

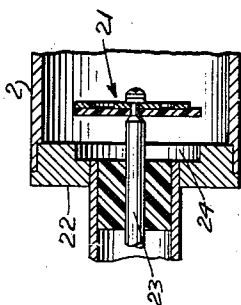
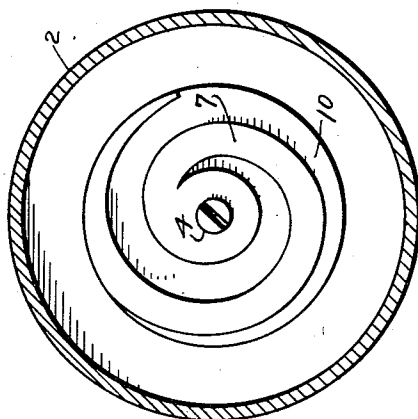
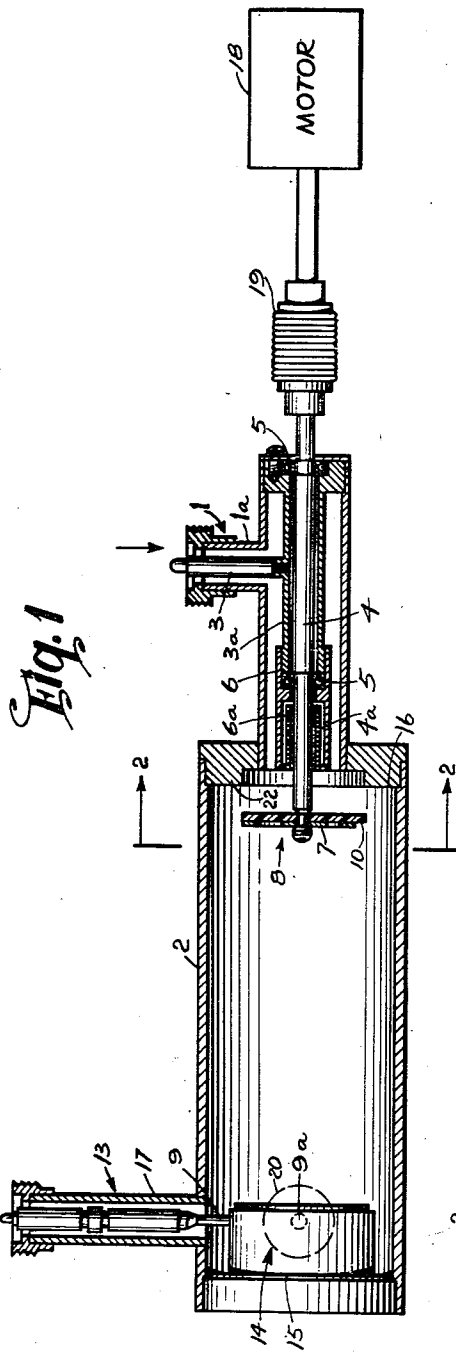
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PHASE SHIFTER

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PHASE SHIFTER

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This invention relates to microwave phase shifters and more specifically to high speed continuous rotary waveguide phase shifters utilizing spiral conductors as circularly polarized antennas.

In many microwave system applications, waveguide phase shifters are needed, generally, for such applications as shifting the angular position of an antenna beam. Heretofore various means and methods of shifting the phase of an output microwave with respect to the input wave have been proposed. The majority of such means have been primarily voltage devices with the disadvantage that the output power transmitted to the load had to be kept very small so as not to disturb the phase relations in the circuit.

In the copending application of W. Sichak, Serial No. 249,363, filed on October 2, 1951, now U. S. Patent No. 2,746,018, a continuous rotary waveguide phase shifter capable of relatively high power transmission is disclosed which comprises a circular waveguide, a helical antenna radiating a circularly polarized wave through the waveguide and a helical antenna to receive the transmitted wave. As one or both of the antennas is caused to rotate about a longitudinal axis, the transmitted electromagnetic energy is shifted in phase when received at the output antenna. The shift in phase between the input and output signal is directly proportional to the relative angular motion of the input and output antennas.

One of the objects of this invention is to provide an improved waveguide phase shifter of exceptionally small physical dimensions and weight and which is capable of relatively high power transmissions.

Another object of this invention is to provide an improved continuous rotary waveguide phase shifter having a relative broad frequency response and a substantially linear phase shift.

