

**March 26, 1968**

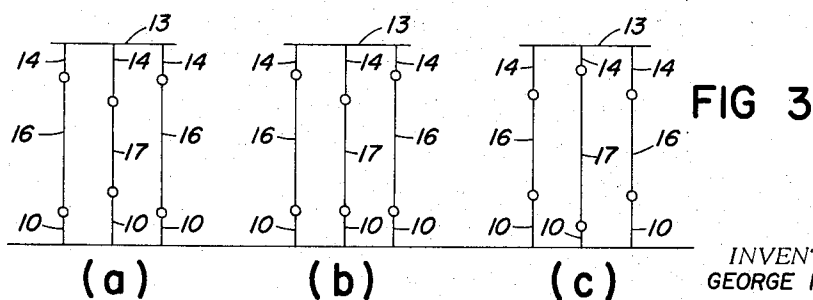
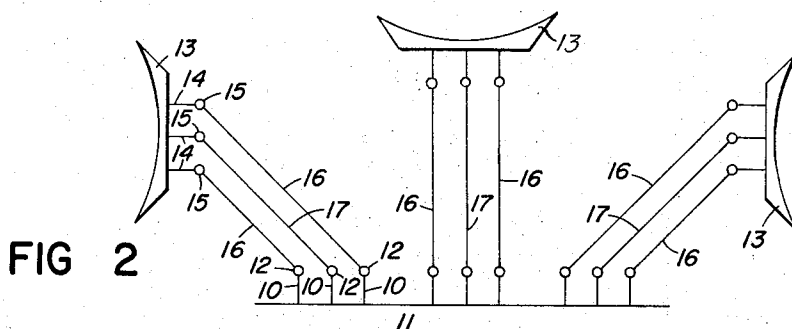
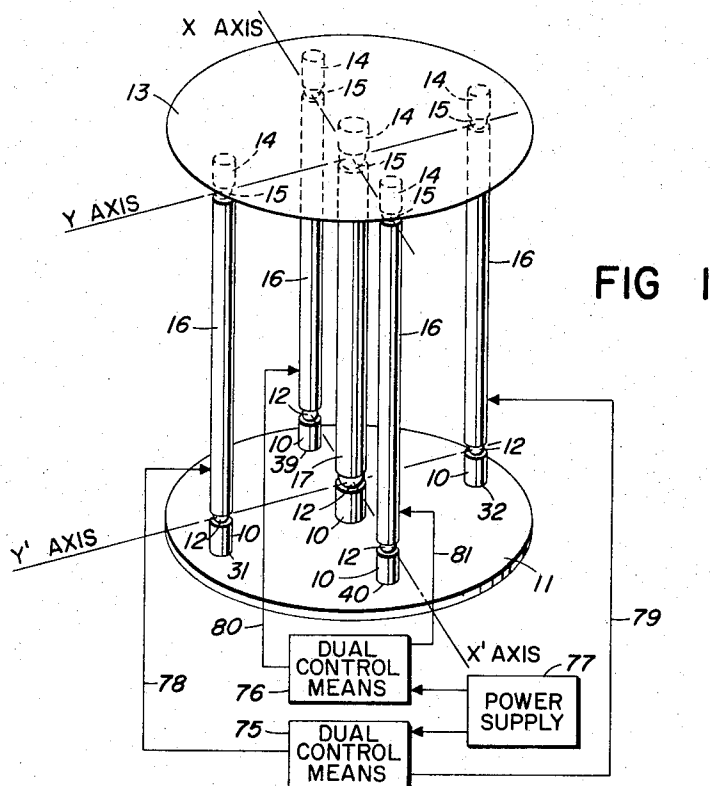
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**3,374,977**

