

Oct. 4, 1966

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ANTENNA BEAM STABILIZER

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2 Sheets-Sheet 1

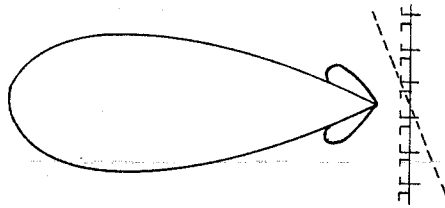


FIG. 1

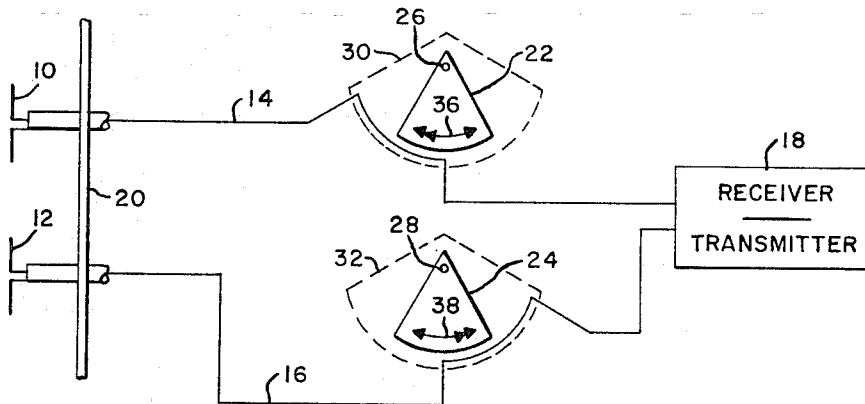


FIG. 2

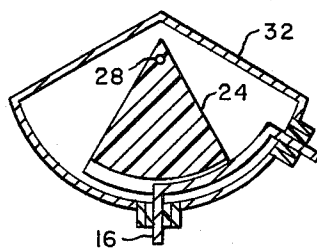


FIG. 3a

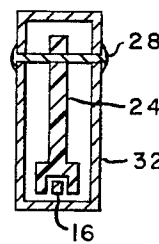


FIG. 3b

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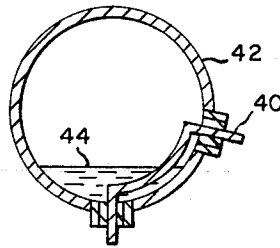


