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FOCUSING DEVICE FOR CENTIMETER WAVES

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FIG. 1

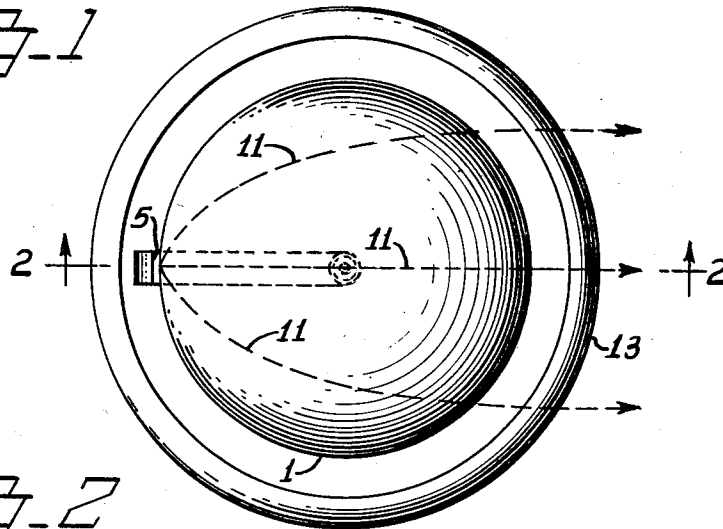
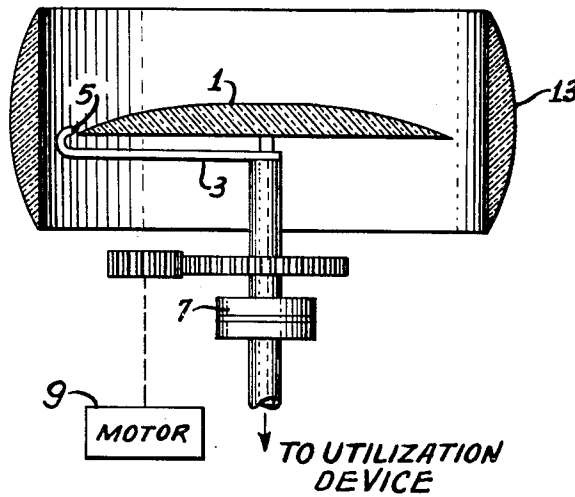


FIG. 2



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FOCUSING DEVICE FOR CENTIMETER WAVES

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7 Claims. (Cl. 250—33.63)

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This invention relates to improvements in the art of focusing radio waves, and more particularly to dielectric lenses.

The principal object of the invention is to provide a lens capable of focusing with negligible aberration over a wide angle, at a low ratio of focal length to aperture.

Another object is to provide a lens which is readily adaptable for scanning purposes, in that it has a relatively sharply curved field which can be scanned conveniently by a feed horn or the like moving in a circular path.

A further object of this invention is to provide an improved antenna system producing a narrow directive beam which can be scanned or revolved throughout an angle of 360 degrees in one plane, such as the horizontal.

The invention will be described with reference to the accompanying drawing, wherein:

Figure 1 is a plan view of a directive scanning antenna system embodying the invention, and

Figure 2 is a section in the plane 2—2 of Fig. 1.

Similar reference characters are applied to similar elements throughout the drawing.

The illustrated structure includes a disc shaped body 1 of dielectric material such as polystyrene, paraffin, or sulphur. The disc 1 is of varying thickness as shown in Fig. 2, being thickest at its center and tapering toward its edge. A wave guide 3 terminates at the edge of the disc 1, with its mouth 5 directed radially toward the center of the disc. The mouth 5 may radiate energy as a radiator or receive energy as a receiver. The wave guide 3 extends below the disc 1 to a point substantially beneath the center, thence downward along the axis of the disc to a utilization device, not shown, such as a radio transmitter or receiver. A rotary joint 7 is included in the vertical portion of the guide 3. The part above the joint is rotatable about the vertical axis, and may be driven by a motor 9. The disc 1 is substantially entirely immersed in the dielectric medium, in this instance the air through which the radio waves, that is, the electromagnetic energy, to be focused are propagated.

It can be shown theoretically that for a sphere of refracting material in which the index of refraction varies from 1 to $\sqrt{2}$ according to the formula

$$n = \sqrt{2 - R^2}$$

where R is the ratio of the radial distance from the center to the point under consideration to the radius of the sphere, a distant object will be imaged perfectly upon the surface of the sphere. This formula is derived in "Mathemati-

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cal Theory of Optics" by R. K. Luneberg, pp. 208—213. By simple analogy, a disc whose refractive index varies from center to periphery in the same manner will act like a lens, operating in only two dimensions instead of three.

