

[72] Inventors Charles T. Brumbaugh, Jr.,
Norwalk;
Jerry L. McFarland, Fullerton; Jack W.
Preston, Placentia; Richard W. Wesley,
Yorba Linda, Calif.

[21] Appl. No. 821,207
[22] Filed May 2, 1969
[45] Patented Mar. 9, 1971
[73] Assignee North American Rockwell Corporation

3,500,428 3/1970 Allen 343/854
3,392,393 7/1968 Spitz 343/754

Primary Examiner—Eli Lieberman
Attorneys—William R. Lane, L. Lee Humphries and Rolf M.
Pitts

[54] **CONSTRAINED LENS TYPE ANTENNA**
11 Claims, 14 Drawing Figs.

[52] U.S. Cl. 343/753,
343/771, 343/853, 333/31, 333/84

[51] Int. Cl. H01q 19/06,
H01q 21/00

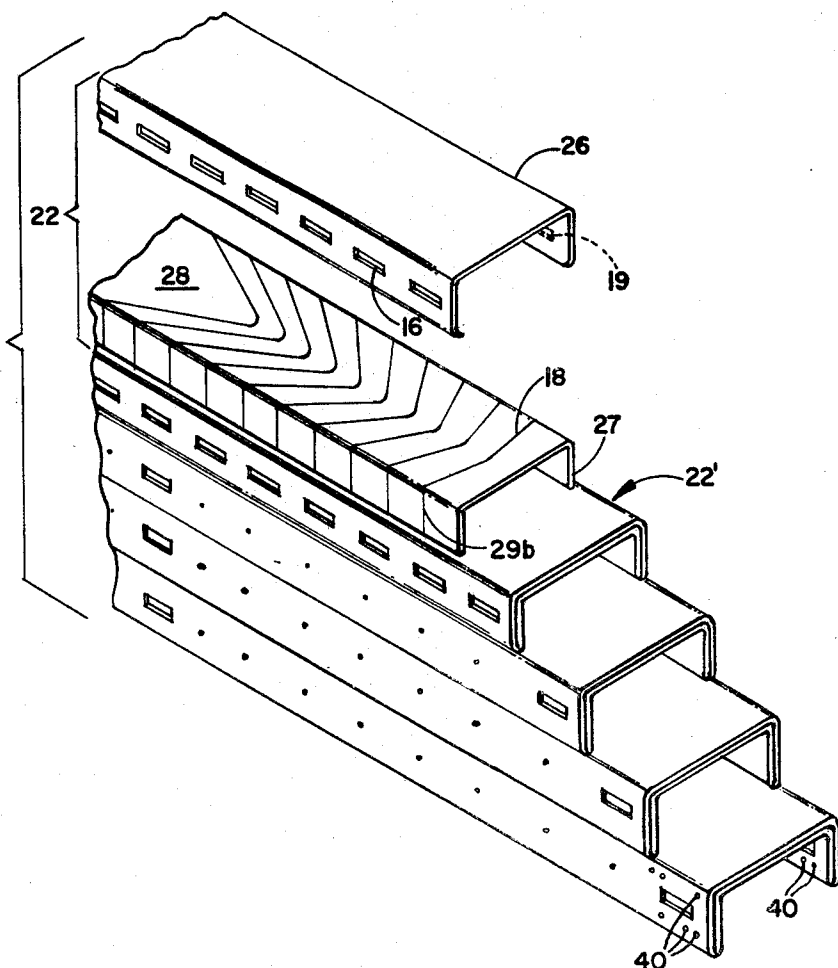
[50] Field of Search 343/754,
755, 854; 343/753, 771, 853; 333/31, 84

[56] **References Cited**

UNITED STATES PATENTS

2,986,734 5/1961 Jones et al. 343/754

ABSTRACT: A constrained lens-type antenna including a lens having a controlled aperture phase distribution and utilizing stripline circuitry. The lens is formed of a plurality of mutually parallel stripline assemblies, each assembly comprising a pair of mutually nested dielectric U-channels sandwiching a dielectric slipsheet having a plurality of deposited electrically conductive lines of selected lengths as discrete delay elements. The outer surface of the opposing walls of the U-shaped channel assembly include microwave ports, each being electromagnetically coupled to an associated terminus of a mutually exclusive one of said delay elements, the ports in one of the opposing walls being exposed to a feed horn, serve as feed ports, while the ports in the other of the opposing walls serve as radiating ports. The novel use of stripline circuitry provides a lens assembly of minimum bulk and weight while also having improved geometrical tolerances and performance.



