

[54] **CIRCULAR SYMMETRIC BOOTLACE
LENS SYSTEM**

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represented by the Secretary of the Navy**

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[51] Int. Cl. **H01q 3/26**

[58] Field of Search **343/753, 755, 854, 911 R, 754,
343/777**

[56] **References Cited**

UNITED STATES PATENTS

3,145,382 8/1964 Cuming et al. **343/911 R**

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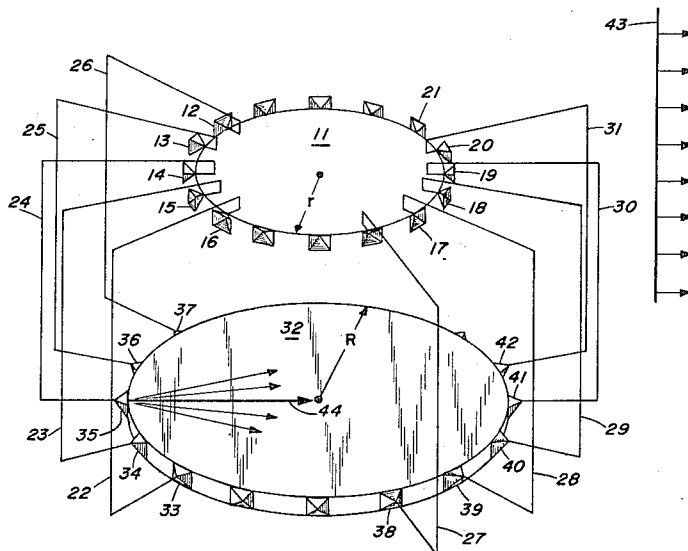
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[57]

ABSTRACT

The Circular Symmetric Bootlace Lens is a system of focusing energy into a well collimated beam. The system comprises a circular parallel plate lens and a circular array of elements. Energy is launched into the circular parallel plate lens and is collected by elements on the opposite side of the lens and then passes through equal length transmission lines to the circular array of elements where it is radiated.

