

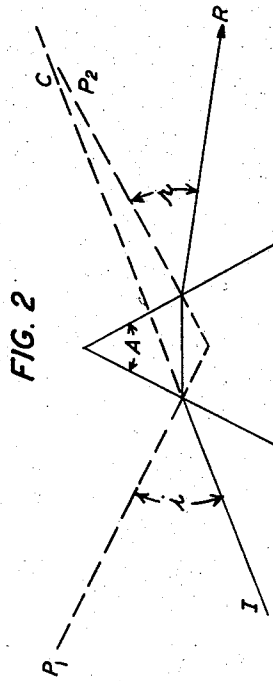
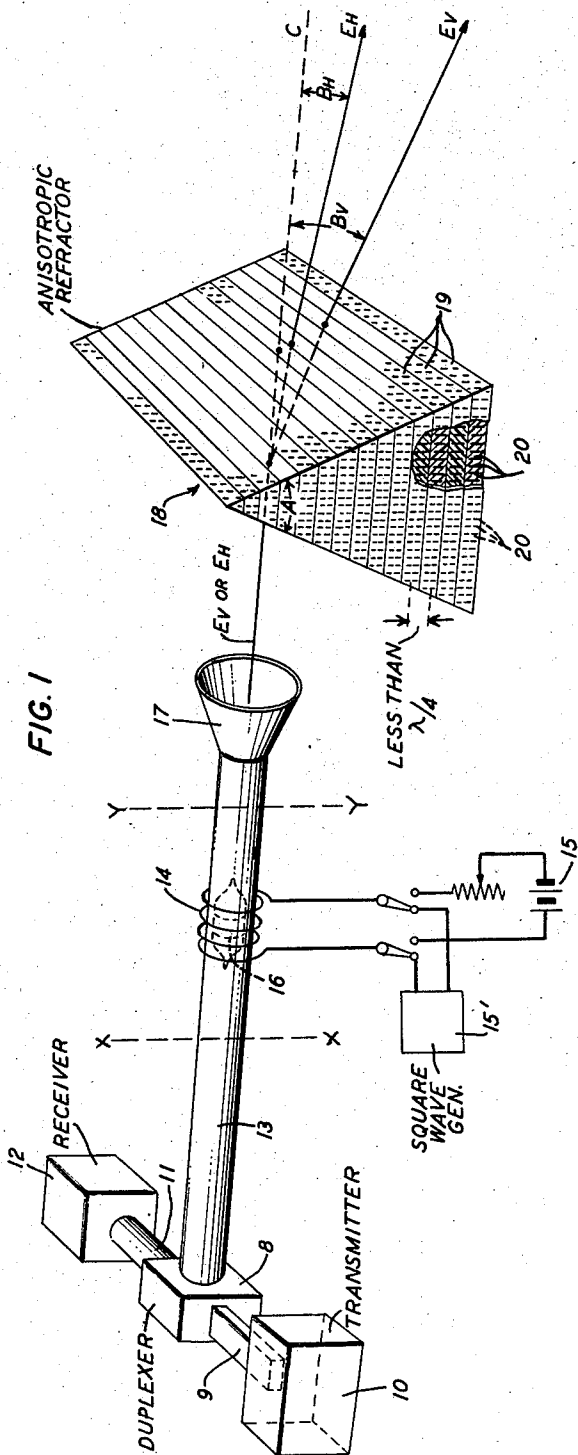
June 23, 1959

D. C. HOGG
ANTENNA SYSTEM HAVING A DIRECTIONALLY
VARIABLE RADIATION PATTERN

2,892,191

Filed April 29, 1955

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

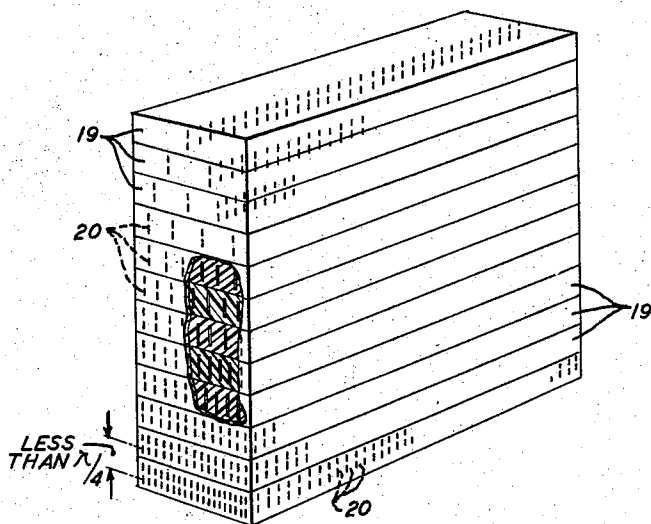
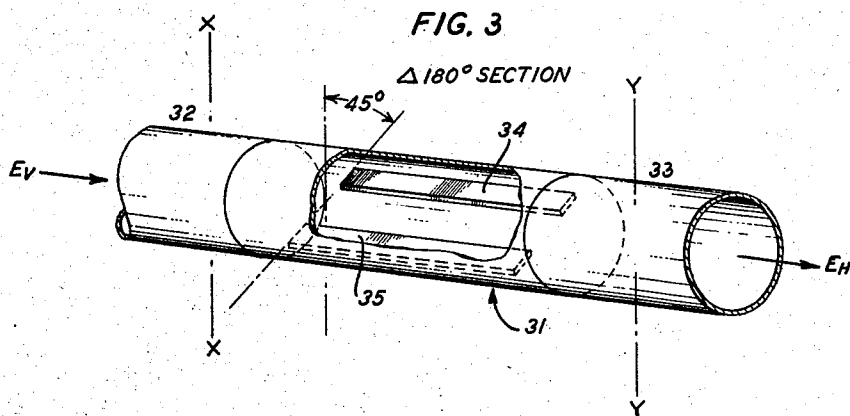