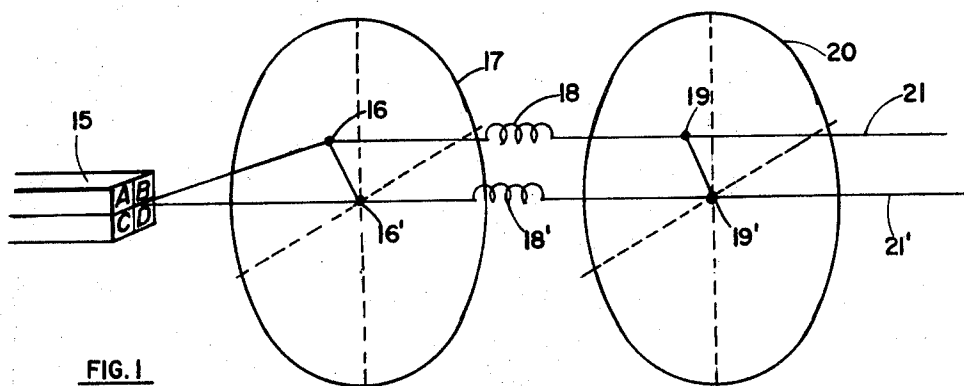


FIG. 1

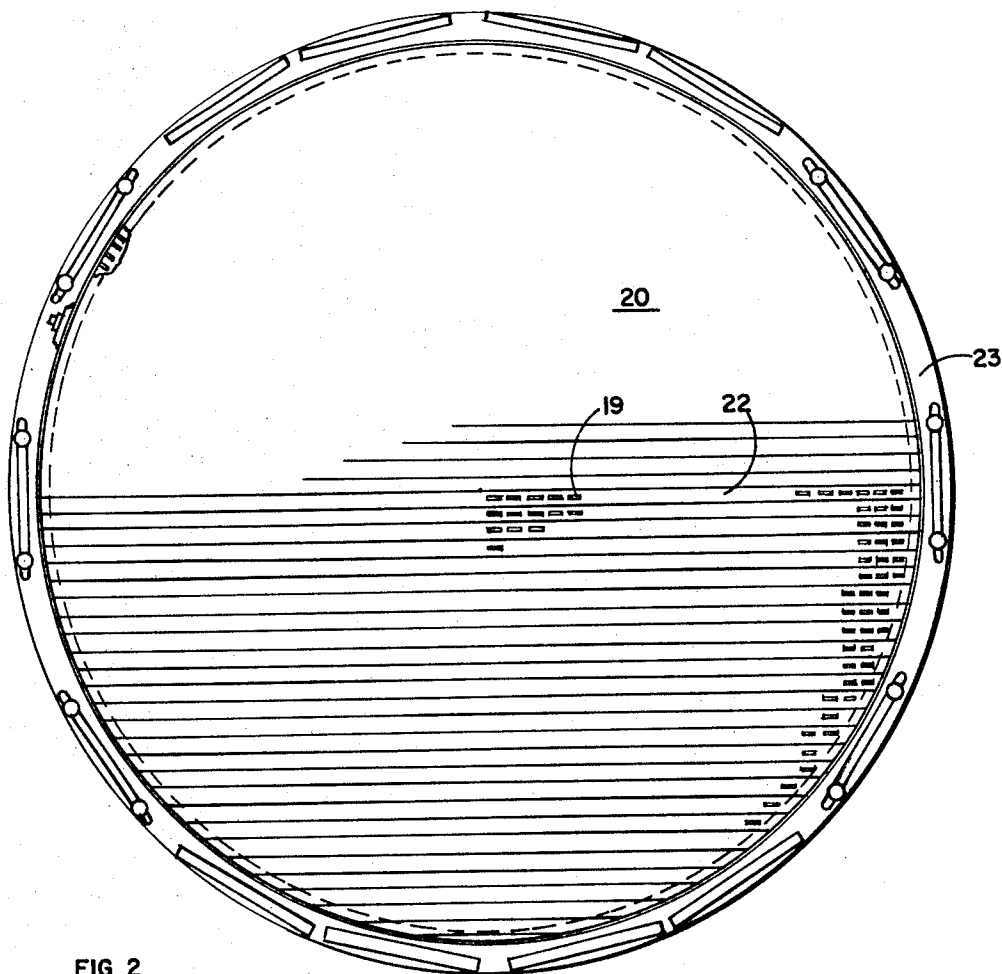


FIG. 2

INVENTORS
 CHARLES T. BRUMBAUGH
 JERRY L. McFARLAND
 BY JACK W. PRESTON
 RICHARD W. WESLEY

Raymond Pitts
 ATTORNEY

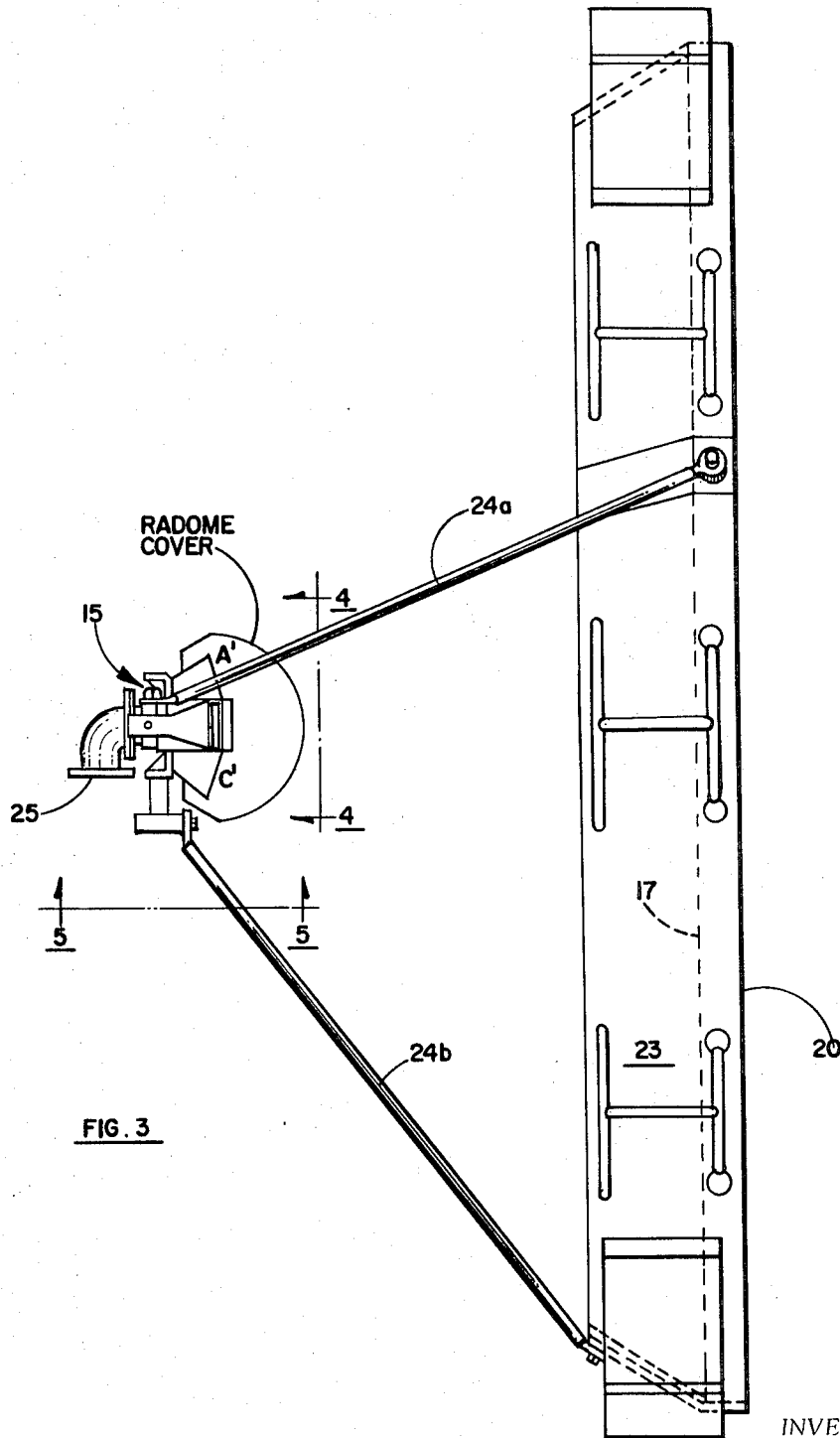


FIG. 3

INVENTORS
 CHARLES T. BRUMBAUGH
 JERRY L. McFARLAND
 BY JACK W. PRESTON
 RICHARD W. WESLEY

Robert M. Ellis
 ATTORNEY

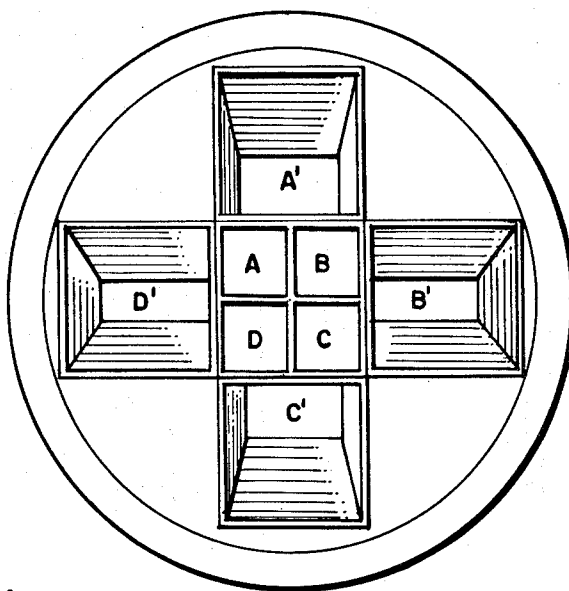


FIG. 4

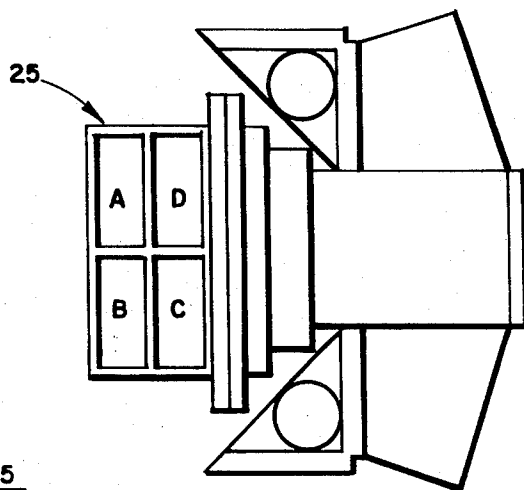


FIG. 5

INVENTORS
 CHARLES T. BRUMBAUGH
 JERRY L. McFARLAND
 BY JACK W. PRESTON
 RICHARD W. WESLEY
Raymond Pitts
 ATTORNEY

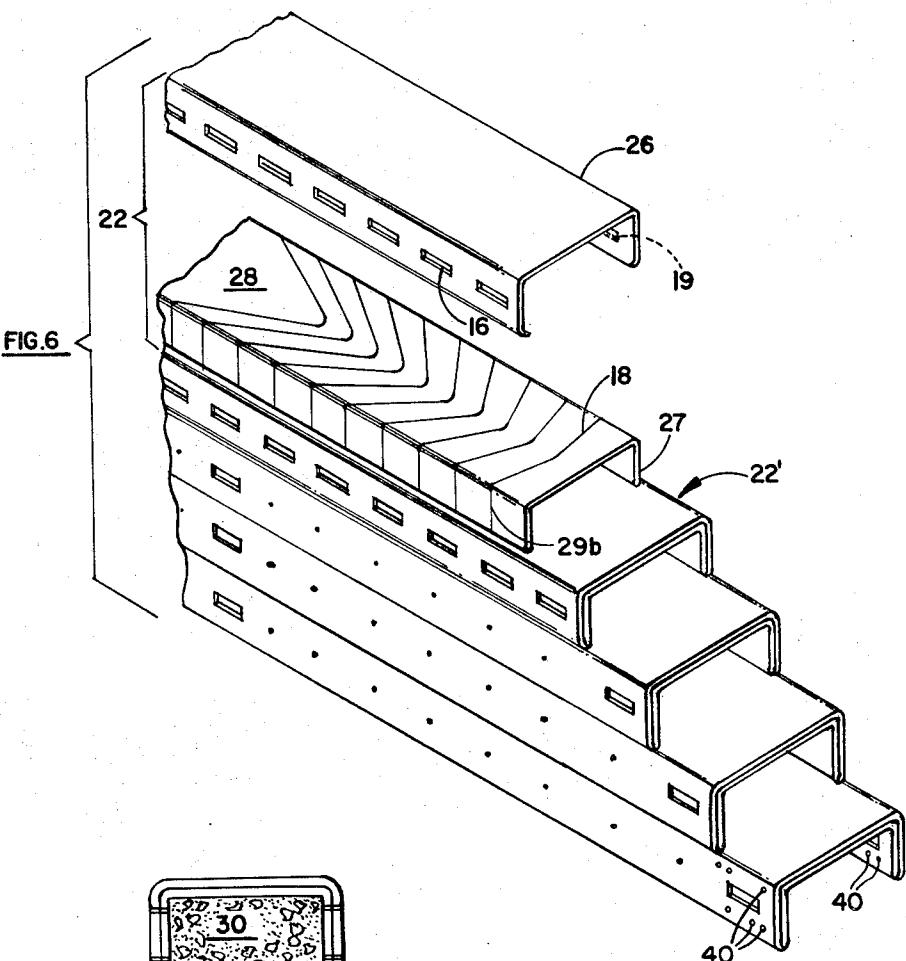


FIG. 6

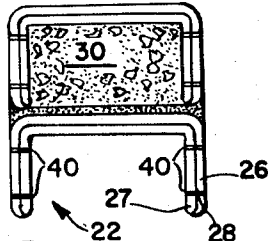


FIG. 7

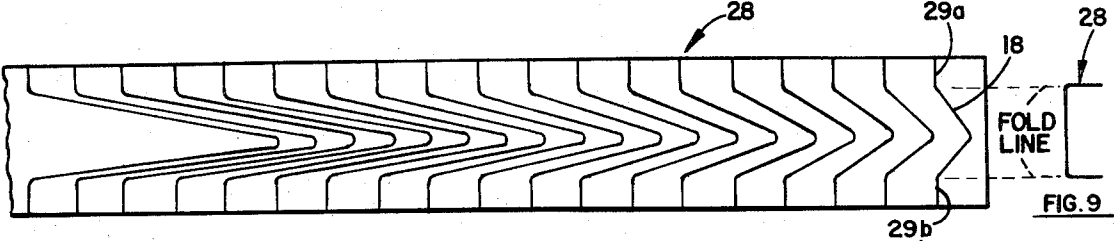


FIG. 8

FIG. 9

INVENTORS
CHARLES T. BRUMBAUGH
JERRY L. McFARLAND
BY JACK W. PRESTON
RICHARD W. WESLEY
Raymond P. Little
ATTORNEY

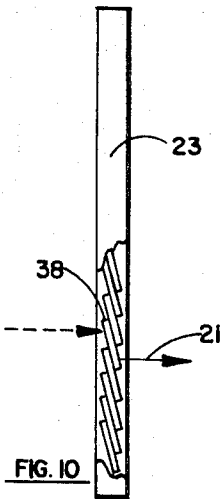


FIG. 10

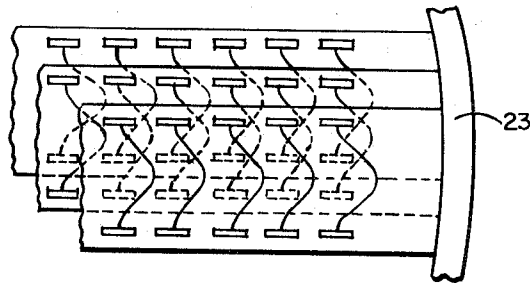


FIG. 11

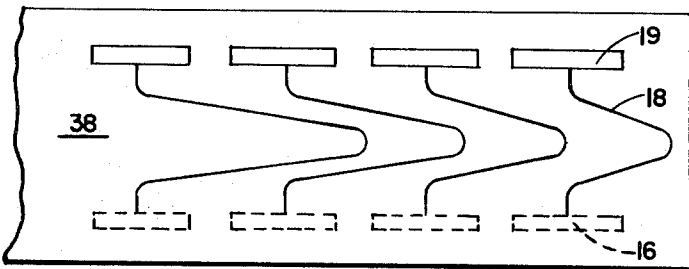


FIG. 12

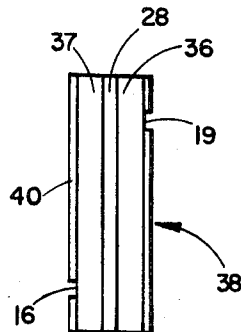


FIG. 13

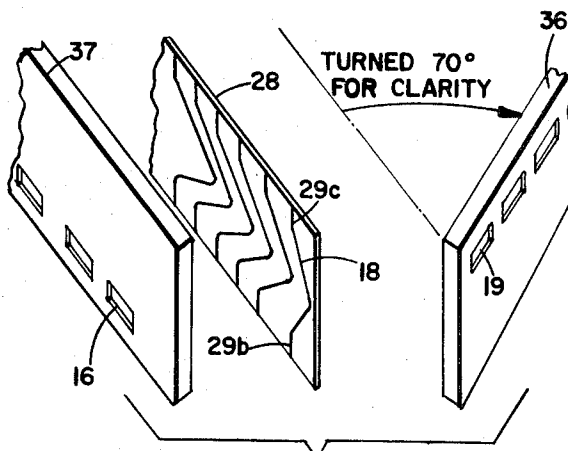


FIG. 14

INVENTORS
CHARLES T. BRUMBAUGH
JERRY L. McFARLAND
BY JACK W. PRESTON
RICHARD W. WESLEY
Raymond E. Bates
ATTORNEY

CONSTRAINED LENS TYPE ANTENNA

BACKGROUND OF THE INVENTION

