This invention relates to a directional antenna system for radar. It particularly concerns a system in which a primary radiator circles about the focal point of a reflector, the latter being independently reciprocated, preferably in a plane.

For producing a sharp and narrow directional radar beam that can be directed at any point in space, the directional antennas in use generally comprise a primary radiator and a reflector which are rotatable together about a vertical axis and are tiltable about a horizontal axis. In some cases the entire system is mounted for rotation about a vertical axis and only the appertaining directional antenna is tiltable in a vertical plane.

Aside from the necessity for aiming the directional antenna at a target point at any lateral and elevational angle, there sometimes arises the problem of imparting to the directional antenna an additional movement, preferably a rapid one. For example, for the automatic tracking of targets, the directional antenna is usually caused to perform an additional scanning movement by employing a rotating directional beam deflected away from the symmetry axis of the reflector. Furthermore, in such installations it may sometimes be preferable to provide for the possibility of a search limited to a small angular space sector. This is useful in the event of inaccurate target information or lack of target information. Such additional searching movement is performed, for instance, by rapid to and fro, or upward and downward, movement of the directional beam in a vertical plane simultaneously with a slow change in the lateral angle of the directional antenna.

The present invention, in a more specific aspect and preferred embodiment, relates to a directional antenna assembly, generally of the above-mentioned kind, in which a primary radiator and a reflector, having a rotationally symmetrical surface, are operated to selectively execute a scanning movement by means of a directional beam which rotates about and is deflected away from the symmetry axis of the reflector and to carry out a searching movement by means of a directional beam which performs a back and forth movement within a plane.

Numerous directional antenna systems have become known which, in addition to the lateral and elevational motion of the antenna, afford an additional scanning or searching movement of the directional beam, in the above-mentioned sense. There are also directional antenna systems which selectively permit a scanning as well as a searching movement of this kind. In one of the known systems, the last-mentioned kind, two separate antennas are provided, one being designed for an additional scanning movement and the other for an additional searching movement. The relatively great space requirements, and also the greater weight, as well as the necessary switching from one to the other antenna are the more obvious disadvantages of this system. As an alternative proposal, in which a single antenna is used for both the scanning as well as for the searching movement, the entire antenna is placed in motion, the scanning movement being effected by rotation of the antenna with the antenna axis deflected relative to the axis of rotation, whereas the searching movement is effected by tilting the antenna within a plane. In this case the moving masses are relatively large so that, because of the desired great velocities, considerable forces of acceleration are required for performing these movements. Similar disadvantages obtain with another known directional antenna system in which the entire antenna is reciprocable about a vertical axis and the reflector is additionally tiltable about a horizontal axis relative to the primary radiator. In this case, furthermore, the means for producing the mentioned scanning movement are more complicated since the entire antenna is the case if a deflection of the beam of about 1° is chosen for the scanning movement, whereas the searching movement is to cover a tilting range of about 10°. It is a more specific object of my invention to readily permit such a deflection of the beam to be performed by a relatively small expenditure of power and to provide a simple search mechanism. This is especially so if, aside from the mentioned movements, the possibility of varying the degree of deflection must be provided for. This is the case if a deflection of the beam of about 1° is chosen for the scanning movement, whereas the searching movement is to cover a tilting range of about ±10°.

It is a more specific object of my invention to readily permit such a deflection of the beam to be performed by a relatively small expenditure of power and to provide a simple search mechanism. This is especially so if, aside from the mentioned movements, the possibility of varying the degree of deflection must be provided for. This is the case if a deflection of the beam of about 1° is chosen for the scanning movement, whereas the searching movement is to cover a tilting range of about ±10°.

To this end, and in accordance with my invention, I provide a radar directional antenna system which comprises a primary radiator circularly movable about the focal point of the reflector, preferably in a plane perpendicular to the axis of symmetry of the latter. The reflector is movable about an axis perpendicular to its axis of symmetry, the symmetry axis of the reflector being coincident with the axis of rotation of the primary radiator in the position of rest of the reflector, that is, when the latter is not reciprocating. In this system, the circular movement of the primary radiator with the reflector at standstill performs the above-mentioned scanning movement. The reciprocating motion of the reflector, for example with the primary radiator at standstill, performs the above-mentioned searching movement of the directional beam. By combining the two antenna operating principles into a single system, not only are the advantages inherent in the individually used alternatives maintained, but in addition there results the elimination of the above-mentioned disadvantages of the antenna devices heretofore available for performing an additional searching motion as well as an additional scanning motion of the directional beam.