FIG. 5A

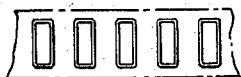
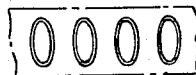


FIG. 5B



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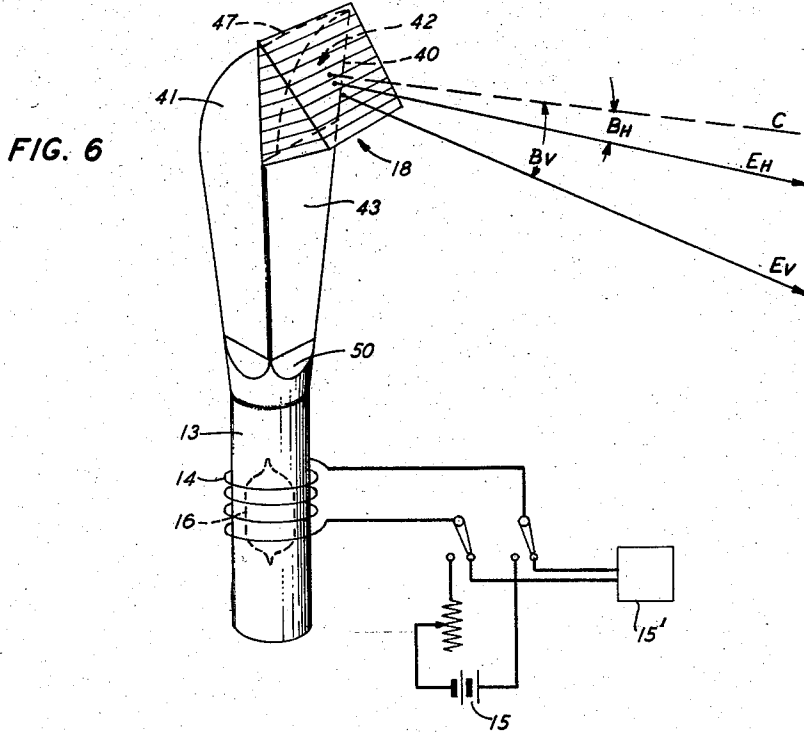
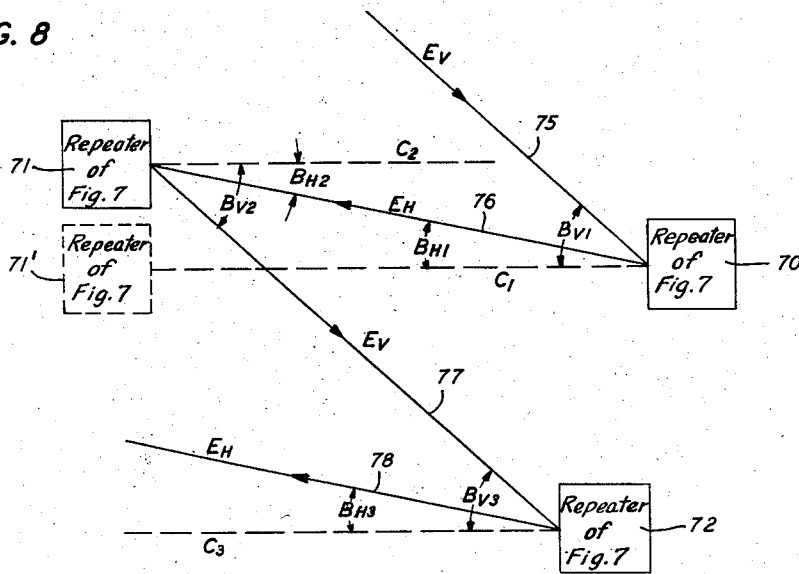