Most radar system requirements demand that the antenna system be capable of transmitting and receiving electromagnetic energy in a number of different operational modes, in the most efficient manner possible. In particular, it is often desired to obtain a high gain pencil beam mode with extremely low sidelobes combined with special functions such as ground map and four beam conical scan modes over wide bandwidths, and to do this with the lightest and most compact structure conceivable.

High gain antennas which exhibit very wide bandwidth characteristics belong to a class known as true time delay antennas. A true time delay antenna is one wherein the electrical length from the input to every point in the radiating aperture plane is a constant. These systems include reflectors, distributed lenses, constrained lenses and corporate feed systems and others. Of these, the reflector system is the most practical, wideband lightweight antenna but it exhibits high sidelobes due to spillover and aperture blockage. The other systems can be designed to yield very low sidelobes and multimode operation but they all possess weight and/or volume penalties, and in some cases include several mechanical tolerance limitations. An example of a dish-type antenna having a preselected or controlled phase aperture distribution is described, for example, in U.S. Pat. No. 3,355,738 issued to J. A. Algeo for Microwave Antenna Having a Controlled Phase Distribution.

The term constrained lens relates to the prior art use of a plurality of discrete transmission lines, each line having a selected phase length, whereby the curved (approximately spherical) wave front of a primary feed may be converted to a substantially planar wave front of selected directivity. An advantage of such type of lens over a dish or reflector-type lens is the avoidance of aperture blockage caused by the feed, coupled with the ease of controlling beam shape and sidelobes by adjustment of the associated discrete elements, relative to the difficulties of accurately shaping a dish or "spoiled parabola" to achieve a selected aperture phase distribution.

The prior art of constrained lens antennas is limited to the use of coaxial cables as discrete delay lines, each coupled to an associated pair of microwave input and exit ports, thus forming a large, dense and expensive assembly, which demonstrates performance limitations or aperture phase distribution inaccuracies due to tolerances in the electromechanical connections of the individual coax sections and due to geometric variations in the shapes and orientations of the loops formed by such coax sections.

SUMMARY OF THE INVENTION

By means of the concept of the subject invention, a lens is formed by means of strip line assemblies, whereby the above-noted shortcomings of prior art constrained lens antennas are avoided.

In a preferred embodiment of the invention there is provided a constrained lens-type antenna comprising a lens having a controlled aperture phase distribution and adapted to cooperate with a switchable feedhorn cluster for effecting selected antenna modes. There is provided a plurality of discrete and mutually parallel laminated strip line assemblies, each assembly comprising a laminated pair of rigid dielectric plates. A dielectric slip sheet, having a plurality of electrically conductive delay lines of selected length deposited thereon, is sandwiched between the dielectric plates of the laminated pair. Opposing faces of the laminated assembly are clad with an electrically conductive coating, at least one of said faces having a plurality of microwave ports formed by apertures in the coating, each aperture being in registry with an associated terminus of a mutually exclusive one of said delay lines for effecting electromagnetic coupling between each port and an associated delay line element. Thus, two arrays of ports are provided, the ports of a first array being coupled to a first end

of respective ones of the delay lines and the ports of a second array being coupled to the opposite end of said ones of the delay lines.

