United States Patent

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[15] **3,699,582**

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[54] SLOTTED CABLE GLIDE SLOPE ANTENNA

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[52] **U.S. Cl.** **343/739,** 343/771, 343/853

[51] **Int. Cl.**.....**H01q 13/10**

[58] **Field of Search**.....343/767, 771, 739, 853

[56] **References Cited**

UNITED STATES PATENTS

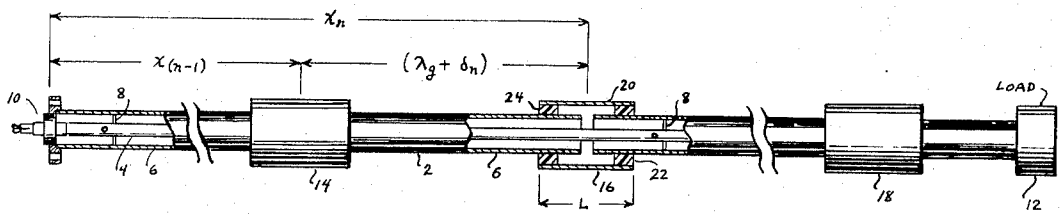
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Primary Examiner—Eli Lieberman

[57] **ABSTRACT**

This invention relates to antennas for use in glide slope systems for the instrument landing of airplanes. The antenna disclosed here may be used, as a phase-compensating element, in an end-fire glide slope array, to control the slope angle over a desired azimuth sector. A coaxial transmission line, fed from one end, has a number of gaps in the outer conductor which leak current onto the outside surface of the line. The separation between gaps varies along the line, being chosen to give a predetermined phase distribution of the radiation current. Tuning to an assigned frequency channel may be accomplished by filling the line to a specified pressure with a gas of relatively high dielectric constant.