FIG. 8



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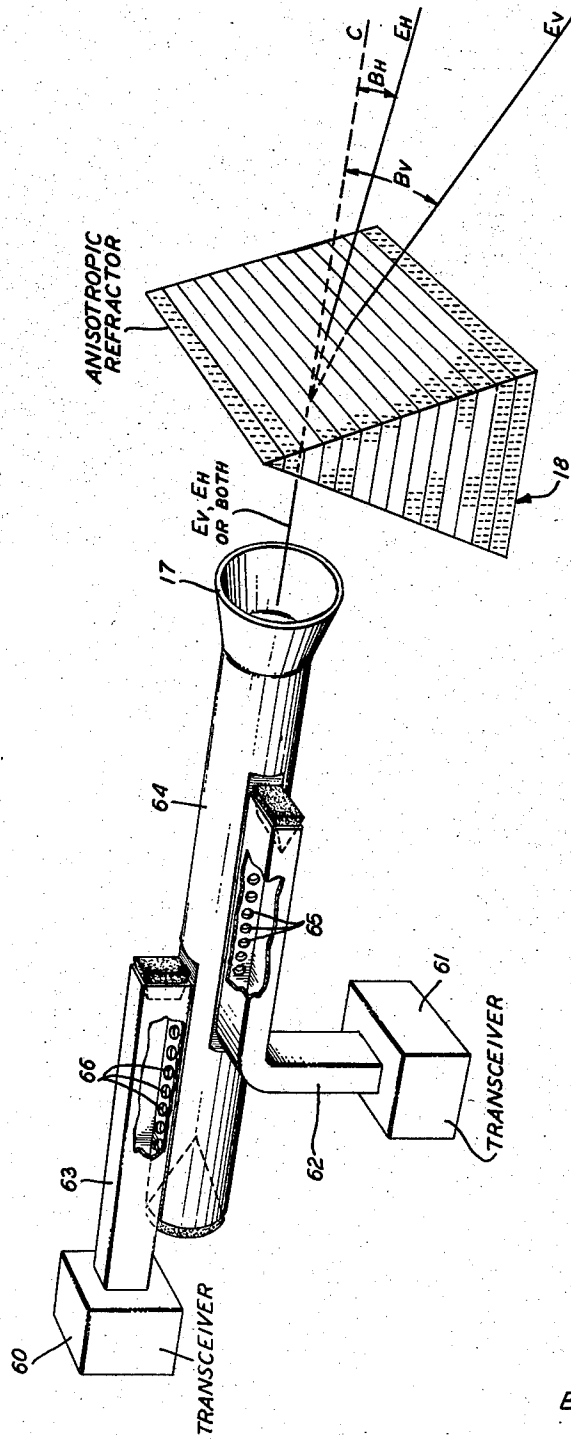
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FIG. 7



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2,892,191

ANTENNA SYSTEM HAVING A DIRECTIONALLY VARIABLE RADIATION PATTERN

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Application April 29, 1955, Serial No. 504,734

16 Claims. (Cl. 343-754)

This invention relates to directional antenna systems for high frequency electromagnetic wave energy and more particularly to antenna systems for rapid lobe switching or for simultaneous transmission and/or reception of more than one electromagnetic signal in more than one direction.

By far the great majority of directional antenna systems heretofore employed in microwave transmission systems depend upon mechanically moving structures to effect changes in radiation pattern. Thus, in antenna systems designed primarily for lobe switching, the rapidity with which the lobe switching may occur has been hampered by the speed limitations of the mechanically moving structures. Other systems for changing the directivity of the radiation pattern have utilized an array of many radiating elements to which energy is fed with varying relative phase relationships. These systems however are large, complex and cumbersome. Another system varies directivity of the radiation pattern by varying the frequency of the electromagnetic energy which transmits a refracting means whose index of refraction varies with frequency. This latter system suffers through the requirement of excess bandwidth.

It is, therefore, an object of the present invention to accurately control by electrical means, utilizing minimum bandwidth, the radiation pattern of an electromagnetic wave antenna.

It is a further object of the invention to provide an antenna system for angular lobe switching that is of simple and compact construction and independent of mechanical motion as a unit or by any of its components.

In the art it is known that two different information bearing signals may be simultaneously transmitted and/or received between two locations without interference or crosstalk as may be the case between two microwave relay stations. This may be accomplished in a bandwidth no wider than that required for one information bearing signal by propagating the signals as orthogonally polarized waves. However, a highly desirable feature would be to have this type of simultaneous radiation directionally selective.

Therefore, it is an additional object of the invention to electrically control the radiation pattern of a first microwave antenna station to provide simultaneous transmission and/or reception of information bearing signals of the same frequency band to and from second and third stations separately located.

These and related objects are achieved in the present invention by applying orthogonally polarized waves to a refracting device which deviates the waves by different amounts corresponding to the polarizations of the waves, thereby controlling the directivity of a microwave antenna system's radiation pattern. In particular, an anisotropic refractor is employed, i.e., a refractor which exhibits an electrical path of a particular length to a given portion of a first wave front polarized in a given direction, while exhibiting a different length electrical path to the same portion of a second wave front polarized perpen-

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dicularly to the first wave front. Thus orthogonally polarized waves see different indices of refraction in their propagation through the refractor and thus are deviated from their incident paths by different amounts.

In accordance with one of the preferred embodiments of the invention to be hereinafter described in detail, a conventional antenna structure is modified by the inclusion of an anisotropic refractor and a device for rotating the electric-field vector orientation of a linearly polarized wave between vertical and horizontal. As a consequence a train of waves alternating in polarization between vertical and horizontal are radiated from the refractor in alternating directions, thus lobing a plane.

