

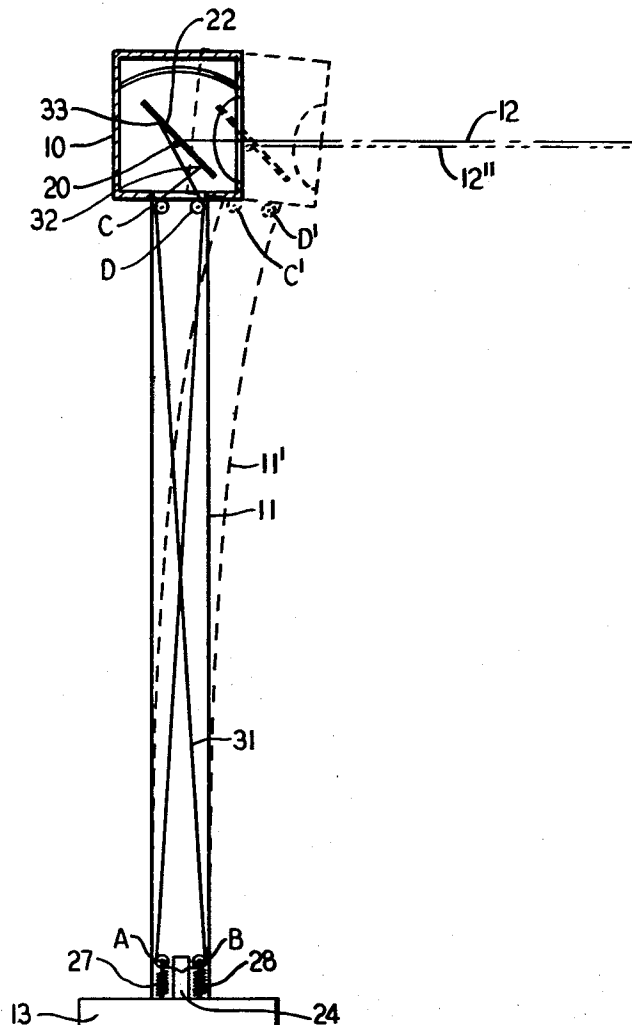
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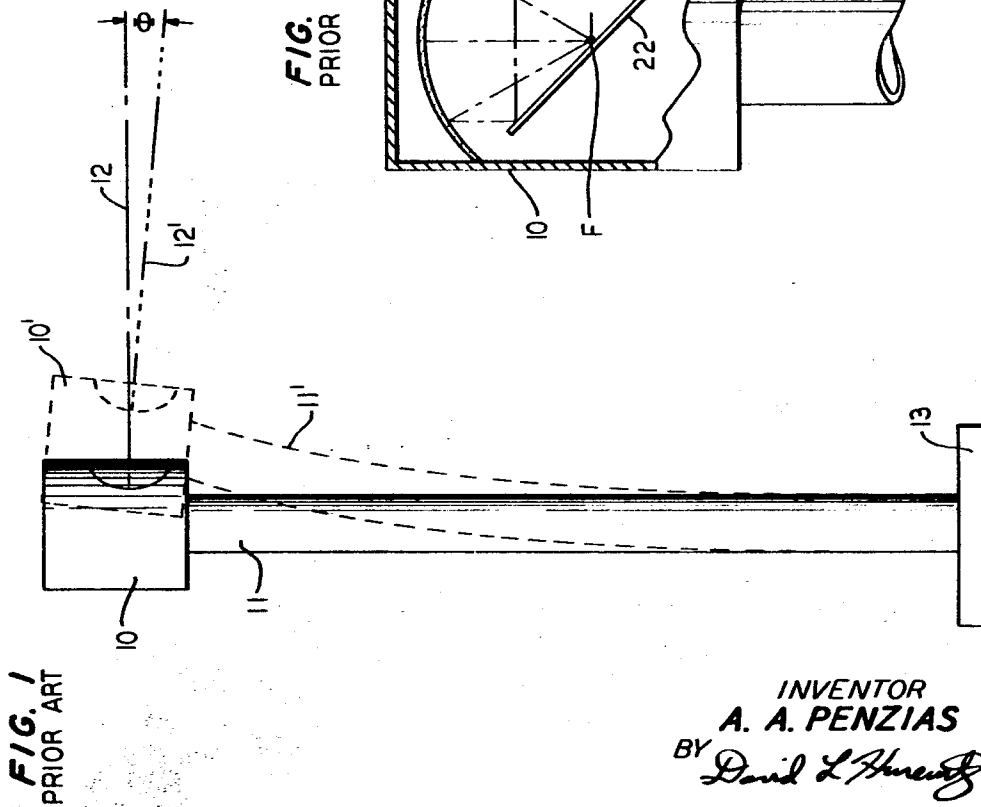
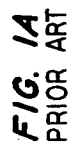
