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ANTENNA NOTATION SYSTEM

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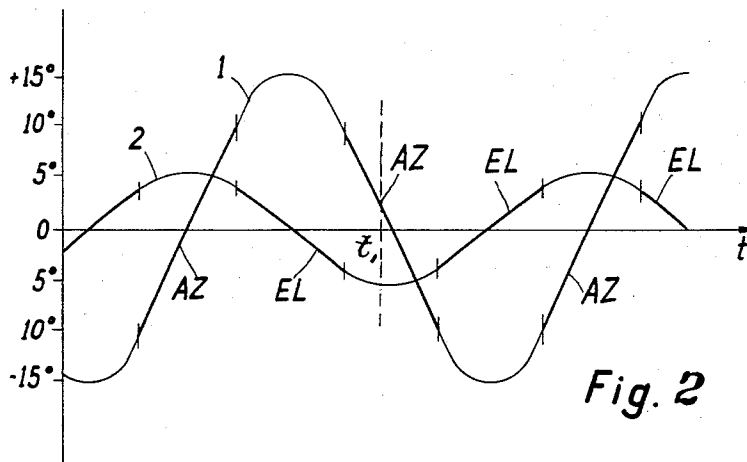


Fig. 2

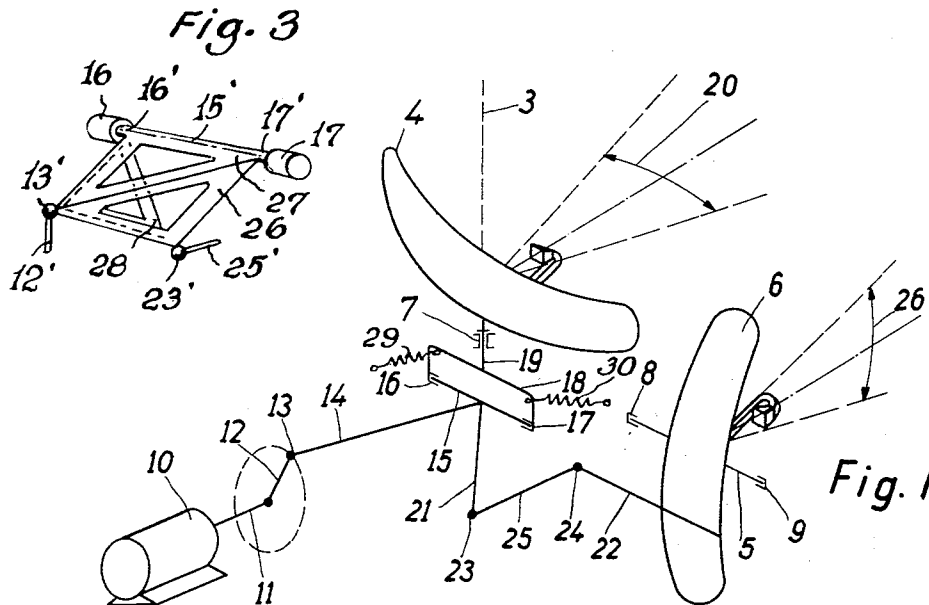


Fig. 1

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ANTENNA NUTATION SYSTEM

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The invention relates to an apparatus for the angular displacement in a system of two directional antennas scanning sectors in different planes.

Such antennas are employed in so-called ground-controlled-approach (GCA) devices used in supervising instrument landing of airplanes. In a radar device used in such a GCA system, two fan-shaped beams are employed, one of which is angularly displaced within a predetermined azimuth angular range, while the other beam is moved in a predetermined elevational angular range, perpendicular thereto.

The first of these two beams has a small lobe in the horizontal direction and has its maximum lobe in the vertical direction, while the second beam is small in the vertical direction having its maximum lobe in the horizontal direction. Each of these beams periodically scans a predetermined space sector in which the supervised airplane is to approach the airfield.

