

Nov. 2, 1965

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3,216,017

POLARIZER FOR USE IN ANTENNA AND TRANSMISSION LINE SYSTEMS

Filed Dec. 4, 1962

2 Sheets-Sheet 1

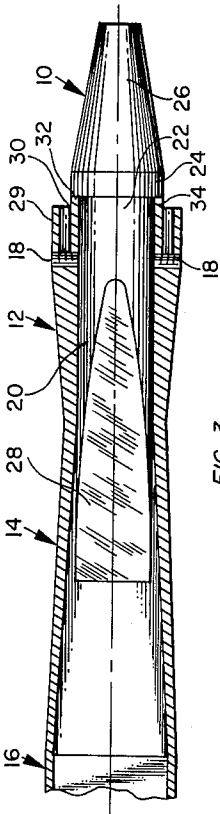
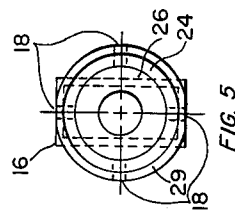


FIG. 3

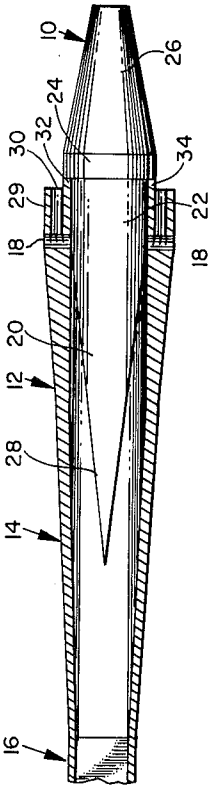


FIG. 2

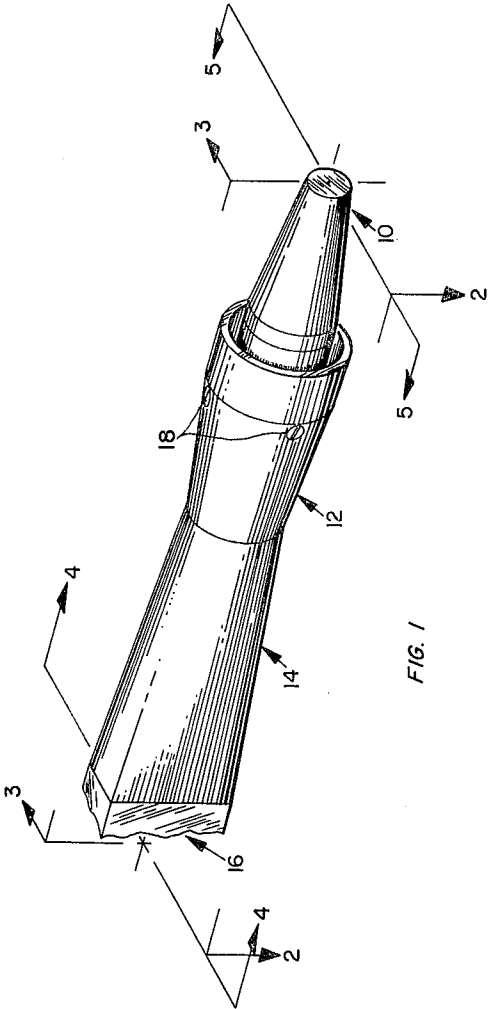


FIG. 1

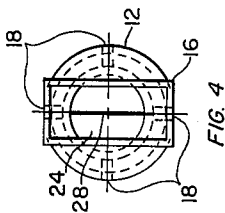


FIG. 4

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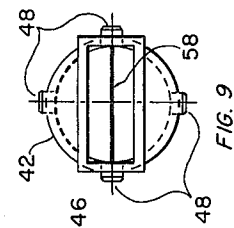
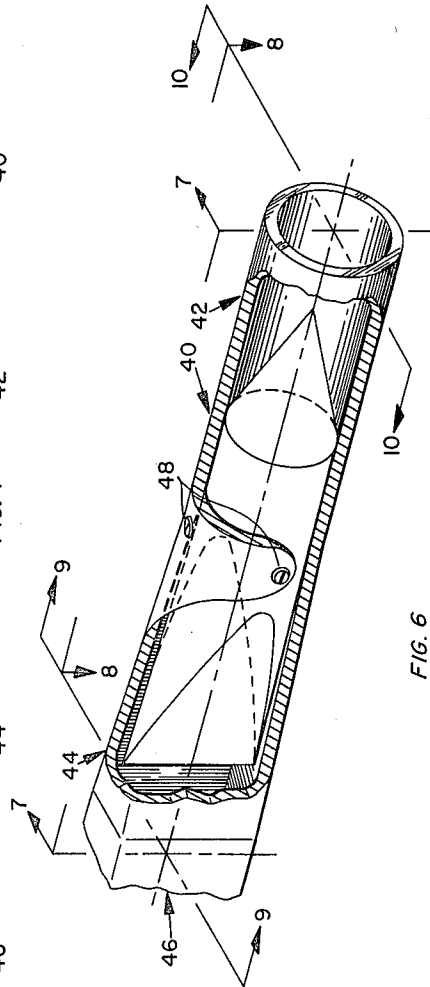
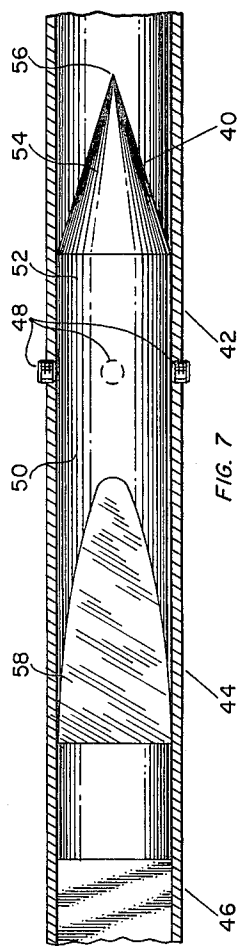
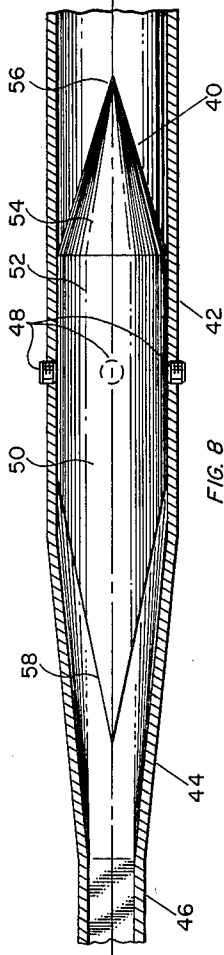
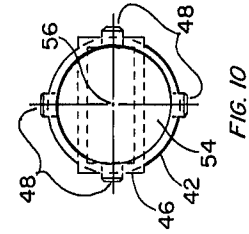
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POLARIZER FOR USE IN ANTENNA AND TRANSMISSION LINE SYSTEMS

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11 Claims. (Cl. 343-756)

This invention relates to a polarizing device for transforming linearly polarized energy to elliptically polarized energy and more particularly to a polarizing device having a rotatably mounted, axially adjustable wedge shaped dielectric polarizer so that when the dielectric polarizer is rotated from a neutral position, a variable degree and sense of elliptical polarization of the energy is obtainable, and when the dielectric polarizer is moved axially the impedance of the polarizing device is varied.

During the extensive development of the electronic arts in the past two decades, a need arose for a device capable of transforming and handling elliptically polarized energy particularly in electronic apparatus operating in the microwave range. Many techniques have been employed but completely satisfactory conversion of linearly polarized energy to elliptically polarized energy has not been heretofore achieved without the use of highly complicated, bulky and expensive mechanization. Whenever a simplified and inexpensive technique was exploited by antenna designers, serious manufacturing problems attached in the form of close tolerances and precision location and size of components. Accordingly, scientists skilled in the antenna art