Feb. 17, 1953 H. IAMS 2,629,052

SCANNING ANTENNA

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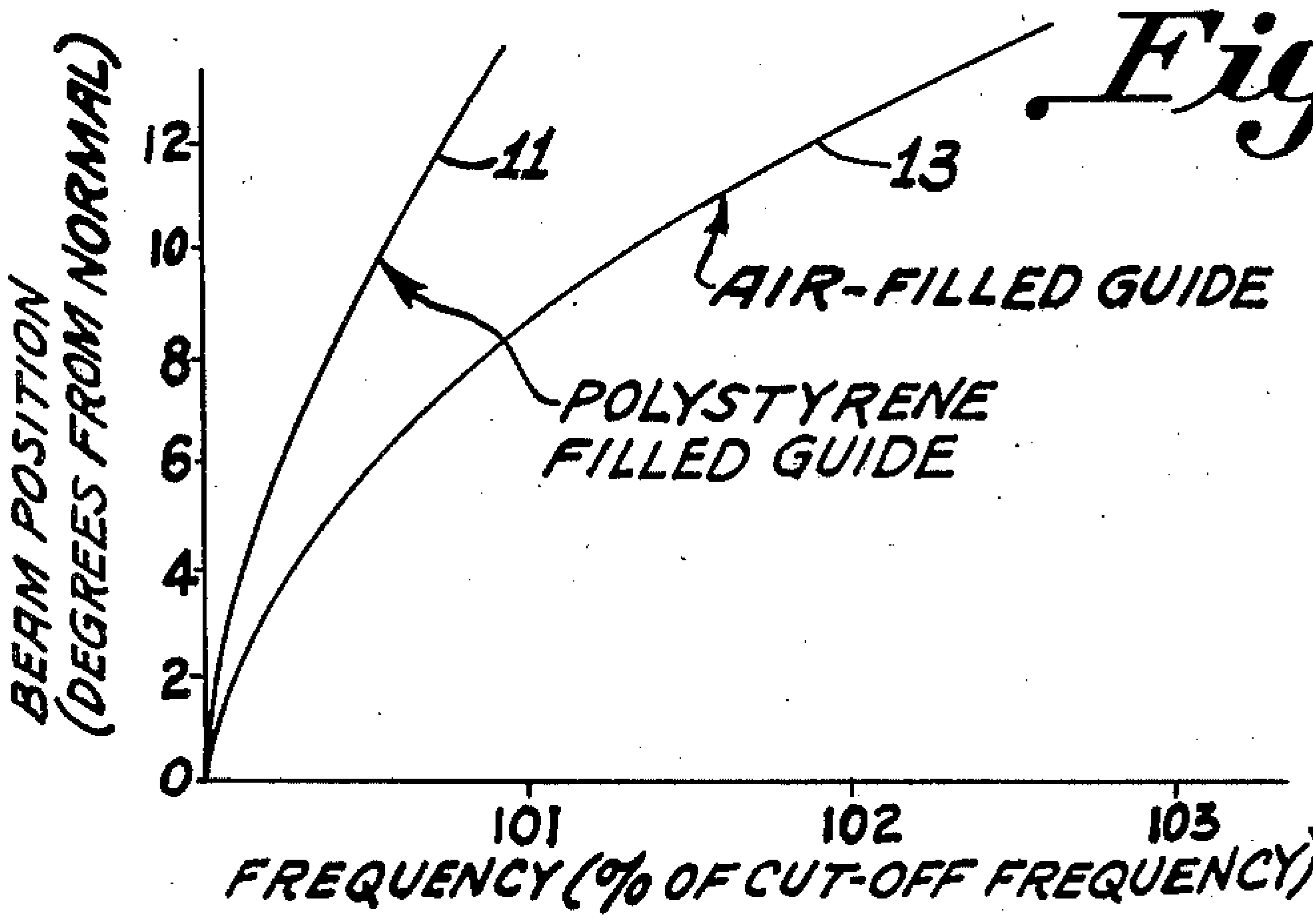
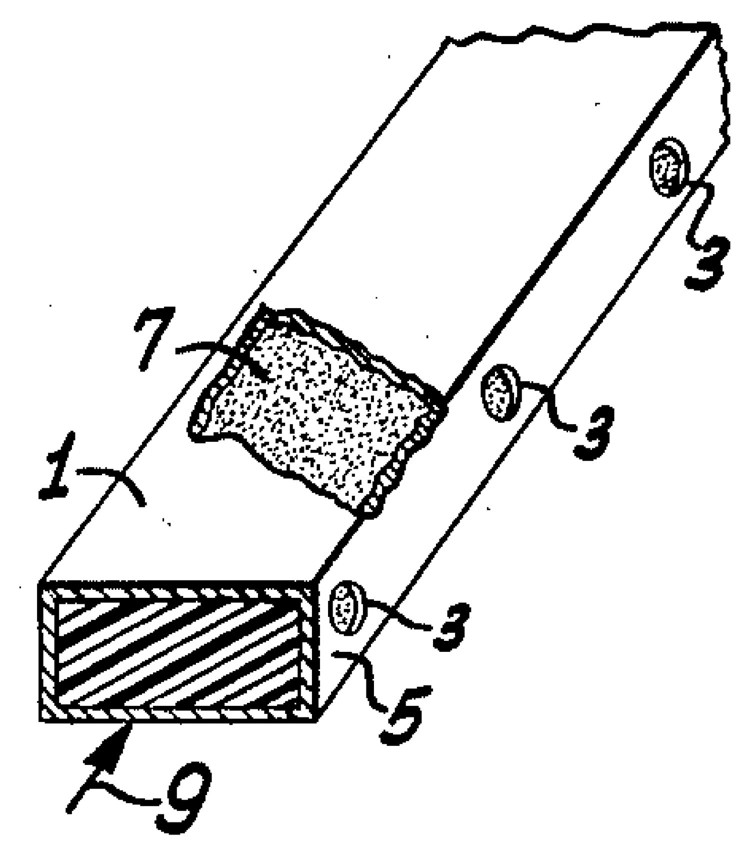