FIG. 4

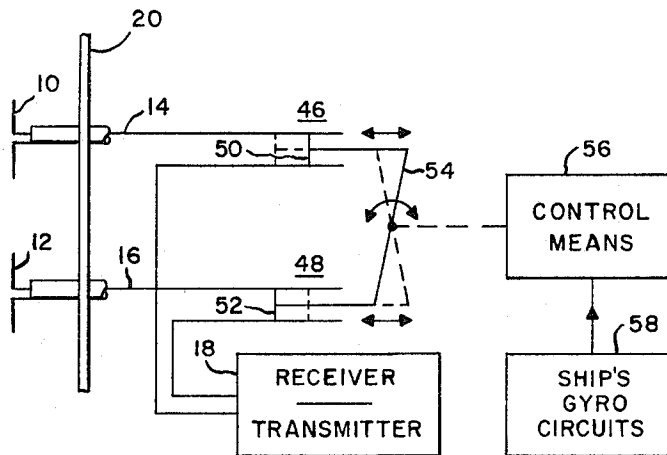


FIG. 5

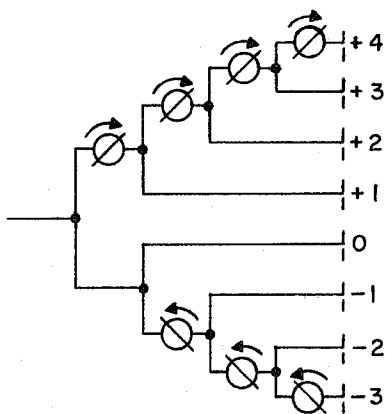


FIG. 6

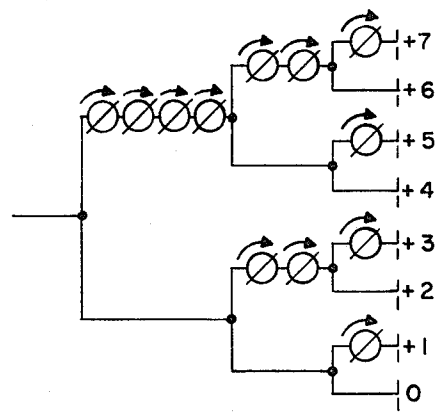


FIG. 7

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5 Claims (Cl. 343-100)

This invention relates to apparatus for stabilizing the beam produced by an antenna. As a specific example, the invention is useful for stabilizing a beam produced by an array antenna carried by a ship which the ocean causes to pitch and roll.

The principles of operation and design of array antennas are well known. As an example of such an antenna, let us consider a large number of similarly oriented (i.e., all vertical, for example) dipoles, arranged in a vertical planar array so that the dipoles form vertical and horizontal rows. The dipoles can be fed by a system of transmission lines, such as waveguides, coaxial cables, etc. limiting our consideration to a single vertical row of these dipoles, such as shown in FIG. 1, it is well known that electromagnetic waves can be radiated with a substantially straight vertical wavefront by proper phasing of signals supplied to the dipoles, so that a beam having the vertical cross section shown in FIG. 1 is produced. It is also known that the resulting beam can be caused to scan up or down by varying the relative phase of signals supplied to the dipoles.

In the case of antennas mounted on movable vehicles, such as ships at sea, pitch and roll of the vehicle give rise to problems of antenna beam stabilization. An antenna can be mounted to the deck of a ship and arranged to radiate a beam at any desired fixed angle relative to the plane of the deck. However, if the ship rolls so that the array of dipoles is tilted to the dotted position shown in FIG. 1, the beam will be directed down toward the surface of the water instead of in the desired direction indicated by the beam profile of FIG. 1. This result can be avoided by stabilizing the beam so that, even though the array of dipoles is tilted to the dotted position of FIG. 1, the beam still retains substantially its original orientation as indicated by the beam contour of FIG. 1.

Objects of this invention are to provide new and improved apparatus for stabilizing antenna beams and to provide such apparatus which is not prohibitively expensive or overly complicated.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawings:

FIG. 1 shows an antenna comprising a vertical row of dipoles and a vertical cross section of an antenna beam produced by such antenna;

FIG. 2 shows one embodiment of apparatus for stabilizing an antenna beam constructed in accordance with the invention;

FIGS. 3a and 3b are two sectional views showing a specific form of apparatus constructed in accordance with the invention;

FIG. 4 shows an alternative embodiment of apparatus constructed in accordance with the invention;

FIG. 5 shows a further embodiment of apparatus constructed in accordance with the invention; and

FIGS. 6 and 7 show applications of apparatus constructed in accordance with the invention to antennas with larger numbers of radiating elements.

Referring now to FIG. 2 there is shown one embodiment of apparatus for stabilizing an antenna beam con-

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structed in accordance with the invention. FIG. 2 includes an array system subject to tilting, utilizing a plurality of radiating elements, shown as dipoles 10 and 12, fed by transmission lines 14 and 16 which also connect to receiver-transmitter 18. As shown, the antenna also includes a planar reflector 20 spaced from dipoles 10 and 12. In the FIG. 2 embodiment, apparatus for stabilizing the antenna beam comprises means for producing adjustable phase shifts, shown as solid dielectric pendulum means 22 and 24, and second means shown as axles 26 and 28 and enclosures 30 and 32.