ANTENNA POSITIONER

Filed June 9, 1966

5 Sheets-Sheet 1



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FIG 4

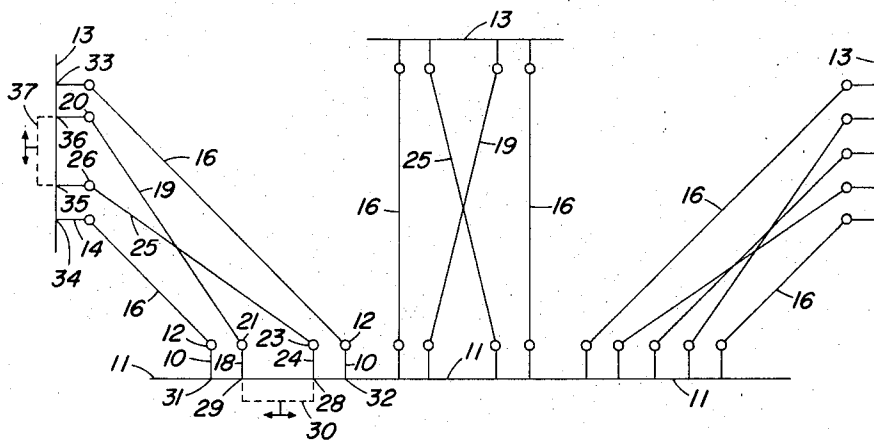
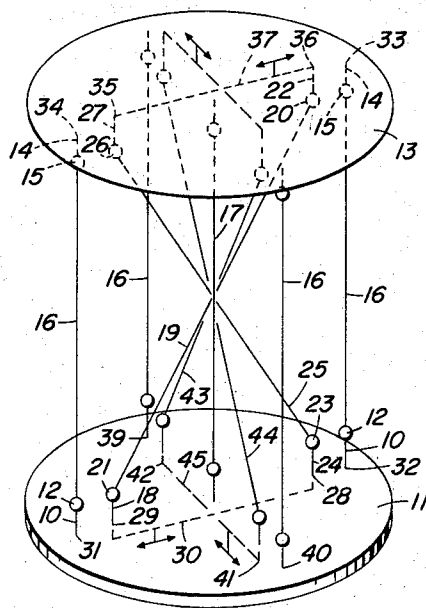


FIG 5

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## ANTENNA POSITIONER

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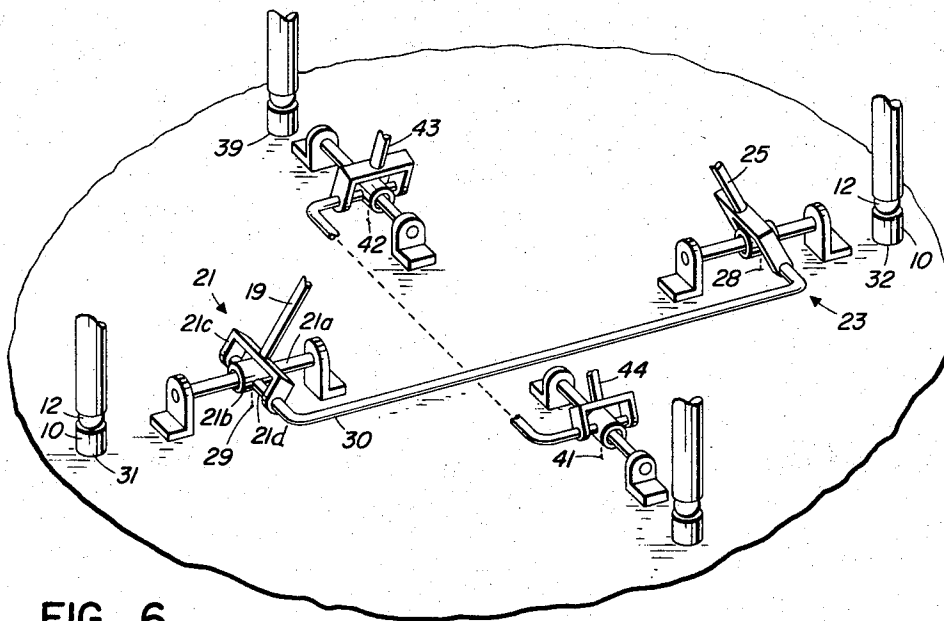