These specific, according to any other proposal, in which a single antenna is used for both the scanning as well as for the searching movement, the
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antenna assembly and from the accompanying drawing, in which:

Fig. 1 is a schematic view of the assembly, the angles \( \alpha \) and \( \beta \) being exaggerated to lend clarity, and

Fig. 2 is a detailed view, seen from above, of part of an antenna assembly, of a modified form.

The initial part of the following description has reference to Fig. 1.

The primary radiator 1 is mounted in front of a rotationally symmetrical reflector 2, which is parabolic for example, and which is mounted on a housing structure 3. The latter encloses the drive means employed for imparting additional movement to the primary radiator 1 and to the reflector 2. The housing 3 is mounted on a standard 4 and is tiltable about a horizontal shaft 5 as shown in the standard. The standard 4 is mounted on a base 6 and is rotatable with respect thereto about a vertical shaft 7. Driving power for the rotational movement of the standard 4 and for the tilting movement of the housing 3 is supplied from respective electric motors 8 and 9 through respective worm gears 10 and 11. By means of these drives, the housing 3, which determines the position of the main axis 12 of the antenna, can be adjusted relative to the lateral angle and relative to the elevational angle.

The primary radiator 1 is mounted on the front end on a wave-guide conductor 13 of linear shape. The conductor 13 is universally pivoted for motion in all angular directions by means of a universal pivot 140 fixed therein and mounted in bearing 14, which is located behind the crest point of the reflector 2 and is carried by housing 3. The rear end of the conductor structure 13 is articulately linked, at universal pivot 130, with a driving disc 15 in eccentrical relation to the drive shaft 160 of a motor 16 so that the axes 17 of the wave-guide structure 13, during operation, defines a circular cone. During such motion, the primary radiator 1 moves in a circle about the main axis 12, but has no rotary motion about the conductor axis 17. The number of rotations about main axis 12 per minute may, for example, be about 1,800, and the angle \( \alpha \) between conductor axis 17 and main axis 12 may be, for example, about 1 to 1.5°. The supply of HP power, not illustrated, to the wave-guide structure 13 is preferably introduced in the vicinity of the universal pivot bearing 14. Motor 16 is mounted on housing 3.

The reflector 2, and its support 200, is likewise tiltable about the center of the pivot bearing 14 carried by housing 3. It is journalled independently of the wave-guide structure 13. It is mounted by means of a pivot 140, for tilting motion about an axis perpendicular to the axis of symmetry of the reflector, the axis of tilt in the illustrated example extending in the horizontal direction. The tilting movement of the reflector is effected by means of a mechanical resonance drive. For this purpose point 18 on support 200 of the reflector 2 is connected with a crank wheel 20 through a driving spring 19. The crank wheel 20 is driven by a motor 21, which is mounted on housing 3, through a worm gear 22. The mechanism is further provided with oscillator springs 23 and 24 which are respectively connected between housing 3 and points 18 and 180 on reflector support 200 and which are so chosen that the natural frequency of the oscillating system formed by the reflector 2, support 200, and the springs 23, 24 is in the range of about 3 to 5 cycles per second. In the rest position of the reflector its axis of symmetry is to be coincident with the rotational axis of the primary radiator 1, which is main axis 12 of the antenna. Main axis 12 is the median position of the symmetry axis of the reflector 2. The tilting range denoted by the angle \( \beta \) between main axis 12 and the symmetry axis 25 or 25° of the deflected or tilted reflector (shown by dot and dash lines) may, for example, be about \( \pm 10^\circ \). For better illustration, the two angles \( \alpha \) and \( \beta \) are shown on the drawing larger than the above-mentioned values. It is understood that pivot 130 is offset sufficiently to accommodate angle \( \alpha \).

