April 27, 1965 C. F. AUGUSTINE ETAL 3,181,091

MICROWAVE PHASE SHIFTER

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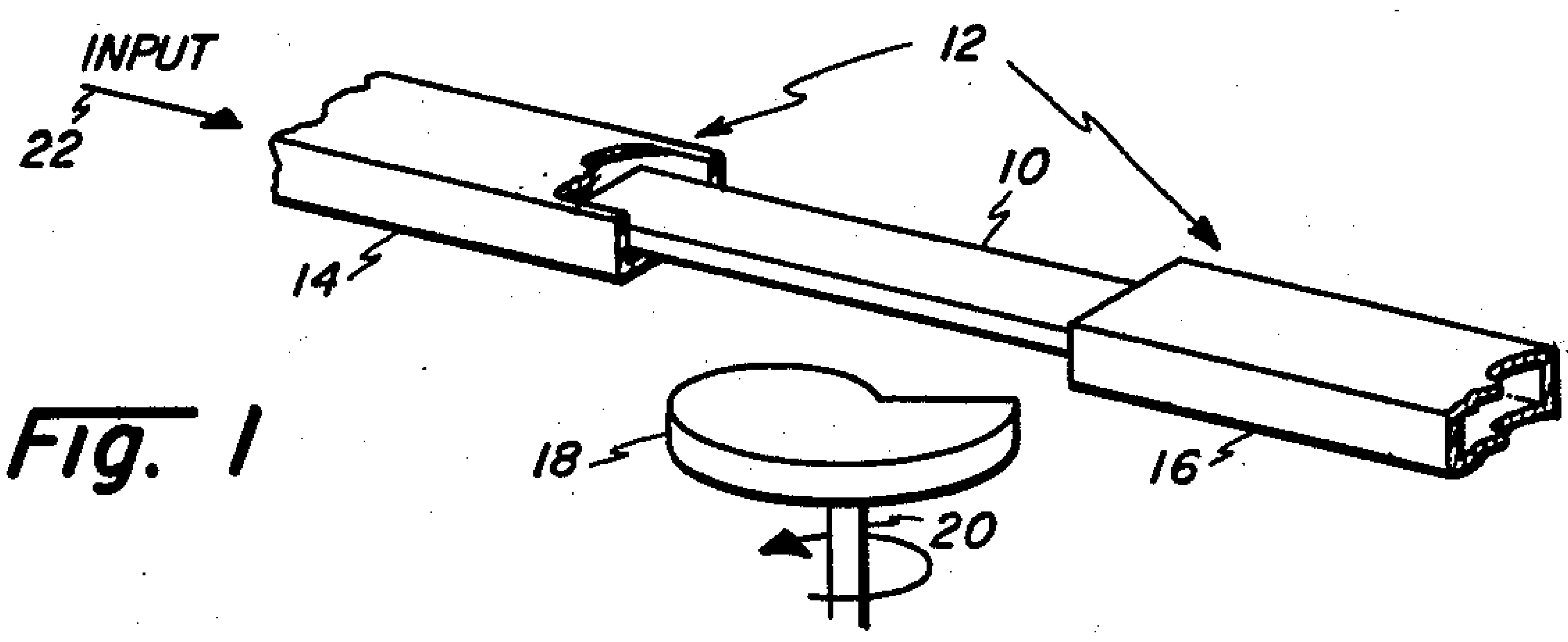

