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BEAM DEFLECTING CAGE FOR ANTENNAS

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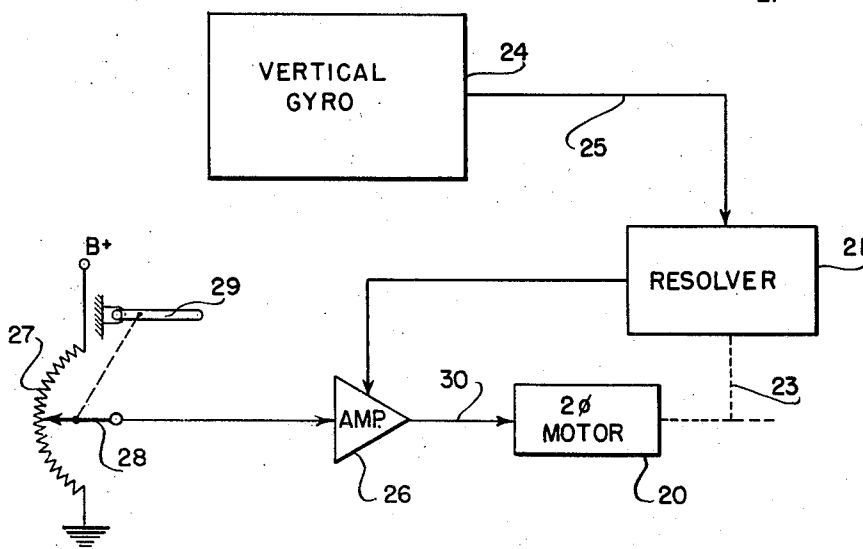
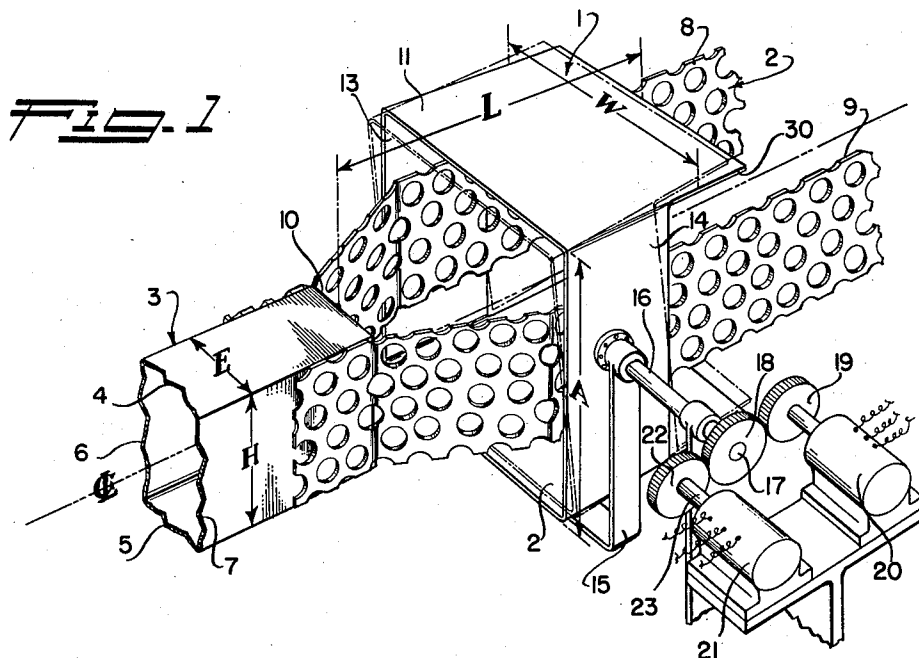


**FIG. 2**

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1

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## BEAM DEFLECTING CAGE FOR ANTENNAS

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6 Claims. (Cl. 343—767)

This invention relates in general to horn type waveguide antennas and more particularly to a beam deflecting cage for bending the directivity axis of such antennas and for suppressing side lobes.

Directional antennas of the horn type are well known in the art and because of their structural simplicity and small frontal area they are potentially more desirable for use in airborne radio echo detection and ranging devices and the like than are antennas of the parabolic reflector type. However, because of the difficulties in controlling the side lobe energy level and in moving the antenna directivity axis for performing a search function or stabilizing the energy beam, use of the horn type antenna has heretofore been limited.