The above-described radar directional antenna according to the invention permits the performing of the above-mentioned additional motions, namely scanning motion and searching motion, selectively and independently of each other. By circular motion of the primary radiator 1 about the main axis 12 with the reflector 2 at standstill a directional beam which is produced with respect to the symmetry axis of the reflector and which rotates about this axis. By imparting tilting motion to the reflector 2 with the primary radiator 1 at standstill, a directional beam is issued which moves up and downwardly. For each of the two additional motions of the directed beam only part of the antenna system is placed in motion so that the required driving means can be given relatively small weight and size. Of particular advantage in this respect is the fact that during searching motion of the beam the reflector, for a given deflecting angle of the beam, need be tilted only one-half the amount of this angle. It is understood that reflector 2 has a sufficiently wide aperture at 201 to give freedom of relative movement to conductor 13 over the angle 2\( \beta \).

Fig. 2 departs, in a few details, from Fig. 1. In Fig. 1 support 200 of the reflector 2 is pivotally mounted, by means of universal joint member 141 affixed thereto, about pivoting element 140 which is attached to the extension of the wave-guide structure 13. Whereas in Fig. 2 the reflector supports 200' are pivotally mounted on axes 50 which are mounted in the sides of the block or housing structure 3°. The tilting movement of the reflector 2 of Fig. 2 is obtained by the same type of mechanical resonance drive that is employed in Fig. 1. For example, at a point on reflector 2 mid-way between the two supporting arms 200', and below the horizontal plane through axes 50, and also below the wave-guide and radiator driving means, a driving compression spring, not illustrated, is attached, with its lower end attached to motor 21 and crank wheel, not illustrated, like that shown in Fig. 1, and are provided to oscillate the reflector 2 about pivots 50. Two springs, not illustrated, which are similar to springs 23 and 24, serve to bias the reflector, and its axis of symmetry, toward the rest or median position. These two springs are attached at the horizontal extension of the 141, and, at the other end, to the reflector 2. One, for example, is attached at the point of attachment of the driving spring, the other being attached at a point on the reflector which is below the pivots 50.

Elements in Fig. 1 corresponding to those of Fig. 1 are correspondingly numbered. The primary radiator 1 of Fig. 2 is energized through a wave-guide system composed of a stationary portion and a movable portion. The movable portion consists of a straight tubular waveguide conductor 13 whose longitudinal axis is indicated at 17, and of a part 131 coaxially fixed thereon having a conical stem 132 upon the free end of which radiating element 1 is mounted. The other end of conductor 13 passes freely through apical aperture 201 in the reflector 2, and through boss 300, which is fixed upon wall 301, and then passes into the driving block 3°. Fixedly and coaxially attached to the inner end of conductor 13 is a hollow coupling sleeve 302, to which is fixedly and coaxially attached a turning arm 303 carrying a balancing mass 304. On the free end of the latter is a universal ball pivot element 130 which is carried in an off-center socket in eccentric 15°. The latter is rotated about the axis of symmetry 12 of the reflector 2 by motor 16 acting through gears 161 and 162.

The movable coupling sleeve 302, together with the stationary portion 305 of the waveguide system presents the well-known waveguide-antenna form. The movable portion is the choke-coupling type and consists of circular flange 306 and ring 307, both terminating the hollow cavity 308. Circular flange 306 does not contact the hollow ring 307 electro-conductively. These parts are sep-
rated by a small circular gap 309, which provides a passage to permit gas pressure in the sealed house 3 to be applied to the hollow interior of conductor elements 13, 131, 132 as described in a pending application Serial No. 608,742 filed on Sept. 10, 1956 by L. Reinhard and H. Klausen. A ring gasket 40 seals the wall 301 to the movable coupling sleeve 302. The latter is journaled in the wall 301 by a plain joint, the joint comprises outer ring 44 which is fixed within an annular flange seat 310 on wall 301, and an inner ring 45 fixedly set upon the coupling sleeve 302. There are two pairs of pivot pins 46, one pair being shown. Each pair has its axis perpendicular to that of the other pair, thus providing two diametrically opposite pivots, one pair being mounted on the outer ring 44, the other pair on the inner ring 45. A movable ring 47 located between rings 44 and 45 carries and articulates four ball bearing rollers 48, two being shown. The inner races of the ball bearing rollers are seated upon respective pivot pins.