Fig. 1

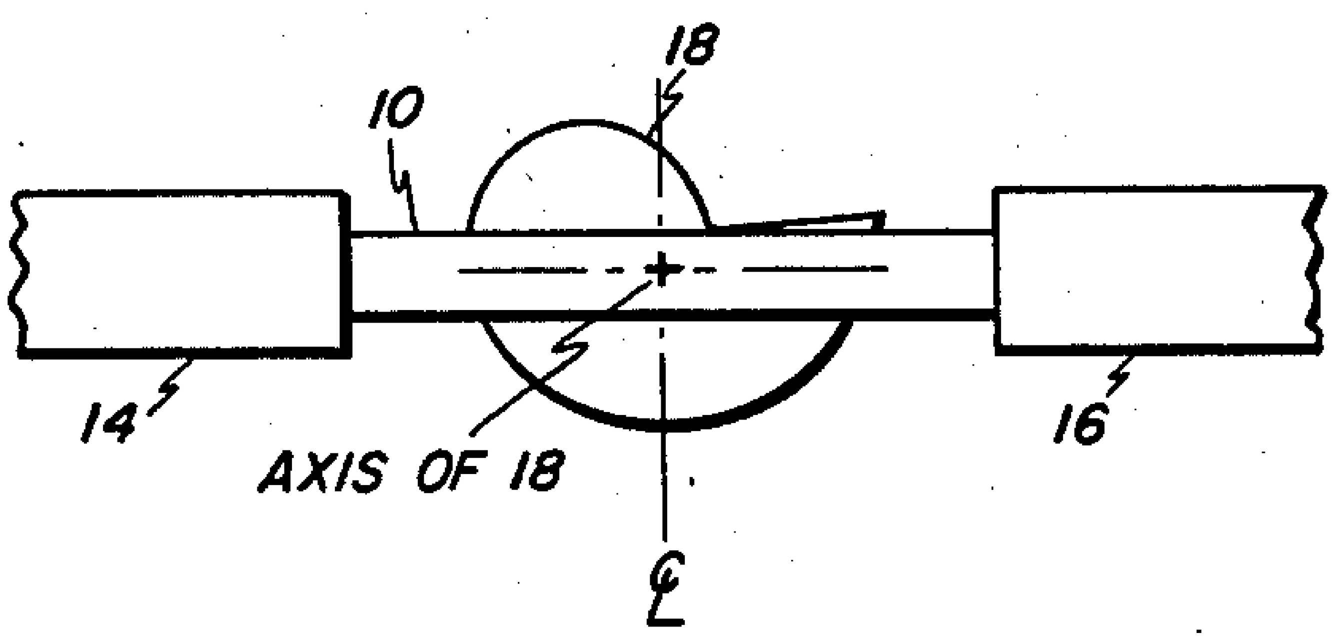

Fig. 2

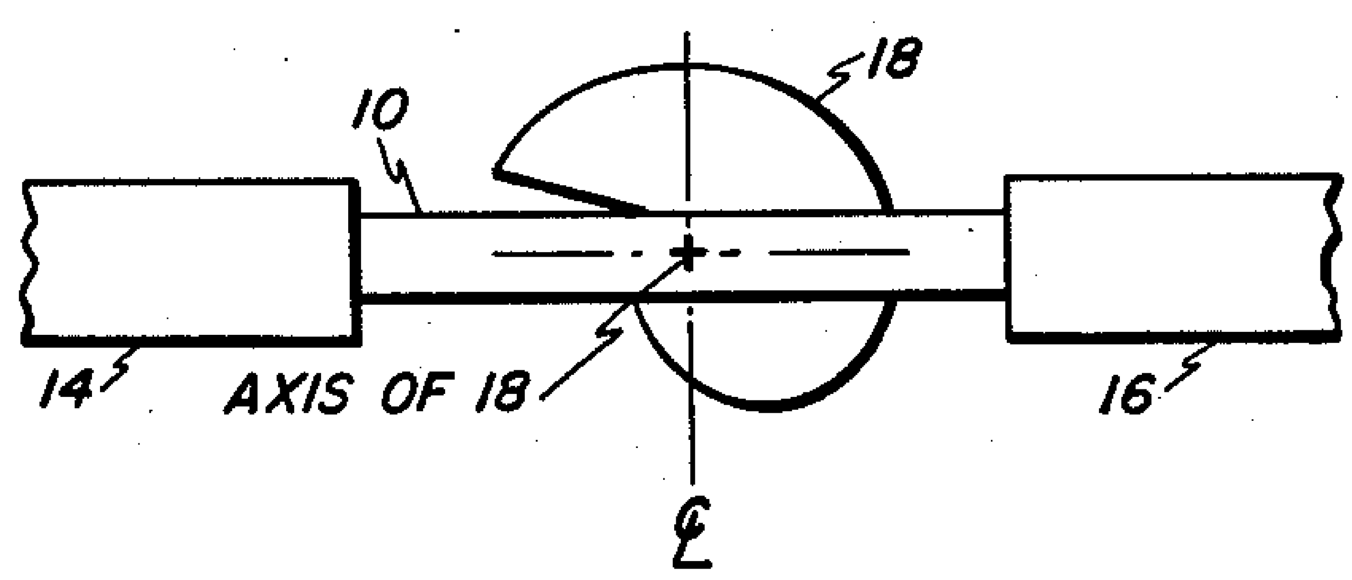