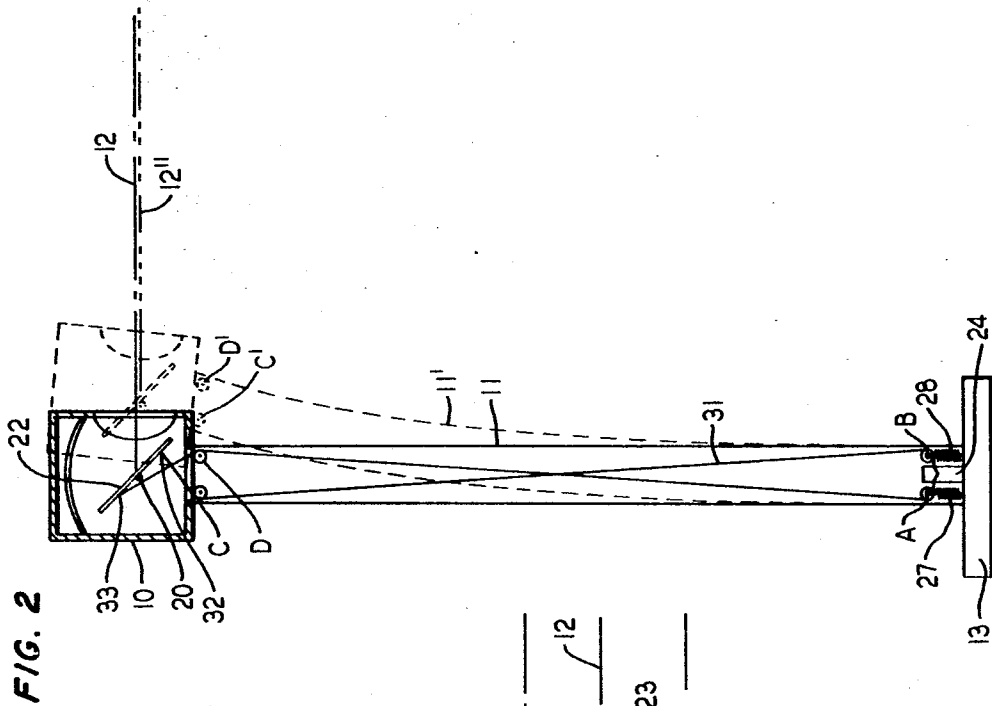
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Primary Examiner—Eli Lieberman
Attorneys—R. J. Guenther and E. W. Adams, Jr.