Fig. 2

Fig. 1



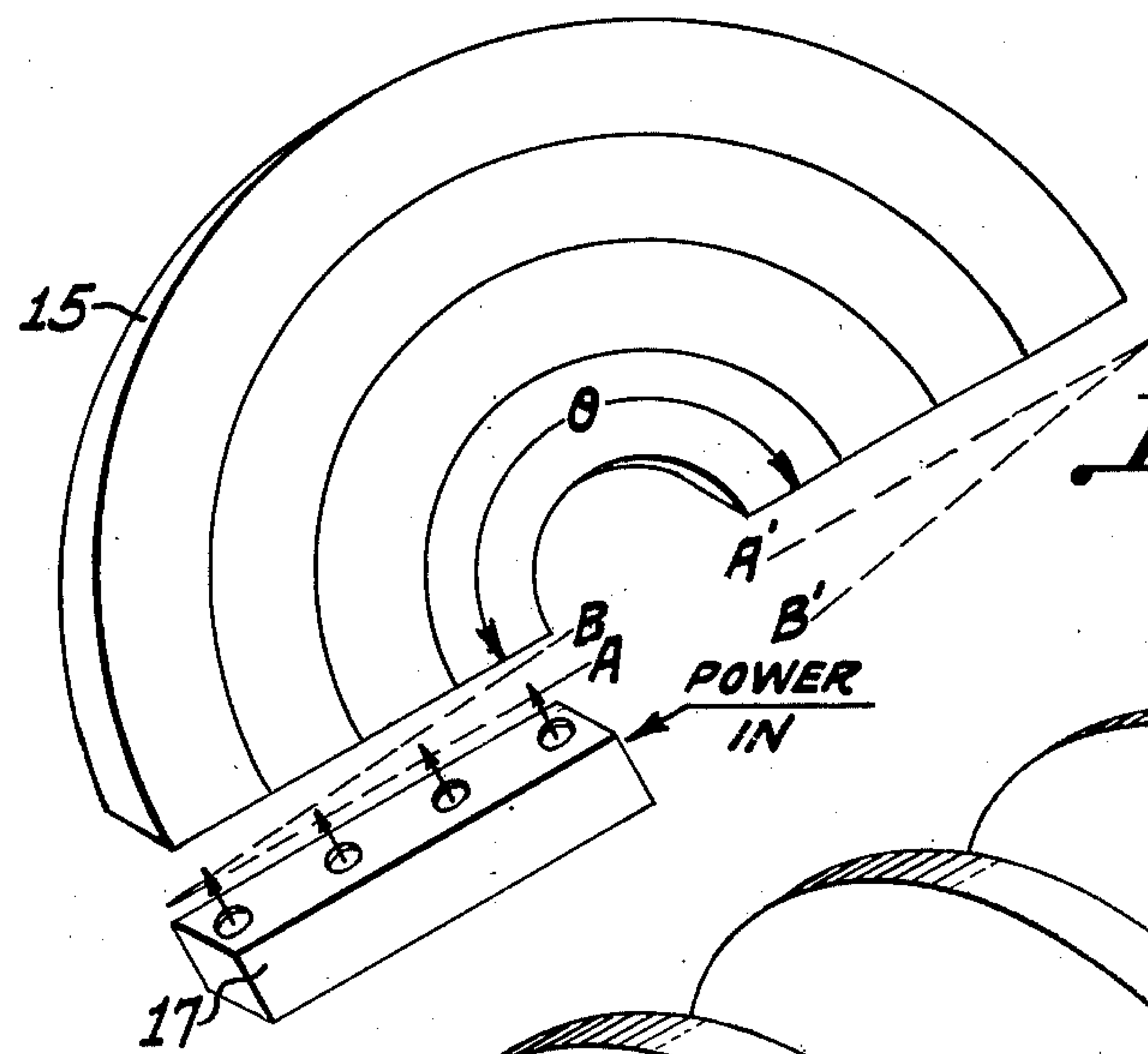


Fig. 3

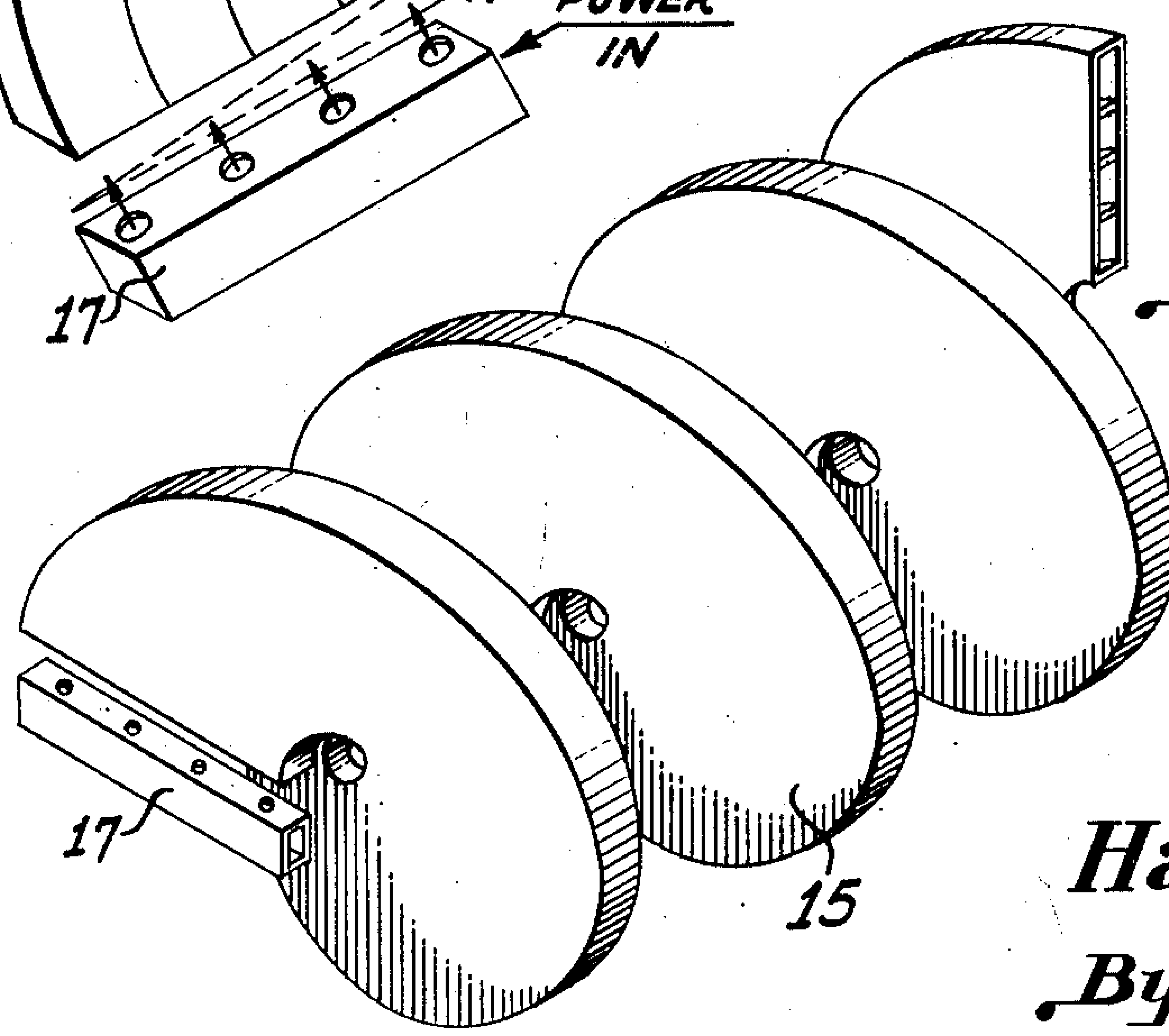


Fig. 4

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SCANNING ANTENNA

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3 Claims. (Cl. 250—33.63)

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This invention relates to scanning antennas, and more particularly to directive antennas for producing a beam whose direction varies with variation in frequency.

It is the principal object of this invention to provide frequency responsive scanning antennas having greater directional response to variation in frequency than prior art devices.

Another object is to provide improvements in scanning antennas of the so-called "leaky waveguide" type.

A further object is to provide improved means for increasing the deflection of the beam produced by a scanning antenna.

More specifically, it is one of the objects of the present invention to improve the deflection sensitivity of frequency-responsive scanning antennas of the leaky waveguide type by filling the waveguide with dielectric material.

Another specific object is to provide "deflection increasers" for frequency responsive scanning antennas, comprising arrays of waveguides of different lengths arranged in such manner as to accentuate the displacement of phase front with variation in frequency.