Fig. 3

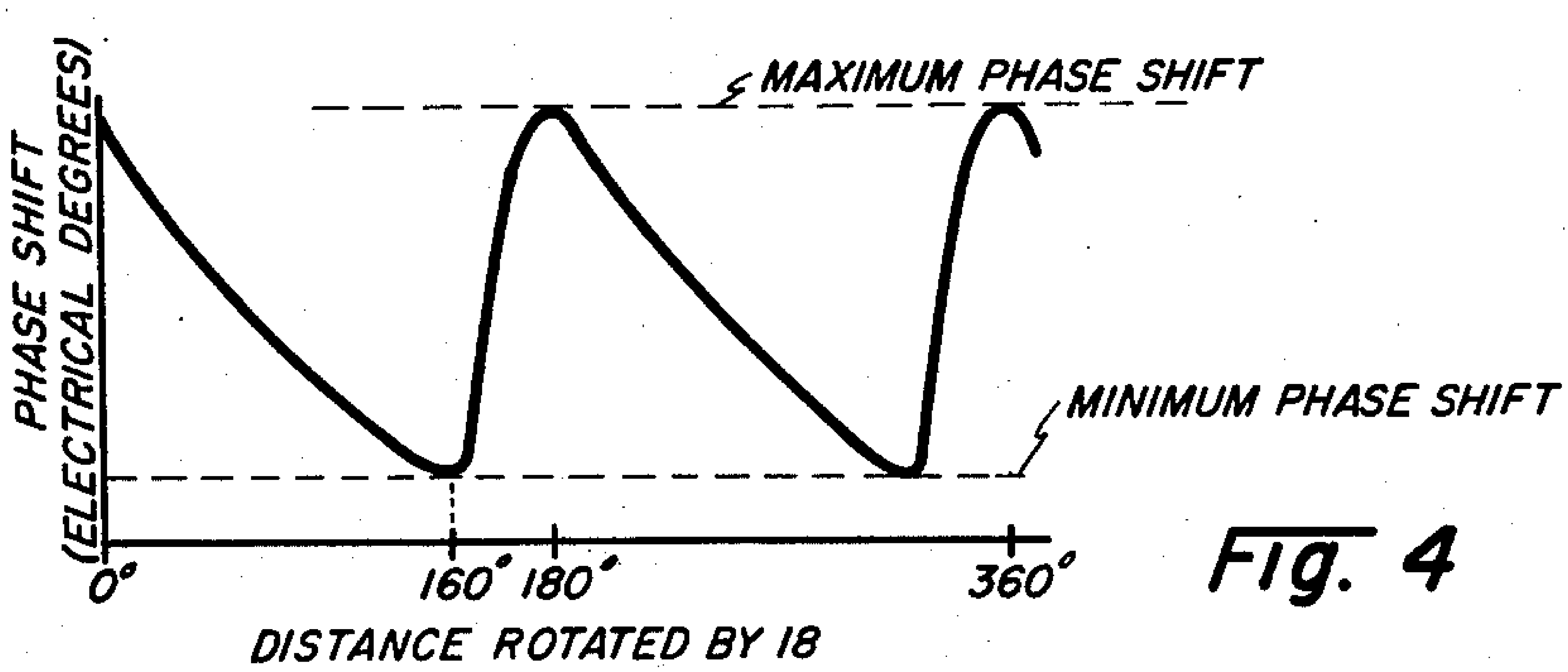

Fig. 4