A further object of this invention is to provide a phase shifter utilizing a spiral conductor as a circularly polarized antenna.

Briefly, a phase shifter according to this invention utilizes a circularly polarized antenna consisting of a round disc of dielectric material on which is mounted a flat spiral conductor, thus creating a spiral antenna which may be used for launching a circularly polarized wave through a circular waveguide section. A receiving antenna having a structure similar to the transmitting antenna or a pair of pickup probes, orthogonally located with respect to each other, may be provided to receive the electromagnetic energy at the output end of the waveguide section. By rotating the input antenna about its longitudinal axis the output voltage is shifted in phase proportional to the relative angular motion of the input antenna.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

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Fig. 1 is a longitudinal cross-sectional view of an embodiment of this invention;

Fig. 2 is a plan view taken along line 2—2 of Fig. 1; and

Fig. 3 is a longitudinal cross-sectional view of a receiving antenna that may be used in place of the output probe arrangement shown in Fig. 1.

Referring to Figs. 1 and 2 of the drawing, a microwave phase shifter in accordance with the principles of this invention is shown in which a source of microwave energy is applied to the phase shifter through a coaxial connector 1. The outer conductor 1a of the input coaxial connector 1 is joined to one end of a section of circular waveguide 2. The inner conductor 3 of the coaxial connector 1 is coupled to a sleeve 3a which supports a rotatable shaft 4 by means of a pair of bearings 5. A sleeve 4a is coaxial to a sleeve 6 to form a radio frequency choke 6a, adjacent the shaft 4 at the end of the sleeve 6. The shaft 4 extending beyond the end of the sleeve couples energy from inner conductor 3a to a conductor 7 carried by a disc 10 of dielectric material as an input spiral antenna 8. While conductor 7 is shown to be ribbon-like in cross-section it may of course be round or any other shape desired. The ribbon-like shape is to be preferred where it is applied to a disc of dielectric material such as where printed circuit technique is employed. Where the conductor 7 is sufficiently sturdy, either of round, ribbon or other cross-sectional shape, the dielectric disc may be omitted. The antenna 8 forms a circularly polarized, radiating spiral, or planar helical conductor adapted to launch a circularly polarized wave for propagation along the circular waveguide 2 in accordance with the H₁₁ mode. The waveguide 2 is dimensioned below cutoff for all higher modes. The energy launched by antenna 8 is received by pickup probes 9 and 9a which are orthogonally located with respect to each other to receive the radiations emitted by said input antenna 8. The ends 15 and 16 of waveguide 2 are at ground potential and situated in back of the input and output connections.

The phase of the output voltage of a circularly polarized antenna receiving a circularly polarized wave is directly proportional to the angle of rotation of the antenna about its longitudinal axis. The output amplitude will be equal to the input amplitude and there will be no phase shift errors, if the ends are perfectly matched.

The dimensions and location of spiral antenna 8 with respect to the ends 15 and 16 of the waveguide 2 are so selected as to obtain a polarization as nearly circular as possible and a good impedance match of the coaxial line. I have found that the preferred spacing should be substantially one quarter wavelength at the operating frequency.

One form of spiral antenna which has been found satisfactory for frequencies near 9375 mc. using a 50-ohm coaxial transmission line for input and output connections is an antenna composed of a dielectric form 10, 1 1/16 inches in diameter and 1/16 of an inch thick, on which is mounted a spiral ribbon-like conductor 7 to which shaft 4 is connected. The spiral winding 7 is fixed firmly, but not necessarily flush with the surface of the dielectric form 10. The energy received by pickup probes 9 and 9a which are orthogonally located with respect to each other is connected to the output connectors 13 and 14. The outer conductors 17 and 20 of the output connectors 13 and 14 are coupled to the waveguide 2. Input antenna 8 and pickup probes 9 and 9a are spaced approximately 3 inches apart. Less spacing results in direct coupling between the antennas and therefore introduces errors.

Referring to Fig. 3, an alternate embodiment of the

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output end of a phase shifter in accordance with the principles of this invention is shown comprising a receiving antenna 21 substantially identical with input antenna 8 and which is used to pick up the circularly polarized energy launched by the transmitting antenna 8. The receiving antenna 21 is connected to a shaft 23 which couples out the received energy. Antenna 21 should preferably be spaced substantially one quarter wavelength from the end 22 of waveguide 22.

