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C. H. CHANDLER

2,704,327

FOCUSsing AND DEFLECTION OF CENTIMETER WAVES

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Fig. 1

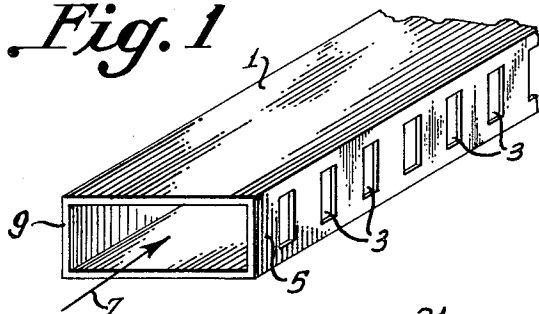


Fig. 2

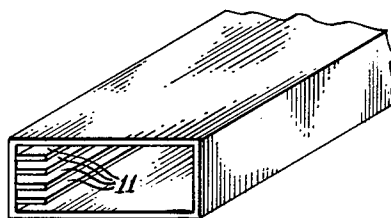


Fig. 3

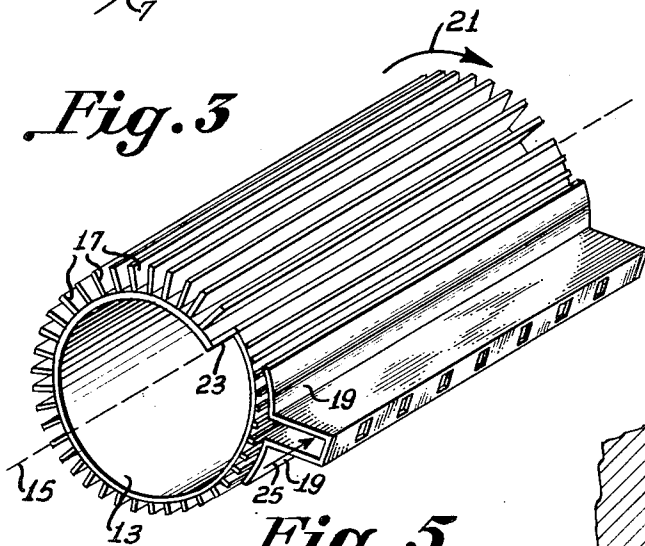


Fig. 4

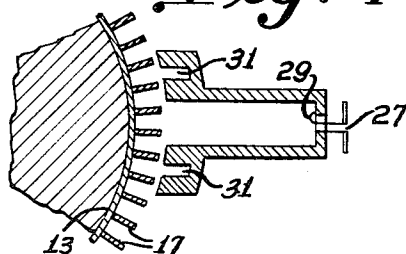


Fig. 5

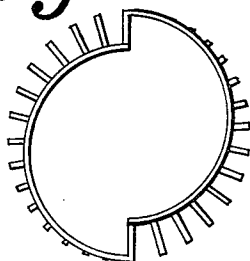
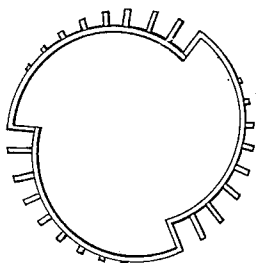


Fig. 6



Inventor:
Charles H. Chandler

By *J. L. Whittaker*
Attorney

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FOCUSSING AND DEFLECTION OF CENTIMETER WAVES

Charles H. Chandler, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

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10 Claims. (Cl. 250—33.63)

This invention relates to scanning antenna systems, for producing a beam of radio energy and periodically sweeping the axis of said beam throughout an arc. The principal object of the invention is to provide improvements in methods and means for feeding a linear array of spaced radiators with a phase displacement between successive radiators, and varying said phase displacement to change the position of the resultant directional beam.

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

Figure 1 is a pictorial view of a wave guide and radiator structure providing a fixed directive pattern,

Figure 2 shows a modification of the structure of Figure 1 illustrating one of the principles involved in the present invention,

Figure 3 is a pictorial view of a scanning antenna system embodying the invention,

Figure 4 is a sectional view of a modification of the structure of Figure 3, and

Figures 5 and 6 show modifications of the rotor of the device of Figure 3.