FIG 6

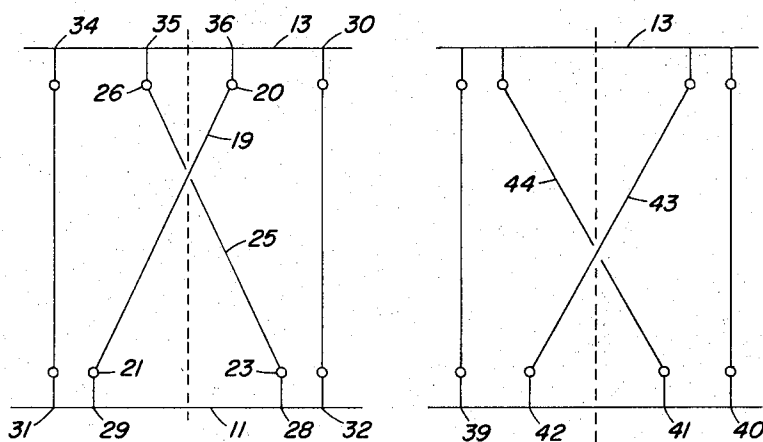


FIG 7

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FIG 8

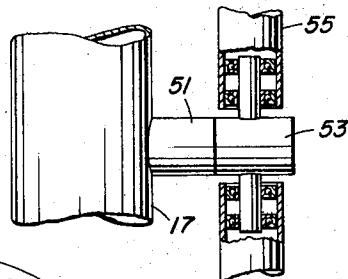
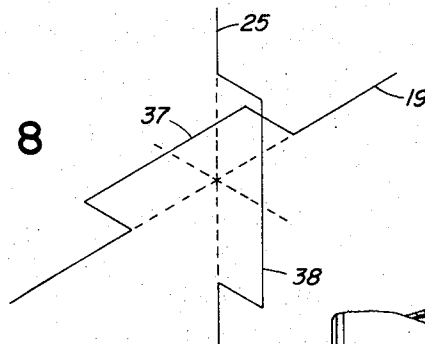
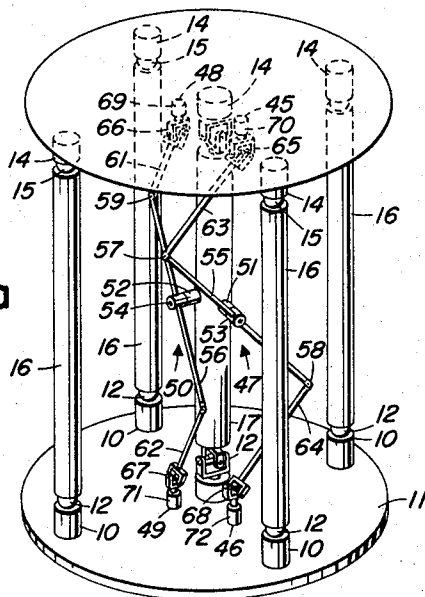


FIG 9b

FIG 9a



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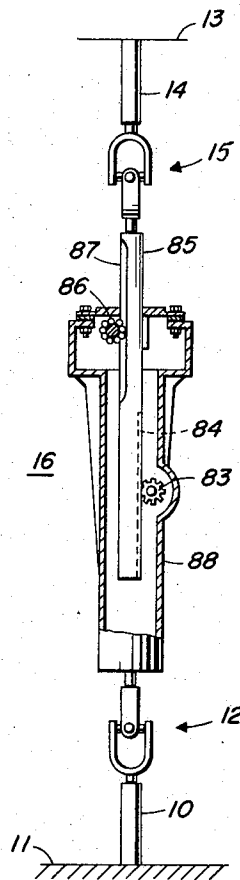
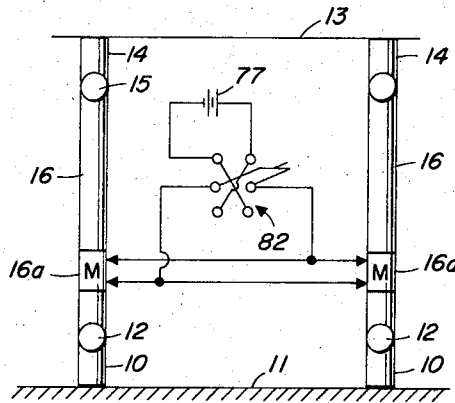
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## ANTENNA POSITIONER

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5 Sheets-Sheet 5



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3,374,977

## ANTENNA POSITIONER

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11 Claims. (Cl. 248—163)

### ABSTRACT OF THE DISCLOSURE

A concept and embodiments of positioning one plane with respect to another (as in antenna positioning) employing linkages and linear drives rather than conventional gear and bearings. Suspension arms are employed between a mounting and a base plane with each arm comprising a single linear drive unit each end of which is pivotably connected to one of the planes. A further fixed length suspension means is incorporated between planes to effect geometric stability. The mounting plane may be positioned by driving diagonally opposite ones of the linear drive units to effect mounting plane rotation about two mutually perpendicular axes with respect to the base plane.

This invention relates generally to position devices and more particularly to a method of varying the relative position of two plane surfaces by means of linear actuators.

The present invention is especially conducive for use as an antenna positioning device and, while described here with emphasis towards such an implementation, is not so limited, since, in general the invention relates to positioning one plane with respect to another.

The present invention, as it applies to antenna positioning devices, allows an antenna carried on a mounting plane to be continually positioned in azimuth and elevation with respect to a fixed base plane throughout a pointing range in excess of hemispherical coverage from horizon to horizon.

Known positioning devices for antennas comprise various configurations employing rotating base mounts for azimuth orientation in conjunction with a tilting yoke by means of which the antenna may be oriented in elevation. These expedients require bulky and expensive azimuth bearings, especially when the antenna is massive, as in the case of currently used parabolic dish antennas which may have diameters of 85 feet and more and represent enormous masses. The employment of conventional gearing in mounts for such antennas present problems of gearing accuracy coupled with problems of bearings which will support massive rotating devices.

Known conventional positioning devices experience high azimuth velocity as the antenna passes through or near zenith and large mass antennas may introduce prohibitive stresses for certain operations.

