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SEARCH ROOM

April 26, 1960 R. L. SMEDES 2,934,762

SELECTIVE POLARIZATION ANTENNA

Filed Nov. 15, 1956 2 Sheets-Sheet 1

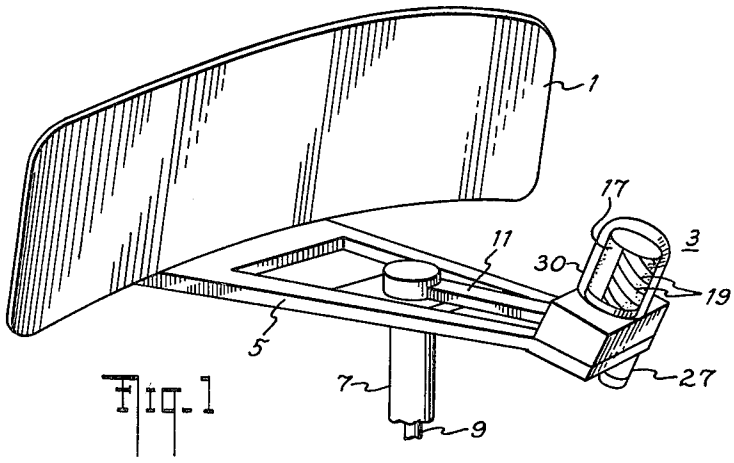


FIG. 1

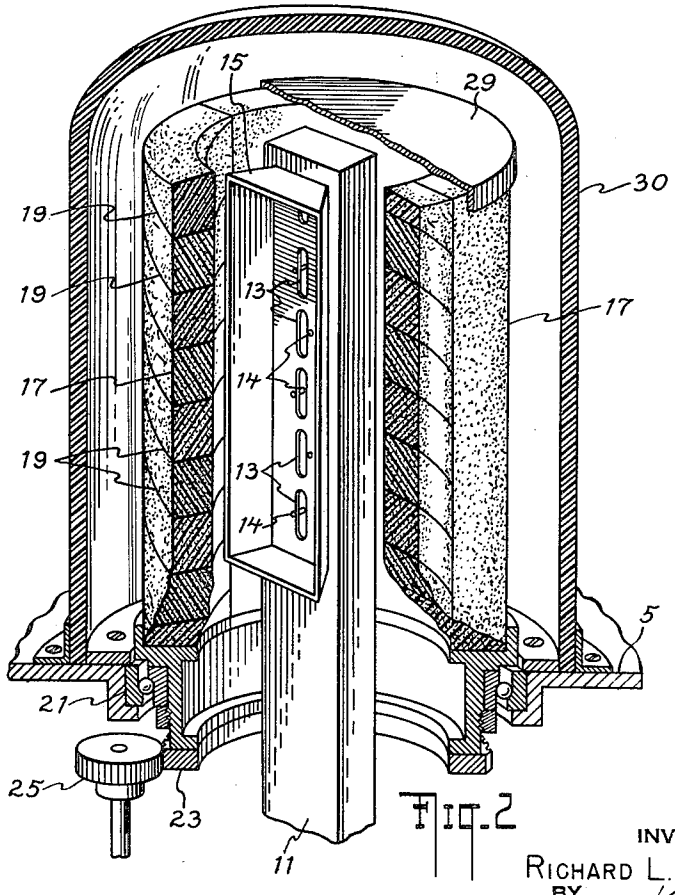


FIG. 2

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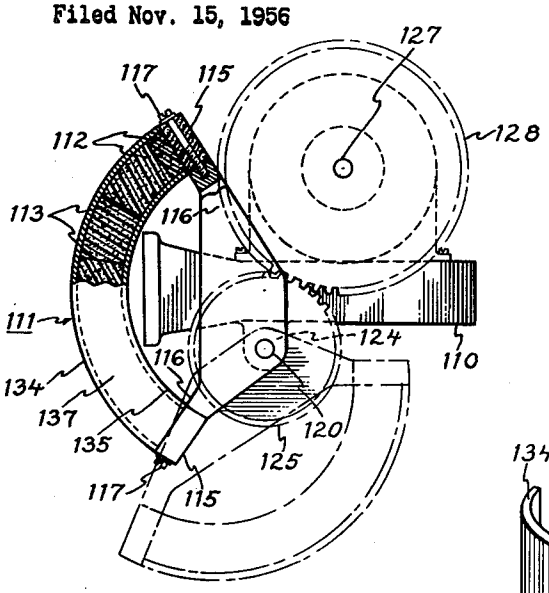


FIG. 3

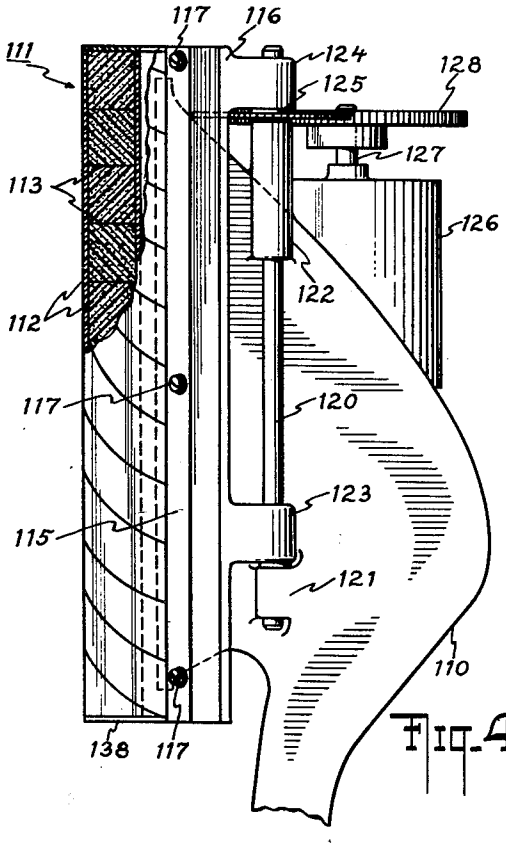


FIG. 4