In accordance with another of the preferred embodiments of the invention also to be described in detail, a conventional antenna system is modified by the inclusion of the aforementioned anisotropic refractor and a device controlling the polarization of the waves so as to simultaneously apply orthogonally polarized waves to the refractor. This results in the wave radiating from the refractor in two different directions simultaneously; each direction being related to one polarization. A special feature residing in this embodiment of the invention is apparent if the orthogonally polarized waves are the vehicle for respectively different information. The double lobed radiation pattern describes transmission to and/or reception from two separately located stations; the two lobes describing different paths and containing waves which may bear different information.

These and other objects and features, the nature of the present invention and its advantages, will appear more fully upon consideration of the several illustrative embodiments now to be described in connection with the accompanying drawings in which:

Fig. 1 is a perspective view of an embodiment of the invention showing an antenna system including a Faraday effect polarization rotator, a radiating horn and an anisotropic dielectric refractor;

Fig. 2, given by way of illustration, is a schematic presentation showing the effect of the anisotropic refractor upon a unpolarized wave propagated through it;

Fig. 3 is a perspective view of an alternative type of polarization rotator, mechanical in nature, which may be used in the embodiment of Fig. 1;

Fig. 4 is a perspective view of an alternative form of anisotropic refractor;

Figs. 5a and 5b are plane views of alternative forms of metallic elements for use in anisotropic refractors;

Fig. 6 is a perspective view of a second embodiment of the invention showing a high gain, deflecting type radiating means in conjunction with an anisotropic refractor;

Fig. 7 is a perspective view of a third embodiment of the invention showing an antenna system including a selective mode transducer; and

Fig. 8 is a plane view of an application of one aspect of the invention to microwave relay systems.

In these figures, corresponding parts are indicated by like reference numerals and characters.

Referring more specifically to Fig. 1, a lobing antenna system is shown as an illustrative embodiment of the present invention comprising the organization to be described of a conventional horn-type radiating element together with a polarization rotator, an anisotropic refractor and the associated terminal equipment therefor. Disposed about a circular wave guide 13 of the metallic shield type, and insulated therefrom, is a coil 14 of electrically conductive metal whose terminals are connected to a variable direct-current voltage source 15 or alternatively to a square wave generator 15' and which provides a magnetic field parallel to the longitudinal axis of guide 13 and thus to the direction of wave propagation. Located within guide 13 along its longitudinal axis, and

within the section covered by coil element 14, is an elongated pencil-like ferrite element 16. Elements 13, 14, 15 and 16 together form a Faraday effect polarization rotator. At one end, circular guide 13 flares outwardly to form a conventional-type horn 17. This flared horn section may be shaped in a truncated, right-conical fashion so as to radiate wave energy in space with a plane wave front.

Offset longitudinally from the end of horn 17 is an anisotropic dielectric prism 18 disposed transversely to the longitudinal axis of guide 13 and horn 17 so as to intercept wave energy radiated from horn 17; the two triangular faces of the prism being in a vertical position, while the rectangular face joining the bases of the triangular faces and the line joining the vertices are in a horizontal position. Prism 18 comprises a plurality of successive horizontal layers 19 of low-loss dielectric material, such as polyfoam, the bottom face of the bottom layer being the base face of the prism. Disposed vertically in each of the horizontal layers is a multiplicity of straight thin metallic wire elements 20 of high conductivity which may be of material such as copper, aluminum or silver, arranged in horizontal rows and columns in matrix fashion; the columns being parallel to the triangular faces of prism 18 and the longitudinal axis of guide 13, and the rows being perpendicular thereto. The number of columns does not vary from layer to layer. The number of rows on the other hand does vary with the layer in which they appear; proceeding from the apex to the base of prism 18 the number of rows may increase with the increase in area of the layer. The vertical distance between midpoints of the wire elements 20 in any two adjacent layers is less than one-quarter wavelength to preclude dispersive effects.

By way of illustrating a specific application of the antenna system of Fig. 1, it is illustrated as being fed from associated terminal equipment comprising a duplexer, transmitter and receiver. A duplexer 8 has three wave guides of the metallic shield type branching from it. A first guide 9 is of rectangular cross section and proportioned so as to support the dominant mode, TE_{10} , and disposed such that the electric-field vector of the wave is vertically oriented. A high frequency transmitter 10 is coupled to the other end of guide 9 whereby transmitter 10 is coupled to duplexer 8. A second guide 11, of circular cross section and proportioned so as to support the dominant mode, TE_{11} , is coupled at one end to high frequency receiver 12 whereby duplexer 8 and receiver 12 are also coupled to each other via circular guide 11. A third guide, which is the hereinbefore mentioned circular guide 13, branches from duplexer 8 whereby vertically polarized waves in the TE_{10} mode generated by transmitter 10 will be launched, with appropriate action by duplexer 8, as vertically polarized TE_{11} wave energy in circular guide 13. It may be noted that circular guide 13 and also guide 11 will support the TE_{11} mode having any radial electric vector orientation including the horizontal. Thus TE_{11} energy in guide 13 linearly polarized with any radial orientation may be launched in guide 11, with appropriate action by duplexer 8, and thence accepted by receiver 12. Full consideration as to the dimensions of circular guides for supporting various modes is presented in any standard textbook on wave guide transmission, such as Southworth, "Principles and Applications of Waveguide Transmission," 1950.