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

Figure 1 is a pictorial view of a portion of a scanning antenna embodying the present invention,

Figure 2 is a graph showing the performance of the device of Fig. 1,

Figure 3 is a pictorial view of a structure like that of Fig. 1 in combination with means for increasing the beam deflection provided thereby, and

Figure 4 is a pictorial view of a modification of the structure of Fig. 3.

It is well known in the radio art that a waveguide having a series of openings along one of its walls will act as a beam forming antenna. Such antennas are often called "leaky waveguide" antennas. Some of the applied energy leaks out each of the openings and is radiated, so that the device behaves as a linear array of radiators. The direction of the beam depends somewhat upon the frequency of the energy applied to the waveguide.

According to the present invention, the effect of frequency upon beam direction is utilized for scanning. Ordinarily, the variation in beam direction with small variations in frequency is too slight to be of substantial utility. I have found that by making the waveguide approximately one-half wavelength wide in the direction perpendicular to the electric vector, and spacing the openings slightly more than one-half wavelength apart, the desired variation of beam direction is substantially at a maximum. The foregoing dimensions are in terms of the wavelength in free space of the energy with which the antenna is to operate.

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The deflection sensitivity (i. e. the change in beam direction for a given change in frequency) may be increased further by filling the waveguide with insulating material having a dielectric constant substantially greater than unity. Polystyrene is an example of such a material, having a dielectric constant $\epsilon=2.56$.

Figure 1 shows a portion of a dielectric filled leaky waveguide antenna. A hollow waveguide **1** is provided with radiator openings **3** in one of its walls **5**, spaced along the length of the guide. The wall **5** is parallel to the electric vector of energy propagating along the guide. The interior is filled with dielectric material **7**. The width w of the guide **1**, from the wall **5** to the opposite wall, is approximately

$$w=\frac{\lambda}{2\sqrt{\epsilon}}$$

where λ is the mean wavelength of the energy with which the antenna is to operate, and ϵ is the dielectric constant of the material **7**.