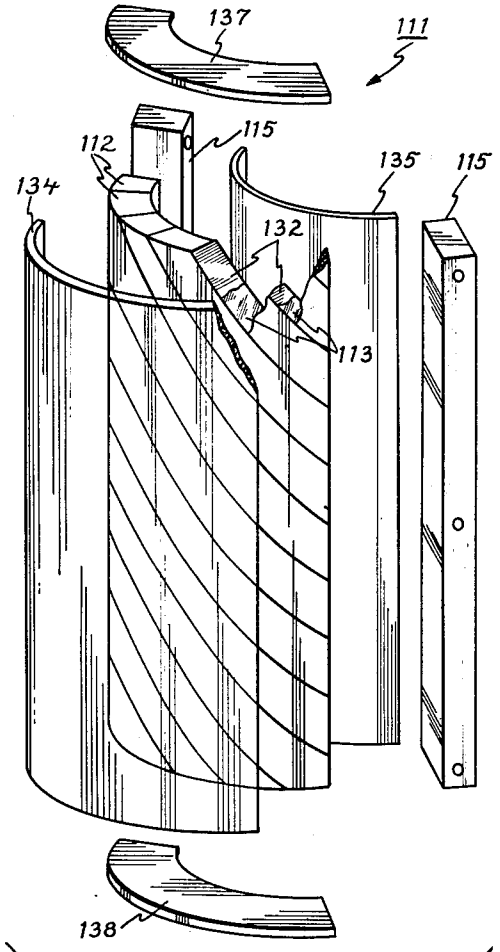


FIG. 5

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SELECTIVE POLARIZATION ANTENNA

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17 Claims. (Cl. 343—754)

This invention relates to improvements in antennas of the type used in radar systems, and more particularly to apparatus for selectively changing the operation of such antennas to work with plane polarization or with circular polarization.