6 Claims, 3 Drawing Figures



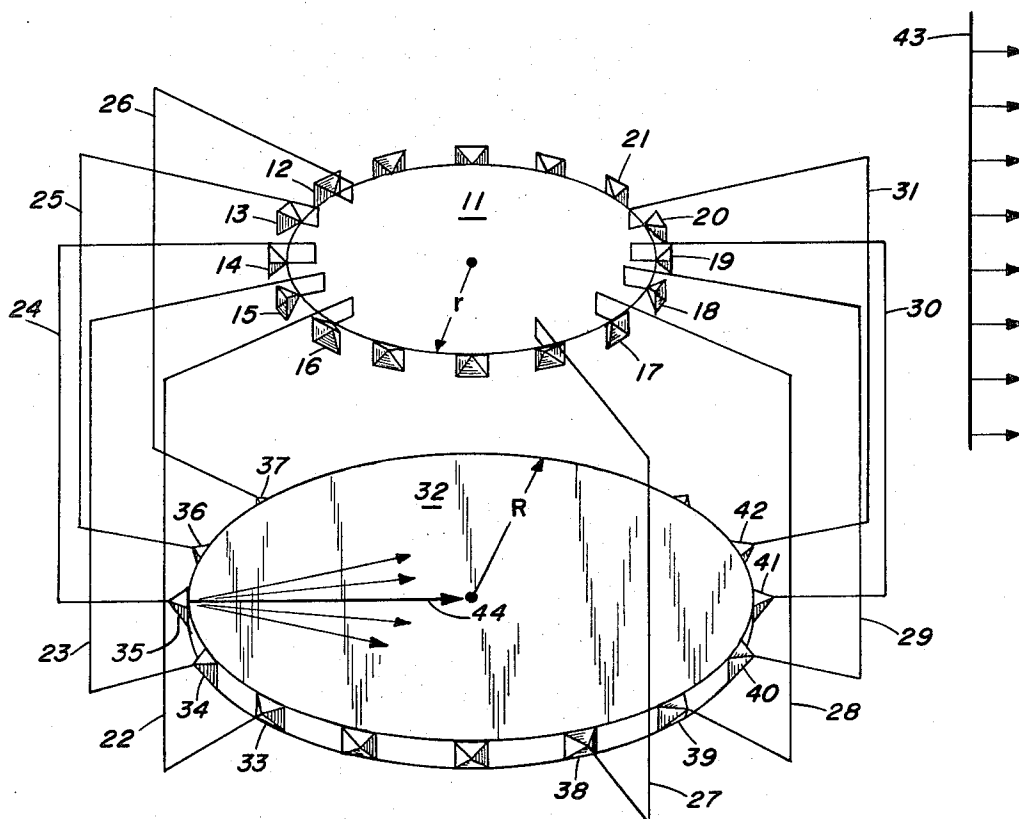


FIG. 1

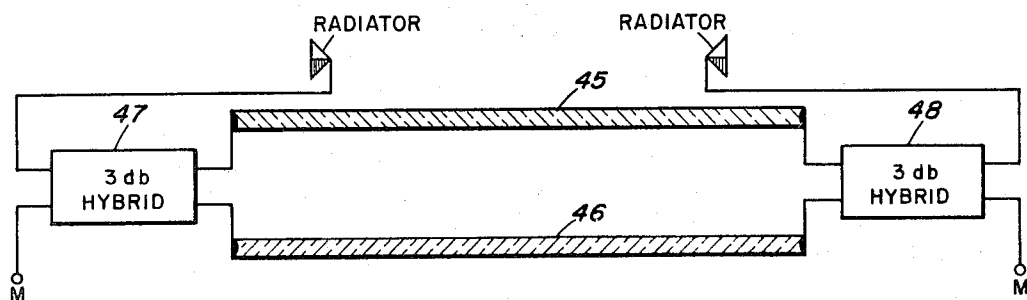


FIG. 3

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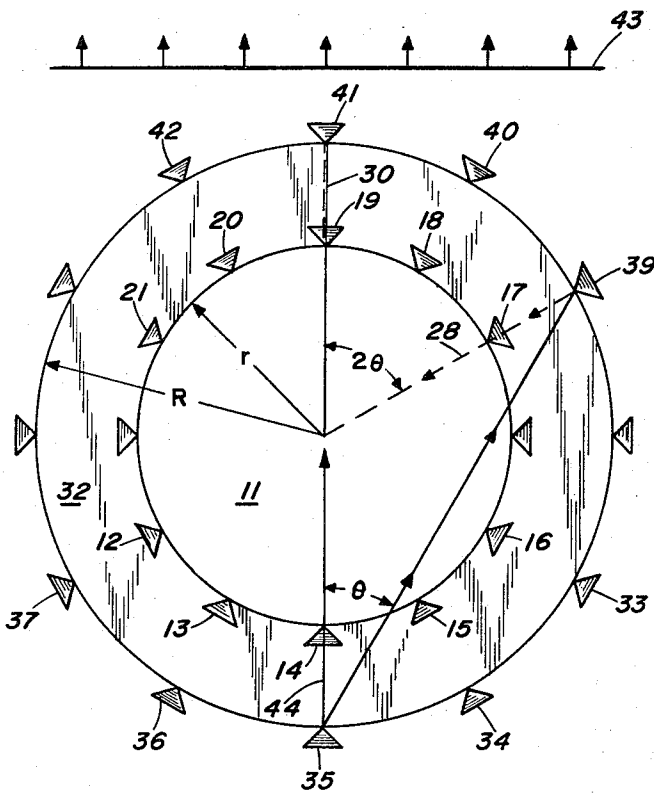


FIG. 2

CIRCULAR SYMMETRIC BOOTLACE LENS SYSTEM

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for The Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention relates in general to circular antennas and more particularly to an antenna system utilizing a lens as a beam forming device.

In the field of scanning antenna systems it has been the general practice to employ a series of linear antenna arrays to permit rapid 360° coverage, and it has also been the general practice to employ mechanically rotating systems to enable the transmission and reception of electro-magnetic energy over 360° of azimuth. Although such devices have served the purpose, they have not proved entirely satisfactory under all conditions of service for the reasons that a considerable amount of complex equipment is required in the case of the use of a series of linear arrays and that, in the case of mechanical scanning devices, the scan rate is extremely slow and requires a large time interval for a complete scan of the horizon. Transmission line feed systems require many components to scan 360° and its switches must have very small phase errors.

