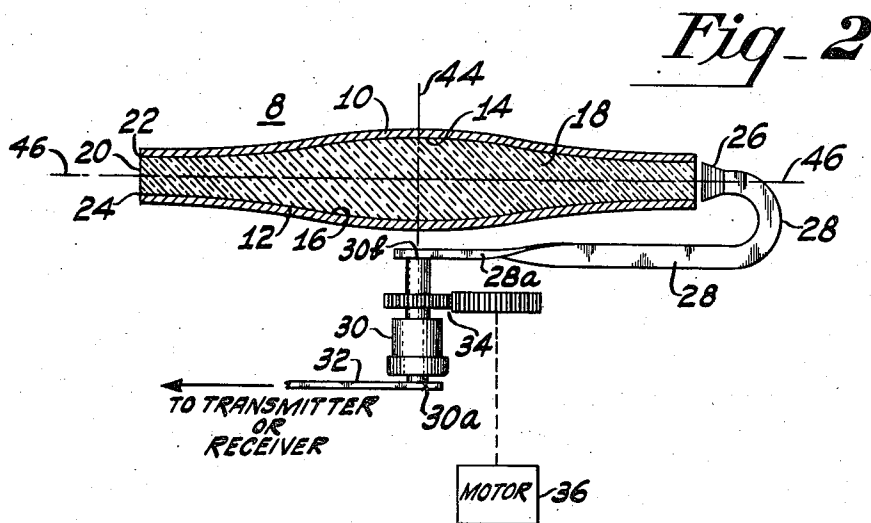
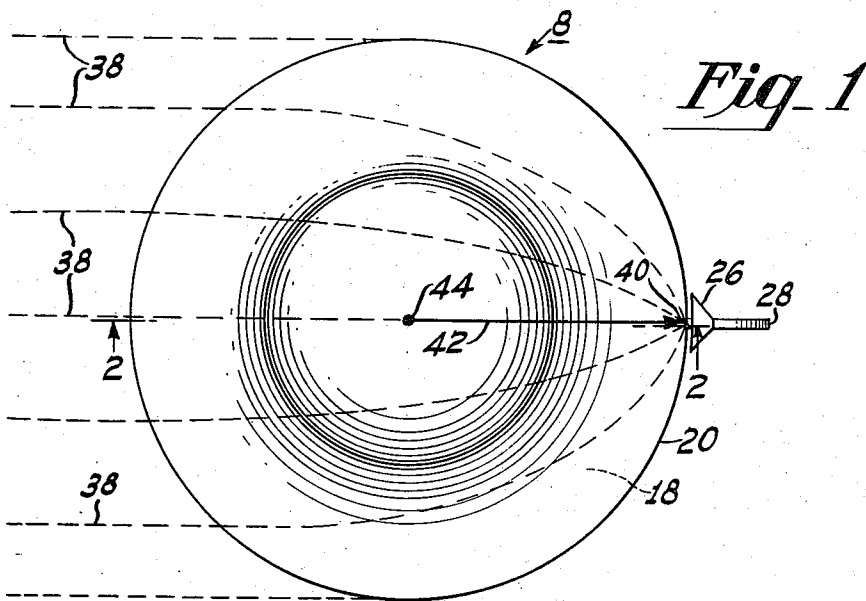


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SCANNING ANTENNA SYSTEM

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SCANNING ANTENNA SYSTEM

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This invention relates to electromagnetic energy scanning apparatus and focusing devices.

It is frequently desirable in scanning an area from an antenna to radiate or receive a collimated beam of energy in a complete 360° circular scan around the antenna. Such scans of 360° are often desired, for example, in radio echo detection devices. This type of scanning is most often accomplished by rotating an entire antenna including a focusing reflector which is rotated through the desired 360° scan angle. However, when the entire antenna is so rotated, the rate of scanning is often slow, and the requisite equipment is often bulky. It has been proposed, in the application of Harley Iams, Serial No. 782,521, filed October 28, 1947, to provide a lens especially adapted for scanning purposes whereby an associated feed device may be rotated around the circular periphery of the lens. This lens of the Iams application, however, operates only for energy polarized with the electric vector normal to the plane of the circular edge of the lens and to the scan circle.

It is an object of the present invention to provide an antenna apparatus for scanning through a complete circle with energy polarized parallel to the plane of the scan circle.

It is a further object of the invention to provide a lens element suitable for such apparatus.

It is a further object of the invention to provide such apparatus which is readily constructed, compact, and permits of rapid scanning by rotation of a horn feed or the like.

These and other objects, advantages, and novel features of the invention will be more apparent from the following description in which like reference numerals refer to like parts and in which:

Fig. 1 is a plan view from above of apparatus according to the invention; and

Fig. 2 is a view partially in cross section along section line 2—2 of Fig. 1.