[54] **STABILIZER FOR REFLECTOR OF A POLE-MOUNTED ANTENNA**
9 Claims, 6 Drawing Figs.

[52] U.S. Cl. 343/839,
 343/882, 343/890, 343/DIG. 2, 52/40
 [51] Int. Cl. H01q 1/12
 [50] Field of Search 343/DIG. 2,
 880, 839, 882, 890; 182/1, 2; 52/40, 301, 649

ABSTRACT: A pole-mounted directional microwave antenna having a plane reflector is disclosed. The antenna package mounted atop the pole contains a reflector which is rotatable in elevation angle providing control of the direction of the axis of propagation. A flexible belt within the pole is run between pivots at the top and bottom of the pole so that deflection of the pole in a plane containing the axis of propagation varies the separation between the pivots and affects movement of the belt. This movement is translated by a mechanical linkage to rotation of the reflector so that the resultant axis of propagation remains parallel to its undeflected orientation, thus automatically compensating for wind-induced pole sway in the direction of propagation. In addition, the elevation angle of the reflector can be set by moving the belt from the ground.





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FIG. 3

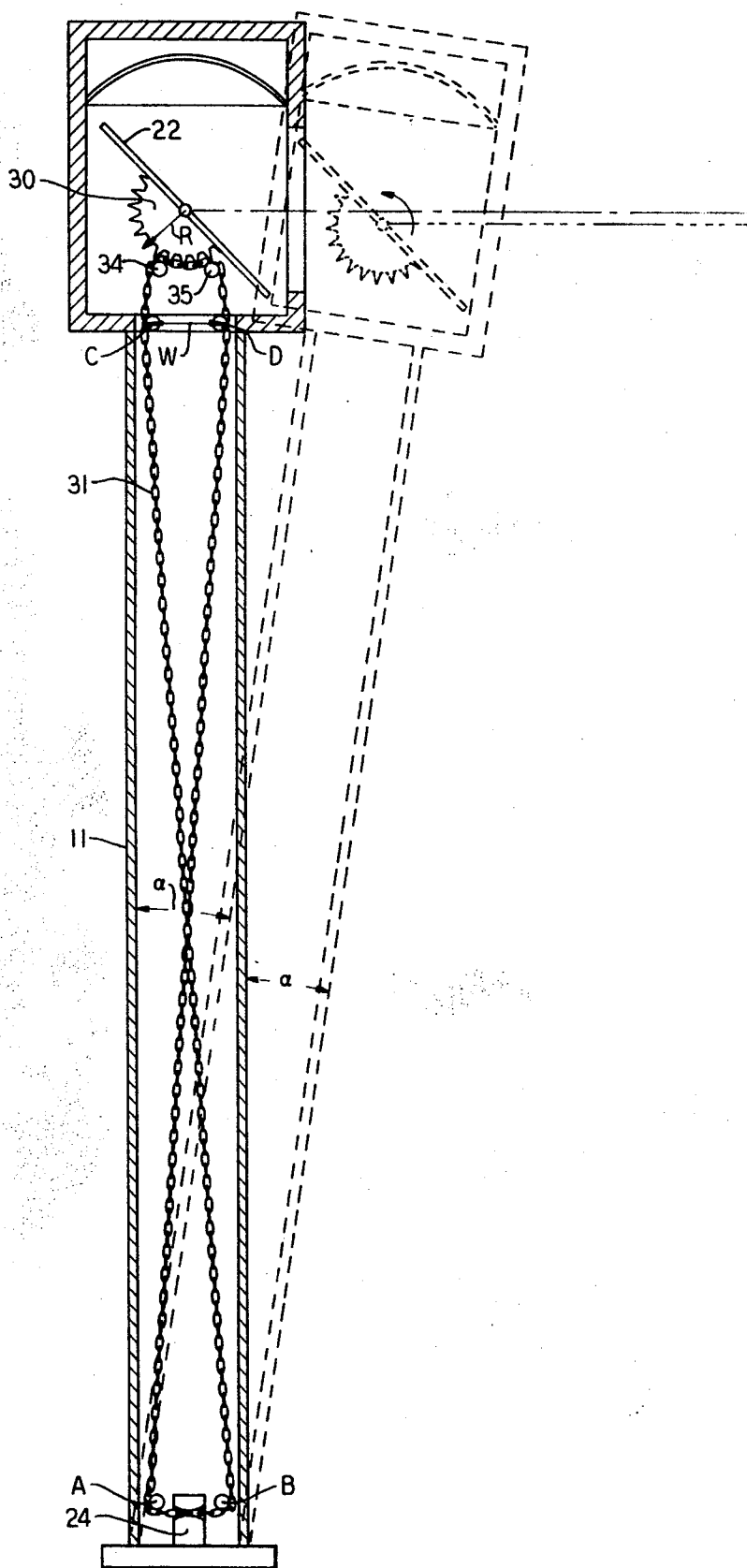


FIG. 4A

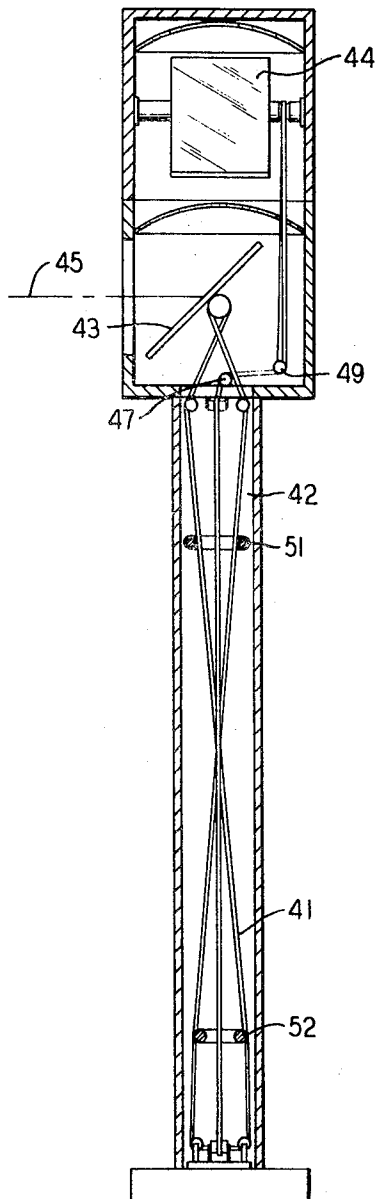
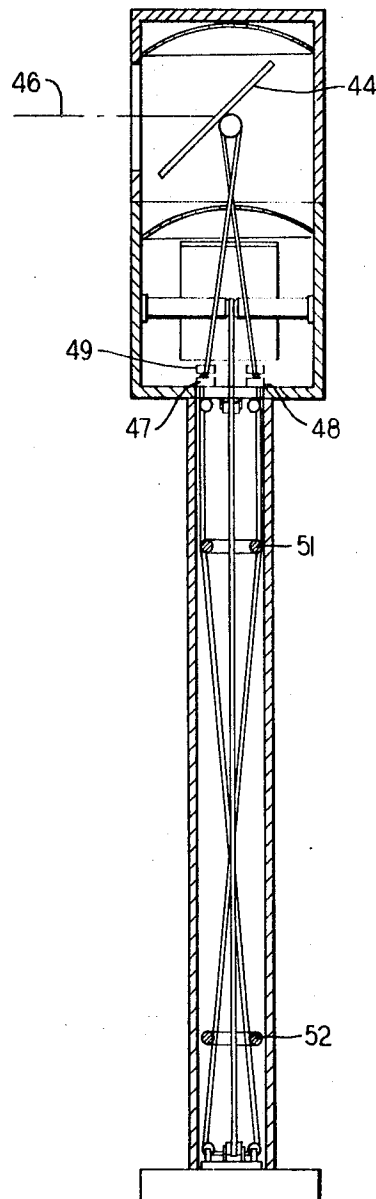


FIG. 4B



STABILIZER FOR REFLECTOR OF A POLE-MOUNTED ANTENNA

BACKGROUND OF THE INVENTION

The invention relates to antenna-mounting structures and, more particularly, to mechanisms for continuously correcting the orientation of a narrow beam antenna to compensate for motion of the mast on which it is mounted.