The symmetry of circular and cylindrical arrays makes them an attractive choice for any application which requires a beam to be scanned through 360°. Most methods of scanning such arrays, however, require relatively complicated switching systems, or their equivalent in networks utilizing numerous phase shifters. The only perfect, symmetric, optical feed system for such an array, which also has a one-to-one correspondence between feed position and farfield beam position, is the Luneberg lens as exemplified in U. S. Pat. No. 3,438,038 to A.E. Marston. Unfortunately, this lens system requires a variable index of refraction n , according to the formula

$$n = \sqrt{2 - \left(\frac{r}{r_0}\right)^2}$$

where r_0 is the radius of the circle. This is a significant constructional disadvantage in having a continuously varying dielectric constant. Another rotationally symmetric, zero phase error, system is the R-2R bootlace system. The disadvantage of the R-2R system is the requirement of 360° of effective feed rotation to provide 180° of beam position movement; additional switching, therefore, must be provided to obtain the other 180° of required coverage.

SUMMARY OF THE INVENTION

The general purpose of this invention is to provide a rapid scan antenna system which embraces all of the advantages of similarly employed scanning antennas and possesses none of the aforementioned disadvantages. To attain this, the present invention contemplates a unique arrangement of a circular lens having a constant index of refraction, a high scanning rate feed system, and equal length transmission lines from the lens to an array of radiating antennas. The lens has similar beam forming properties of the Luneberg lens and has many collecting elements distributed about its surface. The signal to be radiated is injected into the circularly shaped lens at one point on its circle and expands within the circle from that point into many individual portions which are separately picked up by the collecting probes located about the opposite surface of the lens. The signals picked up by each collecting probe is then transferred to the antenna array on equal length transmission lines to a circular array of radiating elements. All the collected signals are then radiated into space providing a highly directional concentrated beam capable of scanning 360° around the horizon.

OBJECTS OF THE INVENTION

An object of the present invention is the provision of a rapid scan antenna system.

Another object is to provide an antenna that will rapidly scan a signal through a total of 360° in azimuth.

Yet another object of the present invention is to provide a simplified lens for a radar antenna system.

Yet another object of the present invention is to provide electronic steerable scanning of a radar array.

Another object of the present invention is to provide a lens constructed of a homogeneous dielectric material having a uniform index of refraction.

A further object of the invention resides in the provision of a lens which is constructed in the form of a circle and that has air as its dielectric.

A still further object of the present invention is to provide a circularly symmetric optical bootlace feed system which does not require a variable index of refraction media and yet is capable of yielding small phase error for large apertures.

Yet another object of the present invention is to provide a bootlace lens antenna system having 360° field coverage for 360° of effective feed motion.

DESCRIPTION OF THE DRAWINGS

Other objects and features of the invention will become apparent to those skilled in the art as the disclosure is made in the following detailed description of a preferred embodiment of the invention as illustrated in the accompanying drawings in which:

FIG. 1 shows a perspective view of one embodiment of the invention;

FIG. 2 shows a top view of the antenna system of FIG. 1;

FIG. 3 shows a cross sectional view of another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to both drawings wherein like reference characters designate like or corresponding parts, there is shown in FIG. 1 a complete circular ring 11 of radiating focusing elements, such as wave guide horns, some of which elements are designated as 12-21. The radiating elements are located, equally spaced in angle, on circular ring 11, having a radius r . Each of the elements on the ring 11 is electrically connected to a probe on lens 32 by electrical connections which may be transmission lines, some of which are designated as 22-31, which are of equal length l . Lens 32 has a radius R , and has a constant index of refraction n . Transmission lines 22-31 are connected to probes 33-42 on the lens which are angularly spaced on the circle in the same manner as are elements 12-21 on ring 11. The index of refraction of lens 32 is taken to be unity if the material of the lens is air, although any other constant index of refraction is suitable.

The signal phase produced by this system can be seen to be dependent solely upon the electrical path length through the lens 32 plus the electrical line length l plus the distance from the transmitting element to the desired equiphase phase front 43. Referring now to FIG. 2, it can be seen that the distance the signal travels within lens 32 from a transmitting probe such as probe 35, to a receiving probe, any of the probes on the lens being capable of transmitting or receiving, is $2nR \cos \theta$ where R is the radius of lens 32, n is the index of refraction of the lens, and θ is the angle between the incident ray 44, if probe 35 is the transmitting probe, and the receiving probe on the opposite side of the lens 32, e.g., probes 38-42. The received signal then exits through the transmission lines 27-31 of length l to the radiating elements 17-21 and the energy then leaves the antenna as a plane wave indicated in FIG. 1 as transmitted plane phase front 43. The distance from lens 11 to the equiphase phase front 43 is $r(1 - \cos 2\theta)$, where r is the radius of ring 11. Thus the total length of travel of the electrical signal entering the system at an element on lens 32 is $2nR \cos \theta + l + r(1 - \cos 2\theta)$.