The present invention provides for antenna pointing coverage in ranges equal to or exceeding those of conventional mounts (such as azimuth-elevation or x-y types) and continuous finite axis velocity motion through any pointing direction; thus eliminating the problems of high or infinite velocities required in conventional mounts when tracking through their "gimbal lock" or "keyhole" positions.

A further object of the present invention is the provision of a positioning device which is essentially a device for varying the position of one plane surface with respect to another plane surface, such that when employed as an antenna mount it may be used independently as a stabilized platform (as for ship installation) by simply compensating the position of linear drive units with the ship's stabilization system.

Still further objects of the invention are the provision

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of a positioning improved system which does not limit elevation travel at the zenith position, permits continuous azimuth travel, eliminates keyholing in any position, eliminates requirements for slip rings and rotary joints by providing a nutating motion of the antenna with respect to the base plane, eliminates the need for costly azimuth bearings or bullgears, and reduces time-consuming installation and alignment procedures by permitting positioning axis adjustments by variation in the lengths of linear drive units.

Patent 3,215,391 to George Storm, entitled, "Positioning Device Continuous in Azimuth and Elevation Using Multiple Linear Drives," and assigned to the assignee of the present invention, discloses a positioning device of the general type herein disclosed, wherein a base and mounting plane are positioned relatively by motion about two mutually perpendicular axes. The reference patent teaches a suspension system comprised of a plurality of suspension arms between planes; such arm comprised of a pair of linear drive units joined by a flexible coupling. The present invention provides a positioning system attaining the same advantages with a reduction in the number of linear drive units employed. The present invention is accordingly featured in the provision of a positioning system employing suspension arms between planes with each arm comprising a single linear drive unit in conjunction with a further suspension means employing fixed length pivotable elements, wherein the mounting plane may be positioned by driving diagonally opposite ones of the drive units linearly and oppositely to effect mounting plane rotation with resulting simplification in the control means to effect orientation of the mounting plane.

These and other features and objects of the present invention will be apparent upon reading the following description in conjunction with the accompanying drawings in which:

FIGURE 1 is an electromechanical functional diagram of a basic embodiment;

FIGURE 2 is a diagram illustrating positioning geometry of the embodiment of FIGURE 1;

FIGURE 3 is a diagram of further geometry which may be embodied in FIG. 1;

FIGURE 4 is a functional diagram of a further embodiment of support geometry;

FIGURE 5 is a diagram of the positioning geometry relating to FIGURE 4;

FIGURE 6 is a partial view illustrating base and mounting plane couplings employable with the embodiment of FIGURE 4;

FIGURE 7 represents still further support geometry employable with the embodiment of FIGURE 4;

FIGURE 8 illustrates offset configurations employable in the diagonal support members of FIGURE 7;

FIGURE 9a is a functional diagram of a further embodiment of the invention;

FIGURE 9b is a mechanical detail of the embodiment of FIGURE 9a;

FIGURE 10 is a functional schematic representation of drive control means which may be employed in the present invention;

FIGURE 11 illustrates a typical linear drive unit which may be employed in the present invention.

A basic embodiment of the invention is shown in FIGURE 1. A base plane 11 is shown which might represent either the ground or the top of a tower. Four mounting posts 10 are affixed to the base plane at the corners of a square so as to define four suspension points 31, 32, 39 and 40 lying in the base plane at the corners of the square. The mounting plane 13 is oriented with respect to the base plane 11 by means of four support arm members each of which includes one of the terminating or post members 10 affixed to the base plane 11 and includes

a further post or terminating member 14 affixed to geometrically opposite suspension points lying in the mounting plane. Each of the support arm members includes an intermediate drive member 16 which is affixed to respective terminating members 10 and 14 through a pair of flexible couplings 12 and 15. The intermediate members 16, as will be further discussed, are comprised of linear actuators the lengths of which may be adjusted selectively by means of drive control means.

FIGURE 1 functionally represents a dual control means 75 selectively applying power from a source 77 through lines 78 and 79 to a first pair of diagonally opposite support arm members. A second dual control means 76 might selectively apply energy from source 77 through lines 80 and 81 to the other pair of diagonally opposite support arm members.

The basic operation of the invention involves simultaneously increasing the length of one of the leg members in a diagonally opposite pair while diminishing the length of the other member. In those instances where the changes in length are equal as well as opposite this action will herein be referred to as driving the diagonally opposite support arm members linearly.

The configuration of FIGURE 1 illustrates the base and mounting planes in zenith position; that is, the suspension points which lie in and define the respective base and mounting planes define support arm axes which are normal to the base and mounting planes such that the planes are parallel. The system thus far described will permit a tilt of the mounting plane 13 about two sets of mutually perpendicular axes with respect to the base plane 11. A first set of these axes is identified as the  $x$  and  $y$  axes, which pass through the flexible couplings 15 associated with pairs of diagonally opposite support arms. A second set of axes is identified as the  $x'$  and  $y'$  axes which pass through the flexible couplings 12 associated with pairs of diagonally opposite support arms.