have long searched for a microwave polarizing device capable of efficiently and effectively converting linearly polarized energy to elliptically polarized energy. Desirably, such polarizing devices should have low tolerance and size requirements, high peak power handling capability in the order of 90% or better, semi-automatic adjustability for variably converting linearly polarized energy to right or left hand elliptically polarized energy, and simple and expedient means for varying the impedance of the device.

For purposes of clarity and understanding of the present invention, the following definitions of several terms hereinafter referred to are hereby incorporated:

Linear polarization.—An electromagnetic wave is linearly polarized when the electric field continuously remains parallel to a fixed line which is perpendicular to the direction of propagation.

Elliptical polarization.—A plane electromagnetic wave, at a given frequency, is elliptically polarized when the extremity of the electric vector describes an ellipse in a plane perpendicular to the direction of propagation.

Circular polarization.—A special case of elliptical polarization wherein the extremities of the electric vector describes a circle in a plane perpendicular to the direction of propagation.

Left-hand circular polarization.—When the direction of rotation of a circular or elliptical polarized wave is such as to be a counterclockwise wave receding from an observer.

Right-hand circular polarization.—When the direction of rotation of a circular or elliptical polarized wave is such as to be a clockwise wave receding from an observer.

Dominant mode.—The mode of energy at the lowest cutoff frequency.

TE₁₀ mode.—The dominant mode of energy in a rectangular waveguide.

TE₁₁ mode.—The dominant mode of energy in a circular waveguide.

Polarizer.—A device which takes a source of one form of polarized energy and transforms it into a source of another form of polarized energy.

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Dielectric.—A non-conducting material, having low energy losses in the microwave range.