This patent application is a continuation-in-part of U.S. patent application Serial No. 485,714 by R. L. Smedes, filed February 2, 1955, now abandoned.

Radar antennas generally are designed to use plane polarization. It is known, however, that under some weather conditions, such as heavy rain, there is considerable advantage in using circular polarization. This results from the fact that raindrops, which are spherical, reflect circularly polarized waves back as circularly polarized waves that are polarized in the opposite sense, whereas most targets are non-spherical and reflect but a portion of the circularly polarized transmitted waves, the reflected portion being elliptically or linearly polarized. Elliptically and linearly polarized waves contain both senses of polarization.

The above described phenomenon has been utilized in some radar systems, by designing the antenna to radiate and receive waves that are circularly polarized in the same sense, but to discriminate against return waves that are circularly polarized in the opposite sense. One such antenna is disclosed in Affel et al. U.S. Patent No. 2,637,847.

Under normal relatively clear weather conditions, it is found that the return signal from a particular target is usually about 7 db less when circular polarization is used than it is when plane polarization is used. Thus the circularly polarized antenna is at a disadvantage except during heavy rainfalls.

One of the principal objects of the present invention is to provide an improved feed system for radar systems, whereby either plane polarization or circular polarization may be selected at will.

Another object is to provide polarization selector means that can be operated conveniently from a point that is remote from the antenna structure.

Another object is to provide a selectively operable polarizration converter device that can readily be applied to existing radar antennas as a modification kit, simply replacing some of the parts and adding others.

A still further object is to provide a polarization converter device that has substantially no deleterious effect on the directive pattern of the antenna to which it is added.

Another object is to provide means for improving the circularity of polarization converter structures that include elements having dielectric constants substantially greater than unity.

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

Fig. 1 is a perspective view of a radar antenna embodying the present invention.

Fig. 2 is a perspective view of the feed structure and

polarization converter of the antenna of Fig. 1, partly broken away to show certain internal details.

Fig. 3 is a plan view of a radar antenna employing another embodiment of this invention.

Fig. 4 is a front elevational view of the structure of Fig. 3.

Fig. 5 is an exploded view in perspective of the polarization converter of Fig. 3.

The antenna shown in Fig. 1 includes a paraboloidal secondary reflector **1** and a feed radiator system **3** supported on a platform **5**. The feed system **3** includes directive radiator means for providing a relatively wide primary beam that covers the reflector **1** and is reflected thereby as a narrow secondary beam. The platform **5** is mounted on a mast **7** for rotation by means of a shaft **9** to rotate the narrow beam in azimuth.

The feed system **3** is shown in detail in Fig. 2. It includes a waveguide **11** closed at its upper end and provided with a series of longitudinally extending slots **13** along the center line of one of its broad walls. The slots **13** are longitudinally spaced at intervals of one-half the guide wavelength, and are coupled to the guide **11** so as to operate in phase, by means of conductive pins **14** disposed adjacent the respective slots alternately on opposite sides thereof and extending into the guide. This arrangement of slots forms a directive array having a pattern that is relatively narrow in elevation, but wide in azimuth. A short conductive horn **15** narrows the azimuth pattern. The resulting beam is directed at the reflector **1** (Fig. 1).

The system as thus far described is similar to prior radar antennas, and operates with horizontally polarized waves. The polarization converter which is added thereto in accordance with this invention includes a hollow cylindrical body **17** of low-loss insulating material such as polystyrene, having embedded in it a series of helical strips **19** of conductive material disposed at an angle of 45 degrees to the axis of the cylinder at the mean diameter. The strips **19** extend over half or less than half of the circumference of the cylinder. The cylinder **17** may be made in the form of a sector, rather than as a complete circular cylinder, the part beyond the strips **19** being omitted. The cylinder **17** is supported at its lower end by a bearing assembly **21**, for rotation about its longitudinal axis. This axis is made to coincide with the virtual source of the feed array, i.e. with the line which is the center of curvature of the phase fronts of the array.