In operation, dipoles 10 and 12 can be fed signals with proper relative phase so as to produce a beam of predetermined orientation (that is to say, a beam whose axis intersects reflector 20 at a particular angle). Dielectric pendulums 22 and 24 are suspended from axles 26 and 28, respectively, so that they can move in the direction indicated by arrows 36 and 38 in a plane perpendicular to reflector 20. Axles 26 and 28 are supported by enclosures 30 and 32 which are mounted so as to be subjected to the same tilting effects as dipoles 10 and 12, lines 14 and 16 and reflector 20. Portions of transmission lines 14 and 16 pass through enclosures 30 and 32, respectively, and inside the enclosures, the transmission lines have arcuate portions closely conforming to the arc which will be traced by the bottom portion of pendulums 22 and 24.

The arrangement of FIG. 2 is such that the pendulums 22 and 24 intersect the field patterns of the arcuate sections of lines 14 and 16. It is well known that placing a dielectric in the field pattern of a transmission line in this manner varies the wave velocity characteristics of the line portions involved, with the result that phase shifts are produced in signals propagating along the lines. It is also known that the magnitude of such phase shift will depend on the quantity and spacing of the dielectric involved.

When the antenna is in the untilted position, as shown in FIG. 2, each of lines 14 and 16 is effected by approximately one-half of the respective associated pendulum. The result is to introduce identical phase shifts in lines 14 and 16. Let us now assume that the antenna system is caused to tilt so that reflector 20 experiences clock-wise rotation. As this happens, the force of gravity acting on pendulums 22 and 24 will cause the pendulums to remain in substantially fixed position relative to the earth. The result is that as the antenna system tilts, the pendulums swing about axles 26 and 28, thereby producing changes in the position of the pendulums relative to the arcuate portions of lines 14 and 16. In the case where the antenna system undergoes clock-wise rotation, the position of pendulum 22 changes relative to line 14 so that a smaller portion of pendulum 22 intersects the field pattern of line 14 and the position of pendulum 24 changes relative to line 16 so that a greater portion of pendulum 24 intersects field pattern of line 16. The decrease in the quantity of dielectric affecting line 14 results in a decreased phase shift in line 14. At the same time, the increase in the quantity of dielectric affecting line 16 results in an increased phase shift in line 16. Considering the effect on the antenna beam, as the antenna tilts clock-wise the beam would tend to be directed toward the sky. However, as just described, a relative phase shift is introduced as a result of the pendulum displacement so that the beam scans downward relative to the reflector 20, and is substantially stabilized relative to the earth. By proper choice of configuration, the beam can be stabilized for a wide range of angles of tilt.

In FIG. 2, receiver-transmitter 18 can be any of many different forms of prior art circuitry used in conjunction with array antennas. The operation of receiver-transmitter 18 is almost entirely independent of the operation of the

portion of the FIG. 2 arrangement constructed in accordance with the present invention. In a radar system carried aboard a ship for example, the entire arrangement of FIG. 2 (with or without unit 18) could be mounted on a rotatable platform. Then, as the platform was rotated, the present invention would act to stabilize the beam against tilting caused by various combinations of roll and pitch of the ship.

FIGS. 3a and 3b are sectional views showing a coaxial line 16 whose arcuate center conductor passes through metal enclosure 32. Pendulum 24, constructed of a solid dielectric having a high dielectric constant, is suspended within enclosure 32 by axle member 28. As shown, pendulum 24 has a U-shaped channel formed at the bottom so that the dielectric material closely encloses the center conductor of line 16 on three sides so as to place a large quantity of dielectric material in the field pattern of the conductor. FIGS. 3a and 3b show one example of how apparatus may be constructed in accordance with the invention. In other applications it may be desirable to provide means for damping the movement of the pendulum to prevent oscillation as the pendulum moves.

FIG. 4 shows another example of apparatus constructed in accordance with the invention. FIG. 4 is a sectional view showing a coaxial line 40 whose center conductor passes through an enclosure 42 containing a liquid dielectric material 44. Operation of the FIG. 4 arrangement is similar to that previously described except that, instead of a swinging pendulum, the liquid 44 changes position as enclosure 42 is tilted.

Referring now to FIG. 5, there is shown an alternative embodiment constructed in accordance with the invention. Components of the FIG. 5 embodiment which are similar to components of the FIG. 2 embodiment bear identical reference numerals. The main difference is in the means utilized for producing adjustable phase shifts.