Dielectric constant.—A measure of the ability of a dielectric material to store electrical potential energy under the influence of an electric field; measured by the ratio of the capacitance of a condenser with the material as the dielectric to its capacitance with a vacuum as the dielectric.

Peak-power handling capability.—The maximum power a waveguide can carry without breakdown. Breakdown being defined as the point at which the electric field produces an arc discharge.

A few of the prior known techniques for converting linearly polarized energy to elliptically polarized energy are as follows:

One well known technique is the Orthogonal Probe Technique which utilizes probes positioned in a circular waveguide to shift the phase angle of the dominant mode TE₁₁ wave energy propagating down the circular waveguide. This technique includes rod-like members positioned at a 45° angle to the electric field vectors of the linearly polarized energy propagating down a circular waveguide. Generally, this method uses at least two rod-like probes approximately 3/8 of a wavelength apart to convert a dominant mode TE₁₁ linearly polarized wave to a dominant mode TE₁₁ circularly polarized wave. The sense of polarization, i.e., right-hand or left-hand circular polarization, depends upon whether the probes are offset 45° to the right or left of the direction of the electric field vectors of the linearly polarized energy. The Orthogonal Probe Technique is unsatisfactory in many respects. By way of example, very close tolerances are required in properly positioning the probes both with respect to the circular waveguide and with respect to each other; semi-automatic adjustability for converting linearly polarized energy to left-hand or right-hand circularly polarized energy is not possible since precise positioning of the probes is a mandatory requirement necessitating absolute and rigid fabrication during manufacturing; simple and expedient means for varying the impedance of the Orthogonal Probe device is not obtainable without bulky, complex and expensive mechanization; and high peak power handling capabilities in the order of 90% or better has not been possible.

Another well known technique is the Dielectric Slab Polarizer Technique which utilizes a flat slab of dielectric material specially shaped and precisely positioned within a circular waveguide. The dielectric slab used in this technique is conventionally referred to as a quarter-wave plate and is approximately three wavelengths long at the center frequency of the linearly polarized energy. The end portions of the quarter-wave plate may assume several configurations to form a quarter-wave matching portion. That is to say, a rectangular, triangular or other geometrically shaped wedge portion of one quarter wavelength long may be removed from the ends of the quarter-wave plate so as to provide a quarter-wave matching portion. The quarter-wave plate is conventionally positioned at an angle of 45° to the right or left of the direction of the electric field vectors of the linearly polarized energy propagating down the waveguide so as to produce a dominant mode TE₁₁ circularly polarized wave from a dominant mode TE₁₁ linearly polarized wave. The sense of polarization, i.e., right-hand or left-hand circular polarization, depends upon whether the quarter-wave plate is offset 45° to the right or left of the direction of the electric field vectors of the linearly polarized energy. Though the Dielectric Slab Polarizer Technique is satisfactory in many respects, it contains several inherent disadvantages some of which are close tolerance requirements with respect to the precise formation of the quarter-wave matching portions; semi-automatic adjustability not easily obtainable

since the quarter-wave plate must be precisely located both angularly and axially and requires absolute and rigid fabrication during manufacturing; simple and expedient means for varying the impedance of the device not obtainable without bulky, complicated and expensive mechanization; and high peak power in the order of 90% or better not achievable.

Another well known technique is the Eccentric Circular Waveguide Technique which employs a distorted section of the circular waveguide to convert a dominant mode TE_{11} linearly polarized wave to a dominant mode TE_{11} elliptically polarized wave. The distorted section of the circular waveguide is elliptically shaped and is three to four wavelengths long at the center frequency of the linearly polarized energy. The conversion of linearly polarized energy to elliptically polarized energy is perfected as a direct result of distorting the mode or electric field shape of the linearly polarized energy propagating down the circular waveguide. This latter technique also involves several inherent disadvantages some of which are the close tolerance requirements with respect to the precise formation of the elliptically shaped distortion; the lack of semi-automatic adjustability of the sense of elliptical polarization; and the absence of simple means for varying the impedance of the device.

In accordance with the present invention, a simple and efficient polarizing device is provided for transforming dominant mode TE_{10} linearly polarized energy to dominant mode TE_{11} elliptically polarized energy by employing an elongated dielectric polarizer having a wedge shaped portion which polarizer is adjustably mounted within a circular waveguide and extends at least partially into a transition waveguide section. The transition waveguide connects the circular waveguide to a rectangular waveguide. The dielectric polarizer is rotatable within the circular waveguide and when in a neutral position, no transformation of the linearly polarized wave to a circularly polarized wave occurs but when rotated clockwise or counterclockwise from the neutral position, the linearly polarized energy propagating along the rectangular waveguide is converted to elliptically polarized energy in one direction or the other, respectively. It should be noted that the rotatable feature of the dielectric polarizer advantageously provides semi-automatic adjustability of the degree and sense of elliptical polarization of the propagating energy. In addition to the rotatable adjustment, the dielectric member is axially adjustable with respect to the circular waveguide for varying the impedance of the polarizing device.