The polarizer may be built up of a series of helical strips of sheet metal and dielectric material bonded together, or the conductive strips may be formed by coating the helical pieces of dielectric with conductive paint before assembly. Another alternative is to machine helical slots in a dielectric cylinder and insert metal strips in the slots.

The lower end of the cylinder **17** is coupled through a drive mechanism including gears **23** and **25** to a motor **27** (Fig. 1). Limit switches, not shown, may be provided in the circuit of the motor **27** to stop the motor only when the cylinder **17** reaches certain predetermined positions where the metal strips **19** are completely outside the primary beam, or where the entire primary beam passes through the strips.

In transmission, the polarization converter operates by resolving plane polarized waves radiated from the slots **13**, into two components, one polarized in a plane parallel to the strips **19** and the other polarized perpendicular thereto. The perpendicular component passes through the assembly with a phase velocity that depends only upon the dielectric constant of the material between the strips **19**, and is independent of the spacing between the strips. The parallel component passes through with a higher phase velocity, owing to the action of the con-

ductive strips as waveguides. This latter phase velocity depends upon the spacing between adjacent strips **19**, as well as upon the dielectric constant of the material between them. The spacing and the radial width of the strips are designed to provide a phase difference of 90° between the emerging parallel and perpendicular components, which thus constitute a circularly polarized wave. A device, such as described, which transmits one component of a pair of mutually perpendicular wave components as a guided wave and the other component as an unguided wave, so that one of the two components emerges displaced 90° in phase from the other component, is commonly known as a quarter wave plate.

In order to obtain circular rather than elliptical polarization, the two wave components that are polarized respectively parallel and perpendicular to the strips **19** must be equal in magnitude, as well as in quadrature time phase. Reflections from the polarizer can have a deleterious effect on the circularity if they are different for the two components. The term "circularity" is defined as the ratio of the amplitudes of the two components.

If the dielectric material had a dielectric constant of unity, the unguided wave component polarized perpendicular to the strips **19** would pass through without reflection. The parallel component may also be made to pass through without reflection by a proper choice of radial width and spacing of the strips **19**, so that they act as a set of half-wavelength waveguides for the guided, parallel component.

When the plates **19** are spaced by a relatively high dielectric constant material such as a solid plastic, the perpendicular component will be partially reflected. The parallel component can be made to undergo the same reflection by designing the strips to act as waveguides that differ from one-half wavelength by the correct amount. This method of maintaining circularity is not expedient because the tolerances in the width and spacing of the conductive strips are too close.

Other arrangements for minimizing or equalizing the reflections of the two components are theoretically possible, but are undesirable in practice because they require special materials or designs that are mechanically unsuitable.

According to the present invention, the reflections of the two wave components are equalized by means of a thin sheet **30** of dielectric material adjacent and conformal to the outer surface of the polarizer. The magnitude of the reflection from this sheet depends upon the dielectric material and its thickness. The relative phase of the reflection depends upon the spacing between the sheet **30** and the polarizer. Owing to the complex interaction between the polarizer and the feed structure, the parameters of the sheet **30** are best determined experimentally.

The polarizer may be designed to act as a half wave transformer to match the guided (parallel) component. Then the sheet **30** is made so as to reduce the reflection of the perpendicular component. This increases the reflection of the parallel component, and thus tends to equalize the reflections of the two components and thereby improve the circularity.

Details of a polarization converter embodying the present invention and designed for operation at 9368 megacycles per second are as follows:

Mean spacing between strips **19**	inches	.500
Helix angle (on 4.055" diameter)	degrees	45
Inside diameter	inches	3.492
Outside diameter	do	4.647

The body **17** was made of a polyester resin having a dielectric constant of 2.9. The sector containing the strips **19** covers an angle of 112°. The outer sheet **30** is .065" thick, and spaced radially from the cylinder **17** by .080". The dielectric constant of the sheet material is 2.56.