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

It is known in the radio art that a linear array of spaced radiators, energized in successively different phase, provides a directional beam tilted at an angle θ to the array, where θ depends on the spacing between adjacent radiators and the phase difference between them.

Referring to Figure 1, a wave guide 1 is provided along one side with a series of apertures, or slots, equally spaced and each extending vertically across the side wall 5. When radio energy is applied to the wave guide 1 in the direction indicated by the arrow 7, it will propagate down the guide in the TE_{1,0} mode, with the electric vector vertical, i. e. parallel to the long dimension of the slots 3.

Some of the energy escapes at each slot and is radiated. Thus each slot acts like a small vertically polarized doublet coupled to the wave guide. The phase difference between each radiator and the next adjacent one is directly proportional to the spacing and inversely proportional to the velocity of propagation of energy through the wave guide. If all the radiator slots are energized in phase, their resultant field will comprise a beam perpendicular to the direction of energy flow through the wave guide.

The velocity of propagation of energy down the wave guide is a function primarily of the distance between its side walls 5 and 9. The presence of a number of longitudinal horizontal ridges or fins 11, as shown in Fig. 2, has substantially no effect on the velocity. Moreover the performance is not materially altered by minor variations in the cross sectional shape of such fins or ridges.

According to the present invention, the effective width of the wave guide is varied cyclically by substituting for one of its side walls a volute or scroll shaped member 13 (see Fig. 3), rotatable about its longitudinal axis 15 to make the distance between it and the side wall 5 vary cyclically. Secured to the outer surface of the scroll 13 are radial fins 17 each of a different radial length and arranged so that their outer edges are elements of a right circular cylinder. The top and bottom walls of the wave guide are provided with extensions 19, curved to conform to the cylindrical surface defined by the fins 17.

In the operation of the device of Fig. 3, the fins 17 act as parts of the top and bottom walls of the wave guide

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in the region between the body of the rotor 13 and the edges of the fixed portion of the wave guide. The clearance between the fins 17 and the flanges 19 should be as small as is practical in order to minimize the escape of energy in this region. Rotation of the scroll 13 about the axis 15, as indicated by the arrow 21, cyclically reduces the effective width of the wave guide from a maximum to a minimum; as the step portion 23 of the scroll goes by the side of the guide, the effective width increases quickly to its maximum value and the cycle is repeated.

Energy supplied to the wave guide in the direction indicated by the arrow 25 propagates at a phase velocity which depends on the effective width. The wavelength λ_1 of the energy flowing in the guide is related to its wavelength λ_e in free space:

$$\lambda_1 = \frac{\lambda_e}{\sqrt{1 - \left(\frac{\lambda_e}{2a}\right)^2}}$$

where a is the effective width of the wave guide, perpendicular to the electric vector.

Suppose the radiator openings 3 to be spaced by a distance equal to the wavelength λ_1 where a is the mean width of the wave guide. Then the wavelength in the guide will vary, during each rotation of the scroll member 13, from a value greater than the radiator spacing to a value less than the radiator spacing. The phase displacement between successive radiator 3, going in the direction of energy flow down the waveguide, will be negative at first (each radiator leading the one before it), then decrease to zero (all radiators in phase), and increase in a positive direction until each radiator lags the one before it by the same angle as it was leading at the beginning of the cycle. The radiator excitations then jump back to their original relationships, and the sequence is repeated.

The beam resultant from simultaneous radiation from all the radiator elements 3 starts with its axis tilted to one side of the perpendicular to the line of the array, moves smoothly at a substantially constant angular velocity to a position on the other side of the perpendicular, then returns to its original position and repeats the motion. This type of beam motion is called "saw-tooth" scanning. It will be apparent that a sine wave or other relationship between beam angle and time may be provided by proper design of the rotor 13.