It is, accordingly, a primary object of the present invention to provide a polarizing device for transforming dominant TE_{10} mode linearly polarized energy to dominant TE_{11} elliptically polarized energy.

It is another object of the present invention to provide a polarizing device which is semi-automatically adjustable for varying the degree and sense of elliptical polarization of the propagating energy.

It is another object of the present invention to provide a polarizing device which has simple and expedient adjustable means for varying the impedance of the device.

It is another object of the present invention to provide a polarizing device which employs a wedge shaped dielectric polarizer for transforming dominant mode TE_{11} linearly polarized energy to dominant mode TE_{11} elliptically polarized energy.

It is another object of the present invention to provide a polarizing device which employs a wedge shaped, rotatably and axially adjustable, dielectric polarizer for transforming dominant mode TE_{11} linearly polarized energy to dominant mode TE_{11} elliptically polarized energy wherein rotation of the dielectric polarizer causes the degree and sense of elliptical polarization to be varied, and axial movement of the dielectric polarizer causes the impedance of the polarizer to be varied.

These and further objects and advantages will become

more apparent upon reference to the following description and claims and the appended drawings wherein:

FIGURE 1 is an isometric view of a polarizing device in accordance with the present invention which is adapted for specific use as an antenna.

FIGURE 2 is a cross-sectional view of the polarizing device taken along the plane 2—2 of FIGURE 1;

FIGURE 3 is a cross-sectional view of the polarizing device taken along the plane 3—3 of FIGURE 1;

FIGURE 4 is an end view of the polarizing device taken along the plane 4—4 of FIGURE 1;

FIGURE 5 is an end view of the polarizing device taken along the plane 5—5 of FIGURE 1;

FIGURE 6 is an isometric view of a polarizing device in accordance with the present invention which is adapted for specific use as a transmission line;

FIGURE 7 is a cross-sectional view of the polarizing device taken along the plane 7—7 of FIGURE 6;

FIGURE 8 is a cross-sectional view of the polarizing device taken along the plane 8—8 of FIGURE 6;

FIGURE 9 is an end view of the polarizing device taken along the plane 9—9 of FIGURE 6; and

FIGURE 10 is an end view of the polarizing device taken along the plane 10—10 of FIGURE 6.

Detailed description of FIGURES 1—5

Referring now in detail to FIGURE 1, there is shown an isometric view of a preferred embodiment of the polarizing device which is adapted for specific use as an antenna. The wedge shaped dielectric polarizer, generally indicated at 10, is mounted in a circular waveguide, generally indicated at 12, and extends at least partially into a transition waveguide section, generally indicated at 14. Transition section 14 connects a rectangular waveguide, generally indicated at 16, to the circular waveguide 12. Polarizer 10 is adjustably held in position within the circular waveguide 12 by the set screws 18.

It will be apparent that other well known means for adjustably holding polarizer 10 in position may be substituted for the set screws 18 without departing from the spirit and scope of the present invention. Although four set screws 90° apart are shown, it is to be understood that merely one set screw may suffice so long as it frictionally holds the polarizer 10 in position within the circular waveguide 12.

Referring now in detail to FIGURES 2—5 there are shown cross-sectional and end views of the polarizer device taken along the planes 2—2, 3—3, 4—4 and 5—5, respectively, of FIGURE 1.

The polarizer 10 comprises a wedge-shaped body portion 20 connected to a cylindrical neck portion 22 which is connected to a cylindrical head portion 24. A conical dielectric rod antenna 26 is connected to the head 24 on the side thereof remote from the neck portion 22. Rod antenna 26 may be blunt ended, as shown, or pointed depending upon the necessary and desired radiation pattern. The body portion 20 of polarizer 10 has a wedge shaped end 28 which appears similar in many respects to the wedge-shaped shank portion of a conventional screwdriver. Set screws 18 frictionally hold polarizer 10 in a desired position within the circular waveguide 12. Wedge-shaped end 28 of polarizer 10 extends at least partially into the transition waveguide section 14 which has one end integrally connected to circular waveguide 12 and the other end integrally connected to rectangular waveguide 16. The open end of the circular waveguide 12 has a peripheral U-shaped flange 29 which serves as a quarter wave choke for reducing side lobes of the radiation pattern. The inside diameter of the circular waveguide 12 is slightly larger than the diameter of the neck 22 of polarizer 10 and slightly smaller than the diameter of the head 24 of polarizer 10 so that polarizer 10 can be slidably inserted into circular waveguide 12 until the peripheral surface 32 of head 24 abuts the edge 34 of

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circular waveguide 12 and frictionally held in a desired angular and axial position by set screws 18.