In order to reduce interference in radio transmission systems omnidirectional antennas have been replaced by highly directive ones. As a consequence, successful transmission from one station to another requires precise alignment of the two antennas and continuous maintenance of this alignment. In the past, steel lattice structures fixed to massive concrete foundations have been constructed to rigidly support the required antennas. These large structures do in fact sway slightly in the wind, but wide beams are used so that even under conditions of sway the radiated beam is intercepted by the next antenna. As narrower beam and higher gain antennas are used, even the minor sway of a 200-foot lattice structure may cause a 0.1° beam to miss the next antenna. For this reason, as well as others, the expensive lattice towers may be replaced in the future with simpler and cheaper masts such as single vertical poles.

The pole-mounted antennas would, of course, experience substantial sway and continuous reorientation would be required to maintain alignment between consecutive antennas in the transmission path. An electromagnetic servomechanism could be used to stabilize the antenna orientation but this would add greatly to the complexity, expense and maintenance of the pole assembly. For structural reasons, the pole could not be as high as the older lattice towers and hence many more repeater stations would be required. Thus, expensive stabilizing mechanisms would mitigate the value of the inexpensive pole mounting.

SUMMARY OF THE INVENTION

In accordance with the present invention, an inexpensive stabilizer is provided for a pole-mounted highly directional narrow beam antenna. The orientation of the beam is controlled by the orientation of a surface in an antenna package which is mounted atop the pole. This surface, which may be a reflector for directing the antenna beam, is rotatably connected relative to the pole and when wind loading or other external forces cause the pole to bend or deflect in a plane containing the beam axis a belt and pulley arrangement converts this deflection into linear motion which is translated into a compensatory rotation of the surface. An alternative mechanism for stabilizing the beam axis orientation is disclosed in copending application Ser. No. 867,150 filed on an even date herewith by A. B. Crawford and assigned to the assignee hereof.

The reflector is normally a plane surface and will be referred to herein as a mirror since the surface is coated with or made of a material which is reflective to the frequencies being propagated. Conventionally, this mirror is fixed to the antenna package at the time of installation and hence bending of the pole and antenna package causes undesired elevation rotation of the beam propagation axis.

In accordance with the invention, instead of being fixed, the mirror is rotatably connected to the package and a flexible belt is run from the mirror down the length of the pole guided by means of pulleys and returned up the pole to the mirror. The pulleys are arranged so that deflection of the pole in the plane containing the beam axis causes the relative lengths of the upward and downward portions of the belt to vary. This causes rotation of the elevation angle of the mirror so that the axis of propagation is maintained parallel to its position in the undeflected condition.

The bending of the pole will of necessity cause the altitude of the antenna to be reduced, but reducing the height of the beam axis to a parallel position even on the order of a foot

does not impair coupling with a distant antenna, whereas the rotation in elevation of the beam axis by an angle of only 1° causes a narrow beam to miss the next antenna completely as it would either pass above or below the aperture.

Deflection of the pole in a plane not containing the beam axis causes no change in the elevation of the beam axis but merely displaces it to the right or the left. As in the case of the reduced height, such a laterally displaced parallel path intercepts the next antenna aperture, and therefore compensation is required only for components in the plane containing the beam axis. However, as a conventional repeater station has antennas facing in different directions, it is necessary to provide independent pulley systems for each mirror which has a propagation direction different from the others.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a pictorial representation of a conventional pole-mounted antenna illustrating the rotation of the beam axis caused by deflection of the pole.

FIG. 1A is a cross-sectional view of a conventional antenna package suitable for use with the pole-mounted antenna of FIG. 1.

FIG. 2 is a pictorial representation of a pole-mounted antenna modified in accordance with the invention to correct for deflection in the plane containing the beam axis of the antenna.

FIG. 3 is a cross-sectional view of a modified embodiment of the stabilizer in accordance with the invention.

FIGS. 4A and 4B are mutually perpendicular cross-sectional views illustrating the present invention as modified to provide stabilization for two independently oriented antenna packages.

Elements common to various figures are designated by similar reference numerals.

