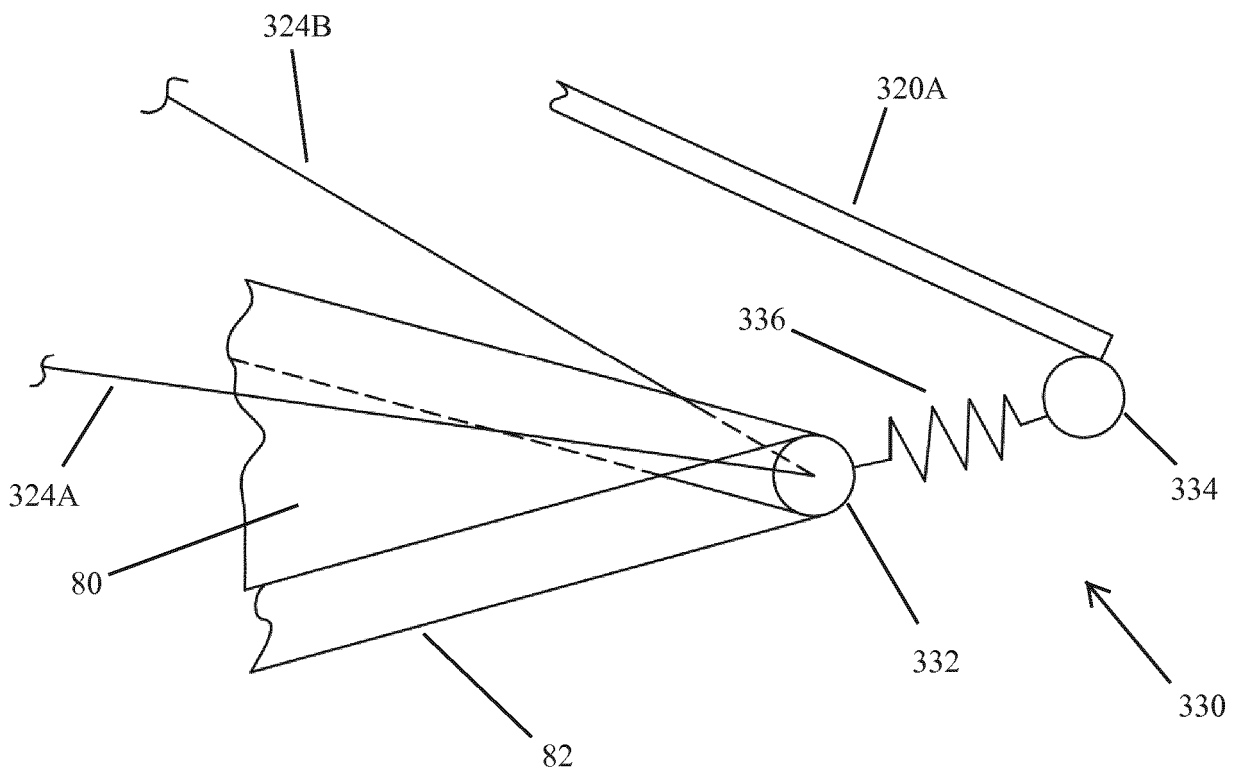


Fig. 16

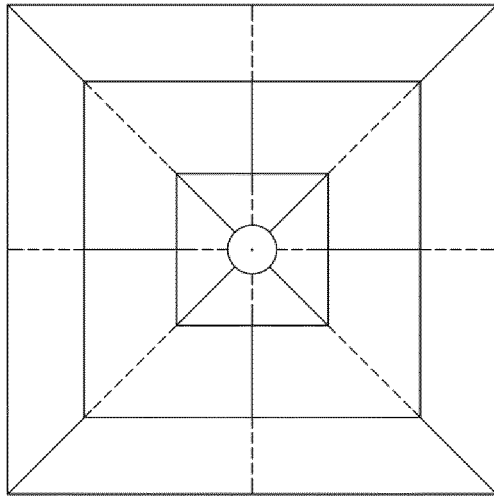


Fig. 17A

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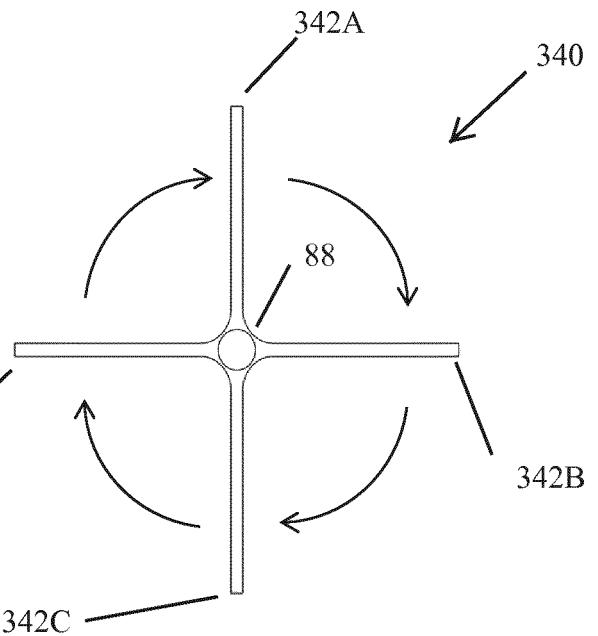