In accordance with the invention a pair of dielectrically separated metallic bodies have wave-guiding surfaces facing each other between which the energy is to pass. The wave-guiding surfaces are each rotationally symmetrical with respect to a common axis, and the spacing therebetween is predetermined so that collimated energy entering the circular edge of the space between the bodies is focused at another point on the edge of the space. The metallic bodies preferably comprise a metallic coating on a dielectric member. A radiator or receptor placed at the focal point may then be rotated along the circu-

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lar edge of the space between the wave-guiding surfaces.

Referring now more particularly to the drawing, a lens element or focusing device 8 includes a pair of metallic bodies 10, 12 having wave-guiding surfaces 14 and 16 respectively facing each other defining therebetween a space 18 filled with a dielectric medium. In the example shown, the space 18 is filled with a solid dielectric. The surfaces 14, 16 may comprise metal plates juxtaposed with the upper and lower surfaces of the dielectric medium 18 or surface electrodes may be plated or otherwise applied to said medium. The space 18 has a substantially circular edge 20 which lies between the circular margins 22, 24 of the wave-guiding surfaces 14, 16 respectively.

The focusing device 8 has associated with it a radiator or receptor, such as a horn antenna, depending on whether it is desired to radiate or receive electromagnetic energy. The horn antenna 26 is closely adjacent to the edge 20, say a fraction of the edge radius, and preferably a small fraction, say one-tenth. Horn antenna 26 at its other end is coupled to one terminal of a rectangular waveguide 28, the other terminal of which is coupled to a rotary joint 30. The rotary joint 30 in turn is coupled to a rectangular waveguide 32, the latter being connected to a transmitter or receiver (not shown) if desired through a suitable transmit-receive arrangement such as is customary in radio echo detection apparatus. The rotary joint 30 may be of the type disclosed at page 427 of Microwave Transmission Circuits, edited by G. L. Ragen and published as Volume 9 of the Radiation Laboratory Series by the Massachusetts Institute of Technology. By means of two transitions 30a and 30b the rectangular guide 32 is coupled through the rotary joint 30 to the rectangular guide 28.

The horn antenna 26 feeds, or receives, through the focusing device 8, energy polarized with the electric vector in the plane of the periphery circular edge 20 and parallel to the planes of the peripheries or circular margins 22, 24. Because of the type of rotary transition here shown, in order to obtain the desired polarization, the waveguide 28 contains a 90° twist 28a at a suitable point therein. The rotary joint 30 may be driven through suitable gearing 34 by a motor 36. Other means for obtaining the desired circular motion of horn antenna 26 will be evident from the various rotary joints described at pages 446 to 455 of the same volume.

It is known, as pointed out for example in the volume entitled Mathematical Theory of Optics

by R. L. Luneberg, pages 208 to 213, that if a lens of a non-homogeneous dielectric medium is immersed in a dielectric medium of dielectric constant 1, and if the lens is spherical and has a radius R, and if r be the distance from the center of the sphere to a point therein, then if the dielectric constant n throughout the lens satisfies the formula

$$n = \sqrt{2 - \left(\frac{r}{R}\right)^2} \quad (1)$$

collimated rays falling on the surface of the sphere will be focused at a point diametrically opposite, that is, the point intersected by the radius vector from the center of the sphere having the same direction as the incident rays.

By analogy to plane geometric optics, if electromagnetic energy be propagated with the electric vector parallel to the plane of a disk-like space defined by the surfaces of two metallic bodies, then an equivalent effective index of refraction n_1 is:

$$n_1 = \sqrt{e - \left(\frac{\alpha_0}{2a}\right)^2} \quad (2)$$

where e is the dielectric constant of the material in the space defined between the metallic bodies, α_0 is the free space wavelength, and a is the spacing between the wave-guiding surfaces at the point in question. Equating the values of n_1 and n gives the law of dependency or the function which the spacing between the surfaces 14 and 16 should obey in order to cause the energy to be focused at the circular edge 20 of the disk-like space. The spacing between the wave-guiding surfaces to accomplish the desired focusing is found to be:

$$a = \frac{\alpha_0}{2\sqrt{e + \left(\frac{r}{R}\right)^2 - 2}} \quad (3)$$

Collimated rays 38 shown schematically in Fig. 1 are thus focused at a point 40 which is intersected by the radius vector 42 drawn parallel to the rays 38 from the axis of symmetry 44 of the device 8 to the edge 20. The device 8 and the associated scanning apparatus are particularly adapted for the radiation or reception of exceedingly short wavelengths of electromagnetic energy. It is preferred to construct the device 8 by forming a polystyrene disk to fill the space defined by the metallic elements 10, 12 which may then be deposited as a metallic coating, which may be silver or the like. A typical device 8, made of polystyrene dielectric coated with silver, and with a radius R from the axis 44 to the edge 20 of 10 inches, has substantially a half power beam width of $2\frac{1}{2}$ degrees and lobes reduced by 13.6 decibels from the maximum of the main lobe. The free space wavelength at the operating frequency is 1.5 centimeters and the maximum separation a , at the axis 44 is .33 centimeters.