In normal operation of the above-described arrangement, one array is adapted to be fed or illuminated by feedhorn means and the second array serves as a transmitting array, the delay line elements interconnecting associated pairs of illuminated and transmitting ports effecting a preselected aperture phase distribution. By means of such laminated arrangement using stripline circuitry, photo etching and bonding techniques may be employed, whereby a more nearly uniform product is achieved in production. Also, by the use of such arrangement and techniques, more accurate geometrical control is obtained for a given configuration, resulting in improved antenna performance. Further, the use of such laminated stripline circuitry provides a lens antenna assembly of minimum weight and bulk, thereby improving the suitability of such assembly for airborne use. Moreover, such arrangement readily lends itself to low cost, high volume production of high-performance microwave arrays.

Accordingly, it is an object of the subject invention to provide an improved antenna array.

It is another object of the invention to provide a constrained lens-type antenna having improved performance.

It is a further object to provide an array element for a lens-type antenna and employing stripline circuit elements.

Still another object is to provide a laminated array of improved accuracy and reduced weight, bulk and cost.

These and other objects of the invention will become apparent from the following description, taken together with the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of a dielectric lens system, illustrating the principles thereof;

FIG. 2 is a front elevation of a representative antenna array in which the inventive concept may be advantageously employed;

FIG. 3 is a side elevation of the antenna of FIG. 2 and showing the feedhorn thereof;

FIG. 4 is a front elevation of the feedhorn of FIG. 3;

FIG. 5 is a plan, or bottom view, of the feedhorn of FIG. 3;

FIG. 6 is a perspective view, partially exploded, of a portion of the lens of FIG. 2 and showing certain details of the arrangement thereof;

FIG. 7 is a vertical section taken through two stacked lineal arrays of the assembly of stacked lineal arrays of FIG. 6;

FIG. 8 is a plan view of the slipsheet employed in the lineal arrays of FIGS. 6 and 7;

FIG. 9 is an end view of the slip sheet of FIG. 8 as folded about the fold lines thereof, and illustrating the shape thereof as employed in FIGS. 6 and 7;

FIG. 10 is a view in elevation, partially in section, of an alternate embodiment of the stacked arrays of FIGS. 2 and 6 and employing a shingled arrangement;

FIG. 11 is a phantom front view of a portion of the embodiment of FIG. 10, showing in further detail the shingled arrangement;

FIG. 12 is a plan view of a representative array or shingle of the shingled assembly of FIG. 11;

FIG. 13 is a vertical section of the shingle assembly of FIG. 12; and

FIG. 14 is an exploded view of a portion of the assembly of FIGS. 12 and 13.

In the FIGS. like elements refer to like parts.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The principle of operation of a constrained lens antenna is shown in FIG. 1. Energy is radiated from a microwave feed 15, such as a monopulse multimode feed, forming an approximately spherical phase front. This energy is picked up by suitable elements 16 distributed over an entrance aperture 17.

The energy picked up by a given entrance aperture element is then transferred via an associated delay line 18 to a corresponding element or port 19 of an exit aperture 20. The emergent energy from elements 19 is radiated as a series of rays 21. The total electrical delay from the feed bridge 15 to the exit aperture 20 for every ray is the same. That is to say:

$$k_0 l_1 + k_m l_2 = \text{constant} = k_0 f + k_m l_{20} \quad (1)$$

where:

$$k_0 = \frac{2\pi}{\lambda_0} = \text{propagation constant of free space}$$

λ_0 = wavelength in free space

$$k_m = \frac{2\pi}{\lambda_m} = \text{propagation constant of the delay medium}$$

λ_m = wavelength in the delay medium

l_1 = distance from the feed to any point 16 on the entrance aperture

l_2 = distance from point 16 on the entrance aperture to a corresponding point 19 on the exit aperture via the delay line

l_{20} = a fixed distance in the lens on the system axis

f = focal length

This is precisely the condition for a collimated true time delay antenna system. For beams other than the collimated ones, the phase delay is made to produce the appropriate phase distribution.

While ordinarily (in the prior art) the delay medium takes the form of multichannel branched waveguides or coaxial transmission lines, the constrained lens antenna of the subject invention uses a unique stripline packaging technique to produce a transmission line which is very lightweight and has a low volume, as to be especially advantageous for airborne applications.

A representative arrangement of an exit aperture 20 comprising a coplanar plurality of radiating elements or ports 19 is shown in front elevation in FIG. 2. As illustrated, such coplanar arrangement of elements is comprised of a plurality of discrete and mutually parallel lineal arrays 22 of radiating elements or ports 19 mounted within a ringlike frame 23. The backside of the device of FIG. 2 is similarly arranged and includes an entrance aperture 17 having a plurality of stripline assemblies 22 of lineal arrays of radiating elements exposed to a feedhorn 15 mounted aft of frame 23 by support rods 24a and 24b, as shown more particularly in the side elevation of FIG. 3. Such feedhorn may be of the switchable multihorn-type for providing a selected feed for achieving a desired antenna beamwidth or mode in a multimode radar system application. Such multihorn feed arrangement is shown more particularly by the front elevation view in FIG. 4 of the feedhorn 15 of FIG. 3, while the multiport input 25 thereto is shown more particularly in the bottom view of feed 15 in FIG. 5. The details of the construction and operation of such feed are known in the art and do not form a part of the inventive concept and may be departed from or varied without effecting such inventive concept.