An object of this invention is to provide an efficient beam deflecting cage for bending the main lobe or energy beam of a horn type waveguide antenna for performing a search function or for stabilizing the beam, or both, as required in airborne radar antenna applications.

Another object of this invention is to provide a beam deflecting cage which will also suppress the side lobes of a horn type waveguide antenna by re-directing the side lobe energy into the main beam energy thereby increasing the efficiency of the antenna and obviating the other inherent disadvantages of a high side lobe energy level.

Another object of this invention is to provide a beam deflecting cage for horn type waveguide antennas which will function efficiently over a reasonably wide frequency range and which will operate to reduce the standing wave ratio in the antenna.

Still another object of this invention is to provide a beam deflecting cage and horn antenna arrangement which has a low frontal area and which requires the movement of only the cage for controlling the aiming direction of the antenna. Since the cage is a relatively small mass, a simple, light-weight directional control mechanism is adequate, making the antenna arrangement highly suitable for airborne radar applications.

Further and other objects will become apparent from a reading of the following description especially when considered in combination with the accompanying drawing wherein like numerals refer to like parts.

In the drawing:

Figure 1 is a fragmentary perspective view of the beam deflecting cage and antenna arrangement of this invention; and

Figure 2 is a schematic block diagram of an actuator system for the beam deflecting cage of Figure 1.

Beam deflecting cage 1 is shown in the drawing with an open horn type waveguide antenna 2. The antenna includes a waveguide segment 3 having a pair of narrow walls 4 and 5 and a pair of wide walls 6 and 7 defining a passage generally rectangular in cross section and properly dimensioned to propagate electromagnetic energy in the desired mode. A pair of waveguide extension members 8 and 9 are secured to the energy exit end 10 of waveguide segment 3 to form a two-walled horn type antenna structure effectively extending the wide

2

walls 6 and 7 outwardly and forwardly of the hollow waveguide segment 3 to confine the energy in the electric or "E" plane direction while leaving the antenna open in the magnetic or "H" plane direction.

The detailed construction features of antenna 2 do not form an essential part of this invention and, accordingly, a description thereof will be omitted from this specification. Such details are covered however, in a co-pending application by Edward Lovick, Jr., entitled, "Traveling Wave Device" which bears Serial No. 484,115 and a filing date of January 26, 1955, now Patent No. 2,783,440. It should be understood that for purposes of this invention antenna 2 is illustrative only and that cage 1 as hereinafter described in detail may be used with any type of horn antenna.

Beam deflecting cage 1 includes a pair of energy deflecting plates 11 and 12 arranged generally parallel to each other and to the narrow walls of waveguide segment 3. Plates 11 and 12 may be made of any suitable material, however, a conductive material such as aluminum or brass appears to be the most effective. A pair of side braces or spacers 13 and 14 are integrally connected with the side edges of plates 11 and 12 to form a box-like cage structure maintaining plates 11 and 12 in the generally parallel relationship.

Cage 1 is rotatably supported by a suitable mounting bracket 15 located between aperture 10 of the antenna and the forward end of extension members 8 and 9 so that the cage is generally coaxially aligned with the antenna. As shown in Figure 1 deflecting plates 11 and 12 are generally parallel with the "E" plane of the antenna and are adapted to rotate about the axis of shaft 16 which is normal to the centerline of the antenna and to the "H" plane thereof whereby the rotation of the shaft will tilt cage 1 with respect to the antenna and as hereinafter described change the antenna aiming direction in the "H" plane. The outer end 17 of shaft 16 is provided with a pinion gear 18. A driving gear 19 operatively engaging pinion 18 is adapted to transmit the torque produced by a two-phase motor 20 to shaft 16 and thereby effect rotation of cage 1.

A resolver 21 which is driven by pinion 18 through gear 22 and shaft 23, provides an output proportional to the rotational position of the cage relative to an established zero reference position for controlling the actuation of motor 20. As shown in Figure 2, the output from a vertical gyro 24, which device is normally provided as a part of the navigation system in an aircraft, is applied to resolver 21 through lead 25 to provide a regulated resolver input voltage which will stabilize the aiming direction of the antenna and effectively isolate the same from the normal movements of the aircraft when in flight. The output of resolver 21 is applied to a feedback amplifier 26 and algebraically added to a controlled voltage obtained from a suitable source of electrical potential identified as B+ through a potentiometer 27. By simply moving potentiometer pickup arm 28 with the aid of lever 29 or other suitable means, the desired voltage may be applied to amplifier 26 for mixing with the resolver output voltage. The output 30 of feedback amplifier 26 is applied to the two-phase motor 20 to effect rotation thereof in either direction depending upon the magnitude and phase relationship between the voltage inputs to the feedback amplifier. Thus, by rotating pickup arm 28 on potentiometer 27, corresponding rotation of cage 1 about shaft 16 may be effected to change the aiming direction of the antenna for performing a search function or the like while maintaining antenna stabilization.