Many ocean-going ships already include gyroscope circuits arranged to provide outputs which are functions of roll and pitch of the ship for use in the stabilization of ship-mounted guns and for other purposes. The FIG. 5 embodiment utilizes such available outputs for stabilizing the beam produced by an antenna.

In FIG. 5 units 46 and 48 are adjustable phase shifters shown as being of the well-known "line stretcher" type wherein the length of active transmission line is changed by physical movement of a moveable shorting member. Thus, adjustable phase shifters 46 and 48 each comprise essentially two parallel sections of transmission line which are interconnected by moveable shorting members 50 and 52, respectively.

In the illustrated arrangement, the moveable shorting members 50 and 52 are mechanically coupled to the opposite ends of an arm 54, and arm 54 is arranged to permit rotation about a central axis. Arm 54 is caused to rotate about its central axis by control means 56 which responds to pitch and roll information supplied from the ship's gyro circuit 58. Control means 56 may be any suitable means for converting information supplied by the ship's gyro circuits into mechanical movement of arm 54. It will be seen that the arrangement is such that tilting of the ship results in rotation of arm 54 which causes shorting member 50 to move in one direction, while shorting member 52 moves in the opposite direction. The result is that an increased phase shift is produced in line 16 as a result of an increase in the active length of line 16, while at the same time a decreased phase shift is produced in line 14 as a result of the decrease in the active length of line 14 (or vice-versa).

This is the same result produced by the tilting of the FIG. 2 arrangement and the over-all effect will also be the same—the antenna beam will be caused to scan. As with the FIG. 2 arrangement, by proper choice of parameters this change in beam direction can be made to correspond to the physical tilt of the antenna system, so

that the antenna beam remains substantially stabilized with respect to the earth.

This method of stabilizing the antenna beam has several practical advantages over stabilization achieved by mounting the entire antenna on a stabilized platform controlled by information from the ship's gyro circuits, as in certain prior art applications. The mass involved in moving only the phase shift means as compared to moving the entire antenna system is much smaller, thereby inherently involving less inertia and less power consumption to accomplish control.

FIGS. 6 and 7 show schematically how the invention may be applied to arrays incorporating vertical rows of many radiating elements. FIGS. 6 and 7 each show a row of eight radiating elements in the form of dipoles. Referring back to FIG. 2, it will be remembered that for any particular direction of tilt, one of the pendulums 22 and 24 produces an increased phase shift while the other produces a decreased phase shift. This can be indicated by letting the double-headed ends of arrows 36 and 38 in FIG. 2 represent the relative rotation required to produce an increase in phase shift; it will be seen that the double-arrow heads indicate opposite directions of relative rotation to produce increased phase shift. In FIGS. 6 and 7 there are included groups of circles each having an associated arrow. Each circle represents a device such as that shown in FIGS. 3a and 3b (or the equivalent) and the arrows correspond to the double-arrow heads of FIG. 2 to indicate the direction of increased phase shift.

For purposes of explanation, it will be assumed that for a given angle of tilt, apparatus such as shown in FIG. 3a produces an arbitrary unit of phase shift (i.e. a phase shift of +1 or -1 according to the direction of rotation). To the right of the dipoles in FIGS. 6 and 7 are numbers whose magnitude and sign indicate the changes in relative phase of signals supplied to the dipole in the presence of a given angle of tilt. These numbers indicate that the given angle of tilt causes a phase shift of one unit between each pair of neighboring dipoles, so that there is a uniform variation in phase shift across the row of dipoles. As is well known, the uniform variation of phase shift across a row of radiating elements is effective to change the direction of the beam which will be radiated. By utilizing apparatus constructed in accordance with the present invention, it can be arranged that the variation in phase shift across the aperture of the antenna is related to the angle of tilt so that even though the antenna tilts, the antenna beam remains substantially stabilized.

