United States Patent [19]

Nemit

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[45] **Feb. 26, 1974**

[54] **WIDE-ANGLE PLANAR-BEAM ANTENNA ADAPTED FOR CONVENTIONAL OR DOPPLER SCAN USING DIELECTRIC LENS**

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[21] Appl. No.: **316,240**

[52] **U.S. Cl.** **343/754,** 343/854

[51] **Int. Cl.** **H01q 19/06,** H01q 3/26

[58] **Field of Search**......343/754, 854, 876, 106 D, 343/108 M

[56] **References Cited**

UNITED STATES PATENTS

2,720,589	10/1955	Proctor	343/854
3,255,453	6/1966	Horst	343/754
3,363,251	1/1968	Sferrazza	343/754

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[57] **ABSTRACT**

An antenna involving a plurality of vertical-array-excited parallel-plate coordinate converters feeding a dielectric lens in the shape of a partial toroid. Each corresponding element of the array feeding each parallel-plate coordinate converter is fed in parallel through a wave guide feed arrangement from a Doppler line feed or phased array feed. The radiated beam shape tends to hold its focus and, therefore, has uniform width in elevation over the full azimuth beam width at all useful elevation beam positions.

6 Claims, 4 Drawing Figures

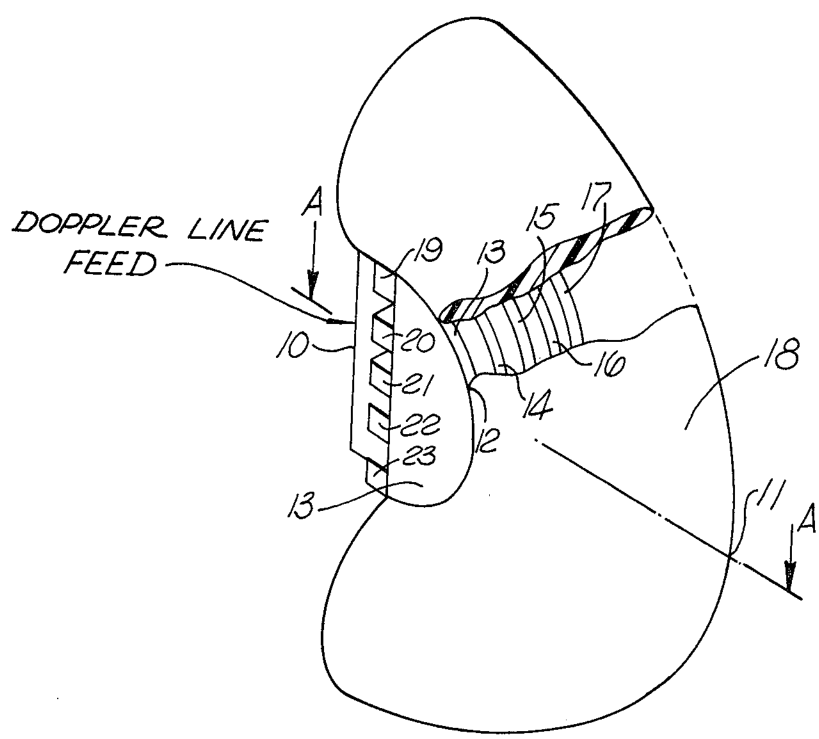


Fig. 1.