Now, considering that the control means 75 through lines 78 and 79 drives the associated diagonally opposite pair of support arms linearly so as to foreshorten one by the extent that it lengthens the other, the mounting plane 13 will pivot with respect to the base plane 11 about the  $x$  and  $x'$  axes. Similarly, control means 76 through lines 80 and 81 may drive the associated support arms linearly to rotate the mounting plane 13 with respect to the base plane 11 about the  $y$  and  $y'$  axes. These two actions may be effected separately or simultaneously, and this basic action defines the general pointing geometry of the invention.

Since the drive members which form the intermediate member of each of the four support arms are flexibly coupled to terminating members 10 and 14, a further support means is necessary to attain geometric stability in the system. This further support means is comprised of a further support arm means which includes fixed length terminating members 14 and 10 affixed to the respective planes and an intermediate member or members of fixed length flexibly coupled to the terminating members. This further support means is affixed or mounted between the planes so as to be geometrically symmetrical with respect to the suspension points defined by the four support arm members lying at the corners of the squares in their respective planes. In the embodiment of FIG. 1, the further support means comprises a center post arrangement terminating in the intersection of the diagonals of each of the mounting squares.

FIGURE 2 represents the pointing geometry of the basic FIG. 1 embodiment wherein the mounting plane 13 is shown at zenith position with respect to the base plane 11 and additionally is shown oriented  $90^\circ$  with respect to the mounting plane 11. The geometry of FIGURE 2 is characteristic of the pivot action about each of the aforedefined axes. The zenith position illustrated in FIGURE 2 illustrates that intermediate members 16 of the pair of diagonally opposite support arm members are of

equal length like that of the fixed length intermediate member 17 associated with the center post. The tilting geometry effects a  $90^\circ$  tilt to the left by shortening the intermediate member associated with one support arm while lengthening the diagonally opposite intermediate member by the same amount. The fixed length center post intermediate member 17 simply pivots. A tilt of the mounting plane 13 to the right is accomplished by an equal and opposite drive of the same pair of diagonally opposite support arm members. It is noted that the center post member is coplanar with each of the diagonally opposite pairs of support arm members.

The embodiment thus described is geometrically stable at all positions with the exception of the zenith position illustrated in FIGURE 1 and again in FIGURE 2. At the zenith position, the structure may collapse and a practical embodiment, wherein positioning through zenith is required, might then include further mechanical means to prevent collapse at the zenith position yet permit positioning through the zenith position. The embodiment of FIGURE 1 is nonetheless geometrically stable and permits stable positioning of the mounting plane with respect to the base plane in continuous fashion from horizon to horizon with the exception of zenith position. From the geometry of FIGURE 2 it is seen that a further drive of the diagonally opposite support arm members would tilt the mounting plane with respect to the base plane in excess of  $90^\circ$  such that pointing coverage would exceed a hemisphere.

The geometrical instability at zenith in the embodiment of FIGURE 1, wherein the intermediate members of the diagonally opposite support arms and that of the further support means are of equal length, may be overcome by a modification in accordance with the geometry of FIGURE 3. FIGURE 3 illustrates three variations in the basic geometry of FIGURE 2 wherein the intermediate member 17 of the further or center post support means is chosen to have a fixed length unequal that of the intermediate members 16 of the diagonally opposite support arms at zenith position. A first approach is choosing the lengths of the terminating members 14 and 10 associated with the center post to exceed the length of the terminating members associated with the diagonally opposite drive arms. A second variation increases the length of the terminating member 14 associated with the center post only. A still further third variation decreases the lengths of both of the fixed length terminal members 10 and 14 associated with the center post. In each of the support means depicted in FIGURE 3, geometric stability is realized in all positions including the zenith position—that is, the structure is not collapsible at zenith. However, the geometry of the modifications of FIGURE 3 dictates that the intermediate members 16 associated with the diagonally opposite driving arms cannot be driven linearly, that is, one arm 16 would have to be foreshortened by a different amount than the diagonally opposite arm is lengthened. For any particular geometry as illustrated in FIGURE 3 a more sophisticated drive control means would therefore be required.