In order to obtain a substantially uniform illumination of aperture 10 in waveguide 3 for maximum antenna gain, the spacing between deflection plates 11 and 12 should be in the neighborhood of three times the wide

dimension of the aperture, though where space is critical the distance between the deflection plates may be decreased to approximately twice the wide dimension of the waveguide aperture without seriously affecting the antenna gain.

The width "W" of deflection plates 11 and 12 should be no less than the width of the horn at the location of the cage. The width may be made much greater however when desired, such as to serve more than one antenna, since the side braces or spacers 13 and 14 appear to have little or no effect on the electrical characteristics of the cage.

The effectiveness of beam deflection plates 11 and 12 in bending the energy beam and in suppressing side lobes is largely dependent upon the deflection plate dimension in the direction of energy propagation generally axially of the antenna and upon the dimension "L" which represents the distance of the leading edge 30 of the deflection plates from aperture 10 of the antenna. In general it may be stated that the dimension of the deflection plates in the direction axially of the antenna should be approximately equal to one wave length of the energy being propagated, but this design parameter is secondary to the "L" dimension requirements since the latter has considerably more effect on the antenna operating efficiency. Conventional microwave transmitting and receiving equipment is adapted to operate on the first order transverse electric (TE<sub>10</sub>) mode of the electromagnetic energy. The presence of higher order modes which are near the first order mode, will interfere with the operation of the equipment. Consequently, it is essential that at least the second, third and fourth higher order modes be suppressed. The even harmonic modes such as the second, fourth, etc. will be suppressed by virtue of the construction of the cage wherein deflection plates 11 and 12 are spaced equidistant on either side of the antenna centerline. However, the odd number higher order modes will be suppressed only if the dimensioned "L" is properly selected. In order to propagate energy in the first order transverse electric (TE<sub>10</sub>) mode and exclude the next odd number higher order mode, which is the TE<sub>30</sub> mode, the phase relationship between the two must be 180° apart at the leading edge 30 of plates 11 and 12.

This condition may be made to exist by selecting the distance "L" in accordance with the following expression:

$$\pi = (\beta_1 - \beta_3)L$$

where  $\pi$  represents the desired 180° phase relationship and where  $\beta_1$  and  $\beta_3$  represent the phase change per unit of length of the first and third order modes respectively at leading edge 30 of deflection plates 11 and 12 for a given spacing of the plates.

Quantitative values for  $\beta_1$  and  $\beta_3$  may be obtained from the following standard microwave theory expressions for the relationship between phase and wavelength:

$$\beta_1 = \frac{2\pi}{\lambda} \times \sqrt{1 - \left(\frac{\lambda}{2A}\right)^2} \quad (2)$$

$$\beta_3 = \frac{2\pi}{\lambda} \sqrt{1 - \left(\frac{3\lambda}{2A}\right)^2} \quad (3)$$

where  $\lambda$  represents the free space wave length for the energy being propagated; and "A" represents the spacing between deflection plates 11 and 12.

Knowing the free space wave length of the energy traveling through the antenna and the dimension "A" of the cage, a solution for  $\beta_1$  and  $\beta_3$  may be readily obtained from Equations 2 and 3. By inserting the values thus obtained into Equation 1 and solving for "L" the proper location of cage 1 may be established for suppressing the second odd harmonic (TE<sub>30</sub>) mode. The succeeding higher odd harmonic modes (TE<sub>50</sub>) etc., are low in power and far enough up the frequency scale from the TE<sub>10</sub> mode that even though present, they have substantially

no effect on the equipment associated with the antenna and therefore may be neglected.

The determination of the distance "L" between the aperture and the leading edge of deflection plates 11 and 12 provides, in essence, an analytical method of tuning the cage and antenna. This also may be done, of course, experimentally.