Mode of operation of FIGURES 1-5

A detailed mode of operation of the polarizer device of FIGURES 1-5 is as follows:

With the polarizer 10 in the position shown, i.e., the sharp edge of the wedge 28 parallel to the long side of the rectangular waveguide 16, any dominant mode TE₁₀ linearly polarized energy propagating down the rectangular waveguide 16 toward the circular waveguide 12 will not be transformed or converted into dominant mode TE₁₁ elliptically polarized energy. This is so because the sharp edge of the wedge 28 of polarizer 10 is perpendicular to the electric vector of the dominant mode TE₁₀ linearly polarized energy propagating down the rectangular waveguide 16. The wedge 28 of polarizer 10 in this case produces no phase shift of the electric field, but produces only a transformation from the dominant mode TE₁₀ linearly polarized energy in the rectangular waveguide 16 to the dominant mode TE₁₁ linearly polarized energy in the circular waveguide 12. This transformation from TE₁₀ mode to TE₁₁ mode is caused by the gradual transition of the waveguide system from the rectangular to the circular. It is well known by antenna experts that the dominant mode in a rectangular waveguide is the TE₁₀ mode and the dominant mode in a circular waveguide is the TE₁₁ mode. Accordingly, a detailed technical explanation of this transition is not considered necessary for purposes of describing the present invention.

To achieve the desired degree and sense of transformation, one or more of the set screws 18 are loosened and polarizer 10 rotated clockwise or counterclockwise up to 90° displaced from the position shown. With the polarizer in its new position, any dominant mode TE₁₀ linearly polarized energy propagating down the rectangular waveguide 16 toward the circular waveguide 12 will be transformed into dominant mode TE₁₁ elliptically polarized energy. This is so because the sharp edge of the wedge 28 of polarizer 10 is no longer perpendicular to the electric vector of the dominant mode TE₁₀ energy propagating down the rectangular waveguide 16. The polarizer 10 due to its shape and the difference in dielectric media between the polarizer 10 and the air filled rectangular waveguide 16, produces a shift in phase of the electric vector of the dominant mode TE₁₁ linearly polarized energy propagating toward the circular waveguide 12. In time quadrature this phase shift produces a rotation of the electric vector. This rotation is such that the extremities of the electric vector describe an ellipse. The sense of rotation, either clockwise or counterclockwise, and the degree of ellipticity being determined by the angular displacement of the dielectric polarizer 10 from its neutral position.

Before the loosened set screws 18 are tightened, the polarizer 10 may be axially moved for impedance matching purposes. This is possible because the polarizer 10 constitutes an obstruction in the path of the propagating energy. A portion of this propagating energy strikes the polarizer 10 and is reflected back in a reverse direction. This is called "reflected energy." The ratio of the propagating energy to the reflected energy constitutes the impedance transformation of the device. An ideal condition occurs when there is no reflected energy. Thus, any axial movement of the polarizer 10 will produce a change in the amount of reflected energy, thereby producing a change in impedance of the polarizing device.

After the polarizer is axially adjusted and the desired impedance attained, the loosened set screws 18 are tightened. The polarizer device is now adjusted for both receiving and transmitting of dominant mode TE₁₁ elliptically polarized energy and more desirably adapted for receiving and transmitting dominant mode TE₁₁ elliptically polarized energy in the microwave range.

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For exemplary purposes only, the following dimensions and characteristics of the polarizer device depicted in FIGURES 1-5 were found highly satisfactory. It should be noted that the wavelengths referred to in the dimensions and characteristics below listed are free space wavelengths.

Dimensions

Transition Length—2 wavelengths long at center frequency of operation.

Circular Waveguide Diameter—

$$d_1 = \frac{d}{\sqrt{K}}$$

where

d_1 —Physical diameter of circular waveguide when dielectric polarizer is in position;

d —Diameter of a circular waveguide which would propagate the dominant mode TE₁₁ elliptically polarized energy when the dielectric polarizer is not in position; and

K —Dielectric constant of the dielectric polarizer.

Length of Taper—1½ wavelengths long at center frequency of operation.

Characteristics

Dielectric Constant—2 to 3.

Dissipation Factor—0.0003.

Efficiency (based on directive gain)—75%.

Axial ratio at design frequency—0.5 db.

Percent bandwidth for 3 db ellipticity—20%.

Percent bandwidth for 1.5 VSWR—30%.

Power handling in percent of rated rectangular waveguide—90%.

3 db beamwidth (practical limits)—20° to 70°.

Maximum side lobes—minus 20 db.

Front-to-back ratio (40° cone)—minus 30 db.

It is to be understood that the polarizer device depicted in FIGURES 1-5 may also receive dominant mode TE₁₁ elliptically polarized energy. In this case, the polarizer 10 transforms the dominant mode TE₁₁ elliptically polarized energy to the dominant mode TE₁₁ linearly polarized energy which then propagates down the transition waveguide section 14 wherein it is transformed to the dominant mode TE₁₀ linearly polarized energy which in turn propagates down the rectangular waveguide 16 away from the circular waveguide 12.