An understanding of the operation of the illustrative embodiment of Fig. 1 may best be obtained by considering the respective functions of the Faraday effect rotator comprising elements 13, 14, 15 and 16 and the anisotropic refractor 18. Consider first the function and operation of the Faraday effect rotator. Current flowing in coil 14 will create a magnetic field with flux lines parallel to the longitudinal axis of guide 13 and consequently parallel to the longitudinal axis of ferrite-element 16. Con-

sider the case in which the field current is low and thus the magnetic field is weak. A vertically polarized wave E_v entering guide 13 will be propagated through the guide and pass through ferrite 16. In this passage the electric-field vector of the wave at different points in space will remain in a vertical position throughout since the magnetic field is too weak to effect the polarization. With a high field current and consequently a strong longitudinal magnetic field, vertically polarized wave E_v enters guide 13 and remains vertically polarized until reaching ferrite 14. At this point, ferrite 14 under the influence of the magnetic field commences to affect a rotation upon the electric-field vector. The rotation continues until the wave exits ferrite 14 when the rotation is arrested and E_v has been changed to a horizontally polarized wave E_h . Thus the function of the Faraday rotator in this embodiment is to present vertically and horizontally polarized waves to horn 17 to be radiated in space; which of the two polarizations appears being controlled by the direct-current voltage source 15 or, alternatively, the square wave generator 15'. The Faraday rotator is well known in the art; full treatment of its theory and principles including structural considerations is presented in Hogan, "The Microwave Gyrator," Bell System Technical Journal, January 1952.

The prism 18 is anisotropic in the sense that a linearly polarized wave of one orientation passing through will be deviated at an angle different from that of a linearly polarized wave having another orientation. Consider Fig. 2, where a linearly polarized wave I is incident upon one face of prism 18 at an angle i to a line P_1 perpendicular to the face. As the wave front passes into prism 18, the phase velocity of wave I decreases; the change in phase velocity depending upon the change in dielectric constant exhibited to the wave by the new medium. As a consequence, and in accordance with well known optical principles, the wave is refracted downward in the direction of greatest density of material. The refractive index then, depends upon the density distribution in the prism, and the dielectric constant exhibited to the polarized wave. It is clear that had there been no prism, wave I would have continued in a straight line along C. Upon emerging from the opposite face of prism 18, wave I is once again refracted since the phase velocity increases upon re-entering the air medium. The angle of refraction r at the second face of the prism is the angle between the wave R (which is wave I twice refracted) and line P_2 which is perpendicular to the second face and is the path a wave would follow had it entered the prism along P_1 . This angle of refraction is readily shown, by using Snell's law, to be

$$(1) \quad r = \arcsin [\sin A \sqrt{n^2 - \sin^2 i} - \cos A \sin i]$$

where

r = angle of refraction at the second face

A = angle of the prism at the vertex

n = index of refraction

i = angle between I and P_1

From Equation 1 it is clear that changing the index of refraction n will result in a change in the angle of refraction at the second face even though the other prism parameters and the angle of incidence remain constant. Now the index of refraction does change with a change in polarization of the wave propagated through the prism.

Referring again to Fig. 1, consider a horizontally polarized wave E_h incident upon the left face of prism 18. The electric-field vectors of E_h , then, are perpendicular to the vertical wire elements 20. Thus a specific dielectric constant is exhibited to the wave, decreasing the phase velocity accordingly and defining an index of refraction n_h for horizontally polarized waves. Since the electric-field vectors and wire elements 20 are substantially orthogonal, the value of n_h , as is well known, will be

close to unity. As a consequence wave E_h , emergent from prism 18 will be only slightly refracted. If it were possible to have every one of elements 20 perfectly perpendicular to the electric-field vector then n_h would be exactly unity.

The vertically polarized wave E_v , on the other hand, is parallel to wire elements 20, and as a consequence a different dielectric constant will be exhibited by prism 18 than was exhibited to horizontal wave E_h . The phase velocity of E_v through prism 18 is thus less than was that for E_h , whereby vertically polarized wave E_v is subject to an index of refraction n_v different from and greater than n_h . Therefore, E_v and E_h will emerge from prism 18 each at different angles B_v and B_h respectively, measured in a vertical plane, from the linear extension C of incident E_v and E_h . That is, E_v and E_h will be deviated by angles B_v and B_h respectively. It is convenient to know what change in the angle of refraction will be produced by the value of n changing from n_h to n_v . This is determined by differentiating Equation 1 with respect to n . The result is

(2)

$$\frac{dr}{dn} = n \sin A [(n^2 - \sin^2 i)(1 - n^2 \sin^2 A - \sin^2 i \cos 2A + \sin 2A \sin i \sqrt{n^2 - \sin^2 i})]^{-1/2}$$

where $dn = n_v - n_h$.

For the purpose of illustration it may be helpful to obtain values of dr and dn in this manner. Let $i=0$ for convenience. For a prism angle $A=17.5$ degrees and $n=1.500$; a change in refractive index dn that will result in a change in the angle of refraction dr is expressed by

$$dn = 3dr$$

The following table gives some values of dn for small changes dr :

dr (degrees)	dn
0.5	.03
1.5	.09
2.5	.15
3.5	.20

Thus, to produce a change in the angle of refraction of 2.5 degrees, it is required that $dn = n_v - n_h = .15$; thus $n_v = 1.575$ and $n_h = 1.425$.