The targets within this sector are indicated on an indicating tube in azimuth and elevation together with indications of the approach path. Deviations of the targets or planes from their prescribed paths are transmitted via a radio link by the ground observer to the pilots, suitably via radio telephone. Thus, any pilot will be capable of steering his plane along the prescribed landing path.

It has been known to produce angular displacements of radar antennas emitting such beams, which displacements are out of phase by 90°. Mechanical gear means are often employed to obtain these movements. However, it has been observed that there is a detrimental vibrational interaction between the movements of the antennas, due to play in the gears, when one antenna is stopped to change the direction of its movement. Due to the 90° phase shift between the antennas, the second antenna is subjected to inertia-type vibrations just when it is operating at maximum scanning speed and while it is electrically activated in the transmitter-receiver system. Such vibrations could be avoided by using precision gearing, but the teeth of such gearing wear rather rapidly and then this gearing loses its precision. Furthermore, such gearing is expensive. The antennas in such known devices are displaced by means of a connecting rod driven by a rotating member. In this case, the angular displacements of the antennas take place non-uniformly, i.e., these antennas move faster through certain sectors. Thus, such antenna movement would not be defined by a simple sinusoidal curve. Theoretically, such movement could be rendered symmetrical, i.e., perfectly sinusoidal, by providing a connecting rod of infinite length.

It is a primary object of the present invention to provide an apparatus for angularly moving two directional antennas in phase-shifted relationship and in different scanning planes along sinusoidal displacement curves.

It is another object of the invention to establish a 90° phase shift, or any other desired phase shift, between two scanning directional antennas rotating in different direc-

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tions about different axes, while means are provided to overcome the difficulties outlined in the foregoing.

It is a further object of the invention to provide a new and improved drive means for two angularly moving radar antennas having a phase shift of 90° and moving in different directions about different axes.

It is a still further object of the invention to provide a rod movable about a predetermined control axis of a shaft being rotatably mounted in two aligned bearings which are secured to one of the antennas and capable of rotation therewith about an axis which is not parallel to said control axis, while a lever is connected to the first-mentioned arm and to the first-mentioned shaft. This lever, thus, experiences only such oscillatory component of the rod motion as takes place about the control axis. The movement of the lever is transmitted via joints and linkages to the second antenna. The free end of the rod is rotated, whereby the rod describes a cone having its apex where the rod joins the lever at the control shaft. Rod, lever and shaft may be replaced by a pyramidal structure.

Still further objects and the entire scope of applicability of the present invention will become apparent from the detailed description given hereinafter; it should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

In the drawing:

Figure 1 shows schematically an antenna system according to the present invention;

Figure 2 is a diagram explaining the mode of operation thereof, and

Figure 3 shows schematically in a perspective view a structural modification of the system illustrated in Figure 1.

In Figure 1, two directional antennas 4 and 6 are shown. The antenna 4 is mounted on a vertical shaft 19 and is periodically rotated about an axis 3. The shaft 19 is journaled in a bearing 7. The antenna 4 moves in the azimuth plane. The antenna 6 is secured on a horizontal shaft 5 which is rotatably mounted in bearings 8 and 9. A motor 10, for example an electric motor, is provided as a drive means for the two antennas. A shaft 11 of this motor 10 drives crank 12 positioned radially of the shaft 11. Thus, the free end of the crank 12 describes a circle 12' during rotation of the shaft 11, taking place in the direction of the arrow. The free end of the crank 12 carries a ball and socket joint 13 connected to one end of a rod 14. The opposite end of the rod 14 is secured to a shaft 15 which is rotatably mounted in bearings 16 and 17. Obviously, as the crank 12 rotates, the left end of the rod is displaced both in azimuth and in elevation. These bearings 16 and 17 are interconnected by means of a yoke 18 which is secured to the vertical shaft 19 supporting the antenna 4 and rocking it as the rod moves back and forth in azimuth displacements. The bearings 16 and 17 fix the elevational position of the shaft 15 and the center of rotation of the right end of the rod 14 about the axis of shaft 15. This axis serves as a control axis for the antenna 6, as will be explained below.