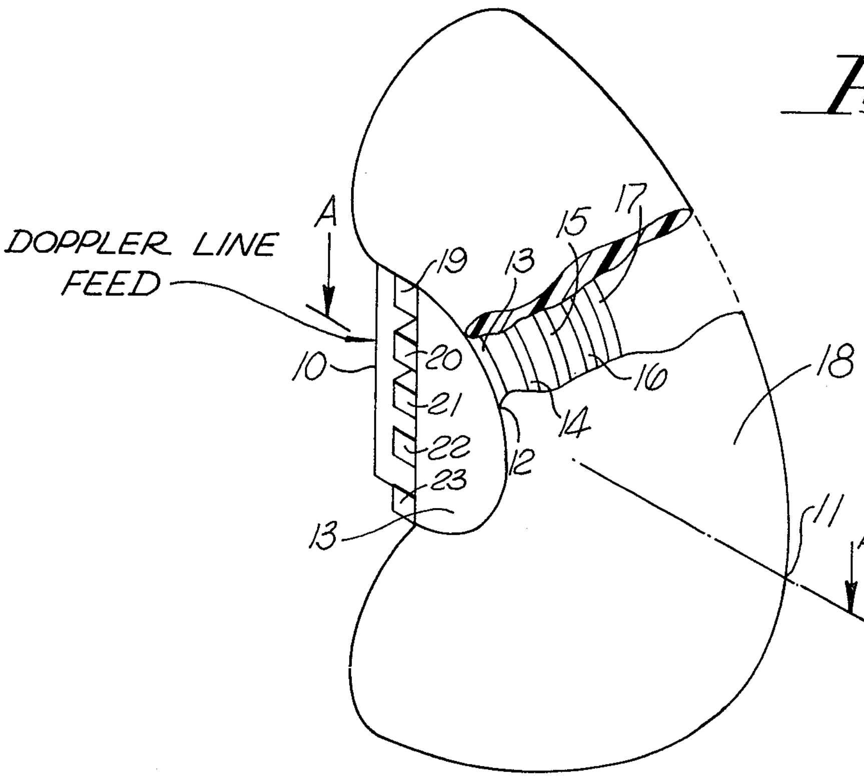


Fig. 2.

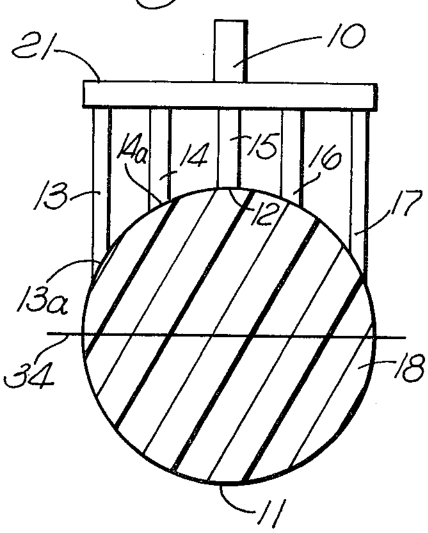


Fig. 3.

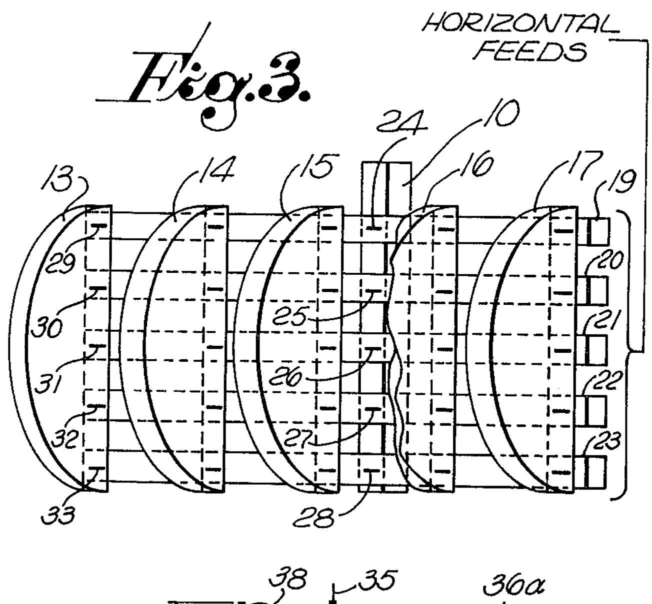
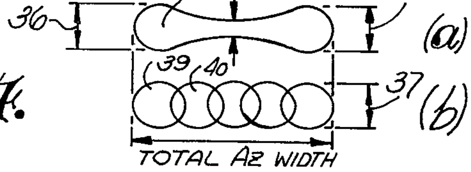


Fig. 4.