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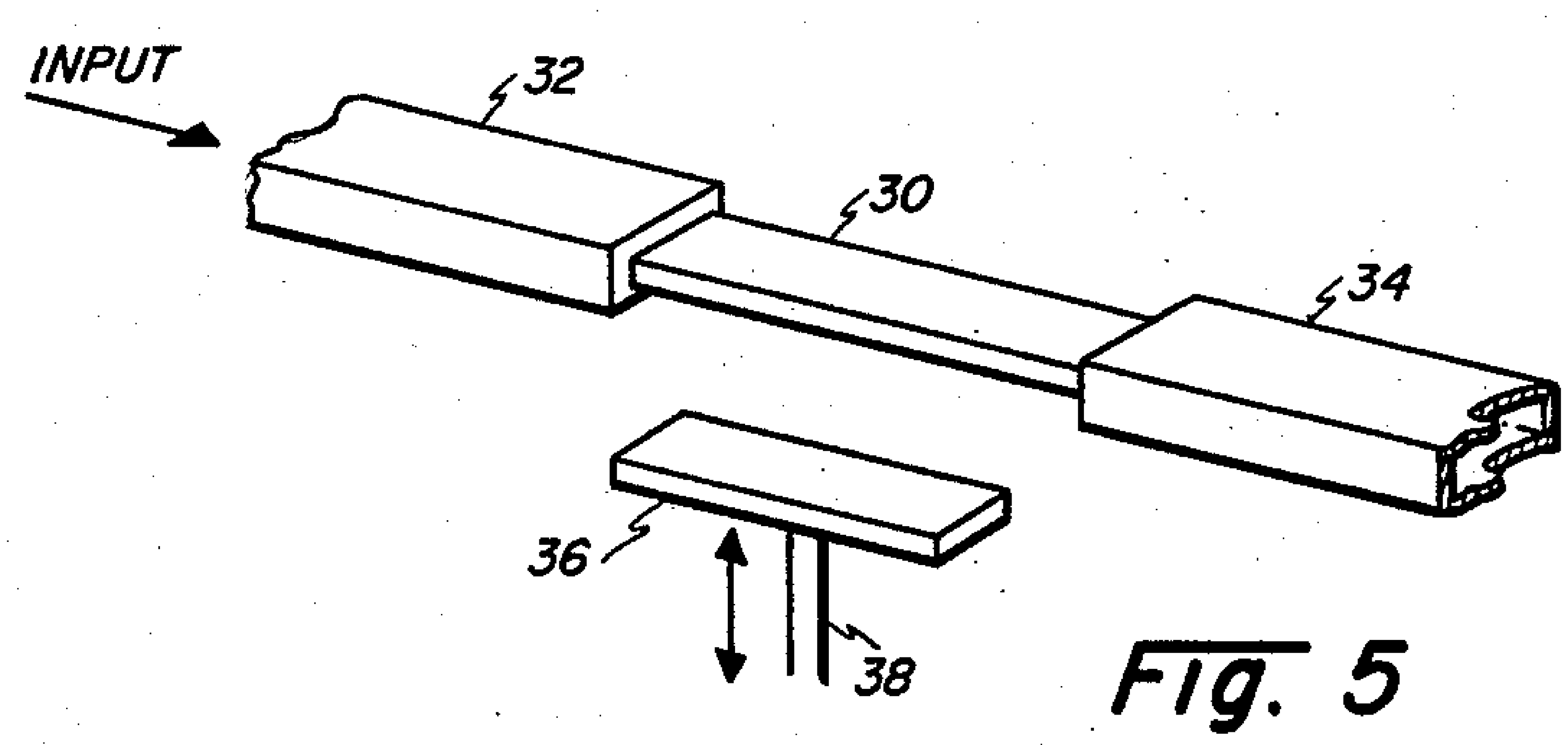