FIGURE 4 illustrates a further embodiment of the invention wherein the further support means between the base and mounting planes is comprised of diagonally inclined or  $x$  brace members of fixed length. The inclusion of the fixed length center post member 17 in the embodiment of FIGURE 4 is optional. A pair of diagonally inclined further support arms is associated with each pair of diagonally opposite support arm members in a coplanar arrangement. Each of the diagonally inclined members is flexibly coupled to a fixed length terminating member at further suspension points within the base and mounting planes. The further suspension points lie on a line between the suspension points associated with the coplanar pair of diagonally opposite support arms. Thus, a first pair of diagonal support arms comprised of fixed length intermediate members 19 and 25 are coplanar with

one pair of diagonally opposite support arm members and the  $y$  and  $y'$  axes. A second pair of diagonally inclined support arms which include fixed length intermediate members 43 and 44 are coplanar with the other pair of diagonally opposite support arm members and the  $x$  and  $x'$  axes. Arm 19 is coupled through flexible coupling 21 and fixed length terminal member 18 to suspension point 29 in the base plane and through flexible coupling 20 and fixed length terminal member 22 to suspension point 36 in the mounting plane. The associated coplanar diagonal support arm including fixed length intermediate member 25 is likewise coupled through flexible couplings 23 and fixed length terminating member 24, to a suspension point 28 in the base plane and through flexible coupling member 26 and fixed length terminating member 27 to suspension point 35 in the mounting plane. The other pair of diagonal inclined support arms are seen to be similarly terminated.

The suspension points 29 and 28 in the base plane and suspension points 35 and 36 in the mounting plane for one pair of diagonal support arms are indicated functionally in FIGURE 4 as being mechanically interlinked by linkages 30 and 37 respectively so as to define a fixed separation therebetween with the suspension points further indicated as being free to translate along the line between the suspension points. This expedient is necessary in order that the diagonally inclined support arms may include fixed length intermediate members so as to provide geometric stability at all positions including zenith and further to permit a linear drive of the diagonally opposite pair of support arm members. The tilt geometry of the embodiment of FIG. 4, further depicted in FIG. 5, necessitates that the center support member (if included) be of fixed length. This requirement is necessary if the system is to be linearly driven. Since the requirement is inconsistent with fixed length diagonal support members with pivots 20, 21, 23 and 26 fixed to the mounting and the base plane, the coplanar pairs of diagonal support members are affixed to the base and mounting planes through sliding pivots such that they are free to adjust for the tilt geometry. FIG. 5 illustrates generally the pointing geometry of the embodiment of FIG. 4 wherein the diagonally opposite pairs of support arm members are lengthened and foreshortened from the zenith position defined lengths by the same amounts. It can be shown by further inspection of the geometry that the coplanar diagonal arm members, in being of fixed lengths, must shift or translate within the plane to permit the desired drive motion. The geometry of FIG. 5 includes the pair of diagonal brace members including intermediate members 19 and 25 and thus the tilt of the mounting plane 13 depicted in FIG. 5 is about the previously defined  $x$  and  $x'$  axes. A like geometry is defined for tilt about the  $y$  and  $y'$  axes and would include those diagonally inclined support arms which include fixed length intermediate members 43 and 44.

The diagonal arm members are depicted in FIGURE 5 as being free to translate within the planes which they define at their respective points of suspension in the base and mounting planes. The manner in which this expedient may be implemented is illustrated in FIGURE 6. FIGURE 6 illustrates terminations which may be embodied at the base plane suspension points, it being understood that similar terminations would be employed in the mounting plane. Diagonal coplanar members 19 and 25 terminate in suspension points 29 and 28 respectively in the base plane. These terminations are shown to comprise a universal joint so mounted to the base plane that translation of the suspension point defined thereby along a line between the associated coplanar diagonally opposite support arms is possible. The flexible coupling 21 associated with arm 19 is comprised of a shaft 21a mounted by means of appropriate brackets above the base plane such that the axis of the shaft passes through the flexible couplings associated with the coplanar pair of

support arm members. Thus, the flexible couplings 12 associated with a pair of diagonally opposite support arms are in line with the mounting shaft 21a of the coupling 21. A sleeve member 21b is rotatably mounted on shaft 21a and fitted with a transverse pin 21d to which a yoke member 21c is rotatably mounted. The diagonal support arm 19 is affixed rigidly to the yoke member 21c. The suspension point 29 associated with the diagonal arm 19 is seen to lie at that point in the base plane 11 which falls beneath the position of the transverse pin member 21d. The distance from the base plane to the shaft 21a then becomes the fixed length terminating member 18 associated with the arm 19. The coplanar diagonal support arm 25 is likewise flexibly coupled to the base plane such that the suspension point 28 defined thereby is free to translate along a line between the suspension points 31 and 32 associated with the coplanar pair of diagonal supporting arms. The distance between the two sliding or translating suspension points 29 and 28 is maintained fixed by an interconnecting link 30. The other pair of diagonal support arms which include intermediate members 43 and 44 are likewise terminated in the base plane and interconnected by a linkage such that the distance between terminations is maintained constant and they may translate along a line between the suspension points 39 and 40 associated with the coplanar pair of support arms. Each of the diagonal support arm pairs would be terminated by similar mechanisms (not illustrated) in the mounting plane 13.