The construction and arrangement of the lens having an entrance aperture 17 and exit aperture 20 of FIGS. 2 and 3 and embodying the inventive concept is shown in greater particularity in FIG. 6.

Referring to FIG. 6 there is illustrated a perspective view, partially exploded, of a portion of the lens of FIGS. 2 and 3 and showing certain details of the arrangement thereof. There is provided a plurality of discrete and mutually-parallel, stacked laminated stripline assemblies 22. Each assembly 22 comprises a laminated pair of mutually nested, rigid dielectric U-channels 26 and 27, (shown in vertical section in FIG. 7), sandwiching a flexible dielectric slipsheet 28 having a plurality of electrically conductive coplanar lines 18 of selected lengths deposited thereon as discrete delay elements. Each delay line 18 has two terminii 29a and 29b a corresponding terminus of each of the delay elements 18 being regularly spaced along sheet 28, as shown in FIG. 8, with the same regularity as the

occurrence or spacing of microwave ports 16 and 19 in assembly 22. The sheet 28, when installed in the sandwiched situation of FIG. 7, is folded about fold lines shown in the end view of FIG. 9.

The inner and outer U-shape surfaces of laminated assembly 22 of FIG. 6 (e.g., the outer surfaces of dielectric U-channels 26 and 27) are electrically conductively coated, as to comprise a metallic clad assembly, entrance and exit or feed ports 16 and 19 being etched or otherwise formed in the metallic cladding of opposing walls of dielectric U-channel 26, each port being in registry with an associated terminus of a mutually exclusive one of the delay lines 18. In other words, an entrance port 16 will be in registry with one terminus 29b of a delay line 18 while the corresponding exit port 19 will be in registry with the other terminus 29a of delay element 18. Locii of shorting pins 40 through the opposing walls of the laminated U-channel assembly describe microwave cavities containing separate ones of ports 16 and 19 and associated terminii 29a and 29b as to effect efficient and close-tolerance electromagnetic coupling therebetween. Such shorting pins, shown more particularly in FIG. 7, serve to suppress spurious energy modes. In practice, a foam plastic filler 30 may be inserted in the volume enclosed by the stacked U-shaped channel assemblies, as indicated in FIG. 7, in order to structurally stiffen the lens assembly.

In normal operation of the above-described arrangement, microwave electromagnetic energy impinging upon an entrance port 16 is coupled to a terminus 29b of delay line 18 by means of the above-described microwave cavity, conducted through delay line 18 and electromagnetically coupled to an associated output or exit, port 19. The cooperation of all such selectively delayed couplings of entrance and exit port pairs defining the lens, provides a desired aperture phase distribution.

Although the laminated microwave stripline lens assembly has been described in terms of parallel stacked U-shaped channels, the concept of the invention is not so limited and a shingled arrangement may be alternatively preferred, as shown in FIGS. 10-15 inclusive.

Referring to FIG. 10, there is illustrated in side elevation, partially torn away, an alternate embodiment of the dielectric lens assembly of FIG. 2, and illustrating a shingled arrangement for a plurality of discrete and mutually parallel laminated stripline assemblies 38. As illustrated, an impinging ray of microwave energy is received from the left and at the top of a single or laminated stripline assembly 38 is selectively delayed therethrough, and emergent therefrom at the lower portion on the right side thereof as emergent beam 21.

As shown in FIGS. 12 and 13, each such stripline assembly 38 comprises a laminated pair of relatively rigid dielectric plates 36 and 37 and a dielectric slipsheet 28 having a plurality of electrically conductive delay lines 18 of selected lengths deposited thereon, slipsheet 28 being sandwiched between the plates 36 and 37 of the laminated pair of dielectric plates. Opposing faces 39 and 40 of laminated assembly 38 are clad with an electrically conductive coating, each of faces 39 and 40 having a plurality of microwave ports formed by apertures 19 and 16 in such coatings. Each aperture is in registry with an associated terminus of a mutually exclusive one of the delay lines 18 for effecting electromagnetic coupling between a port and an associated delay line element. Apertures 19 in coating 39 and apertures 16 in coating 40 form lineal arrays of ports in a respective one of plates 36 and 37 and parallel to and proximate an opposite edge of laminated assembly 38. Thus, as shown in the exploded view of FIG. 14, apertures 16 form a lineal array in plate 37 parallel to and proximate the bottom edge thereof and in registry with associated ones of terminii 29b of delay lines 18, while apertures 19 form a lineal array in plate 36 parallel and proximate the top thereof and in registry with associated ones of terminii 29a of delay lines 18. Thus, the array of apertures in each of coatings 39 and 40 form a lineal array of ports parallel to and proximate an opposite edge of laminated assembly 38 and being electromagnetically

coupled to opposite termini 29a and 29b of delay lines 18. Thus, as shingle assembly 38 is utilized in the shingled arrangement of FIGS. 10 and 11, the upper array of apertures 19 in face 39 of dielectric plate 39 may comprise an entrance aperture of the lens assembly, while the lower array of apertures 16 in face 40 of plate 37 may comprise an exit aperture.