Fig. 5

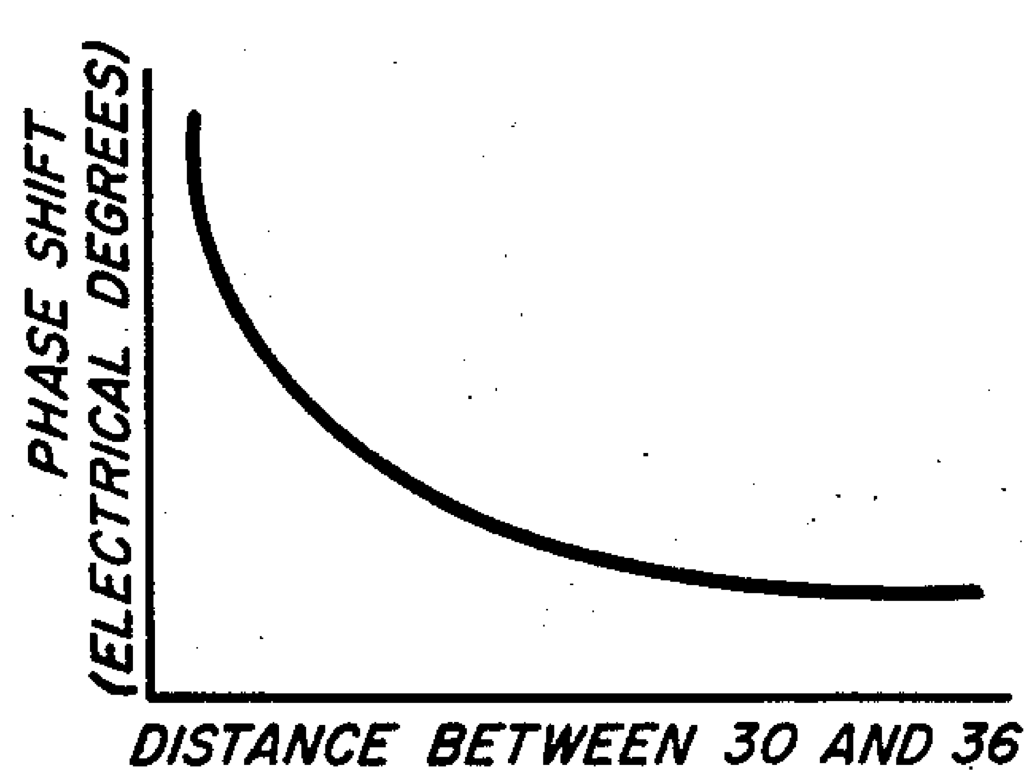

Fig. 6

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MICROWAVE PHASE SHIFTER

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3 Claims. (Cl. 333—31)

This invention relates to an improved microwave phase shifter and more particularly to an improved mechanically adjustable microwave phase shifter.

Microwave phase shifters presently in use do not provide sufficiently good phase resolution as is required for certain applications. That is, they cannot be adjusted in sufficiently small increments to obtain desired phase shifts.

This invention relates to a microwave phase shifter which provides improved phase resolution. In accordance with the invention, a dielectric waveguide section is inserted in a standard waveguide line. Disposed in close proximity to the dielectric section is a dielectric member which is movable relative to the dielectric section to change the electrical coupling beween the member and the section and thereby control the phase shift produced.

An object of this invention is to provide a microwave phase shifter having improved phase resolution.

Another object of this invention is to provide a microwave phase shifter which includes a dielectric waveguide section and a dielectric member spaced from and movable relative to the dielectric section to produce a change in phase.

Other objects and advantages will become apparent from the following detailed description and from the appended drawings and claims.

In the drawings:

FIGURE 1 is a perspective view, partly broken away, of a preferred embodiment of the invention.

FIGURE 2 is a top view of the embodiment in FIGURE 1 shown in a position of maximum phase shift.

FIGURE 3 is another top view of the embodiment in FIGURE 1 shown in a position of minimum phase shift.

FIGURE 4 is a graph showing the change in phase produced by the embodiment in FIGURE 1.

FIGURE 5 is a second embodiment of the invention.

FIGURE 6 is a graph showing the change in phase produced by the embodiment in FIGURE 5.

In the preferred embodiment of FIGURE 1, a dielectric waveguide section 10, preferably of solid material, is inserted into a standard hollow, rectangular waveguide line generally indicated at 12. The section 10 is made of a dielectric material such as polystyrene and is inserted into the rectangular openings of sections 14 and 16 of the line 12.

Disposed at a relatively short distance from the section 10 and substantially parallel thereto is a dielectric member 18 having a desired configuration to produce a change in the electrical coupling between the member and the section 10 upon its rotation. Preferably, the outline of the member 18 may be a segment of an Archimedean spiral having the following equation in polar coordinates:

$$r=A\theta$$

where

$r=$ radius of the spiral at any given point
$A=$a constant, and
$\theta=$number of degrees

By using a member 18 of spiral configuration, a substantially linear change in phase shift can be achieved as will be hereinafter described.