The overall operation of the embodiment of the invention represented in Fig. 1 may now be considered. Vertically polarized waves generated by transmitter 10 and passing through duplexer 8, enter the transmission line at guide 13 and are propagated past ferrite element 16 as a succession of alternating vertically and horizontally polarized waves E_v and E_h conforming to the square wave variation in the magnetic field created by coil 14 and direct-current voltage source 15 or square wave generator 15'. This train of alternating orthogonally polarized waves is radiated into space by horn 17 and is then incident upon prism 18. Prism 18, being anisotropic, discriminates between the alternating waves, deviating the vertically polarized waves E_v by an angle B_v from its incident direction and deviating the horizontal wave E_h by an angle B_h . Waves traveling in the opposite direction, that is waves received by the antenna system will, by the converse, pass through prism 18 and enter horn 17 if the horizontal waves E_h approach prism 18 at angle B_h and the vertical waves E_v at an angle B_v . The received waves may then proceed through guide 13 and thence to receiver 12 via duplexer 8. However, the received waves need not pass through the Faraday rotator in the reverse direction if a suitable duplexing device or direction discriminating coupler is located between ferrite 16 and horn 17 to shunt them to another guide.

Looking at the overall antenna system represented by the embodiment of Fig. 1, it may be conveniently considered as a transmission path which is of a greater electrical length for one linear polarization than for another to which is characterized by the phase velocity differential through prism 18 for the orthogonally polarized waves. Although the waves in this embodiment of the invention are deviated in the vertical direction, the direction of deviation is purely a matter of choice. For example, a horizontal deviation may be achieved by rotating the anisotropic refractor 18, 90 degrees and also rotating each of the orthogonally polarized waves E_v and E_h by the same amount in the same direction maintaining their orthogonality. This may be readily accomplished by physically rotating prism 18 and by having a 90-degree twist in rectangular guide 9 or by placing a rotatable 180-degree differential phase shifting dielectric vane in guide 13 oriented 45 degrees to the vertical. Similarly the waves may be deviated in any other radial direction by appropriate rotation of prism 18 and the orthogonal waves E_v and E_h .

While the non-mechanical, non-reciprocal Faraday rotator means for providing orthogonally polarized waves is illustrated in Fig. 1 and is particularly suited for an electrically controlled embodiment of the invention, a mechanical, reciprocal device may also be utilized. A typical device of this type familiar in the art is the 180-degree differential phase shifter illustrated in Fig. 3. This device, appearing between vertical lines x and y in Fig. 3, may be substituted for the Faraday rotator appearing between lines x and y in Fig. 1. A section of circular wave guide is located longitudinally between two stationary circular guides 32 and 33 and is free to mechanically rotate therebetween about its longitudinal axis. Within this Δ 180-degree section are disposed two thin dielectric fins 34 and 35 extending longitudinally along the cylinder, and extending radially towards the center, each from diametrically opposite positions on the cross sectional circumference. When the Δ 180-degree section 31 is rotated such that fins 34 and 35 are disposed 45 degrees to the vertical, the orthogonal components of vertically polarized wave E_v entering section 31 from guide 32 will experience a 180-degree differential phase shift during their propagation through section 31. As a result the vertically polarized entering wave E_v will emerge from section 31 into guide 33 as a horizontally polarized wave E_h . Mechanically rotating fins 34 and 35 back 45 degrees to a vertical position results in no differential phase shift between the orthogonal components of vertical wave E_v and so E_v will pass through section 31 unchanged in polarization. This device is theoretically and structurally discussed in detail in Southworth, supra. However, since the rapidity with which the direction of the radiation pattern of the antenna system may oscillate is limited by the rapidity with which the polarization of the wave may be changed, such a mechanical rotator will primarily be used when slow rates of lobing are contemplated.

The anisotropic refractor took the form of a dielectric prism in the illustrative embodiment of Fig. 1. An equivalent electrical effect may be obtained by a refractor which need not necessarily conform geometrically to a prism. Fig. 4 represents an alternative and equally adequate form. The geometry of this structure is that of a rectangular parallelepiped comprising dielectric layers 19 and straight metallic wire elements 20 disposed and arranged according to the description previously presented with respect to prism 18, i.e., the number of wire elements per column (or equivalently the number of rows) in each horizontal matrix increases in each successive horizontal layer, viewing the layers from top to bottom. The straight wire elements 20 may be replaced by other shapes producing somewhat different effects. Thus alternative shapes may be small rectangles as illustrated in Fig. 5A or ellipses as in Fig. 5B. In these cases

the refractive index n_h of a horizontally polarized wave (the longer side of the rectangular element or the major axis of the ellipse being vertical) will not be close to unity as was the case with the straight wire elements 20 since the rectangle and ellipse have small components parallel to the horizontal electric-field vector. As a consequence these alternative forms will deviate the horizontal wave by a greater angle than in the case of the straight elements 20.