A polarizing device constructed in accordance with the foregoing dimensions will also transform dominant mode TE₁₀ linearly polarized energy to dominant mode TE₁₁ circularly polarized energy when the polarizer is rotated approximately 40° clockwise or counterclockwise from the position depicted in FIGURES 1-5 (neutral position), which is approximately such that the sharp edge of the wedge 28 of polarizer 10 is parallel to the long sides of the rectangular waveguide 16. Accordingly, the transformation of the energy will be from TE₁₀ mode linear to TE₁₁ mode elliptical polarization whenever the polarizer 10 is rotated any amount less than or more than approximately 40° from its neutral position.

Detailed description of FIGURES 6-10

Referring in detail to FIGURE 6, there is shown an isometric view of an alternate embodiment of the polarizing device which is adapted for specific use as a transmission line. The wedge-shaped dielectric polarizer, generally indicated at 40, is mounted in a circular waveguide, generally indicated at 42, and extends at least partially into a transition waveguide section, generally indicated at 44. Transition section 44 connects a rectangular waveguide, generally indicated at 46, to the circular waveguide 42. Polarizer 40 is adjustably held in position within the circular waveguide 42 by the set screws 48.

It will again be apparent that other well known means for adjustably holding polarizer 40 in position may be

substituted for the set screws 48 without departing from the spirit and scope of the present invention. Although four set screws 90° apart are shown, it is to be again understood that merely one set screw may suffice so long as it frictionally holds the polarizer 40 in position within the circular waveguide 42.

Referring now in detail to FIGURES 7-10, there are shown cross-sectional and end views of the polarizing device taken along the planes 7-7, 8-8, 9-9 and 10-10, respectively, of FIGURE 6.

The polarizer 40 comprises a wedge-shaped body portion 50 connected to a cylindrical neck portion 52 which is connected to a conical head portion 54. Conical head portion 54 is pointed, as shown at 56, for impedance matching purposes. The body portion 50 of polarizer 40 has a wedge shaped end 58 which appears similar in many respects to the wedge-shaped shank portion of a conventional screwdriver. Set screws 48 frictionally hold polarizer 40 in a desired position within the circular waveguide 42. Wedge-shaped end 58 of polarizer 40 extends into the transition waveguide section 44 which has one end integrally connected to circular waveguide 42 and the other end integrally connected to rectangular waveguide 46. The inside diameter of the circular waveguide 42 is slightly larger than the diameter of the neck portion 52 of polarizer 40 so that polarizer 40 can be slidably inserted into the circular waveguide 42 and frictionally held in a desired angular and axial position by set screws 48.

The mode of operation of the embodiment of FIGURES 6-10 is substantially the same as that above set forth in detail with respect to the embodiment of FIGURES 1-5. The primary difference being that the transformed dominant mode TE₁₁ elliptically polarized energy continues to propagate down the circular waveguide 42 away from the rectangular waveguide 46 rather than being radiated into the atmosphere, as in the case of the polarizer device depicted in FIGURES 1-5. Also, the dimensions and characteristics of the polarizer of FIGURES 6-10 is substantially the same as the polarizer of FIGURES 1-5. In addition, it has also been found that the transformation of energy from linear to circular polarization takes place when the polarizer 40 is rotated 40° from its neutral position (position shown in FIGURES 6-10).

It will be apparent from the foregoing that the present invention provides a unique technique for converting dominant mode TE₁₀ linearly polarized energy to dominant mode TE₁₁ elliptically polarized energy without the use of highly complicated, bulky and expensive mechanization. The use of a wedge-shaped dielectric polarizer angularly and axially adjustable within a circular waveguide in combination with a gradually tapered transition waveguide for coupling a rectangular waveguide to the circular waveguide, uniquely overcomes the inherent disadvantages of prior known polarizing devices.

The rotatable feature of the present polarizer effectively and efficiently provides semi-automatic adjustability of the degree and sense of elliptical polarization of the propagating energy. In addition, the axial adjusting feature of the present invention accurately provides expedient means for varying the impedance of the polarizing device.

It will also be apparent that the polarizing devices of the present invention are simple in construction, economical to manufacture and highly reliable in achieving the desired objects and performing the intended functions.