In the preferred operation the motor 21 (Fig. 1) turns crank 20 to reciprocate spring 19 at the natural frequency of the entire oscillatory system of the reflector.

Although all four possible displacements of the antenna can be carried out simultaneously, the simultaneous tilting of housing 3, and its turning, together with the described movements of the primary radiator and the reflector, has no practical advantage, for the instant purposes. For this reason, the above description refers to the rest position of the parabolic reflector, the preferred operation being with the pivot of the reflector at rest.

The significance of the frequency range of 3 to 5 cycles per second of the resonance drive is as follows: Antenna motion frequencies below 3 c.p.s. no resonance drive is obtained. A simple drive positively or constrictedly drives the antenna is sufficient, because the forces of acceleration can be kept relatively small. The advantages of the resonance drive make themselves felt, relative to "rigid" or constrained drives, only, or principally, when the antenna-motion frequency exceeds 3 c.p.s. The desire to have the searching movement of the antenna occur as rapidly as possible is, on the other hand, limited by the fact that a satisfactory echo pulse or tip can be produced on the radar screen only if the target is "illuminated" sufficiently long by the radar beam. Consequently the lateral velocity of the laterally displaced directional radar beam must be obtained at impulse energy, a given frequency of the succession of pulses, and a given width of the directional beam, and for given sizes of the target, not exceed a certain limit value. In view of these limitations, in radar devices of the type described in the application, the largest frequency of searching movement permissible in the most favorable case is approximately 5 c.p.s.

It will be understood by those skilled in the art, upon a study of this disclosure, that, with respect to constructional devices, the invention permits of a great variety of modifications and may be embodied in devices other than the one particularly illustrated and described, without departing from the essential features of the invention, and within the scope of the claims annexed hereto.

1. A radar directional antenna apparatus comprising a mechanical system, a radar-beam reflector forming part of the system, the reflector having an apertured apex, a focal point, and an axis of symmetry passing through the apex and focal point, means for oscillating the reflector about a joint behind the reflector, the oscillating being such that the said axis moves upwardly or downwardly in a plane, a wave guide conductor which passes through the apertured apex, a primary radiator mounted upon the forward end of the conductor, pivot means for the conductor which is behind the reflector, independent means for moving the conductor on its pivot to move the radiator about the focal point of the reflector independently of the said oscillation of the reflector, pivot support structure for said system, and means to turn the support structure about two perpendicular axes.

2. A radar directional antenna system comprising a first supporting structure, first pivot means for the said structure, second pivot means for moving the reflector about the axis of the first pivot means to provide a generally horizontal traverse, a second supporting structure pivoted to the first supporting structure on second pivot means for upward and downward movement about an axis transverse to the pivot axis of the first supporting structure, second drive means to move the support structure about the transverse axis, third pivot means carried by the second supporting structure, a wave guide conductor pivotally mounted by the third pivot means, a primary radiator mounted on the front portion of the wave guide conductor, third drive means to move said conductor on said third pivot means in a direction generating a conoidal surface, whereby the primary radiator circles about an axis, a symmetrical reflector independently pivotally mounted upon the second structure for upward and downward tilting movement, the said rotation of the primary radiator effecting substantially a circling about the focal region of the reflector when the latter is not oscillating, fourth drive means for tilting the reflector upwardly and downwardly about its pivot, each of the four drive means being independently operable, whereby the circling of the primary radiator is performable, but not exclusively so, with the reflector not oscillating, and the upward and downward tilting of the reflector is performable, but not exclusively so, with the primary radiator not circling.