Although the refractors described have been of the dielectric type, ferromagnetic refractors may be utilized in a similar manner. For example, ferrite material subject to a magnetic field transverse to the propagation path of electromagnetic waves passing through it will exhibit different permeabilities to orthogonally polarized waves, one of which is parallel to the magnetic flux lines. As a consequence the amount a wave is deviated as a result of its propagation through the ferrite will depend upon whether it is parallel or perpendicular to the magnetic field. This type of refractor has a very desirable feature in that the permeabilities and thus indices of refraction exhibited to the waves may be varied very readily by increasing or decreasing the intensity of the magnetic field. Thus, the angle by which the waves are deviated may be readily varied by varying the magnetic field intensity. The plane in which the angular deviation occurs may be changed by an appropriate and like rotation of the polarization of both the orthogonal waves, accompanied by a rotation of the magnetic field in the same direction and by the same amount.

An important application that the embodiment of the invention represented in Fig. 1 readily lends itself to is in radar systems. Very rapid small angle lobing of an antenna beam may be achieved since no mechanically moving parts need be involved; the limitation on the frequency of lobing being the inherent speed limitation of the ferrite 16 in rotating the wave polarization (this is of the order of several kilocycles per second).

Fig. 6 represents a second embodiment of the invention, similar to Fig. 1, whereby the Faraday rotator and anisotropic refractor are utilized in an antenna of known high gain properties without substantially effecting any of the design considerations that make it high gain. The radiating device of this embodiment may be of the type disclosed in United States Patent 2,416,675, granted March 4, 1947, to A. C. Beck and H. T. Friis. As shown on Fig. 6 this antenna comprises a vertical horn portion 43, having a front wall, back wall and side walls in the form of an inverted square pyramidal structure. A parabolic deflector 47 is attached to the back edge of horn 43. Deflector 47 is positioned so as to face both horn 43 and the opening 42 which is formed in the plane of the front wall of horn 43 by the front edges of shields 40 and 41, of deflector 47. At the lower portion of the antenna a transition section 50 tapers gradually from the square cross section of the throat aperture of horn 43 to the circular cross section of connecting wave guide 13. A prism 18 of the form hereinbefore described is positioned in front of aperture 42 and particularly is positioned substantially contiguous to the boundaries of aperture 42 to cover the aperture. Therefore waves emitted from the throat of horn 43 are incident upon the concave face of parabolic deflector 47 and are thereby deflected at a desired angle, maintaining a plane wave front, whence they are then incident upon the face of prism 18. Lobing of the radiation pattern then occurs in exactly the same manner as described with respect to Fig. 1.

Fig. 7 represents an embodiment of the invention for purposes of illustration, wherein a high frequency selective mode transducer replaces the Faraday rotator of Fig. 1. As a consequence, not only may the radiation pattern of the antenna system be lobe switched, but the received and/or transmitted energy pattern may be a simultaneous double lobe, wherein the lobes diverge in a given plane.

Resulting therefrom, two different signals (information carrying signals if desired) in the form of orthogonally polarized waves may be simultaneously transmitted to, or received from, two separately located sites or stations, or a first signal may be transmitted to a first site while a second signal may be simultaneously received from a second site, in a system of the type hereinafter to be discussed with respect to Fig. 8.

The antenna system of Fig. 7 comprises a selective mode transducer ending in horn 17 and an anisotropic refracting prism 18. Both horn 17 and prism 18 may be of the type hereinbefore described with respect to Fig. 1 and accordingly disposed each to the other. The selective mode transducer comprises two rectangular wave guides 62 and 63 of the metallic shield type electrically coupled to a single circular wave guide 64 also of the metallic shield type. Rectangular guide 62 is disposed with its widest cross sectional dimension horizontal so that the dominant mode transmitted therein, that is the TE_{10} , has its electric-field vector oriented vertically. A section of guide 62 is adjacent to, and the vertical wall thereof is contiguous with, a section of circular guide 64. Located in this section are several circular apertures 65, such that TE_{10} energy from rectangular guide 62 may be launched in circular guide 64 as TE_{11} energy. Rectangular guide 63, on the other hand is disposed with its widest cross sectional dimension vertical so that although TE_{10} energy is also supported therein, the electric-field vector is horizontally oriented. A section of guide 63 is also adjacent to circular guide 64, but in this case it is the horizontal wall that is contiguous thereto and contains coupling apertures 66 for launching TE_{10} energy in circular guide 64 as TE_{11} energy. Since the wave in guide 63 is horizontally polarized while that of guide 62 is vertically polarized, the waves launched simultaneously in circular guides 64 by rectangular guides 62 and 63 will be in the form of cross-polarized TE_{11} wave energy. These cross-polarized waves are stable and not undesirably subject to cross-talk between their respective information carrying signals. One end of circular guide 64 flares outwardly to form horn 17 which may be a truncated, right-conical shape. The reverse end of guide 64 is terminated in a reflectionless manner by a termination which is of electrical high loss material. Similarly one end of guide 62 and guide 63 is also terminated in this manner. The opposite ends of guides 62 and 63 are respectively coupled to transceivers 61 and 60. The selective mode transducer thus described was originally disclosed in the copending S. E. Miller application, Serial No. 245,210, filed September 5, 1951, to which reference may be had for a detailed theoretical and structural analysis and description.

