

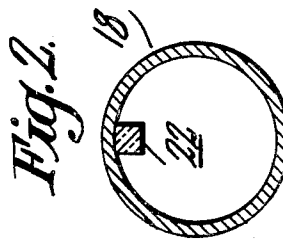
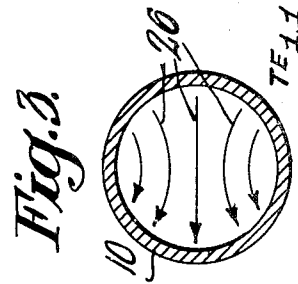
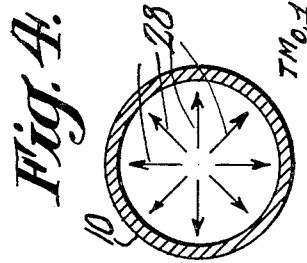
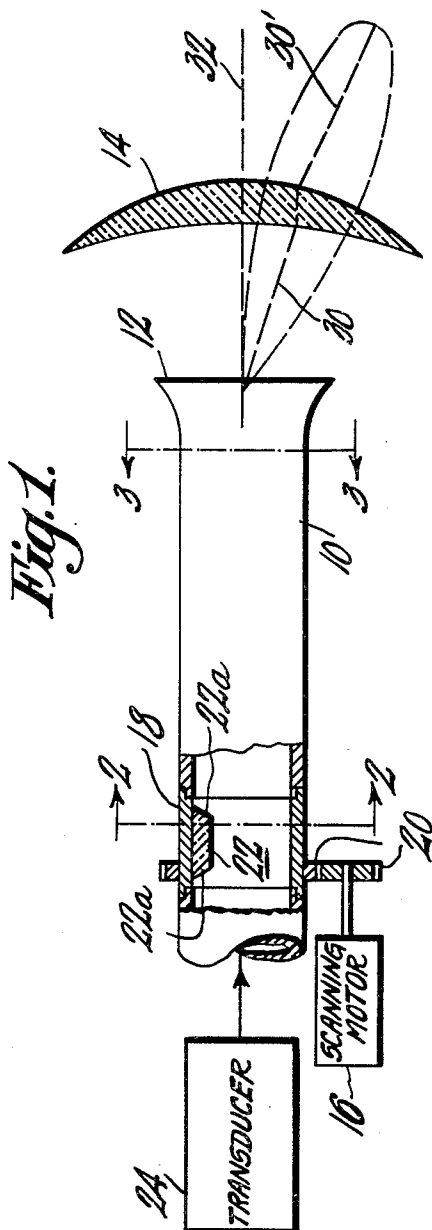
Dec. 11, 1956

W. P. BOLLINGER

2,774,067

MICROWAVE SCANNING ANTENNA SYSTEM

Filed Aug. 17, 1949



INVENTOR  
**Waldon P. Bollinger**  
 BY *J. L. Whitaker*  
 ATTORNEY

1

2,774,067

## MICROWAVE SCANNING ANTENNA SYSTEM

Waldon P. Bollinger, Haddonfield, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application August 17, 1949, Serial No. 110,782

7 Claims. (Cl. 343—762)

This invention relates to antenna systems, and more particularly to a scanning antenna system.

It is often convenient to have an antenna system in which the radiation is lobed, the axis of the lobe being at an angle to an axis about which the lobe rotates. Such scanning systems are sometimes termed "conical" scanning systems because the lobe axis describes a cone in its revolution about the axis of revolution. Such a conical scanning system is used, for example, in conventional conical scanning radar sets.

An object of the invention is to provide a particularly simple and desirable conical scanning system.

It is a further object of the invention to provide an improved means for lobing the radiation pattern of an antenna system at an angle from the axis of symmetry of the system.

Another object of the invention is to provide a novel conical scanning system.

In accordance with the invention, I provide the open mouth radiating portion of a circular hollow pipe waveguide with two modes of energy at the same frequency, said modes being excited co-phasally at the waveguide mouth. The modes are such that the energy of one combines additively with the energy of the other on one side of the waveguide mouth and combines in a cancelling manner with the energy on the other side of the waveguide mouth to give a radiation pattern the lobe axis of which is inclined angularly from the waveguide axis at the mouth.