Lenses of the above described type, either spherical or disc-like, have never been used because of the manifest impracticability of making a body whose refractive index varies in the required manner. The essence of the present invention lies in overcoming this difficulty.

The effective refractive index of a material is inversely proportional to the velocity of propagation of electromagnetic wave energy through the material:

$$n = \frac{c}{v}$$

where n is the refractive index, v is the velocity of propagation through the material, and c is the velocity of propagation through empty space. I have found that the velocity of propagation of electromagnetic energy through a thin body of dielectric material depends upon the thickness of the body in the direction parallel to the electric vector of the wave. Accordingly, by making the thickness of the disc 1 vary as a function of distance from the center, it is possible to obtain the same performance as though the refractive index were varied. The relationship between thickness and effective refractive index was determined experimentally for polystyrene at a wave length of $1\frac{1}{4}$ centimeters, with the following results:

Radius (per cent of maximum)	0	20	40	60	80	90	100
Desired n	1.41	1.40	1.36	1.28	1.17	1.09	1.0
Thickness (inch).....	0.260	0.250	0.225	0.185	0.140	0.105	0
Thickness/wavelength.....	0.528	0.508	0.457	0.376	0.284	0.213	0

In the system illustrated the disc 1 is proportioned in accordance with the above or similar data. From the data it is seen that the thickness is less than a free space wavelength. Energy applied to the lower end of the wave guide 3 is radiated from the mouth 5 into the edge of the disc 3 generally toward the center. The energy is refracted substantially as shown by the dash lines 11 in Fig. 1 and emerges from the opposite edge of the disc in parallel paths with linear phase fronts lying perpendicular to the line extending through the center of the disc and the mouth of the wave guide. Thus the disc 1 concentrates the more or less diffuse radiation from

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the wave guide 3 into a beam which is extremely narrow in azimuth. The plane of this beam can be rotated throughout 360 degrees by rotating the mouth 5 of the wave guide 3 about the periphery of the disc 1. It will be apparent that the disc 1 may be rotated with the wave guide or may remain stationary without having any effect on the performance.

In order to concentrate the radiation to some extent in elevation a further lens member 13 surrounds the disc 1. The lens 13 is in the form of a hollow cylinder tapering from a maximum thickness at its equator to a minimum at its upper and lower ends. The cylinder 13 is also made of refractive material, and each vertical element of it acts like a two dimensional lens in a plane at right angles to that of the disc 1.

It will be apparent to those skilled in the art that a stack of discs 1 may be used when it is desirable to have a cylindrical lens having a greater cross-section area than is provided by one disc alone.

I claim as my invention:

1. A device for focusing radio waves in linear phase fronts lying in a single plane, comprising a body of dielectric material symmetrical with respect to a line perpendicular to said plane, and having a thickness parallel to said line which varies inversely as the distance from said line in such manner that the effective refractive index n of said body to waves travelling parallel to said plane varies from point to point as:

$$n = \sqrt{2 - R^2}$$

where R is the ratio of the radial distance of a point on said body from said line to the maximum radial distance, and means for directing radio waves to be focused toward said body substantially along a radius from said line in said plane.

2. A scanning antenna for radio waves, comprising a disc-shaped body of dielectric material, symmetrical about a line extending perpendicularly from the center of said disc, and decreasing in thickness from said center to the edge of said disc, the maximum thickness being less than the wavelength of the energy with which the antenna is to operate; a radiator ad-

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jacent the periphery of said disc and arranged to direct energy toward the center of said disc, said radiator being movable in a circular path around said periphery.

3. The invention as set forth in claim 2, including a cylindrical wall of dielectric material surrounding said disc, the thickness of said wall varying in such manner that each vertical element thereof constitutes a two dimensional convex lens.

4. An antenna device comprising a disc-shaped body of dielectric material having a substantially circular periphery and decreasing in thickness from the center to the said periphery of said disc, the maximum thickness being less than a wavelength at the operating frequency, and a radiator or receiver adjacent a point of the periphery of said disc and arranged to direct energy toward the center or receive energy from the center of said disc, said radiator being movable in a circular path around said periphery.

5. The antenna claimed in claim 2, further comprising means to rotate said radiator around said circular path.

6. The antenna device claimed in claim 4 further comprising a motor, said radiator or receiver being driven rotatably about said circular path by said motor.

7. The antenna device claimed in claim 6, said radiator or receiver comprising a waveguide having an open-mouth portion facing the center of said disc.

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