DETAILED DESCRIPTION

FIG. 1 illustrates antenna package 10 mounted atop hollow pole 11. Package 10, shown in FIG. 1A, contains conventional narrow beam antenna apparatus which may comprise, for instance, a parabolic reflector 21 and a plane reflector or mirror 22 which is permanently positioned within package 10 to reflect the parallel waves from parabolic reflector 21 so that they pass through a weather-covered aperture 23 in the wall of package 10 to form a beam having an axis 12. The illustrated structure is assumed to be conventional and therefore antenna feeds which would be located at F, the focal point of parabolic reflector 21, and their connection to appropriate electronic circuits such as a receiver, transmitter or repeater, are not shown. The antenna apparatus may, of course, be of the type without plane mirror 22 in which case parabolic reflector 21 would have to be positioned to radiate a beam directly through aperture 23. What is essential to the present invention is that the antenna couples with electromagnetic radiation along a narrow beam having an axis 12, whose orientation is determined by the orientation of a surface such as mirror 22 in package 10.

Pole 11 and package 10 are preferably cylindrical and mounted coaxially in order to resist a wind-caused twisting moment about the axis of the pole and correction for this moment is assumed to be unnecessary. However, if pole 11 is rigidly secured to foundation 13, a force or a component of force will cause the pole to bend, and the dotted image in FIG. 1 is an exaggerated illustration of deflection of pole 11 in the plane containing beam axis 12. As can be seen, a force component from left to right will cause the pole to deflect to position 11' and package 10 will be tilted to position 10'. The beam axis will lie along a line 12' which is displaced below the original position of axis 12 by an angle Φ . It is evident that if the pole is deflected in the manner the beam may intercept the ground and not the next antenna which is aligned with beam axis 12. A force from right to left will cause the opposite effect and the displaced beam axis would lie above the original beam orientation 12.

FIG. 2 illustrates an assembly similar to that of FIG. 1 except that it has been modified in accordance with one embodiment of the invention by the addition of a belt and pulley system within hollow pole 11. Mirror 22 is rotatably connected to package 10 about an axis 20 normal to and intercepting beam axis 12. One end of flexible belt 31 is fastened to mirror 22 at point 32 and passed around pivot C, down the length of pole 11 to pivot B, around pivot B to pivot A up the length of pole 11 to pivot D, around pivot D to point 33 where the opposite end of belt 31 is connected to mirror 22. Pivot points A, B, C and D as well as points 32 and 33 lie in the vertical plane containing beam axis 12 and pivots A and B are on opposite ends of a cross-sectional diameter at the bottom of pole 11, while pivots C and D are on opposite ends of a parallel diameter at the top of pole 11. Thus belt 31 crosses itself within pole 11.

As indicated in the dotted image, a force component from left to right in the vertical plane containing beam axis 12 causes pole 11 to bend to position 11', deflecting along a curve which is illustrated as having a parabolic shape; but any small angle deflection will be stabilized by the pulley system. The dotted configuration is, of course, greatly exaggerated for purposes of illustration, and it can be seen that the linear separation between pivots A and D (in position D') is increased relative to the linear separation between pivots B and C (in position C') by such a deflection. Movement of belt 31 between pivots A and B is prevented by clamp 24. Thus, when pole 11 deflects, the distance between A and D increases while the distance between C and B decreases, and since belt 31 is connected to mirror 22 so that it crosses itself, belt 31 will move to increase its length between A and D by pulling point 33 toward pivot D causing mirror 22 to rotate counterclockwise about axis 20. The decreased distance between A and C will allow a length of belt 31 to pass pivot C and lengthen the segment between point 32 and C. The pivots may be pulleys appropriate to belt 31 as they act merely as guides for the belt.