The surfaces 14, 16 and the bodies 10, 12 are preferably symmetrical with respect to a central plane 46 between them. Then the bodies 10, 12 may be made from the same die, or two dies of the same contour may be used to form the surfaces of a disk of polystyrene or the like filling the space 18 and on which the metallic bodies 10, 12 may be deposited or otherwise affixed.

If it is desired to compensate failure of the energy to focus at the edge 20, the wave-guiding surfaces 14, 16 may have contours different from those determined by the foregoing formula.

In the operation of the scanning apparatus,

pulses of energy may be sent out from a transmitter through waveguide 32, the rotary joint 30, waveguide 28 and horn antenna 26. Thus the energy is fed to the focusing device 8 substantially at a point on the circular edge 20 of the disk-like space between the surfaces 14, 16 polarized with the electric vector parallel to the plane 46. The rays of energy then follow paths somewhat as illustrated by the dotted ray lines inside the space 18 to the diametrically opposite side of device 8 and exit from device 8 as a beam indicated by ray lines 38 well collimated in, and polarized with the electric vector parallel to, the plane of the scan circle. This beam rotates about the device with rotation of the rotary joint 30 driven by motor 36 through the gears 34. Conversely, received or returned echo energy collimated on incidence at device 8 and polarized with the electric vector parallel to the scan circle is focused at a point on the circular edge 20 of the space between wave-guiding surfaces 14, 16. If horn antenna 26 is at this focal point the energy passes successively through horn antenna 26, waveguide 28, rotary joint 30 and waveguide 32 to a receiver, if one at the moment be connected instead of the transmitter. It will be apparent that, because the moving parts are light and rotatably driven, the scanning apparatus may be made to scan at a relatively rapid rate through a 360° scanning angle. Such rapid scanning rates are difficult to achieve with conventional structures.

The invention as described includes a scanning apparatus which may scan through a 360° scan angle and a novel focusing device which has particular advantages for this type of scanning apparatus because the focal field falls upon the circular periphery of the focusing device, and the apparatus can give high rates of scan.

What I claim is:

1. Scanning apparatus comprising a pair of dielectrically separated metallic bodies having wave-guiding surfaces facing each other and each rotationally symmetrical with respect to a common axis, the peripheries of said surfaces having substantially the same radius, and a radiator or receptor closely adjacent and facing toward the space defined between said surfaces and toward said axis respectively to direct or receive energy polarized with the electric vector thereof parallel to the planes of said peripheries to travel within the space between said surfaces and to exit from or be received from the side of said space radially opposite said radiator or receptor.

2. The apparatus claimed in claim 1, said radiator or receptor being movable to different points along a circular path in a plane normal to and centered on said axis, said path being substantially that defined between said peripheries of said body surfaces.

3. The apparatus claimed in claim 1, said radiator or receptor being rotatably movable along the edge of the space between said surfaces in a plane normal to and on a path centered on said axis.

4. The apparatus claimed in claim 1, the distance of separation a between said surfaces at any point a distance r from said common axis being defined by the equation

$$a = \frac{\alpha_0}{2\sqrt{e + \left(\frac{r}{R}\right)^2 - 2}}$$

where R is the peripheral radius of said surfaces and e is the dielectric constant of the dielectric separating said metallic bodies.

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5. The apparatus claimed in claim 1, further comprising a solid dielectric member, said bodies comprising a metallic coating on said member.

6. The apparatus claimed in claim 1, further comprising means to drive said radiator or receptor in a circular path about said axis with a radius substantially equal to that of each said body periphery.

7. A focusing device comprising a pair of dielectrically separated metallic bodies having wave-guiding surfaces opaque to electromagnetic energy at the operating frequency and facing each other and rotationally symmetrical with respect to a common axis, said bodies having substantially the same radius, said surfaces defining therebetween a disk-like space with a circular edge, a dielectric being the sole filling in said space, the distance of separation between the surfaces at any point bearing a predetermined relation to the radial distance in the disk-like space from said axis to said point, so determined that rays of collimated electromagnetic energy polarized with the electric vector parallel to the plane of said disk-like space and entering said space at the edge thereof is focused substantially at the point on said edge intersected by the radius vector from said axis parallel to and in the same direction as that of said rays said predetermined relation being

$$a = \frac{\alpha_0}{2\sqrt{e + (r/R)^2} - 2}$$

where a is the separation between the surfaces at a distance r from said axis, and R is the peripheral radius of each body.

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comprising two metallic bodies having rotational symmetry with respect to a central axis and symmetrical with respect to a central plane normal to said axis and having surfaces opaque to electromagnetic energy at the operating frequency and facing each other to define therebetween a space, said bodies having substantially the same radius, and a dielectric separating said bodies and being the sole filling of the said space so defined, said plane being parallel to the electric vector of the energy to be focused, the distance of separation a between said surfaces at any point a distance r from said common axis being defined by the equation

$$a = \frac{\alpha_0}{2\sqrt{e + (r/R)^2} - 2}$$

where R is the peripheral radius of said surfaces and e is the dielectric constant of the dielectric separating said metallic bodies.

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