WIDE-ANGLE PLANAR-BEAM ANTENNA ADAPTED FOR CONVENTIONAL OR DOPPLER SCAN USING DIELECTRIC LENS

CROSS REFERENCE TO RELATED APPLICATIONS

U.S. Pat. application Ser. No. 272,451 filed July 17, 1972, entitled "A Technique for Generating Planar Beams from a Linear Doppler Line Source or Linear Phased Array" (Jeffrey T. Nemit, inventor) contains disclosure pertinent to the description of the present invention. Accordingly, the disclosure of that application is incorporated herein by reference as though fully set forth herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to scannable antennas and, in particular, to antenna systems for air navigation and guidance systems requiring vertical angle determination.

2. Description of the Prior Art

The above-referenced U.S. patent application is itself descriptive of an improvement in antenna systems known and used in connection with the so-called Doppler-scan technique. The related prior art preceding that invention is typically described and referenced in U.S. Pat. Nos. 3,613,096 and 3,670,338. U.S. Pat. application Ser. No. 210,669, filed Dec. 22, 1971, is also a useful reference for background information in describing the state of the prior art. Those references also are useful in understanding the nature of the problems encountered in Doppler-scan systems, for example. The utility of the present invention is particularly great in connection with systems of those types.

U.S. Pat. application Ser. No. 272,451 (above-referenced) describes a device employing a circular aperture, parallel-plate wave guide converter excited by a linear Doppler-scan array or alternatively by an electronic-scan phased array or the like. The purpose of that parallel-plate structure, as is fully described in that application, Ser. No. 272,451, is the conversion of fundamentally conical-coordinate beams to planar-coordinate beams. That device is employed as an element in the novel combination of the present invention as hereinafter described.

In U.S. Pat. No. 3,653,057, entitled "Simplified Multi-Beam Cylindrical Array Antenna with Focused Azimuth Patterns Over a Wide Range of Elevation Angles," a system for tailoring the beam shape of a scanning antenna for wide-angle performance in the nonscanning coordinate is described. That device uses multiple beams to achieve the desired effect, and while satisfactory in typical L-band systems, is relatively inefficient at C-band and above.

The manner in which the present invention builds on the techniques of the prior art and the extent to which it affects improvements thereover will be evident as this description proceeds.

SUMMARY OF THE INVENTION

The combination of the present invention involves the use of a plurality of coordinate-converting parallel-plate wave guide arrangements in accordance with the aforementioned U.S. Pat. application Ser. No. 272,451, as parallel-feeds for a dielectric lens in the shape of a partial toroid. The lens antenna arrangement produced is vertically oriented functionally; i.e., it is intended to produce vertically scannable beams having predetermined azimuth characteristics which remain substantially constant over the useful elevation scanning angles. The referenced U.S. Pat. No. 3,653,057, on the other hand, is horizontally oriented by the same criterion.

It may be said that the general objective of the present invention is the production of a basically vertically oriented antenna (although its use as a horizontally oriented device is not precluded) to form horizontal fan beams of substantial azimuth angular width, the said antenna being adapted for scanning in elevation without deterioration of the focus uniformity of the beams at various elevation beam positions. Use of a simple linear array does not accomplish this objective because it beams have a conical shape when scanned. The circular parallel-plate wave guide described in the aforementioned U.S. Pat. application Ser. No. 272,451, used by itself, provides the required planar-beam for consistency with coordinate systems utilized in the so-called Doppler-scan air navigation and guidance systems. However, the use of that circular parallel-plate wave guide arrangement, as described in the reference, is limited in wide angle coverage in the nonscanning coordinate, due to defocusing which distorts the elevation beam width at wide azimuth angles.