3. A radar directional antenna system comprising a first supporting structure, first pivot means for the said structure, first drive means to turn said structure about the axis of the first pivot means to provide a generally horizontal traverse, a second supporting structure pivoted to the first supporting structure on second pivot means for upward and downward movement about an axis transverse to the pivot axis of the first supporting structure, second drive means to move the second supporting structure about the transverse axis, third pivot means carried by the second supporting structure, a wave guide conductor pivotally mounted by the third pivot means, a primary radiator mounted on the front portion of the wave guide conductor, third drive means to move said conductor on said third pivot means, a primary radiator mounted on the front portion of the wave guide conductor, third drive means to move said conductor on said third pivot means in a direction generating a conoidal surface, whereby the primary radiator circles about an axis, a symmetrical reflector independently pivotally mounted upon the second structure for upward and downward tilting movement, the said rotation of the primary radiator effecting substantially a circling about the focal region of the reflector when the latter is not oscillating, fourth drive means for tilting the reflector upwardly and downwardly about its pivot, each of the four drive means being independently operable, whereby the circling of the primary radiator is performable, but not exclusively so, with the reflector not oscillating, and the upward and downward tilting of the reflector is performable, but not exclusively so, with the primary radiator not circling, the symmetry axis of the reflector being coincident with the axis of said circling of the primary radiator.

4. A radar directional antenna system comprising a first supporting structure, pivot means for the said structure, first drive means to turn said structure about the axis of the pivot means to provide a generally horizontal traverse, a second supporting structure pivotally mounted to the first
supporting structure on second pivot means for upward and downward movement about an axis transverse to the pivot axis of the first supporting structure, second drive means to so move the second supporting structure about the transverse axis of universal pivot means carried by the second supporting structure, a wave guide conductor pivotally mounted by said universal pivot means, a primary reflector mounted on the front portion of the wave guide conductor, third drive means to move said conductor on said universal pivot means in a direction generating a generally conoidal surface, whereby the primary radial circles about an axis, a symmetrical reflector independently journalled by said universal pivot means, the said circular motion of the primary radiator being substantially about the focal region of the reflector, fourth drive means for tilting the reflector upwardly and downwardly about said universal pivot means, each of the four drive means being independently operable.

5. A radar directional antenna system comprising a symmetrical reflector and a primary radiator mounted for circular motion about an axis, the circular motion being about the focal point of the reflector in a plane perpendicular to the axis of symmetry of the reflector, the reflector being mounted for reciprocating movement about an axis perpendicular to its axis of symmetry, the axis of symmetry of the reflector being coincident with the axis of said circular motion of the primary radiator when the reflector is not carrying out said reciprocating movement, the said circular motion of the primary radiator with the reflector at standstill performing a scanning movement, the said reciprocating movement of the reflector being operable with the primary radiator at standstill to carry out a searching movement of the directional beam, and means for turning the primary radiator and the reflector together about coordinates electrically.

6. A radar directional antenna system comprising a first supporting structure, first pivot means for the said structure, first drive means to turn said structure about the axis of the first pivot means to provide a generally horizontal traverse, a second supporting structure pivoted to the first supporting structure on second pivot means for upward and downward movement about an axis transverse to the pivot axis of the first supporting structure, second drive means to so move the second supporting structure about the transverse axis, third pivot means carried by the second supporting structure, a wave guide conductor pivotally mounted by the third pivot means, a primary radiator mounted on the front portion of the wave guide conductor, third drive means to move said conductor on said third pivot means in a direction generating a conoidal surface, whereby the primary radial circles about an axis, a symmetrical reflector independently pivoted on the second structure for upward and downward tilting movement, the said rotation of the primary radiator effecting substantially a circling about the focal region of the reflector when the latter is not oscillating, fourth drive means for tilting the reflector upwardly and downwardly about its pivot, each of the four drive means being independently operable, whereby the circling of the primary radiator is performable, but not exclusively so, with the reflector not oscillating, and the upward and downward tilting of the reflector is performable, but not exclusively so, with the primary radiator not circling, the symmetry axis of the reflector being coincident with the axis of said circling of the primary radiator when the reflector is in median position with respect to said tilting movement thereof.

7. A radar directional antenna apparatus comprising a mechanical system, said system including structure means mounted for tilting about a mainly horizontally directed axis, a radar-beam reflector forming part of the system, the reflector having an apertured apex, a focal point, and an axis of symmetry passing through the apex and focal point, means for pivotally moving the reflector upon the said structure means and power-driven means for automatically oscillating the reflector about a point behind the reflector independently of and without moving the said structure means, the oscillation being such that the said axis moves in a plane, a wave guide conductor which passes through the aperture apex, a primary radiator mounted upon the forward end portion of the conductor, universal pivot means for mounting the conductor on the structure means, the pivot means being behind the reflector, independent means for moving the conductor on said pivot means to effect the said motion, the focal point of the reflector, whereby the primary radiator can be so moved while the reflector is not subjected to said oscillation.