In this manner, deflection of pole 11 causes movement of belt 31 and this linear movement is translated into a compensatory rotation of mirror 22 so that the beam axis will lie along a line 12'' parallel to the orientation of the undeflected axis 12. The deflection of pole 11 will, of course, reduce the height of the entire package and hence line 12'' will be below that of the undeflected beam axis orientation but the radiated beam will broaden sufficiently so that if the beam lies on a parallel though lower line, it will intercept the next antenna in the transmission path acceptably.

In order for the compensatory rotating mechanism for mirror 22 to function properly, belt 31 must be maintained taut. This can be accomplished by securing pivots A and B on adjustable mounts such as spring loaded turnbuckles 27 and 28 which provide the appropriate tension.

The stabilizing mechanism can also be used to provide initial adjustment of mirror 22 for purposes of alignment, clamp 24 is loosened and after setting the tension on pivots A and B by means of turnbuckles 27 and 28 belt 31 is moved until the desired elevation of mirror 22 is achieved and clamp 24 is then secured.

The proper amount of compensatory rotation is provided by adjusting the connection points 32 and 33 on mirror 22. As these points are moved further from axis 20, the rotation provided by a given linear movement of belt 31 will be reduced. Damping of the rotation of mirror 22 may be provided by a conventional shock absorber.

An alternative mechanical linkage of belt 31 and mirror 22 is shown in FIG. 3. Mirror 22 is provided with a toothed sprocket 30 of radius R and belt 31 is a chain appropriate to interlock with sprocket 30. Chain 31 is guided by additional pivots 34 and 35 to mesh with sprocket 30 as shown.

With respect to FIG. 3, the principle of the invention may be illustrated by considering pole 11 to deflect rigidly to the right through a small angle α . This increases the distance between A and D by an amount $W \sin \alpha$ where W is the separation between pivots C and D. Likewise, the deflection

of pole 11 decreases the separation between B and C by the same amount. Mirror 22 rotates in a counterclockwise direction by an angle $(W \sin \alpha)/R$ in order to accommodate the belt 31. If, for example, the deflection causes a rotation of exactly $\alpha/2$ the radiated beam from package 10 remains undeflected, that is, parallel to its original orientation. In this case R is chosen to equal $2W$, since $\sin \alpha$ is approximately equal to α for the range of angles of which any practical pole would deflect.

An actual pole will probably not deflect rigidly taking on a curved shape such as a parabola instead. In this case, the angular deflection with respect to the vertical will be larger than in the case above for the same amount of horizontal displacement. This must be compensated for by making R somewhat smaller than $2W$, and while the exact size of R can only be determined from an investigation of the characteristics of the specific type of pole, the principle is identical.

In the event that the antenna is of the type which is without plane reflector 22 or if rotation of a plane reflector is impractical, the principles of the invention can be applied by rotatably mounting the package 10 atop pole 11 and controlling the rotation of the entire package by means of a similar belt and pulley system.

Forces in directions other than the plane of the beam axis can be resolved into two components in the plane of the beam axis and perpendicular to that plane. Elevation compensation as described above must be provided for the components in the plane of the axis in order to avoid the beam's missing the next antenna completely. However, correction of perpendicular components need not ordinarily be corrected as they will displace a parallel beam in a manner similar to the reduced height caused by the lowering of the entire package and this will not affect coupling with the succeeding antenna in any practical way.

FIGS. 4A and 4B illustrate two mutually perpendicular cross-sectional views in which two antenna packages are stacked atop a pole. In a commercial application it would be expected that repeater stations in a transmission system would have at least two antenna packages, their beam axes, such as 45 and 46, being displaced from one another. Hence, correction of force components parallel to both axes 45 and 46 is required.