5 Claims, 4 Drawing Figures



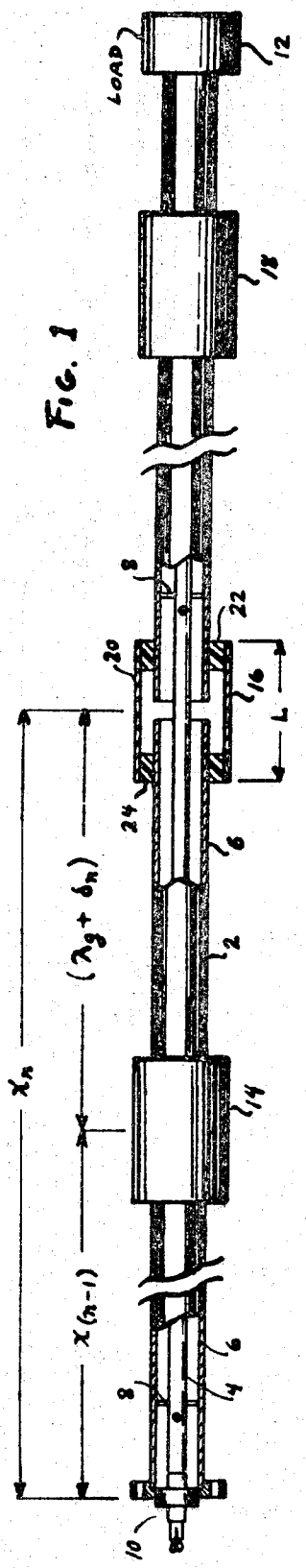


Fig. 1

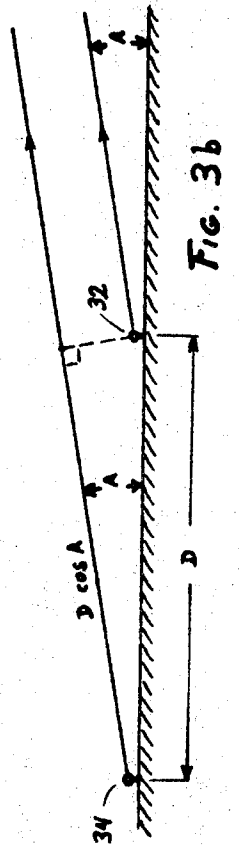


Fig. 3b

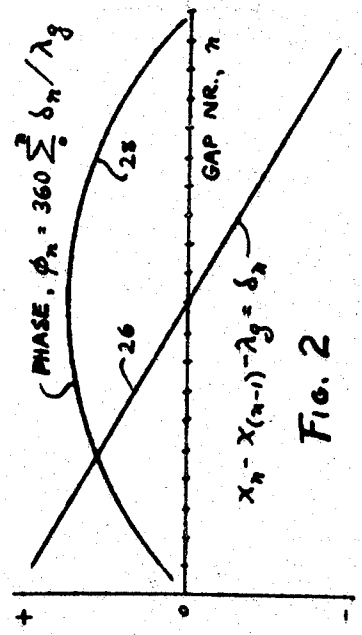


Fig. 2

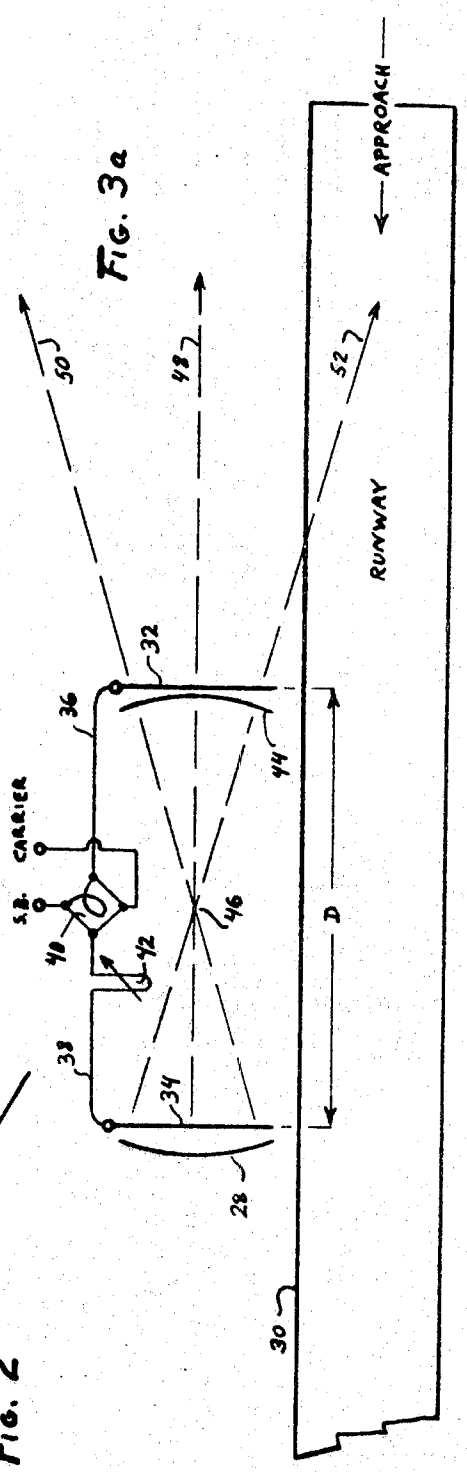


Fig. 3a

INVENTOR.

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SLOTTED CABLE GLIDE SLOPE ANTENNA

This antenna is structurally similar to the one described in my co-pending application Ser. No. 855,142 filed Sept. 4, 1969, titled "Slotted Cable Localizer Antenna" except for the fact that the gap spacings are non-uniform, and the antenna is fed at only one end.

HISTORY

In 1942, soon after the appearance of equi-signal image-type glide slope systems, Kandoian, U. S. Pat. No. 2,367,680, proposed an end-fire glide slope array, citing the hazard of the tall pole required for the image-type systems. No solution was, however, presented for the primary difficulty with this arrangement, namely, the high undesirable transverse shape. The shape of the glide slope surface, which follows directly from the geometry of path lengths associated with any simple end-fire array, is, of necessity, a narrow cone, with axis horizontal, coinciding with the physical axis of the array. In following such a glide slope surface, an airplane could not deviate in azimuth from this axis without receiving an extraneous "fly-down" signal. The multi-lobe pattern, which is produced by the variation in path difference versus the angle off-axis, is, in fact, a figure of revolution about the axis, the effect of azimuth being indistinguishable from that of elevation. What was clearly needed was a simple antenna element to use in the end-fire array which would cancel or compensate for the effects of path difference due to azimuth angle, while leaving the elevation performance unchanged.