While several embodiments of the present invention have been described in detail, it is to be understood that other modifications are contemplated which would be apparent to persons skilled in the art without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. A polarizing device comprising, in combination:
 - (a) a rectangular waveguide;

- (b) a circular waveguide;
- (c) a tapered waveguide transition section coupling one end of said rectangular waveguide to one end of said circular waveguide;
- (d) elongated dielectric means positioned within said circular waveguide and extending into said transition section; and
- (e) means for adjustably holding said dielectric means within said circular waveguide so as to provide both angular and axial adjustment of said dielectric means with respect to said circular waveguide;
- (f) said circular waveguide having a diameter wherein said circular waveguide will not propagate wave energy when said dielectric means is not in position within said circular waveguide so that,

$$d_1 = \frac{d}{\sqrt{K}}$$

where d_1 equals the physical diameter of said circular waveguide when said dielectric means is in position, d equals the diameter of a circular waveguide which would propagate the dominant mode TE₁₁ of said energy when said dielectric means is not in position, and K equals the dielectric constant of said dielectric means;

- (g) said dielectric means being rotatable to a first position which causes dominant mode TE₁₁, linearly polarized energy to be propagated in said circular waveguide, being rotatable to a second position which causes dominant mode TE₁₁, left-hand, circularly polarized energy to be propagated in said circular waveguide, and being rotatable to a third position which causes dominant mode TE₁₁, right-hand, circularly polarized energy to be propagated in said circular waveguide;
- (h) said dielectric means being rotatable to any position other than said first, second and third positions, to achieve a variable degree and sense of transformation of said dominant mode TE₁₁ linearly polarized energy to dominant mode TE₁₁ elliptically polarized energy; and
- (i) said dielectric means is axially adjustable with respect to said circular waveguide for varying the impedance of said device.

2. A polarizing device in accordance with claim 1 wherein the length of said transition section is approximately two wave lengths long in free space at the center frequency of said energy.

3. A polarizing device in accordance with claim 2 wherein the length of said body portion of said dielectric means is approximately one and one-half wavelengths long in free space at the center frequency of said energy.

4. A polarizing device in accordance with claim 3 wherein the physical diameter of said circular waveguide is approximately one-half wavelength long in free space at the center frequency of said energy.

5. A polarizing device comprising, in combination:

- (a) a rectangular waveguide;
- (b) a circular waveguide;
- (c) a tapered waveguide transition section coupling one end of said rectangular waveguide to one end of said circular waveguide, said transition section being approximately two wave lengths long in free space at the center frequency of said energy;
- (d) elongated dielectric means positioned within said circular waveguide and extending into said transition section; and
- (e) means for adjustably holding said dielectric means within said circular waveguide;
- (f) said dielectric means comprising a wedge-shaped body portion connected to a cylindrical head portion, said body portion being approximately one-half wavelength long in free space at the center frequency of said energy and said head portion having a diameter slightly smaller than the diameter of said circular

waveguide so that said dielectric means may be slidably inserted into said circular waveguide;

- (g) said dielectric means being rotatable within said circular waveguide and having a first position in which the dominant mode TE₁₁ linearly polarized energy is propagated in said circular waveguide, said dielectric means when rotated clockwise from said first position to a second position, causes said dominant mode TE₁₁ linearly polarized energy to be transformed into dominant mode TE₁₁ left-hand circularly polarized energy; and when rotated counter-clockwise from said first position to a third position, causes said dominant mode TE₁₁ linearly polarized energy to be transformed into dominant mode TE₁₁ right-hand circularly polarized energy, said dielectric means when rotated to any position other than said first, second and third position achieves a variable degree and sense of transformation of said dominant mode TE₁₁ linearly polarized energy to dominant mode TE₁₁ elliptically polarized energy;
- (h) said dielectric means being axially adjustable with respect to said circular waveguide for varying the impedance of said device;
- (i) said circular waveguide having a physical diameter of a value such that said circular waveguide will not propagate wave energy when said dielectric means is not in position within said circular waveguide so that

$$d_1 = \frac{d}{\sqrt{K}}$$

where d_1 equals the physical diameter of said circular waveguide when said dielectric means is in position, d equals the diameter of a circular waveguide which would propagate the dominant mode TE₁₁ of said energy when said dielectric means is not in position, and K equals the dielectric constant of said dielectric means.

6. A polarizing device in accordance with claim 5 wherein said dielectric means further includes a dielectric rod antenna connected to said head portion on the side remote from said body portion for radiating and receiving polarized energy into and from free space, respectively.

7. A polarizing device in accordance with claim 6 wherein the other end of said circular waveguide has a peripheral U-shaped flange portion which serves as a quarter wave choke for reducing side lobes of the radiation pattern of the dominant mode TE₁₁ polarized energy radiated from said rod antenna, said rod antenna extending away from said other end of said circular waveguide and lying substantially outside of the plane of said other end of said circular waveguide.

8. A polarizing device in accordance with claim 5 wherein said dielectric means further includes a cone-shaped portion connected to said head portion on the side remote from said body portion, said cone-shaped portion extending away from said body portion and positioned within said circular waveguide.