The FIG. 6 arrangement will be termed a taper-tree type of arrangement. As shown, beam stabilization using the FIG. 6 type of arrangement requires seven devices constructed in accordance with the invention for a row of eight radiating elements. The FIG. 7 arrangement will be termed a binary-tree type of arrangement. As shown, beam stabilization using the FIG. 7 type of arrangement requires twelve similar devices constructed in accordance with the invention for a row of eight radiating elements. Alternatively, the FIG. 7 arrangement could be constructed using phase shifters which provide different rates of change of phase shift. Thus, in FIG. 7 a series set of two phase shifters could be replaced by a single phase shifter which provides a rate of change of phase shift double that of one of the original phase shifters. Similarly, the series set of four phase shifters in FIG. 7 could be replaced by a single phase shifter which, for a given change in tilt, provides a change in phase shift four times as great as the change provided by one of the original four phase shifters. In this way the number of phase shifters required for the FIG. 7 approach would be reduced to seven. It will be obvious that the rate of change of phase shift provided by a given phase shifter is dependent on its design and that by

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proper design, phase shifters with desired characteristics can be provided.

The types of arrangements shown in FIGS. 6 and 7, or variations thereof, can be adapted for use with any desired number of radiating elements. In the preceding discussion of FIGS. 6 and 7 particular reference has been made to FIG. 2 and FIGS. 3a and 3b, it will be obvious however, that apparatus of the type shown in FIG. 5 is equally applicable to systems of the types shown in FIGS. 6 and 7.

It will be understood that although portions of the preceding description have used terminology relating to the radiation of signals, the concepts involved apply equally to radiation and reception of signals. Also, the term "radiating element" covers horns and other devices, as well as dipoles such as included in the illustrated embodiments.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention and it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. In an array antenna system subject to tilting, which utilizes a plurality of radiating elements fed by a plurality of transmission lines to radiate a beam, apparatus for stabilizing the antenna beam comprising:
 - dielectric means for producing phase shifts by varying the wave velocity characteristics of portions of said transmission lines;
 - and second means for maintaining said dielectric means in substantially fixed position so that changes in position of said transmission lines due to tilting of the antenna system result in changes in the relative position of said dielectric means and said transmission lines;
 - the apparatus being so constructed and arranged that said changes in relative position produce phase shifts in said transmission lines which are effective to substantially stabilize the antenna beam in spite of tilting of the antenna system.
2. In an array antenna system subject to tilting, which utilizes a plurality of radiating elements fed by a plurality of transmission lines to radiate a beam, apparatus for stabilizing the antenna beam comprising:
 - dielectric pendulum means for producing phase shifts by varying the wave velocity characteristics of portions of said transmission lines;

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and second means for supporting said pendulum means in substantially fixed position so that the pendulum means intersects the field pattern of portions of said transmission lines and changes in position of said transmission lines due to tilting of the antenna system result in changes in the relative position of said pendulum means and said transmission lines;

the apparatus being so constructed and arranged that said changes in relative position produce phase shifts in said transmission lines which are effective to substantially stabilize the antenna beam in spite of tilting of the antenna system.

3. Apparatus in accordance with claim 2, wherein the second means comprise a container and the dielectric pendulum means comprises a dielectric liquid constrained in said container.

4. Apparatus in accordance with claim 2, wherein the dielectric pendulum means comprises a slab of solid dielectric material;

said second means comprises an axle about which the pendulum can swing and said axle is positioned on a horizontal line which is perpendicular to the beam direction;

and the apparatus is constructed and arranged so that the force of gravity aids in maintaining the fixed position of the pendulum means.

5. In an array antenna system subject to tilting, which utilizes a plurality of radiating fed by a plurality of transmission lines to radiate a beam, apparatus for stabilizing the antenna beam comprising:

first means for producing adjustable phase shifts in desired ones of said transmission lines by the physical movement of electrical shorting members in portions of said transmission lines resulting in changes in the active lengths of said transmission lines;

and second means for controlling said first means in response to tilting of said antenna system so that the relative difference in phase of signals supplied to neighboring radiating elements is a function of the degree of tilt;

the apparatus being so constructed and arranged that the antenna beam is substantially stabilized in spite of tilting of the antenna system.

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