The embodiment of FIGURE 4, in employing diagonal support arm members, requires design around mechanical interference of the intermediate members at their points of intersection.

FIGURE 7 illustrates an expedient which might be used to minimize the mechanical interference by choosing the distance between the suspension points for a given pair of diagonal arms in one of the base and mounting planes to be less than that in the other. The other pair of diagonal arms might then be mounted with equal and opposite suspension point separations such that the intersection of the arms including intermediate members 19 and 25 lies above the intersection of the intermediate members 43 and 44 associated with the other pair. This minimizes the design requirements for avoiding a mechanical interference for either pair of arms to a relatively simple offset arrangement as depicted in FIGURE 8 wherein, for example, the arms 19 and 25 are formed with offsets 37 and 38 in the vicinity of their point of intersection such that mechanical interference may be avoided.

A still further embodiment of the invention is illustrated in FIGURE 9a in which the center post support member is supplemented with Watts linkage mechanisms, one associated with each of the pair of pivot axes. The arrangement of FIGURE 9a permits a linearly driven suspension mechanism in accordance with the invention which is geometrically stable in all positions including the zenith position. By incorporating the Watts linkage mechanisms, the problem of mechanical interference, such as would be encountered in the previous described embodiment, is minimized.

With reference to FIGURE 9a, a first Watts linkage mechanism 47 is arranged in a plane parallel to the plane through which the  $y$  and  $y'$  axes pass and a second Watts linkage mechanism 50 is arranged in a plane parallel to the plane through which the  $x$  and  $x'$  axes pass.

The Watts linkage mechanisms are terminated in flexible couplings (universal joints) and additional fixed length terminating members to the base and mounting planes. Linkage 47 is comprised of a center arm 55 the longitudinal axis of which is pivotally supported by means of a hub 53 about a post 51 which is affixed normal to the center post intermediate member 17 at the midpoint of member 17. Arm 55 is connected to a further arm

member 63 through a pivot (hinge) 57 to allow a pivoting action between arms 63 and 55 within the plane of the linkage mechanism. The other end of center arm 55 is connected to a second terminating arm 64 by means of a pivot (hinge) 58. The ends of arms 63 and 64 are flexibly coupled through universal joints 65 and 68 to fixed length terminating members 70 and 72 which are affixed to suspension points 45 and 46 each of which lies on a line corresponding to a diagonal between the suspension points associated with a first pair of actuating arms. The center arm 55 is actually two arms rotatably mounted normal to the hub 53. FIGURE 9b illustrates each half of center arm 55 being rotatably mounted to hub 53 by means of post members fixed normal to hub 53 and appropriate bearings.

The second Watts linkage mechanism 50 is comprised of a center arm 56 pivotally supported by means of a hub 54 about a further post 52 affixed normally to the center of post 17 such that the mechanism 50 lies in a plane transverse that of mechanism 47. Mechanism 50 is similarly terminated through flexible coupling members 66 and 67 to fixed length terminating members 69 and 71 which are affixed to suspension points 48 and 49 each of which lies on a line between the diagonally opposite pair of actuator arms. Linkage 50 is thus maintained parallel to the center post member 17 and lies in a plane parallel to the plane through which the  $x$  and  $x'$  axes pass. The Watts linkage mechanisms operate in a known manner to maintain equal translation of the ends which terminate in the flexible couplings within the plane with rotation of the center arm member. By means of these linkages, geometric stability is realized for all relative positions between the base and mounting planes including the zenith position illustrated, and the positioning of the mounting plane may be accomplished by linear drive of the diagonally opposite ones of the actuators which lie in the respective planes parallel to the two linkages.

FIG. 10 is a functional schematic embodiment of a dual control means as it may be associated with a diagonally opposite pair of drive members. Power source 77 is illustrated as a battery which may be selectively connected in either polarity to drive motors 16a associated with each linear actuator 16. A first position of switch 82 affects a simultaneous foreshortening of one actuator 16 with a lengthening of the other member and the relative drive may be reversed by the opposite switch position. As illustrated functionally in FIGURE 1, a circuit as shown in FIGURE 10 may be associated with each of the pairs of diagonally opposite support members which are to be driven.

FIGURE 11 illustrates a typical linear drive mechanism in the form of a rack and pinion assembly. One end of the assembly housing 88 may be terminated through a flexible coupling 12 to a fixed length base terminating member 10 affixed to the base plane 11. The actuating rod 85 is formed with a rack gear 84 which cooperates with a drive pinion 83. The drive pinion 83 then might be driven by one of the drive motors 16a depicted functionally in FIGURE 10. The actuating rod 85 is constrained from rotation by means of a bearing member 86 riding in a keyway 87 formed in the rod. The rod 85 may then be terminated through a flexible coupling 15 to a fixed length terminating member 14 affixed to the mounting plane 13. The rack and pinion mechanism may serve as the intermediate member 16 of the previously discussed support arm members. Ball screw devices and hydraulically controlled piston arrangements may serve equally well as the linear actuators of the invention.