A further feature of the invention resides in the particularly simple means to excite the second mode which may comprise merely a dielectric body attached to the waveguide inner wall. The section of the waveguide wall which has the dielectric body attached thereto may be rotatable thereby to rotate the lobe. An understanding of the operation and theory of the invention will be enhanced by consideration of the copending application of Nathaniel I. Korman, Serial No. 766,927, filed September 30, 1947 and entitled "Antenna Feed System."

The above and other objects, advantages and novel features of the invention will be more fully apparent from the following description when taken in connection with the accompanying drawing in which like numerals refer to like parts and in which:

Figure 1 is a side view of an antenna system embodying the invention;

Figure 2 is a cross sectional view along the section line 2—2 of Figure 1; and

Figures 3 and 4 are cross sectional views along the section line 3—3 of Figure 1 illustrating the electric vectors of modes which may be propagated in the waveguide.

Referring now more particularly to Figure 1, a hollow pipe waveguide 10 of circular cross-section (circular waveguide) has an open mouth 12 adapted to radiate energy. The waveguide has a suitable inner diameter to permit propagation of the  $TM_{0,1}$  and the  $TE_{1,1}$  modes. A lens system, for example, of the suitably curved dielectric type, schematically designated by the reference

2

numeral 14, is placed with its focal point substantially at the waveguide mouth 12. A scanning motor 16 drives a waveguide section 18 through suitable gearing 20 to rotate said section about its longitudinal axis. The section 18 of waveguide 10 has attached to its inner metallic wall a dielectric body or block 22 which is assymetric with respect to the longitudinal axis of the waveguide 10. A transducer 24, which may be a generator or receiver of high frequency waves, supplies or receives energy to or from waveguide 10 preferably in the  $TM_{0,1}$  mode. The operation will be considered with transducer 24 as a generator, and the converse operation if it is a receiver will then also be clear to those skilled in the art.

Figures 3 and 4 illustrate by vectors 26 and 28 respectively the configuration of the electric vectors in the  $TE_{1,1}$  and  $TM_{0,1}$  modes propagated through waveguide 10. Transducer 24 may generate energy entering waveguide 10 in the  $TM_{0,1}$  mode. As the energy approaches the section 18, and strikes the dielectric block 22, which preferably has tapered end portions 22a to reduce reflections, the  $TE_{1,1}$  mode is also excited, as illustrated by vectors 26 in Figure 3. The amount of energy which is so excited will depend upon the length, size, and configuration of the block 22. The energy proceeds down waveguide 10 toward the mouth 12, the distance between the section 18 and the mouth 12 being calculated so that, due consideration being given to the phase velocities of the energy excited in each mode, the energy will reach the mouth with the modes substantially in phase. Accordingly, when the vectors 26 have reached their maximum amplitude, so also have the vectors 28 at the mouth of the guide. It will be apparent that the two energy configurations are vectorially added.

Since the two modes have different types of symmetry, the  $TE_{1,1}$  mode having substantially even symmetry about a central vertical plane and the  $TM_{0,1}$  mode having substantially odd symmetry about a central vertical plane, at least at the central horizontal axis, it is apparent that the total energy leaving the mouth of the guide will have electric vectors of larger amplitude on one side than on the other. A half cycle later the vectors 26 will have reversed direction, and also the vectors 28, so that the same side which had larger vectors a half cycle prior again has larger vectors. The relationship between these modes may still be simply described as co-phasal, since each reaches maximum amplitude together, even though on one side of the central vertical plane the vector signs or directions are opposed. The energy so radiated will tend to travel off in a lobe the axis 30 of which is inclined at an angle to the waveguide axis 32. The lens 14, in accordance with well-known microwave optical principles, may increase the angular inclination of the axis 30 in a manner schematically represented by the axis 30'. As the scanning motor 16 turns section 18 and dielectric block 22 is rotated therewith, the radiation axis 30' will rotate about the central axis 32, thereby providing conical scanning. The section 18 may be joined to the waveguide portions on either side thereof by the usual choke joints (not shown) in a manner well known to the art. Also it should be noted that other means than the dielectric block section of waveguide are well known in the art for effecting a transfer of energy from one mode, say the  $TM_{0,1}$  to another, say the  $TE_{1,1}$  and these might alternatively be used. I have here shown what I consider a preferred form of the invention.