If the two axes were parallel, then a single belt and pulley system could correct both by simply linking the two mirrors 43 and 44, but where the axes are not parallel as illustrated, independent correction is required. Two belts 41 and 42 are shown, each essentially identical to the belt assembly in FIG. 2. Belt 41 lies in the plane of beam axis 45 reflected by mirror 43 and belt 42 lies in a plane of beam axis 46 reflected by mirror 44. The two systems operate independently. Additional pivots such as 47, 48, 49 and 50, required to thread belt 42 past mirror 43 and its associated components are added without affecting the operation. In addition, it may be advantageous to provide guides such as 51 and 52 within the pole to prevent the two belts 41 and 42 from interfering with one another within the pole. These guides may be appropriate pairs of pulleys or alternately tori (O-rings), as shown, where belt 42 would pass through the center of torus 52 and around the exterior of torus 51 while belt 41 would pass through the interior of torus 51 and the exterior of torus 52. Such guides would cause belts 41 and 42 to cross themselves at different heights.

Notwithstanding the fact that FIGS. 4A and 4B show axes 45 and 46 perpendicular to each other, this perpendicularity is not necessary. In fact, any angular orientation of the two packages is possible and merely requires orienting each belt assembly in the plane containing the proper beam axis.

In all cases it is to be understood that the above-described arrangements are merely illustrative of a small number of the many possible applications of the principles of the invention. Numerous and varied other arrangements in accordance with these principles may readily be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An antenna-mounting structure for constraining the beam axis of a directional antenna to parallel lines comprising, antenna means for coupling with electromagnetic radiation along said beam axis whose orientation is controlled by the orientation of a surface,
a support member rigidly fixed at one end to a foundation, means for rotatably connecting the other end of said support member to said surface,
flexible connecting means fixed at a point relative to said foundation and mechanically linked to said surface,
means for guiding said connecting means so that two portions of said connecting means, both extending from the mechanical linkage at said surface to said fixed point, lie substantially in a deflection plane containing said beam axis and cross each other at least once such that deflection of said support member in said deflection plane causes the relative lengths of the two portions of said connecting means to vary whereby said surface rotates about an axis perpendicular to said deflection plane to control the elevation angle of said beam axis.
2. An antenna-mounting structure as claimed in claim 1 wherein said surface is a plane reflector rotatably mounted such that the orientation of said reflector controls the elevation angle of said beam axis.
3. An antenna-mounting structure as claimed in claim 1 wherein said surface is fixed to a rotatable sprocket and wherein said connecting means is a continuous flexible belt mechanically interacting with said sprocket.
4. An antenna structure as claimed in claim 1 further comprising means for maintaining said connecting means taut under all conditions of deflection.
5. An antenna structure for stabilizing the elevation angles of a plurality of directional antennas comprising, a plurality of substantially similar structures as claimed in claim 1, wherein a single support member is common to each of said structures and each of said structures is oriented to have a deflection plane distinct from each of the planes of the other of said plu-

ality of structures.

6. An antenna-mounting structure as claimed in claim 1 wherein said support member is a hollow pole and said surface, said connecting means and said guiding means are located within said pole.
7. An antenna-mounting structure as claimed in claim 6 wherein said connecting means is a flexible belt mechanically linked to said surface and each of said two portions are guided by one of two pivots located at opposite points on a cross-sectional diameter at the top of said pole and respectively by an opposing one of two pivots located at opposite points on a parallel diameter at the bottom of said pole.
8. An antenna-mounting structure for constraining the beam axis of a directional antenna to parallel lines comprising, antenna means for coupling with electromagnetic radiation along said beam axis whose orientation is controlled by the orientation of a plane reflector,
a hollow pole rigidly fixed at one end to a foundation, means for rotatably connecting the other end of said pole to said reflector,
a flexible belt within said hollow pole fixed at one point relative to said foundation and mechanically linked to said reflector,
means for guiding said belt the length of said pole so that said belt lies substantially in a deflection plane containing said beam axis and extends downward from the mechanical linkage at said reflector to a first of two pivots at said foundation, around said first and a second of said two pivots, upward across the downward portion of the belt to the mechanical linkage at said reflector,
and means for clamping said belt between said first and second pivots to prevent its motion relative to said foundation.
9. An antenna-mounting structure as claimed in claim 8 wherein deflection of said pole causes the relative lengths of said upward and downward portions of said belt to vary causing rotation of said reflector.

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