If it is imagined that an observer from a distance looks down the beam toward this antenna and is able to "see" the cross-sectional shape of the total beam, that beam would appear somewhat in the shape of a "dogbone." This is because defocusing at azimuth angular extremes tends to fatten the beam in the elevation coordinate at those azimuth extremes. The present invention, which is particularly adapted to use a radar C-band operation and above, employs an optical technique to provide the required wide-angle beam in azimuth in an arrangement affording the planar coordinates effected by the aforementioned Ser. No. 272,451 device as a feed, while providing a more idealized focusing to eliminate the so-called "dogbone" effect.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a pictorial view of an antenna arrangement in accordance with the present invention.

FIG. **2** is a top view taken along the section line AA of FIG. **1**.

FIG. **3** is an expanded pictorial view showing the details of the feed arrangements for the plural parallel-plate converters of the combination.

FIGS. **4**(*a*) and (*b*) are respective beam cross-sections for prior art and present systems.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. **1**, a pictorial view of the antenna assembly according to the present invention is presented. The lens **18** is partially cut away to show the parallel-plate coordinate converters **13, 14, 15, 16** and **17.** Those parallel-plate wave guide converters are excited in parallel from a common Doppler-line feed **10** and a plurality of wave guide coupling sections **19, 20, 21, 22** and **23.** The semi-circular apertures of these parallel-plate wave guides act as individual feeds operating into a toroidal shape lens of the general Luneburg type. The effect of the lens in combination with these apertures is to produce the correct "ring"phase for focusing in elevation at a different azimuth angle. Thus, it may be said that the azimuth beam is composed of a plurality of overlapping individual narrower beams, and here the general theory of forming an azimuth beam builds from the aforementioned U.S. Pat. No. 3,653,057. Accordingly, it may be said that each of the vertical parallel-plate wave guide apertures acts as a feed to a lens which produces a focused beam at discrete and different azimuth angles for each of the parallel-plate devices. The combination of all those beams produces the wide angle beam in azimuth with substantially constant elevation width. Looking ahead to FIG. 4, this effect is illustrated. As hereinabove indicated, the observer looking down the beam sees a "dogbone" beam shape, per FIG. 4(*a*), when the parallel-plate device is used a lone as set forth in the aforementioned U.S. Pat. application Ser. No. 272,451. In FIG. 4(*a*), the elevation dimension of the scannable beam **38** is minimum at **35** and broadens out at **36** and **36***a* to give the so-called "dogbone" shape. According to the present invention, on the other hand, the plurality of individual beams making up the azimuth fan shape are typically **39** and **40**, etc., in FIG. 4(*b*). Those individual beams correspond to the radiations of **13**, **14**, etc., from FIG. **1**, as focused by the lens **18** in accordance with the further description hereinafter.

A relative dielectric constant of about four for the toroidal lens results in an optimization of the quadratic and fourth-order azimuth phase errors, thereby achieving nearly constant phase. The inside perimeter of the toroidal lens at **12** is circular, as is the outside perimeter in two planes viewed at **11**.

Referring now to FIG. **2**, which is a view looking down in accordance with the section line AA in FIG. **1**, the cross-section of the lens **18** will be seen to be circular. Assuming that the section line illustrated in FIG. **1** passes through points **11** and **12**, the horizontal wave guide coupling section **21** will be the one evident in FIG. **2**. Its connection to the parallel-plate wave guide converters **13** through **17**, as seen in FIG. **2**, is typical of the connection of the other wave guide coupling sections **19**, **20**, **22** and **23** at the respective vertical placements. The actual apertures of the individual parallel-plate wave guide converters are made to conform to the shape of the lens. That is, it will be seen from FIG. **2** that parallel-plate wave guide apertures of **13** and **14** are chamfered at the point of contact with the lens as illustrated at **13***a* and **14***a* in FIG. **2**.

Concerning materials for the elements of the present combination, it will be understood that the parallel-plate wave guides, and all other wave guide parts illustrated, may be made of the common conductive materials used for wave guide construction. The toroidal lens may be constructed from a modified cross-linked polyolefin material. Such material is available under the tradename "Custom poly K-Flex," a product manufactured by Custom Materials, Inc. of Chelmsford, Mass.