Having thus described the invention as a particularly simple system for producing a conical scan and which comprises a circular waveguide in which two modes of different symmetry leave the mouth thereof in phase to obtain a lobe the axis of which is inclined to the axis of the waveguide and having shown how rotation of the lobe

3

axis about the waveguide axis is readily derived, what I claim as my invention is:

1. In a scanning antenna system, a circular hollow pipe waveguide having a throat portion and having an open mouth portion for radiation or reception of electro-magnetic energy, said portions having a longitudinal axis and having transverse dimensions to propagate at an operating frequency a first mode having components of odd symmetry with respect to a plane passing through and containing said axis and to propagate energy at said frequency in a second mode having components of even symmetry with respect to said plane, means comprising a section of said waveguide between said throat and said mouth portions to couple such energy in each of said modes in said mouth portion to such energy in one only and not the other mode in said throat portion with said coupled energy in said two modes in the mouth portion being co-phasal at the mouth thereby to direct the principal axis of the directive energy pattern of said mouth portion to one side of said plane, and means to move said coupling means around said axis, whereby the position of said plane is moved and said principal axis of said radiation is moved around said axis extended.

2. In a scanning antenna system, a circular hollow pipe waveguide having a throat portion and an open mouth portion for radiation or reception of electro-magnetic energy, said portions having a longitudinal axis and having transverse dimensions to propagate at a given operating frequency the  $TE_{1,1}$  mode and the  $TM_{0,1}$  mode, means in a section of said waveguide between said throat and mouth portions to couple between said portions such energy in each of said modes in said mouth portion to such energy in the said  $TM_{0,1}$  mode only and not the other said mode in said throat portion, said coupled energy in said two modes in said mouth portion being co-phasal at the mouth thereby to direct the principal axis of the directive energy pattern of said mouth portion to one side of said plane, and means to move said means in said section around said axis, whereby the position of said plane is moved and said principal axis of said pattern is moved around said axis extended.

3. The system claimed in claim 2, further comprising a lens with said waveguide mouth substantially at the focal point thereof.

4. The system claimed in claim 2, further comprising a transducer coupled to said circular waveguide at an

4

end thereof remote from said mouth and coupling to energy solely in said  $TM_{0,1}$  mode and not in the other mode in said throat portion.

5. In a scanning antenna system, a circular hollow pipe waveguide having metallic walls enclosing a dielectric medium and a throat portion, a mouth portion to radiate or receive electro-magnetic energy at the operating frequency, and a section between said throat and mouth portions, said waveguide having a longitudinal axis and having transverse dimensions to propagate such energy in the  $TM_{0,1}$  mode and to propagate such energy in the  $TE_{1,1}$  mode, said section having a dielectric body movable about said axis attached to the inner waveguide wall of different dielectric constant from the medium enclosed within the waveguide walls, said body being asymmetrical with respect to the said waveguide axis, said section coupling between said mouth portion and said throat portion such energy in the throat portion in the  $TM_{0,1}$  mode only and not in the  $TE_{1,1}$  mode with energy in each of said modes in the said mouth portion co-phasal at the mouth, thereby causing the principal axis of the directive energy pattern of said mouth portion for such energy to have an angle with the said waveguide axis extended.

6. The system claimed in claim 5, said waveguide section and said dielectric body being rotatable, thereby to rotate the said principal axis of said pattern about the waveguide axis extended.

7. The system claimed in claim 5, further comprising a dielectric lens system with said waveguide mouth positioned at the focal point of said lens system.

#### References Cited in the file of this patent

##### UNITED STATES PATENTS

|           |                |                |
|-----------|----------------|----------------|
| 2,129,669 | Bowen          | Sept. 13, 1938 |
| 2,283,568 | Ohl            | May 19, 1942   |
| 2,433,368 | Johnson et al. | Dec. 30, 1947  |
| 2,473,446 | Riblet         | June 14, 1949  |

##### FOREIGN PATENTS

|         |               |               |
|---------|---------------|---------------|
| 582,856 | Great Britain | Nov. 29, 1946 |
|---------|---------------|---------------|

##### OTHER REFERENCES

"Theory and Application of Microwaves," by Bronwell and Beam; Mc-Graw-Hill Book Co., 1st ed. 2nd impression, 1947 ch. 18.