Cage 1 not only provides a means for tilting the aiming axis of the antenna in the "H" plane direction, but also effectively suppresses the side lobe energy level in both the "E" and "H" planes. By re-directing the "H" plane side lobe energy into the primary energy pattern, the side lobes in the "E" plane are thereby drawn into the main lobe pattern by an action which may be most clearly described as "suction-like." The net benefits obtained with the cage is to improve the over-all electrical characteristics of the horn type antenna and to provide a simple means for bending the energy beam so that it may possess all of the desirable features of the conventional parabolic reflector type antennas while remaining simpler in construction and lighter in weight with a very much smaller frontal area.

While a specific embodiment of the invention has been shown and described it is for purposes of illustration only and accordingly it should be understood that certain alterations, modifications and substitutions may be made to the instant disclosure without departing from the spirit and scope of the invention as defined by the appended claims.

I claim:

1. A directional antenna comprising, a generally rectangular waveguide for propagating electromagnetic energy in the desired mode, the wide walls of said waveguide extending beyond the narrow walls thereof and forming a flared horn physically confining the energy only in the electric plane, a pair of plates generally parallel to each other and to the narrow walls of the waveguide, said plates extending forwardly of the antenna aperture and spaced apart a distance greater than the wide dimension of the waveguide and substantially equi-distant on either side of the antenna centerline whereby side lobe energy will be re-directed into the primary radiation pattern, a frame supporting said plates for rotation about an axis generally normal to the antenna centerline and to the wide walls of the waveguide for tilting the antenna aiming axis, and drive means engaging said frame for controlling the rotational movement of said plates.

2. A directional antenna comprising, a generally rectangular waveguide for propagating electromagnetic energy in the desired mode, the wide walls of said waveguide extending beyond the narrow walls thereof and forming a flared horn physically confining the energy only in the electric plane, a pair of conductive plates generally parallel to each other and to the narrow walls of the waveguide, said plates extending forwardly of the antenna aperture and spaced electrically from the narrow walls of the waveguide on either side of the antenna centerline whereby side lobe energy will be re-directed into the primary radiation pattern, and frame means supporting said plates.

3. A microwave beam deflecting cage for horn antennas of the type having a rectangular waveguide segment formed by a pair of narrow walls and a pair of wide walls with the latter extending forwardly of the narrow walls to provide an open horn, comprising, a pair of plates generally parallel to each other and to the narrow walls of the waveguide, said plates extending forwardly of the antenna aperture and spaced apart a distance at least equal to twice the wide dimension of the waveguide and substantially equidistant on either side of the antenna centerline whereby energy traveling through the antenna will be deflected by the plates and confined to a narrow, main lobe radiation pattern, a frame supporting said plates for rotation about an axis normal to the antenna centerline, and drive means en-

5

gaging said frame for controlling the rotational movement of said plates relative to the antenna to bend the main lobe radiation pattern in the direction normal to the plane of the plates.

4. A microwave beam deflecting cage for horn type waveguide antennas comprising, a pair of plates generally parallel to each other and to the electric vector of the energy propagated through the antenna, said plates being spaced apart a distance at least equal to twice the wide dimension of the antenna aperture and substantially equidistant on either side of the antenna centerline whereby energy traveling through the antenna will be deflected into a narrow beam, a frame supporting said plates for rotation about an axis generally parallel with said electric vector, and drive means engaging said frame for controlling the movement of said plates for tilting the aiming axis of the antenna.

5. A microwave horn type waveguide antenna comprising, a hollow waveguide generally rectangular in cross section for propagating microwave energy there-through, said waveguide having a pair of narrow walls defining the electric vector of the microwave energy and a pair of wide walls defining the magnetic vector of the energy propagated, said wide walls extending beyond said narrow walls and being flared outwardly to form a two-walled horn open in the direction of the magnetic

6

vector, a cage generally axially aligned with the waveguide and extending forwardly of the aperture of said waveguide, said cage having a pair of energy deflection plates spaced apart and generally parallel with the electric vector for suppressing side lobes, and means for rotating said cage for shifting the energy beam in the magnetic plane.

6. A beam deflecting cage for horn type waveguide antennas comprising, a pair of generally flat deflection plates spaced apart one on either side of the antenna centerline and arranged generally parallel to each other and extending forwardly of the antenna aperture for redirecting the side lobe energy into the primary radiation pattern, and means for rotating said deflection plates about an axis generally normal to the centerline of the antenna and parallel with said deflection plates for tilting the antenna aiming axis.

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