Although the present invention has been defined with respect to particular embodiments thereof it is not to be so limited as changes might be made therein to fall within the scope of the invention as defined in the appended claims.

I claim:

1. Means for mounting a device defining a mounting plane so as to be selectively rotatable about mutually perpendicular axes with respect to a base member defining a base plane, comprising four suspension points lying in and defining each of said base and mounting planes, said suspension points in each of said planes arranged in like geometric symmetry and defining a square lying in each of said planes, four support arm members joining said base and mounting planes each having their respective ends terminated at opposed pairs of suspension points in said plane, further support means joining said base and mounting planes between further suspension points lying in said planes and symmetrically disposed therein on a line lying between diagonally opposite pairs of said four suspension points within each plane, each of said four support arm members terminating in a fixed length member one end of which is rigidly affixed normal to the connected one of said base and mounting planes and the other end of which is flexibly coupled to an intermediate member the length of which may be selectively varied, said further support means including at least one fixed length intermediate member terminated on either end thereof by a fixed length end member having one end affixed normal to the connected one of said base and mounting planes and the other end flexibly coupled to said fixed length intermediate member, and drive members associated with diagonally opposite pairs of the intermediate members of said four suspension arms to simultaneously increase the length of one said intermediate members in a pair while diminishing the length of the other intermediate member in a pair.

2. Mounting means as defined in claim 1 wherein said further support means comprises a fifth support arm member comprised of a fixed length intermediate member terminated in fixed length end members first ends of which are affixed normally to suspension points in said base and mounting planes which lie at the centers of the squares defined by said four suspension points in each said plane.

3. Mounting means as defined in claim 2 wherein the fixed length terminating members associated with said four support arm members are of a like predetermined length and unlike the lengths of the fixed length terminating members associated with said fifth support arm member.

4. Mounting means as defined in claim 2 wherein said fixed length terminating members associated with said four support arm members are of a predetermined like length equal that of the fixed length terminating members associated with one end of said fifth support arm member, the fixed length terminating member associated with the other end of said fifth support arm member being of a length unlike that of the other ones of said terminating members.

5. Mounting means as defined in claim 2 wherein said fixed length terminating members associated with said four support arm members are of a predetermined equal length, and at least one of the fixed length terminating members associated with said fifth support arm member is of an unlike length whereby the intermediate member associated with said fifth support arm member has a length unlike that of the intermediate members associated with said four support arm members when said base and mounting planes are positioned parallel to one another.

6. Mounting means as defined in claim 2 wherein the intermediate members associated with all said support arm members are of equal length when said base and mounting planes are respectively parallel, and said drive members associated with each of said pairs of diagonally opposite ones of said four support arm members effect an equal and opposite adjustment in the lengths of the intermediate members associated therewith.

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7. Mounting means as defined in claim 1 wherein said further support means comprises first and second pairs of diagonally inclined further support arms, the intermediate members of each said further pair lying in a plane defined by the intermediate members associated with diagonally opposite ones of said four support arm members and being disposed transverse of one another within the plane, each of the intermediate members of said further pair being flexibly coupled to first ends of fixed length terminating members the other ends of which are disposed normal to each of said base and mounting planes between pairs of said further suspension points lying on a line between the diagonally opposed suspension points of said coplanar pairs of said four support arm members, the further suspension points associated with each further pair having a fixed separation within the associated plane and being disposed for mutual like translation within the associated plane.

8. Mounting means as defined in claim 1 wherein the drive members associated with each of said diagonally opposite pairs of said four support arm members effect an equal and opposite adjustment in the length of the associated intermediate members.

9. Mounting means as defined in claim 8 wherein the distance between the suspension points associated with said further support arms in said mounting and base planes are equal.

10. Mounting means as defined in claim 8 wherein the separation between the suspension points associated with a first pair of said further support arms is less in one of said base and mounting planes than in the other and the separations between the suspension points associated

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with the other pair of said further support arms are respectively equal and opposite those associated with said first pair of further support arms.

11. Mounting means as defined in claim 2 further comprising first and second further pairs of fixed length terminating members each pair of which lies in the plane defined by said first and second pairs of diagonally opposed ones of said four support arm members, the terminating member of each said further pairs having first ends thereof respectively affixed normal to said base and mounting planes, the other ends of the terminating members of each of said further pairs being flexibly coupled to the terminal ends of a Watts linkage mechanism the center pivot point of which is about an axis normal to the fixed length intermediate member of said fifth support arm member.

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