For a good optical system the difference between the line lengths for all angles of θ is minimal and radius R of lens 32 can be adjusted accordingly for optimum use of the system for any index of refraction n according to the formula $R = R_0/n$ where R_0 is the radius of lens 32 when air is the dielectric constant, approximately $2r$. The radius of lens 32 may be reduced by loading the region in the lens with dielectric material. Suitable high dielectric constant material would allow the lens 32 circle radius to become smaller than the radius of the array of radiators 11.

The circularly symmetric bootlace system, as described thus far, requires a single pole double throw switch (not shown) at each element along lens 11 to select whether this point is connected to a radiating element or to the source of energy. In addition, a single pole N throw switching system is required to select among the N possible beam positions. The N single pole double throw switches may be eliminated by the scheme shown in FIG. 3. Here a cross section of a scanner is shown in which two of the lenses 45, 46, of radius R are utilized and connected through 3 db hybrids 47, 48. This arrangement provides N terminals labeled M which may be connected to a source by the beam selecting switch. It is interesting to note that if the terminals M are left either open or short circuited, a circularly symmetric reflector system results. This is of some practical importance; for example, a vertical stack of scanners, as shown in FIG. 3, could have the terminals, M, cross connected between members of the vertical stack (in the manner of a Van Atta array) so that a passive retrodirective three dimensional reflector system would result. Thus if the system were illuminated by a radar over a large solid angle substantially uniform high return to the radar would result.

It is apparent from the circular symmetry of the antenna that the ability to transmit will be effective for all angles in azimuth and that by the action of the scanning system the energy can be rapidly scanned in all directions of azimuth.

It can therefore be seen that the invention very effectively provides for omnidirectional, rapid scan antenna system which avoids the complexity necessary in the use of linear arrays and which is capable of far greater scanning rates than has heretofore been possible by the use of mechanically rotating systems. This antenna system can be used in a wide variety of applications wherein high scanning rates and 360° coverage are required such as in radar systems used to detect high speed aircraft and missiles, IFF, or as a repeater in a microwave system to name just a few examples. The antenna is also capable of receiving from any direction in azimuth.

It should be understood, of course, that the foregoing dis-

closure relates to only a preferred embodiment of the invention and that numerous modifications or alterations may be made therein without departing from the spirit and the scope of the invention as set forth in the appended claims.

What is claimed and desired to be secured By Letters patent of the United States is:

1. In an omnidirectional rapid scan antenna system, the combination comprising:

a circular array of radiating elements, said array having a radius r ;

a circular lens having a plurality of probes, said lens having a radius R and constructed from dielectric material having a constant index of refraction n , said probes being either energy transmitting probes or energy receiving probes; and

equal length electrical connecting means l coupling each of said probes to its respective radiating element

whereby any transmitted signal travels through the same distance as another signal transmitted through various receiving probes according to the formula

$$2nR \cos \theta + l + R(1 - \cos 2\theta)$$

where θ is the angle between the transmitting probe to a receiving probe directly opposite it and the receiving probe.

2. An antenna system as recited in claim 1, wherein said radiating elements are equally spaced along said array;

wherein said probes are equally spaced along said lens;

a source of electrical energy coupled to said transmitting probes.

3. An antenna system as recited in claim 2 wherein said lens is two spaced, circular conducting plates; and said connecting means comprises transmission lines.

4. An antenna system as recited in claim 3 wherein said dielectric material is air and said index of refraction is 1.

5. An antenna system as recited in claim 4 including switches coupled to said probes whereby said probes may be either transmitting or receiving; and

wherein said elements are wave guide horns.

6. An omnidirectional antenna system comprising:

at least two circular lenses of radius R each having a constant index of refraction n ;

a plurality of radiators arranged in a circular array and

3 db hybrid elements between both of said lenses and connected to each radiator by means of equal length transmission lines.

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