Fig. 17B

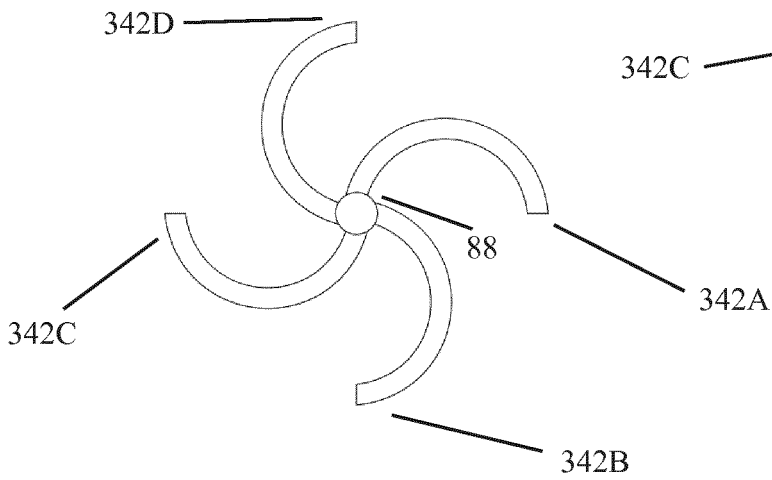
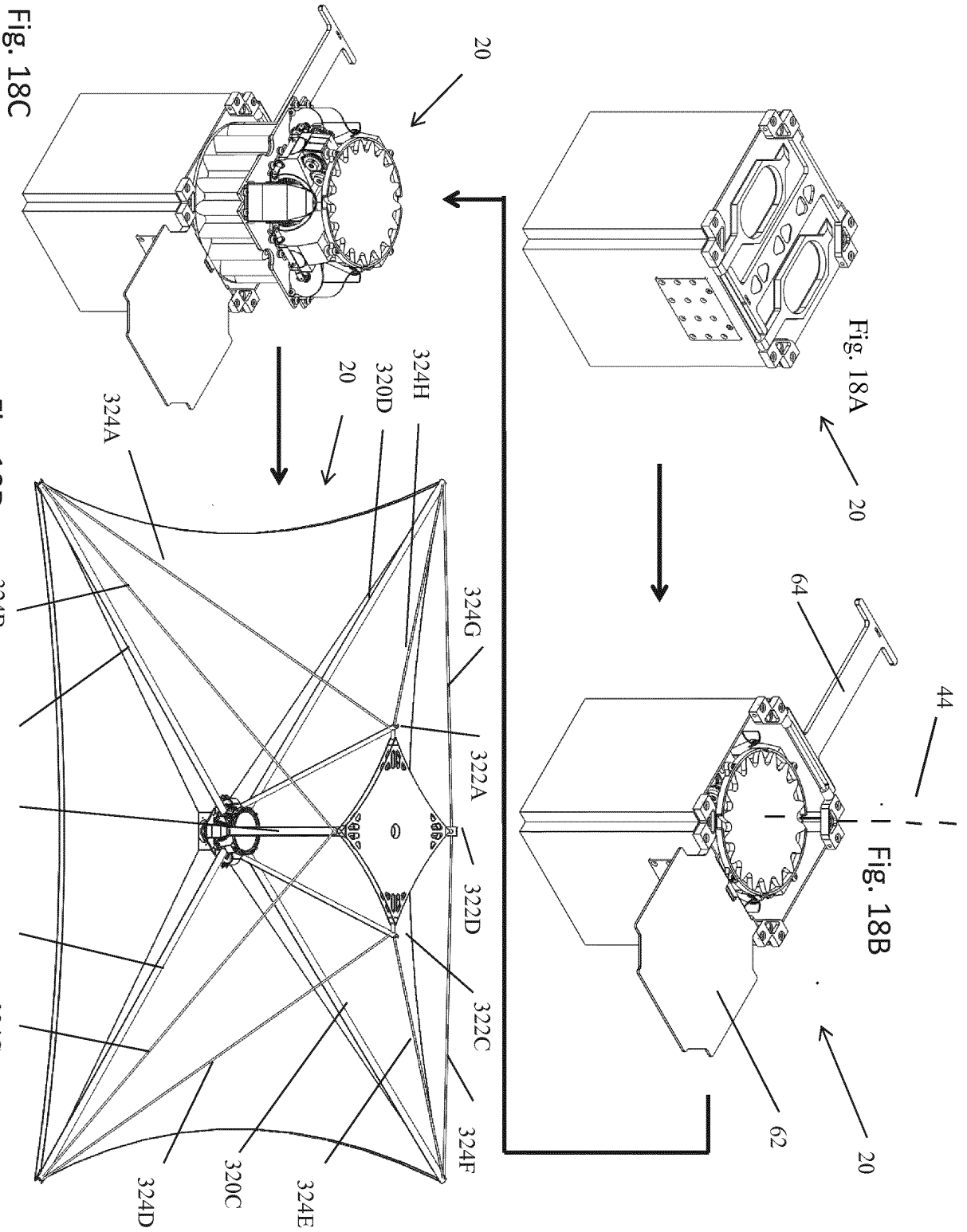


Fig. 17C



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