8. A radar directional antenna apparatus comprising a mechanical system, said system including structure means mounted for tilting about a mainly horizontally directed axis, a radar-beam reflector forming part of the system, the reflector having an apertured apex, a focal point, and an axis of symmetry passing through the apex and the focal point, means for pivotally mounting the reflector upon the said structure means, the oscillation being such that said axis moves upwardly-downwardly in a plane, an extended wave guide system, the symmetry axis of the reflector being coincident with the said axis of symmetry, a primary radiator mounted upon the forward end portion of the conductor, universal pivot means for mounting the conductor on the structure means, which pivot means is behind the reflector, independent means for moving the conductor on its universal pivot, power-driven means for automatically oscillating the reflector independently of and without moving said structure means, the oscillation being such that the said axis is displaced upwardly-downwardly, a wave guide conductor, a primary radiator mounted upon the conductor, means operable independently of the reflector oscillating means for moving the conductor to cause the radiator to circle about the focal point of the reflector when the reflector is not oscillating, the oscillation of the reflector being performable with the primary radiator at standstill and also with the primary radiator in motion.

9. A radar directional antenna apparatus comprising a mechanical system, said system including structure means mounted for tilting about a mainly horizontally directed axis, a radar-beam reflector forming part of the system, a primary radiator having a focal point and an axis of symmetry passing through the focal point, means for pivotally mounting the reflector upon the said structure and for automatically oscillating the reflector independently of and without moving said structure, the oscillation being such that the said axis is displaced upwardly-downwardly, a wave guide conductor, a universal pivot means for the conductor, a primary radiator mounted upon the conductor, power-driven means operable independently of the reflector oscillating means which passes through the conductor on its universal pivot means to cause the radiator to circle about the focal point of the reflector when the reflector is not oscillating, the said circling of the radiator being at least about 1000 revolutions per minute, the oscillation of the reflector being performable with the primary radiator at standstill and also with the primary radiator in motion.

10. A radar directional antenna apparatus comprising a mechanical system, said system including structure means mounted for tilting about a mainly horizontally directed axis, a radar-beam reflector forming part of the system, the
reflector having a focal point and an axis of symmetry passing through the focal point, means for pivotally mounting the reflector upon the said structure and for automatically oscillating the reflector independently of and without moving said structure means, the oscillation being such that the said axis is displaced upwardly-downwardly, a wave guide conductor, universal pivot means for mounting the conductor on said structure means, a primary radiator mounted upon the conductor, power-driven means operable independently of the reflector oscillating means for moving the conductor on the universal pivot means to cause the radiator to circle about the focal point of the reflector and the means for oscillating the reflector comprising a resilient mechanical resonance drive and reflector constraint system, the drive being operative to oscillate the system at its natural mechanical frequency, the oscillation of the reflector being performable with the primary radiator at standstill and also with the primary radiator in motion.

12. A radar directional antenna apparatus comprising a mechanical system, said system including a structure mounted for tilting about a mainly horizontal axis, a radar-beam reflector forming part of the system, the reflector having a focal point and an axis of symmetry passing through the focal point, means for pivotally mounting the reflector upon the said structure and for automatically oscillating the reflector independently of and without moving said structure, the oscillation being such that the said axis is displaced upwardly-downwardly, a wave guide conductor, universal pivot means for the conductor, a primary radiator mounted upon the conductor, means operable independently of the reflector oscillating means for moving the conductor on its universal pivot to cause the radiator to circle about the focal point of the reflector when the reflector is not oscillating, the means for oscillating the reflector comprising a resilient mechanical resonance drive and reflector constraint system, the drive being operative to oscillate the system at its natural mechanical frequency, the mechanical resonance drive and reflector system comprising three springs operatively connected to the reflector, one being a driving spring, mechanical means connected to the driving spring to alternately place it in compression and tension, and two being springs which restore the reflector to a neutral position, the oscillation of the reflector being performable with the primary radiator at standstill and also with the primary radiator in motion.

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