When circularly polarized waves from a distant source or reflecting object arrive at the antenna, the helical strip structure analyzes them into two components that are respectively parallel and perpendicular to the strips. As before, the parallel component is advanced 90° in phase with respect to the perpendicular component. The two components emerge from the inner surface of the structure in phase with each other, but in space quadrature. They combine vectorially to form a plane polarized wave, with horizontal polarization if the arriving circularly polarized waves are polarized in one sense, and with vertical polarization if the arriving waves are polarized in the opposite sense.

Since the slots **14** will respond substantially to horizontally polarized waves, and not to vertically polarized waves, the antenna as a whole will respond best to waves that are circularly polarized in the same direction as the waves it transmits, and will exhibit substantially zero response to pure circularly polarized waves of the opposite sense.

In the normal operation of the antenna of Fig. 1, the polarization converter is in the position shown, with the metal strips **19** out of the path of the primary beam. The dielectric cylinder has no effect on the polarization, and the system operates with horizontal polarization. When heavy rain or clouds cause "clutter" on the display of the radar to which the antenna is connected, the operator closes the power supply circuit to the motor **27**. This rotates the cylinder **17** to position the strips **19** in the path of the primary beam, and the antenna operates with circular polarization.

The motor **27** may be connected so as to be controlled from a remote point, such as the indicator station. The outer member **30** may be closed at the top as shown, to form a protective cover for the feed structure.

Another embodiment of this invention is shown in Figs. 3, 4 and 5. In this embodiment a modified construction of the polarization converter is employed. Furthermore, the converter occupies a cylindrical sector of only about 120°, so that when the converter is removed from in front of the feed array for plane polarization radiation, there is nothing at all in front of the feed array, Fig. 3.

The antenna system, only a portion being shown in Figs. 3 and 4, includes a linear array comprising a waveguide horn **110** adapted to radiate a pattern similar to that provided by wave-guide **11** and slots **13** of Fig. 2. A polarization converter **111** is rotatably mounted with respect to an axis parallel to the long dimension of the mouth of horn **110**. Polarization converter **111** comprises a plurality of alternate helicoidal dielectric strips **112** and conductive strips **113** to form a quarter wave plate of the type previously described. A pair of dielectric supports **115** are affixed, as by cementing, to the radial bounding surfaces of converter **111**. A yoke **116** supports converter **111** by means of screws **117** passing through supports **115**. A shaft **120** is mounted in brackets **121**, **122** affixed to horn **110**. Shaft **120** passes through bearings in arms **123**, **124** of yoke **116**. A gear **125** is disposed concentrically with respect to shaft **120** and is affixed to the underside of arm **124**. A reversible motor **126**, having a rotatable shaft **127**, is adapted to rotate converter **111** by means of a gear **128** affixed to shaft **127** and meshing with gear **125**. Limit switches, not shown, may be provided to stop motor **126** when the converter **111** reaches a first predetermined position (shown by the solid lines in Fig. 3) completely in front of horn **110** or when it reaches a second predetermined position (shown by the dotted lines in Fig. 3) completely outside the path of the energy radiated from horn **110**.

Converter **111** is formed of a plurality of helicoidal dielectric strips **112**, each of the radial surfaces **132** (Fig. 5) of the strips being disposed adjacent a radial surface of another of the strips. Dielectric strips **112** are cut to proper lengths to form, when assembled, a hol-

low cylindrical sector subtending an angle of approximately 120°. The dielectric strips may be fabricated from any material having good dielectric properties at microwave frequencies, such as polyester resin or polystyrene. Conductive strips **113** are formed between each pair of adjacent radial surfaces **132**. The conductive strips may be formed of metal foil and inserted between dielectric strips **112** when the latter are assembled, or may be formed directly on the radial surfaces of the dielectric strips, as by spraying the radial surfaces with a suspension of silver flakes in a fluid binder. The suspension hardens on the surfaces to form a smooth conducting film.