During its rotation, the member 18 is maintained at a constant distance from the dielectric section 10. The member 18 is made of a dielectric material, such as styrafoam, having a dielectric constant much lower than that of section 10. This prevents the member 18 from appearing as a large discontinuity which would induce radiation from the section 10. The member 18 is fixedly supported on a shaft 20 made of a metal, such as brass, which in turn is supported by suitable means (not shown) for rotating the shaft and the member. The rotation may be accomplished either manually or by motorized means.

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In the operation of the embodiment in FIGURE 1, a desired phase shift of the signal input 22 is achieved by rotating the member 18 to a given position with respect to the section 10. The propagation constant of the portion of line 10 that is "covered" by member 18 is different from that of the uncovered portion of the same line. Hence, changing the amount of line 10 covered will produce a change in the insertion phase of the line. In FIGURE 2, the member 18 is shown in a position of maximum coverage of the section 10, thus producing a maximum phase shift as shown in FIGURE 4 at 0°. Each successive 180° rotation will again place the member 18 in a position of maximum coverage to produce maximum phase shift as shown at 180° and at 360° in FIGURE 4.

In FIGURE 3, the member 18 is shown rotated approximately 160° in a counterclockwise direction from its 0° position in FIGURE 2. In this position the coverage provided by the member 18 is at a minimum and the phase shift produced is at a minimum as shown at 160° in FIGURE 4. It will be noted that the change in phase shift is substantially linear in the range between 0° and 160°. Then the phase shift increases sharply to its maximum value at 180°. This cycle is repeated for each additional 180° rotation of the member 18.

The resolution of the above phase shifter, that is, the ratio of mechanical degrees rotated by the member 18 to the electrical degrees phase shift produced, is a function of the spacing between the member 18 and the section 10. The resolution is increased as this spacing is increased. However, the total amount of phase shift that can be produced during a 180° rotation of the member 18 is decreased as the spacing is increased. To control the resolution necessary for different applications, suitable means (not shown) may be provided to move the member 18 towards or away from the section 10 along an axis substantially perpendicular to the longitudinal axis of the section 10. In this way, the spacing between the member 18 and the section 10 can be adjusted to obtain the desired resolution.

A second embodiment of the invention is shown in FIGURE 5. In FIGURE 5, waveguide sections 30, 32 and 34 are the same as sections 10, 14 and 16, respectively in FIGURE 1. However, instead of a rotatable spiral dielectric member 18, there is utilized a rectangular, dielectric member 36 which is substantially parallel to the dielectric section 30 and is movable away from or towards the section 30 along an axis which is substantially perpendicular to the longitudinal axis of the section 30.

The member 36 is supported on a metal shaft 38 which in turn is supported by suitable means (not shown) for movement of the shaft and the member 36 relative to the section 30. This movement produces a change in the electrical coupling between the dielectric section 30 and the member 36 and a corresponding change in the phase shift that is produced. The amount of phase shift increases when the member 36 moves towards the section 30 (without making contact) and decreases as it moves away. As shown in FIGURE 5, the phase shift is reduced exponentially as the distance between the member 36 and the section 30 increases.

The microwave phase shifters described above can provide extremely fine adjustments of phase by a simple mechanical movement of the member 18 or the member

36. Because of their simplicity, they are inexpensive to construct and are reliable in their operation.

Although this invention has been disclosed and illustrated with reference to particular applications, the principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. The invention is, therefore to be limited only as indicated by the scope of the appended claims.

Having thus described our invention, we claim:

1. A microwave phase shifter for a waveguide line comprising

two waveguide sections and a dielectric plate connected between and coupling the two waveguide sections,

and a dielectric member positioned in close proximity to the dielectric plate and movable relative to the dielectric plate to vary the phase shift produced in the line,

the dielectric member having a low dielectric constant relative to that of the dielectric plate.

2. A phase shifter as recited in claim 1 wherein the dielectric member has an outline which is a segment of an Archimedean spiral and is rotatable relative to the dielectric plate to produce a substantially linear change of phase shift in the line.

3. A phase shifter as recited in claim 1 wherein the dielectric member is of rectangular configuration, is disposed in substantially parallel relationship to the dielectric plate and is movable relative to the dielectric plate along an axis substantially perpendicular to the longitudinal axis of the dielectric plate to vary the phase shift produced in the line.

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