SUMMARY

It is an object of this invention to provide a phase-compensating antenna, which may be used as an element of an end-fire glide slope array to control the glide slope angle, maintaining it relatively constant versus azimuth angle, over a specified azimuth sector. The antenna is a coaxial transmission line, the outside surface of which acts as a linear current radiator. Current is fed onto the outer surface by means of numerous shunted gaps in the outer conductor. The spacings between the gaps are chosen to produce the desired current phase distribution, while the gap shunts control the current amplitude distribution. Although these desired relationships hold, in principle, for only a single r.f. frequency, the antenna is readily tunable over a narrow range of frequencies, such as the glide slope band, by filling the line with a controlled amount of a gas such as sulfur hexafluoride having a relatively high dielectric constant.

LIST OF FIGURES

FIG. 1 is a view, partially cut away, of an embodiment of the slotted cable antenna.

FIG. 2 is a graph of two design parameters; one being the excess of gap spacing over guide wavelength, and the other being the resultant phase distribution.

FIG. 3*a* is a plan view of a runway layout, illustrating the use of two slotted cable antennas as phase-compensating elements in an end-fire glide slope array.

FIG. 3*b* is an elevation view of the same end-fire glide slope array.

DESCRIPTION

A satisfactory embodiment of the slotted cable antenna is illustrated in FIG. 1. This construction employs a length of transmission line **2**, of the rigid type, standard to the radio broadcasting industry. Inner conductor **4** is supported concentric without outer conductor **6**, typically by means of insulating pins **8**. Connector **10** provides the means for joining one end of the line to a source of r.f. energy. The opposite end of the line is terminated in a resistive load **12**. Placed at non-equal intervals along the line are numerous gap assemblies of which **14**, **16**, and **18** are typical. Gap assembly **16** is shown cut-away to reveal, at the center of the assembly, the gap in the outer conductor **6**. Inner conductor **4** passes through without interruption. The gap is surrounded by metal sleeve **20** which is supported and separated from the outer conductor **6** by means typified by insulators **22** and **24**. Sleeve **20** thus acts as a capacitive shunt across the gap, the shunting impedance depending upon the sleeve length L and the relative diameters of sleeve **20** and outer conductors **6**. If the length L is too long in terms of the wavelength for the shunt to be considered as a lumped capacitor, it can be computed as a pair of transmission line transformers of length $L/2$ each. In either case, the shunting impedance which is presented across the gap is made to be quite low compared to the line impedance. Insulators **22** and **24** may include sealing means so that any gas pressure existing within the transmission line will be retained.

Consider now what happens when r.f. energy is introduced into the line through connector **10**. The energy propagates freely down the line, passing, in succession, the various gap assemblies typified by **14**, **16**, and **18**. Since, in each case, the gap is shunted by a relatively low impedance, the main line current is only slightly affected. Nevertheless, a small fraction of the total current does escape to flow on the outside of the outer conductor in each case, resulting in radiation. The field produced some distance from the antenna is the cumulative effect of the leakage from all of the gaps. The remaining main line current is absorbed in a matched termination, load **12**.

The amplitude distribution of the radiation current is controlled by varying the gap shunt impedances from end to end of the antenna, the lower the impedance in each case, the less the current that leaks out.

The phase distribution of the radiation current is controlled by the spacing between the gap assemblies. The main line current phase angle rotates through 360° with each guide-wavelength of distance along the line. Thus, if the gaps were spaced exactly one guide-wavelength apart, the various gap radiation currents would be in phase with one another. If, however, the gap spacing is somewhat greater than the guide-wavelength, then the phase of the succeeding gap radiation current lags the phase of the earlier gap radiation current. Also, the converse is true. Utilizing these facts, it is possible to generate any reasonable shape of phase distribution.