The phase angle between the rotation of control shaft 15 and the rotation of the axis 3 of the shaft 19 equals the phase angle between the two antennas 4 and 6, as will likewise be explained hereinafter. In the embodiment of the invention shown in Figure 1, this angle is 90°. Thus, the shaft 15 is perpendicular to the shaft 19, but it should be understood that other angles are possible. Upon rotation of the crank 12, the ball and socket joint 13 rotates about the circle 12', which means, that the rod

14 describes the outer surface of a cone having its apex at the joint of the rod 14 to shaft 15. This rotary movement of the rod 14 can be thought of as the combination of oscillations in both horizontal and vertical planes. The horizontal component thereof acts on the shaft 15 as an angular oscillation in a horizontal plane about the vertical axis 3. Due to the connection of shaft 15 with the shaft 19, by means of the bearings 16 and 17 and the yoke 18, the shaft 19 follows this horizontal oscillation and displaces the antenna 4 correspondingly. The horizontal angle through which the beam propagated from the antenna 4 is swept is designated by the reference numeral 20.

The vertical component of movement of the rod 14 does not act on the antenna 4, because the rod 14 is rotatable about the control axis of the shaft 15, due to the fact that the latter is rotatably supported in the bearings 16 and 17. The vertical motion of the rod 14 is used to rotate the antenna 6. For this purpose, a lever 21 is secured to the shaft 15 and is disposed radially thereof and perpendicularly to the rod 14 in case of a 90° phase shift. A horizontal bar 22 is attached to the antenna 6, said bar 22 not coinciding with the shaft 5, but being disposed parallel thereto. The bar 22 has such length that the two antennas 4 and 6 can be sufficiently spaced from one another. The free end of the lever 21 and the free end of the bar 22 are interconnected by means of a linkage 25 at ball and socket joints 23 and 24, respectively. This linkage 25 converts the oscillatory movements of the lever 21 into reciprocatory movements and, thus, into rocking motions of the antenna 6. The principal lobe of the beam emanating from the antenna 6 now oscillates through a vertical angle designated as 26.

As will become apparent from Figure 2, showing the mode of operation of the device illustrated in Figure 1, the movements of the antennas 4 and 6 differ by a phase angle of 90°. In Figure 2, the heavy-line portions of a curve 1 indicate the horizontal oscillatory displacement of the antenna 4, while the heavy-line portions of a curve 2 illustrate the vertical oscillatory displacement of the antenna 6. The abscissa in the diagram of Figure 2 represents time, while the relative angular displacements from dead center positions of the antennas are plotted on the ordinate. According to Figure 2, the angular displacement amplitude of the antenna 4 (see curve 1) is larger than the angular displacement amplitude of the antenna 6 (see curve 2). Thus, the antenna 4 moves through $\pm 15.5^\circ$ (maximum displacement) from its normal position, i.e., angle 20 of Figure 1 is 31° . The antenna 6 moves through $\pm 5.5^\circ$ (maximum displacement), i.e., the angle 26 in Figure 1 is 11° .

Considering the position of the crank 12 in Figure 1 and its cycle of rotation, it can be seen that this crank 12 is just approaching its uppermost position. Simultaneously, its horizontal oscillatory component is still to the right of center, but just about to go through zero towards the left side. This means that the vertical oscillatory deflection of the two members 14 and 21 about the axis of shaft 15 is approaching the upper maximum deflection where the antenna 6 will direct its beam into its maximum downward position. The antenna 4 follows the horizontal component of the rotating crank 12 and, thus, the antenna 4 is still directed somewhat towards the left with respect to its center position, but is approaching center. If it is assumed that the deflection of the antenna 4 toward the left (deflection of the crank 12 to the right) and the upward deflection of the antenna 6 (downward deflection of the crank 12) are positive displacements, the position of the device shown in Figure 1 is indicated in Figure 2 at the time $t=t_1$. The curve 1 approaches zero and the curve 2 approaches its negative maximum. Accordingly, there is a 90° phase shift between the two curves 1 and 2. This phase shift depends entirely on the angle between the axis of shaft 15 and the axis of shaft 19. If this angle were 45° , the two curves

describing the angular displacements of the antennas 4 and 6 would be in phase. It will be understood that any suitable phase shift between the two curves can be selected by giving the angle between the shaft 15 and shaft 19 a proper and predetermined value.