Such shingled arrangement, in which the radiating apertures or ports are arranged on opposite sides of the flat stripline laminate and at opposite ends or termini of the delay line elements, eliminates the need for the double bend of the U-channel configuration of FIGS. 6, 7 and 9, and allows a much thinner package for the dielectric lens assembly. Although such shingle arrangement has been illustrated as lineal, other singling arrangements may be used. For example, a circular arrangement may be employed, in which case each shingle may be shaped in the form of a ring or arcuate section thereof. Although rigid dielectric plates have been described for supporting the slipsheet and the metallic cladding, it is clear that other dielectric means including nonrigid media may be employed.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the appended claims.

We claim:

1. A constrained lens-type antenna comprising a lens having a controlled aperture phase distribution and including in combination a plurality of discrete and mutually parallel laminated stripline assemblies, each assembly comprising:

a laminated pair of dielectric plates;

a dielectric slipsheet having a plurality of electrically conductive delay lines of selected lengths deposited thereon, said slipsheet being sandwiched between said plates of said laminated pair; and

opposing faces of said laminated assembly being clad with an electrically conductive coating, at least one of said faces having a plurality of microwave ports formed by apertures in said coating, each aperture being in registry with an associated terminus of a mutually exclusive one of said delay lines for effecting electromagnetic coupling between each port and an associated delay line element.

2. The device of claim 1 in which said apertures in said one coating form two parallel lineal arrays of ports, each array being electromagnetically coupled to opposite termini of said delay lines.

3. The device of claim 1 in which said apertures in one of said coatings form two lineal arrays of ports, each array parallel to and proximate opposite edges of said laminated assembly and being electromagnetically coupled to opposite termini of said delay lines, each said assembly being formed as a U-shaped channel, the outer surface of the opposing walls of such channel including a respective one of said two lineal arrays.

4. The device of claim 1 in which said apertures are located in each said coating, forming a lineal array of ports in a respective one of said plates, arrays on opposite faces of said laminated pair being electromagnetically coupled to opposite termini of said delay lines.

5. The device of claim 1 in which said apertures are located in each of said coatings, forming a lineal array of ports parallel to and proximate an opposite edge of said laminated assembly and being electromagnetically coupled to opposite termini of said delay lines.

6. A constrained lens-type antenna comprising a lens having a controlled phase aperture distribution and including in combination:

a plurality of discrete and mutually parallel-stacked U-shaped channel stripline assemblies;

each assembly comprising:

a pair of mutually nested rigid dielectric U-channels sand-

wiching a dielectric slipsheet having a plurality of electrically conductive coplanar lines of selected lengths as discrete delay elements;

the outer surface of the opposing walls of the outer U-shaped channel including microwave windows as ports formed by conductive loops, each window being in registry with an associated terminus of a mutually exclusive one of said delay elements, the inside surface of the inner U-shaped channel being electrically conductively coated; and

a plurality of shorting pins formed through opposing walls of said assembly, the locus of which pins define microwave cavities for effecting electromagnetic coupling between each said windows and an associated terminus of said delay element.

7. A constrained lens-type antenna comprising a lens having a controlled aperture phase distribution and including in combination a plurality of discrete and mutually parallel stacked stripline assemblies, each assembly comprising:

a pair of mutually nested rigid dielectric U-channels sandwiching a dielectric slipsheet having a plurality of deposited electrically conductive coplanar lines of selected lengths as discrete delay elements;

the outer surface of the opposing walls of the U-shaped channel assembly including microwave ports, each being electromagnetically coupled to an associated terminus of a mutually exclusive one of said delay elements.

8. A constrained lens-type antenna comprising a lens having a controlled aperture phase distribution and including in combination a plurality of discrete and mutually parallel U-shaped channel stripline assemblies, each assembly comprising:

a pair of mutually nested rigid dielectric U-channels;

a dielectric slipsheet having a plurality of electrically conductive delay lines of selected lengths, said slipsheet being sandwiched between said nested U-channels;

the outer surface of the opposing walls of the outer U-shaped channel including microwave ports formed by enclosed conductive loops, each port being in registry with an associated terminus of a mutually exclusive one of said delay lines, the inside surface of the inner U-shaped channel being electrically conductively coated; and

opposing walls of said assembly including microwave cavities for effecting electromagnetic coupling between each said windows and an associated terminus of said delay line.

9. A constrained lens-type antenna comprising a lens having a controlled aperture phase distribution and including in combination a shingled plurality of discrete and mutually parallel-laminated stripline assemblies, each assembly comprising:

a laminated pair of dielectric plates;

a dielectric slipsheet having a plurality of electrically conductive delay lines of selected lengths deposited thereon, said slipsheet being sandwiched between said plates of said laminated pair; and

opposing faces of said laminated assembly being clad with an electrically conductive coating, each said face having a plurality of microwave ports formed by apertures in said coating, each aperture being in registry with an associated terminus of a mutually exclusive one of said delay lines for effecting electromagnetic coupling between each port and an associated delay line element.

10. The device of claim 9 in which said apertures in each said coating form a lineal array of ports in a respective one of said plates, arrays on opposite faces of said laminated pair being electromagnetically coupled to opposite termini of said delay lines.

11. The device of claim 9 in which said apertures in each of said coatings form a lineal array of ports parallel to and proximate an opposite edge of said laminated assembly and being electromagnetically coupled to opposite termini of said delay lines.