Figure 4 shows a modification of Figure 3 in which the radiator elements are actual physical doublet antennas 27 instead of slots. A coupling loop 29 serves to transfer energy from the interior of the wave guide to the radiator. The structure of Figure 4 differs also from that of Figure 3 in that the flange on the stationary portion of the wave guide is provided with longitudinal slots 31, about one-quarter wavelength deep. These slots act as traps to prevent the escape of energy through the gap between the stationary and movable parts of the wave guide. Additional slots of different depths may be provided such that at least one of them approximate a quarter wave choke groove at all positions of the rotor. The operation of the structure of Figure 4 is substantially the same as that of Figure 3.

When a high rate of scanning is involved, it is necessary that the rotor member be balanced dynamically to prevent undue vibration. Although this may be accomplished by a proper arrangement of weights on the rotor, it is preferable to make the rotor in the form of two or more symmetrically disposed scrolls, as shown in Figures 5 and 6. These arrangements have the advantage of providing a given number of scans per second with lower rotational speeds than would be required with the single spiral of Figure 3.

With any of the described scanning structures, a typical linear array of radiators will provide scanning through a total angle of 20 degrees with a change in effective width of the feed wave guide from .53 wavelength to .67 wavelength. At a frequency of 24,000 megacycles per second, the required variation in length of the radial fins from the body of the rotor is 0.071 inch.

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I claim as my invention:

1. A scanning antenna system comprising a cylindrical rotor at least a portion of which is of spiral cross-section, spaced radial longitudinal fins on said rotor portion, the radial lengths of said fins varying in accordance with their respective positions so that their outer edges lie on a circle, a stationary longitudinal trough adjacent said rotor and open along the side facing said rotor, said rotor portion with a pair of said fins and said trough together forming a wave guide, and a plurality of spaced radiators coupled to said wave guide at correspondingly spaced points along its length.

2. The invention as set forth in the foregoing claim, wherein said radiators have orifices in said trough in its side opposite said rotor.

3. The invention as set forth in claim 1 wherein the outer metallic surface of said rotor in cross section is two or more portions of spirals in sequence.

4. A wave guide having variable velocity of propagation, comprising conductive walls forming a longitudinal channel open at one side, and a substantially cylindrical drum adjacent said open side, said drum including a plurality of radial longitudinal slots parallel to the direction of propagation in said wave guide and of sequentially different depths and each having side walls and a bottom wall, and means rotating said drum about a longitudinal axis parallel to said slots sequentially to pass each said slot adjacent the open side of said channel with the side walls thereof continuing the said slot side walls and each said slot bottom wall and side walls providing a closure for said channel opposite the open side thereof at each sequential passing.

5. A scanning antenna system comprising an incomplete wave guide member open at one longitudinal side thereof and with opposed longitudinal walls adjacent to the open side, a movable part having a metallic surface and longitudinal metallic fins extending therefrom defining sections on said metallic surfaced part, means to move said movable part to bring the sections selectively into a position adjacent said wave guide longitudinal walls with a pair of said fins in substantial registry with said opposed longitudinal walls and with the

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said pair of fins and said part section therebetween thereby substantially completing the incomplete wave guide, one said movable part section in said position being at a different distance from the opposite wave guide wall than another said movable part section, whereby the completed wave guide has different velocities of propagation dependent on the movable part section brought into said position.

6. The antenna system claimed in claim 5, the movement of said movable part being rotational.

7. A scanning antenna system comprising a wave guide having a longitudinal opening at one boundary surface thereof, a movable member having a metallic wall, metallic longitudinal fins extending from said member wall and having different depths of extension, means to bring said movable member selectively into different positions with the edges of said fins adjacent to and substantially in registry with the edges of said longitudinal wave guide opening whereby in each said position the said opening is substantially closed by the said fins and member wall with said wave guide having transverse dimensions dependent upon said position thereby to change the velocity of propagation therethrough with said different positions.

8. The antenna system claimed in claim 7, the movement of said movable member being rotational.

9. The antenna system claimed in claim 7 wherein there are a plurality of radiators coupled to said wave guide and spaced along its length.

10. The antenna system claimed in claim 9 wherein said radiators have orifices in said wave guide in its side opposite said movable member.

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