Usually, only one transmitter and one receiver are provided in a GCA radar system. Thus, transmitter and the receiver have to be connected to the two antennas alternatively. The time interval between these connections is designated in Figure 2 as follows:

The heavy-line AZ portions of the curve 1 are the intervals when the antenna 4 is connected to the receiver and the transmitter, while the heavy-line portions EL are the intervals when the antenna 6 is connected to the receiver and the transmitter.

Considering further details of the device of Figure 1, a very compact design can be obtained by including the rod 14, the shaft 15 and the lever 21 in a pyramidal structure. This structure actually may be designed in such a manner, that three triangular plates are interconnected, each having a substantially triangular cutout so as to save weight. Figure 3 shows such device, in which 15' is an axis which corresponds to the control axis of the shaft 15. A triangular plate 27 with a triangular cutout is provided with stub shafts 16' and 17' journaled in bearings 16 and 17, respectively. Thus, this plate 27 is rotatable about the axis 15' in the same manner as the rod 14 is rotatable about the axis of the shaft 15 in Figure 1. The free apex of the triangular plate 27 is connected to a ball and socket joint 13' which, in turn, is connected to a crank 12'. Two further triangular plates 26 and 28, also provided with cutouts, are connected to the two sides of the plate 27, which sides do not coincide with or are not parallel to the axis 15'. The common apex of the plates 26 and 28 carries a ball and socket joint 23' which, in turn, is connected to a linkage 25'.

The yoke 18, shown in Figure 1, may be eliminated by connecting the bearings 16 and 17 directly to the antenna 4. The ball and socket joints 13, 23 and 24 could be replaced by other bearings, such as swing bearings. In order to obtain a quiet and smooth operation of the device, the movable parts may be connected to a stationary base by means of springs damping the movements of the displaced inertias, such as springs 29 and 30 in Figure 1, connected between the sides of the yoke 18 and a suitable base or stationary housing.

I claim:

1. Apparatus for periodically oscillating with a pre-selected mutual phase relationship first and second directional antennas rotatably mounted on first and second shafts, respectively, said shafts lying along different axes in space, said apparatus comprising drive means rotating a crank; a control axis shaft disposed transversely of said first shaft; bearing means fixed to said first shaft in alignment with and rotatably supporting said control axis shaft so that rotation of the first shaft nutates the control axis shaft therearound; a rod fixed at one end to and extending radially from the control axis, the other end of the rod joining the crank whereby, during rotation of the drive means, the rod describes a cone and rotates the control axis shaft about its journals, and in different phase nutates said control axis shaft about the first shaft to oscillate the first antenna; a lever joined at one end to the control axis shaft and extending radially therefrom in non-parallel relation with respect to the rod, said lever oscillating whenever the control axis shaft is rotated; and linkage means disposed between the outer end of the lever and a point on the second antenna offset from the second shaft to oscillate the second antenna as the lever is oscillated.

2. In an apparatus as set forth in claim 1, said rod, said control shaft and said lever comprising a pyramidal rigid structure.

3. In an apparatus as set forth in claim 1, damping

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means connected between the element moving at least one of said shafts and a rigid mounting means supporting the shafts.

4. In an apparatus as set forth in claim 1, said first and second shafts being disposed in mutually perpendicular planes, and said control axis being perpendicular to the first shaft and intersecting the axis of the cone described by the rod at the apex thereof, and the first an-

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tenna being adjustable with respect to the orientation of the control axis shaft, whereby the mutual phase relationship between the two antennas can be varied.

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