FIG. 2 illustrates graphically the relation between the parameters of gap spacing and radiation current phase distribution. Curve **26** indicates that the first gaps have a spacing considerably greater than the guide-wavelength, and that the spacing gradually decreases

toward the center of the antenna, where the spacing becomes equal to the guide-wavelength. Beyond the center, the spacing becomes progressively shorter than the guide-wavelength. This means that the early gaps lag their predecessors, while the later gaps lead their predecessors in phase angle. The phase distribution which results from this is approximated by curve **28**, which can be obtained numerically by summing all of the phase shifts from the beginning up to the gap in question. The desired shape, for the problem of the end-fire glide slope, is circular, as will become apparent. It should be noted, however, that the method is not limited to producing circular shapes.

FIG. *3a* shows the approach end of a runway **30** in plan view. Suitably located alongside the runway are two slotted cable antennas serving respectively as forward element **32**, and rear element **34** in an end-fire glide slope array. The antennas are fed by transmission lines **36** and **38** which receive the usual carrier and sideband signals through bridge network **40**. Line-stretcher **42** is provided as a means for adjusting the relative phases of the two antennas to produce the desired glide angle. Rear antenna **34** has the phase distribution **28** which was described in connection with FIG. **2**. Forward antenna **32** in FIG. *3a* is identical except turned end for end so that the closer spaced gaps are nearest the fed end. This has the effect of exchanging lead angles for lag angles, producing the reversed phase distribution **44**. Both phase distributions are designed to be circular. If converted from phase angle to equivalent free-space path length, each distribution curve would have a radius of curvature equal to $D/2$, where D is the front-to-rear separation, the center of curvature being midpoint **46**. This means that when viewed from an airplane at low elevation angle in the direction of the central ray **48**, or anywhere in the azimuth sector between the extreme rays **50** and **52**, the forward and rear antennas appear to be radiating from the common phase-center at midpoint **46**. That is to say, there is no change versus azimuth, in the relative phase of the signals received from the two antennas.

At the same time, viewed in elevation, FIG. *3b*, the behavior is conventional, as from the two point sources. The path difference between the two antennas **32** and **34** to a distant point, varies with elevation angle A, according to $D \cos A$, producing a multi-lobed pattern in the usual way. The main point is, however, that the elevation pattern, whatever it may be, remains unchanged with azimuth within the limited sector controlled by the phase-compensating effect of the slotted cable antennas.

It will be understood that the desired relationship which has been described will hold, in principle, for only a single frequency if the guide-wavelength varies with the frequency as it usually does. The band assigned to glide slope transmissions, 328–336 mc/s, is, however, only about 2.5 percent wide. For any channel in this band, the guide-wavelength can be readily adjusted to the same value by filling the antenna with the proper amount of a high-dielectric gas such as sulfur hexafluoride, SF_6. With rigid pin-supported air line, very nearly the entire space between the inner and outer conductors is available for filling with gas. In this case, the guide-wavelength simply varies inversely as the square-root of the dielectric constant, which, in turn varies with the quantity, or pressure, of gas. Thus, the dielectric constant needs to be controlled over a range of about 5 percent, or from 1.00 to 1.05. This can be accomplished by filling with 1 to 17 atmospheres of SF_6.

I claim:

1. A slotted cable antenna comprising a coaxial transmission line, connector means at one end of said line for joining to a source of r.f. energy, a plurality of gaps in the outer conductor of said line, radiation control means disposed across each of said gaps, said control means presenting in each case an impedance, whereby most of the line current is conveyed across the gap, except for a portion of said current which escapes to flow on the outside of said line, thereby producing radiation, and further, where the spacing of said gaps varies from end to end of said line, producing thereby a predetermined and non-linear phase distribution of the radiation current.

2. An antenna as in claim **1**, with a resistive load connected to the second end of said line.

3. An antenna as in claim **1** with said radiation control means comprising a metal tube, surrounding each of said gaps, but insulated therefrom.

4. An antenna as in claim **1**, with frequency tuning means comprising a quantity of high-dielectric gas filling the space between inner and outer conductors of said coaxial transmission line.

5. An antenna as in claim **1**, where the impedance presented by said control means varies from end to end of said line, producing thereby a predetermined amplitude distribution of the radiation current.

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