9. A polarizing device for transforming dominant mode TE₁₀ linearly polarized energy into dominant mode TE₁₁ elliptically polarized energy, said device comprising:

- (1) a rectangular waveguide having two ends;
- (2) a circular waveguide having two ends;
- (3) a tapered waveguide transition section connecting one end of said rectangular waveguide to one end of said circular waveguide for transforming said dominant mode TE₁₀ linearly polarized energy into dominant mode TE₁₁ linearly polarized energy;
- (4) an elongated dielectric polarizer having a wedge shaped body portion, a cylindrical head portion and a cylindrical neck portion connecting said body portion to said head portion;
- (5) a dielectric rod antenna in the form of a frustum of a cone connected to said head of said polarizer on the side remote from said neck portion for radiating and receiving polarized energy into and from free space, respectively;

- (6) a quarter-wave choke in the form of a U-shaped peripheral flange connected to and encompassing said other end of said circular waveguide for reducing side lobes of the radiation pattern of the dominant mode TE₁₁ polarized energy radiated by said rod antenna into free space; and
- (7) means for adjustably holding said polarizer in a predetermined position within said circular waveguide;

said polarizer being adapted to be slidably inserted into said circular waveguide with said body portion extending at least partially into said transition section, said polarizer being rotatably adjustable within said circular waveguide for providing a variable degree and sense of transformation of said dominant mode TE₁₁ linearly polarized energy to dominant mode TE₁₁ elliptically polarized energy, said polarizer being axially adjustable with respect to said circular waveguide for varying the impedance of said device, said circular waveguide having a diameter such that said circular waveguide will not propagate said dominant mode polarized energies when said polarizer is not in position within said circular waveguide so that

$$d_1 = \frac{d}{\sqrt{K}}$$

wherein d_1 equals the physical diameter of said circular waveguide when said polarizer is in position, d equals the physical diameter of a circular waveguide which would propagate said dominant mode TE₁₁ polarized energies when polarizer is not in position and K equals the dielectric constant of said polarizer, said rod antenna extending away from said other end of said circular waveguide and lying substantially outside of the plane of said other end of said circular waveguide.

10. A polarizing device for transforming dominant mode TE₁₀ linearly polarized energy into dominant mode TE₁₁ elliptically polarized energy, said device comprising:

- (1) a rectangular waveguide having two ends;
- (2) a circular waveguide having two ends;
- (3) a tapered waveguide transition section connecting one end of said waveguide for transforming dominant mode TE₁₀ linearly polarized energy into dominant mode TE₁₁ linearly polarized energy;
- (4) an elongated dielectric polarizer having a wedge shaped body portion, a cylindrical head portion connected to said body portion and a cone shaped portion connected to said head portion on the side remote from said body portion;
- (5) means for adjustably holding said polarizer in a predetermined position within said circular waveguide;

said polarizer being adapted to be slidably inserted into said circular waveguide with said body portion extended at least partially into said transition section and the remainder of said polarizer being positioned within said circular waveguide, said polarizer being rotatably adjustable within said circular waveguide for providing a variable degree and sense of transformation of said dominant mode TE₁₁ linearly polarized energy to dominant mode TE₁₁ elliptically polarized energy, said polarizer being axially adjustable with respect to said circular waveguide for varying the impedance of said device, said circular waveguide having a diameter such that said circular waveguide will not propagate said dominant mode polarized energies when said polarizer is not in position within said circular waveguide so that

$$d_1 = \frac{d}{\sqrt{K}}$$

wherein d_1 equals the physical diameter of said circular waveguide when said polarizer is in position, d equals the physical diameter of a circular waveguide which would propagate said dominant mode TE₁₁ polarized energies when said polarizer is not in position, and K equals the

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dielectric constant of said polarizer.

11. A device for transforming linearly polarized energy to elliptically polarized energy, said device comprising:

- (a) a rectangular waveguide coupled to a circular waveguide by a tapered waveguide transition section; and
- (b) adjustable dielectric means positioned within said circular waveguide and extending into said transition section;

said dielectric means being rotatable to a first position in which said linearly polarized energy is transformed to elliptically polarized energy polarized in one angular direction, and rotatable to a second position in which said linearly polarized energy is transformed to elliptically polarized energy polarized in angular direction opposite to said one angular direction, said dielectric means also being axially adjustable with respect to said circular waveguide for varying the impedance of said device, said transition section having a length approximately two wavelengths long in free space at the center frequency of said energy, and said circular waveguide having a diameter approximately one-half wavelength long in free space at the center frequency of said energy, wherein said circular waveguide will not propagate wave energy when said di-

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electric means is not in position within said circular waveguide so that,

$$d_1 = \frac{d}{\sqrt{K}}$$

where d_1 equals the physical diameter of said circular waveguide when said dielectric means is in position, d equals the physical diameter of a circular waveguide which would propagate the dominant mode TE_{11} of said energy when said dielectric means is not in position, and K equals the dielectric constant of the dielectric means.

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