In the latter method of forming the conductive strips, the method presently preferred, the dielectric strips **112** are first cast from fluid dielectric material. The silver suspension is then sprayed on a corresponding radial surface of each dielectric strip. When the silver film has hardened the coated plastic strips are assembled. At this time the coated strips may be fastened together by inserting a small amount of cement, which is composed of the same material as the plastic strips, between adjacent radial surfaces. However, such a structure is relatively weak, since the silver film does not form a strong mechanical bond with the plastic surface on which it was sprayed. Consequently, mechanical reinforcement is necessary to form a sturdy structure.

Reinforcing sheets to strengthen the converter may be derived from the thin sheet **30** of Fig. 2, which was employed to equalize reflections of the guided and unguided wave components. By dividing the sheet into two sections, one placed on each side of the converter of Fig. 5, the structure is made mechanically rigid. Thus, a pair of curved dielectric sheets **134** and **135** are disposed adjacent and in contact with the respective outer and inner cylindrical surfaces of the assemblage of coated dielectric strips **112**. The dielectric sheets are preferably of the same material as the dielectric strips. Sheets **134**, **135** may be preformed and then bonded to the cylindrical surfaces of the assemblage of strips **112** by a cement, or may be cast in place about the assembled strips. The radial thicknesses of the pair of sheets **134** and **135** is that necessary to equalize the reflections of the guided and unguided components passing through the composite structure, thereby maintaining circularity as was described previously. Thus, dielectric sheets **134** and **135** perform the dual function of mechanically strengthening the converter and electrically improving the circularity of the transmitted waves. A pair of arcuate dielectric strips **137** and **138** are bonded to the respective upper and lower surfaces of the assemblage of strips **112** to complete the structure of converter **111**.

While the invention has been described in its preferred embodiment, it is to be understood that the words which have been used are words of description rather than of limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. A selective polarization converter for antennas of the type having a linear primary feed array adapted to direct a beam of plane polarized electromagnettic wave energy toward a secondary reflector, comprising a hollow cylindrical body of dielectric material adjacent said feed array, and a plurality of helicoidal strips of conductive material embedded in said cylinder throughout a sector thereof, said strips being disposed and proportioned to form a quarter wave plate, said cyindrical body being rotatable to move said quarter wave plate selectively into and out of the path of said beam.

2. An antenna feed structure for selectively irradiating a secondary reflector with plane polarized and circularly polarized electromagnetic wave energy, comprising a linear array of radiator elements, a wave guide extending parallel to the line of said array and coupled to said elements, and a hollow cylindrical body of dielectric material with its axis of revolution substantially in coincidence with the effective source of said array, a sector of said cylinder being provided with a series of helically disposed conductors forming a quarter wave plate, said cylindrical body being rotatable about said axis to selectively position said quarter wave plate in front of said array and behind said array.

3. An anti-clutter modification kit for radar antennas of the type having a linear feed array structure and a parabolic secondary reflector, comprising a hollow cylindrical body of dielectric material adapted to be disposed with its axis of revolution coinciding with the virtual source line of said array, a plurality of spaced helicoidal strips of conductive material supported in a sector of said cylindrical body at an angle of substantially 45 degrees with respect to said axis, said cylindrical body being rotatable about said axis to selectively position said sector into and out of the zone of projection between said array and said secondary reflector.

4. A radar antenna system for selective operation with plane polarized waves or circularly polarized waves, including a directive feed radiator and a reflector, said feed radiator being directed toward said reflector, a polarization converter consisting of a quarter wave plate curved to define a concave inner surface facing said feed radiator, and means for moving said plate selectively into and out of a position between said radiator and said reflector.

5. A radar antenna system for normal operation with plane polarized waves, and operation with circularly polarized waves under weather conditions involving heavy precipitation, including a directive feed radiator structure and a reflector, said feed structure being directed toward said reflector, a polarization converter consisting of a quarter wave plate curved to define a sectoral portion of a cylindrical surface with its axis of curvature coincident with the virtual source of said feed structure, and means for rotating said plate about said axis to move said plate selectively into and out of a position between said feed structure and said reflector.