Energy is supplied to one end of the guide **1**, as indicated by the arrow **9**, and flows toward the other end, a portion of it escaping through each of the apertures **3**. Suppose the frequency to be such that the above relationship between wavelength and guide width is fulfilled exactly. Then the phase velocity in the guide is substantially infinite, and all of the apertures **3** will radiate in phase, producing a beam perpendicular to the wall **5**. Now suppose the frequency to be increased slightly. The phase velocity in the guide is reduced, and the radiation from apertures nearer the end of the guide where the energy is applied will lead (in phase) that from apertures further from said end. This produces a linear phase front at some angle to the wall **5**, and the resulting beam is tilted toward the direction of propagation through the waveguide.

Refer to Fig. 2. The curve **11** shows the beam deviation vs. frequency characteristic of a dielectric filled guide like that of Fig. 1. It is evident that a one percent change in frequency causes a change of about 14 degrees in the direction of the beam. The curve **13** shows that an air-filled guide of optimum dimensions requires a frequency variation of approximately 2½ times as much to cause the same beam deflection.

Referring to Fig. 3 an assembly of waveguides 15 is shown, the individual guides being bent or curved so that their respective ends are in line. Each of the waveguides in the bundle differs in length from its neighbors by a predetermined amount, and the guides are arranged in order of their lengths. For convenience in explanation, it is assumed that each of the waveguides has an inside width which is just equal to $\lambda_0/2$, where λ_0 is the free-space wavelength. The wavelength in the guides is then infinite, and power which enters adjacent waveguides in the same phase emerges still in phase. Now let the frequency be increased by 1 percent. The wavelength in the guides may be computed and found to be $7.07\lambda_0$. The center to center spacing of the guides may be made some convenient distance, such as $0.55\lambda_0$. The difference in path length in adjacent guides ($\theta=180°$) is then $0.55\pi\lambda_0=1.73\lambda_0$. This corresponds to

$$\frac{1.73\lambda}{7.07\lambda}=0.24$$

period delay between adjacent guides. The emerging wave front is then tilted by

$$\sin^{-1}\frac{0.24}{0.55}=\text{about } 26°$$

This is the deflection which is caused by the waveguide assembly, independently of any deflection produced by the leaky waveguide 17.

It will be apparent to those skilled in the art that the waveguides in the assembly 15 need not be bent through an angle of 180 degrees, as shown in Fig. 3, but may extend through a relatively small sector or, if greater deflection sensitivity is desired, may be formed in a helix with several turns as shown in Fig. 4. The difference in length between adjacent guides need not be exactly one wavelength, but may be any constant amount. In the waveguide assemblies either of Fig. 3 or Fig. 4, the lengths of the curved guides are proportional to their respective radii of curvature, each waveguide of an assembly being curved through the same angle as that of the others of the same assembly. The arrangement illustrated may be described as an assembly of waveguides each having a wall in common with an adjacent waveguide and each waveguide being curved.

I claim as my invention:

1. A radio antenna for providing a beam whose direction varies with variation in frequency of energy applied thereto, including a hollow waveguide filled with insulating material having a dielectric constant substantially greater than unity,

a series of radiator apertures in the wall of said waveguide, spaced apart from each other in the direction of propagation of energy along said guide, and an array of further waveguides, one end of each of said further waveguides being positioned with respect to the corresponding ends of the others of said further waveguides so that said ends lie in a line parallel and adjacent to the line of said radiator apertures, and the other ends of said further waveguides being similarly positioned with respect to each other to define a second line, the length of each of said further waveguides differing from those of its neighbors by a predetermined amount.

2. In a scanning antenna system which provides a beam having a substantially linear phase front and varies the direction of said phase front to deflect said beam, means for increasing the deflection of said beam comprising an array of waveguides of different lengths each curved to a substantially semicircular shape, each differing in length from at least one of the others by a predetermined amount, each end of each of said waveguides being positioned with respect to the corresponding ends of the others of said waveguides so that said ends define substantially straight lines; said waveguides being arranged in the order of their respective lengths.

3. In a scanning antenna system which provides a beam having a substantially linear phase front and varies the direction of said phase front to deflect said beam, means for increasing the deflection of said beam comprising an array of waveguides of different lengths each curved to a substantially helical shape, each differing in length from at least one of the others by a predetermined amount, each end of each of said waveguides being positioned with respect to the corresponding ends of the others of said waveguides so that said ends define substantially straight lines; said waveguides being arranged in the order of their respective lengths.

HARLEY IAMS.

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