Referring now to FIG. **3**, the substantially identical parallel-plate wave guide coordinate converters **13**, **14**, **15**, **16** and **17** are as described in the aforementioned U.S. Pat. application Ser. No. 272,451. It will be noted that the space between the parallel-plates, for example, in **13**, is excited by a vertical array of slot antenna elements **29**, **30**, **31**, **32** and **33**. The referenced patent application describes how these slots form an array as part of a conventional scanning or Doppler-scanning source. The corresponding slots in each of the other parallel-plate arrangements **14** through **17** are all excited in parallel. That is, the distribution wave guide **19** connects to the corresponding slot in each of the other parallel-plate arrangements as it does at slot **29** within **13**. Similarly, the distribution wave guides **20**, **21**, **22** and **23** connect to the slots **30**, **31**, **32** and **33**, respectively, and to the corresponding slots in each of the other parallel-plate wave guides **14** through **17**. These horizontal feed distribution wave guides, on the other hand, are themselves separately excited, one to a slot from slots **24** through **28**, communicating with the Doppler-line feed **10**. It will be realized, of course, that the Doppler-line feed **10** could be a conventional scanning arrangement. The slots **24** through **28** are, thus, the scanned or commutated elements and the corresponding slots within each of the parallel-plate wave guide converters are excited in parallel.

The reference to the lens shape as a partial toroid refers to the general shape depicted in FIG. **1**. The segment of the toroid provided must at least extend around the generally circular aperture of the parallel-plate wave guide converters used.

The reference to an axis of the toroid refers generally to a line which would extend through the center of the inside perimeter normal to the parallel-plate wave guides. Thus, the axis would pass centrally through the "hole of the donut."

The inside perimeter of the toroid means the perimeter measured in the center of the "hole of the donut" and the inside perimeter surface means the surface of the toroid inside the arbitrary line **34** through the center of the toroid section in FIG. **2**.

For optimum performance of the antenna arrangement in accordance with the present invention, the designer may find it desirable to insert a matching section at the interface of each of said parallel plate wave guides with the inside perimeter surface of the toroidal lens; however, this is a matter falling within the ordinary skills of this art.

Modifications and variations within the scope of the present novel combination will suggest themselves to those skilled in this art, once the principles hereof are understood. Accordingly, it is not intended that the drawings or this description, which are illustrative and typical only, should constitute a limitation on the present invention.

What is claimed is:

1. An antenna system for radiating planar beams scannable in a first angular coordinate and of substantially constant beam width in the same angular coordinate over a wide range of angles in a second orthogonal angular coordinate, comprising:

a dielectric lens in the shape of a partial toroid having circular-shaped inside and outside perimeter surfaces and a full circle cross-sectional shape in a plane containing the axis of said toroid;

a plurality of parallel-plate wave guide feeds coupled to said lens along a portion of said inside perimeter, said parallel-plate wave guides being normal to the axis of said toroid and spaced in the direction of said axis, said parallel-plate wave guides further having their apertures abutting the inside surface of said toroid;

a scan feed array including a first linear array of antenna elements;

a plurality of second linear arrays of antenna elements, one within each of said parallel-plate wave guide feeds;

and a plurality of coupling transmission lines for coupling each element of said first linear array in parallel with corresponding elements in each of said second linear arrays.

2. Apparatus according to claim **1** in which said dielectric lens is defined as having an approximate dielectric constant of 4.

3. Apparatus according to claim **2** in which said scan feed array comprises the elements of a phased array.

4. Apparatus according to claim **2** in which said antenna elements of said first linear array comprise slots in an associated wave guide transmission line and each of said coupling transmission lines comprises a wave guide.

5. Apparatus according to claim **4** in which the number of said antenna elements in each of said second linear arrays equals the number of said elements in said first linear array, there also being an equal number of said coupling transmission lines.

6. Apparatus according to claim **5** in which each of said coupling transmission lines is coupled to said scan feed array through one of said slots of said first linear array and slots in said coupling transmission lines are provided coincidental with said corresponding antenna elements of each of said second arrays, whereby said parallel feed of corresponding elements of said second array is provided.

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