6. The invention set forth in claim 5, wherein said quarter wave plate comprises a plurality of conductive strips embedded in a body of solid dielectric material and disposed at an angle of substantially 45 degrees to said axis.

7. The invention set forth in claim 6, further including a sheet of dielectric material disposed adjacent and conformal to the outer surface of said quarter wave plate to equalize the overall reflection of the guided and unguided wave components passing through said plate.

8. The invention set forth in claim 7, wherein said sheet of dielectric material is in the form of a hollow cylinder provided with an end closure and substantially enclosing said feed structure and polarization converter.

9. The invention set forth in claim 6, wherein the thickness of said quarter wave plate is an integral number of half wavelengths for the guided wave component passing through said plate.

10. The invention set forth in claim 9, further including a sheet of dielectric material disposed adjacent and conformal to the outer surface of said quarter wave plate to equalize the overall reflection of the guided and unguided wave components passing through said plate.

11. A circular polarization converter for a microwave primary feed system comprising a plurality of helicoidal strips of dielectric material, at least one radial surface of each of said strips being provided with a conductive coating, each of said strips being disposed with each of its radial surfaces adjacent and substantially in contact with a radial surface of another of said strips, whereby said plurality of strips forms a sectoral portion of a hollow cylinder, a first sheet of dielectric material disposed adjacent and in contact with the outer cylindrical surface of

said sectoral portion, and a second sheet of dielectrical material disposed adjacent and in contact with the inner cylindrical surface of said sectoral portion, said first and second dielectric sheets being substantially coextensive and conformal with the respective outer and inner cylindrical surfaces of said hollow cylindrical sectoral portion.

12. A polarization converter as in claim 11 wherein the radial thicknesses of said first and second sheets are adapted to equalize the reflections of two wave components passing through said sectoral portion with respective polarizations parallel to and perpendicular to said radial surfaces.

13. A converter as in claim 11 wherein the radial thickness of said sectoral portion is an integral number of half wave lengths for a linearly polarized wave component passing through said portion with a polarization parallel to said radial surfaces, and the radial thicknesses of said first and second sheets are adapted to equalize the reflections of two wave components passing through said sectoral portion with respective polarizations parallel to and perpendicular to said radial surfaces.

14. The invention set forth in claim 11 further including means for supporting said polarization converter in front of said feed system, whereby said conductively coated radial strip surfaces make an angle of substantially 45 degrees with respect to the polarization of the waves radiated by said feed system.

15. The invention set forth in claim 14 further including means for moving said polarization converter selectively into and out of a position in front of said feed system.

16. A circular polarization converter for a microwave primary feed system comprising a plurality of helicoidal strips of dielectric material, each of said strips being disposed with each of its radial surfaces adjacent a radial

surface of another of said strips, a conductive helicoidal strip disposed between each pair of adjacent radial surfaces, whereby said assemblage of dielectric and conductive strips forms a sectoral portion of a hollow cylinder, a first sheet of dielectric material disposed adjacent the outer cylindrical surface of said sectoral portion, and a second sheet of dielectric material disposed adjacent the inner cylindrical surface of said sectoral portion, said first and second dielectric sheets being substantially coextensive and conformal with the respective outer and inner cylindrical surfaces of said hollow cylindrical sectoral portion.

17. A microwave radiating apparatus for selectively radiating plane polarized or circularly polarized electromagnetic energy comprising, a directive radiator for radiating a beam of microwave energy, and a member of dielectric material having the shape of a sectoral portion of a hollow cylinder disposed in front of said radiator in the path of said beam, said dielectric member having an axis of curvature substantially in coincidence with the effective source of said radiator, said dielectric member being provided with a series of helically disposed conductors forming a quarter wave plate, said dielectric member being rotatable away from said radiator and out of the path of said beam.

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