The bearing motor drive and antenna mounting methods are important if high rotational speeds are to be obtained. Irregular bearing surfaces result in physical unbalance, motor overload, and sudden speed changes, all of which cause phase errors. The motor drive must be constant, because a small speed drift of the driving mechanism results in large phase shift errors at high rotational speeds. To assist in maintaining the motor drive constant a coupling 19 is connected between the shaft 4 and the motor 18.

In operation an input signal is applied from the coaxial line 1 to the input antenna 8. The antenna radiates the input signal, circularly polarized axially along the waveguide section 2 and is received by the pickup probes 9 and 9a for propagation over the output coaxial lines 13 and 14. The pickup probes 9 and 9a are maintained in a fixed position while the antenna 8 is rotated by shaft 4. By controlling the rotation of antenna 8 a phase advance or retardation is obtainable at the output couplers relative to the input signal.

Where the waveguide 2 is made of a solid cylindrical wall, a substantially linearly phase shift is obtained except for two points 180° apart in the angular setting of the phase shifter. This discontinuity at these two points is relatively sharply defined and was discovered to be caused by a resonance of the circular polarization H_{11} mode which occurs in the opposite sense to the main or desired circularly polarized H_{11} mode for which the unit is designed. This sharp discontinuity, while not troublesome for many phase shift uses, may be substantially eliminated by suppression. Different arrangements may be provided for effecting this suppression, such as using impedance grids, or a matching stub in such a manner as to "match out" the discontinuity in the phase shifter network. When receiving antenna 21 is used, the end 22 of waveguide 2 may be recessed as indicated at 24 to improve the impedance match of the phase shifter.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. An antenna for radiating circularly polarized electromagnetic waves comprising a ground conductor having a planar surface, dielectric material in the form of a disc, and a conductor in the form of a planar helix carried by said disc in substantially parallel relation to the planar surface of said ground conductor.

2. An antenna according to claim 1 wherein said conductor is ribbon-like in cross-sectional shape with the wide dimension thereof in the plane of said helix.

3. A phase shifter comprising a waveguide section one end of which has a planar surface, an antenna for radiating a circularly polarized wave along said waveguide sec-

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tion, said antenna having a conductor in the form of a spiral spaced substantially in parallel relation from said planar surface, means to receive said wave at the other end of said section, and means to rotate said antenna whereby the phase of the received voltage with respect to the radiated voltage is proportional to the relative angle of rotation of said antenna.

4. A phase shifter according to claim 3 further including input coupling means, means to couple said antenna to said input coupling means, an output coupling means, and means to couple said receiving means to said output coupling means.

5. A phase shifter according to claim 3 wherein said waveguide section is circular and said means to receive said wave comprises a pair of pickup probes in orthogonal relation to each other.

6. A phase shifter according to claim 3 wherein the means for rotating said antenna includes a shaft and a disc of dielectric material on which said conductor is carried, said shaft being extended through said one end of said section.

7. An antenna according to claim 3 wherein said conductor is ribbon-like in cross-sectional shape with the wide dimension thereof in the plane of said helix.

8. A phase shifter according to claim 3 further including means for coupling a source of radio frequency energy to said antenna, said coupling means having a radio frequency choke disposed at least in part between the fixed and moving parts of said phase shifter.

9. A phase shifter according to claim 3 wherein said means to receive said wave comprises a planar helical conductor disposed axially of said waveguide section.

10. A phase shifter comprising a coaxial input connector, a coaxial output connector, an input antenna for radiating circularly polarized electromagnetic waves having a disc of dielectric material and a planar helical conductor supported thereby, means to receive the radiations from said input antenna coupled to the inner conductor of said coaxial output connector, a circular waveguide section coupled to the outer conductors of said input and output connectors, a rotatable shaft supporting said input antenna and means including a conductive sleeve disposed about said shaft to couple the inner conductor of said input connector to said input antenna.

11. A phase shifter comprising a coaxial input connector, a pair of coaxial output connectors in orthogonal relation to each other, an input antenna comprising a disc of dielectric material and a planar helical conductor supported thereby, means to receive radiations from said input antenna coupled to the inner conductors of said output connectors, a circular waveguide section coupled to the outer conductors of said input and output connectors, a rotatable shaft to support said input antenna, and means including a conductive sleeve disposed about said shaft to couple the inner conductor of said input connector to said input antenna.

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