In one mode of operation, orthogonally polarized TE_{10} waves are simultaneously generated by transceivers 61 and 60 and are introduced into the respective feed ends of rectangular guides 62 and 63. The waves are propagated through circular guide 64 as cross-polarized TE_{11} wave energy. The cross-polarized waves are radiated in space by horn 17 such that they are incident upon prism 18. After propagation through anisotropic prism 18, the cross-polarized waves are deviated from their incident direction by angles B_v and B_h , respectively. Thus the radiation pattern of the antenna system is double lobed with the lobes diverging from each other at an angle substantially equal to B_v minus B_h , measured in a vertical plane.

In a second mode of operation, two orthogonally polarized waves simultaneously propagating through space and approaching anisotropic prism 18 at angles B_v and B_h respectively, are refracted through the prism, passing directly into horn 17. Upon reaching the apertured couplings 65 and 66 the orthogonal waves are decoupled from circular guide 64 to their respective rectangular guides and thence to transceivers 60 and 61.

In a third mode of operation, a first wave is trans-

mitted from the antenna system at an angle B_v , while a second wave, orthogonally polarized to the first wave is simultaneously received at an angle B_v , or the converse. There will be little or no interference or cross-talk between the two waves since they are orthogonally polarized.

In a fourth mode of operation wave energy is fed alternately to guides 62 and 63. The succession of waves emerging from prism 18, alternating between orthogonal polarizations, lobes the vertical plane in a manner substantially similar to that of the embodiment of Fig. 1. Although the angular deviation is vertical in the illustrative embodiment of Fig. 7, it may be changed to any other planar orientation by appropriate rotation of the anisotropic refractor 18 and the orientation of the orthogonal wave thereto presented, in the manner previously described in connection with Fig. 1.

The selective mode transducer herebefore described is merely illustrative and any device performing a similar function is appropriate in the antenna system and within the scope of the inventive concept. For example, the double polarization feed for horn antennas disclosed in the M. Katzin, United States Patent 2,364,371, issued December 5, 1944, may adequately be substituted for the selective mode transducer and horn 17.

A cogent application of the embodiment of Fig. 7 in accordance with the invention, is to microwave relay transmission systems comprising a multiplicity of repeater stations as illustrated in Fig. 8. A repeater station 70, including the embodiment of the invention illustrated in Fig. 7, may receive continuous information bearing signals as a vertically polarized wave train along propagation path 75 at an angle B_{v1} . Repeater 70 then transmits the information bearing waves as a horizontally polarized wave train. These waves may be transmitted unrefracted along C_1 to repeater 71', but only if the anisotropic refractor of repeater 70 is properly designed in the manner discussed above with respect to Fig. 1. Alternatively, the horizontally polarized waves may be transmitted along path 76 at an angle B_{h1} to line C_1 (C_1 would be the unrefracted path of the horizontal waves). The waves along path 76 are thus received at repeater 71 at an angle B_{h2} . Repeater 71 may then retransmit these waves now vertically polarized, along a propagation path 77, at an angle B_{v2} , to repeater 72 which is receptive at angle B_{v3} . The above operation being continuous, any one repeater simultaneously transmits and receives in respectively different directions. This transmission, reception and retransmission process may be continued as many times as required using an appropriate number of repeater stations. If the positions of the repeater stations are fixed because of practical considerations, then the angular orientations of the transmission paths joining them define the required indices of refraction of the respective anisotropic refractors, thus determining the parameters according to which the respective refractors must conform. If, on the other hand, the parameters of each refractor are fixed beforehand, the angular geographic relations of the repeaters, each to the other, are consequently defined. The fourth mode of operation, above described, of the embodiment in Fig. 7 makes the embodiment applicable to a rapid lobing radar antenna system previously explained as one possible application for the embodiment of Fig. 1.

In all cases, it is understood that the abovedescribed arrangements are simply illustrative of a small number of the many specific embodiments which can represent applications of the principles of the invention. Numerous and varied other arrangements can readily be devised in accordance with these principles by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A high frequency antenna system comprising means for supporting electromagnetic wave energy, electrical

means for rotating the electric-field vector of said wave energy, means for radiating wave energy in space with a plane-wave front, and an anisotropic dielectric prism located in the path of said radiated wave energy, whereby said prism deviates said wave energy from its predetermined path with a magnitude dependent upon the direction of said electric-field vector of said wave energy.

2. In a high frequency antenna system for linearly polarized electromagnetic waves, wave transmission means having different electrical path lengths measured in the direction of propagation for different transverse incremental portions of the wave front of said waves, said electrical path length variation defining an index of refraction of said transmission means, said index of refraction of said transmission means being variable with electric-field vector orientation of said waves, and means for applying orthogonally polarized waves alternately to said transmission means, at different points in time, respectively.

3. In a high frequency antenna system for linearly polarized electromagnetic waves, wave transmission means having different electrical path lengths measured in the direction of propagation for different transverse incremental portions of the wave front of said waves, said electrical path length variation defining an index of refraction of said transmission means, said index of refraction of said transmission means being variable with electric-field vector orientation of said waves, and means for rotating the polarization of said waves to vary the direction of radiation of said antenna system.

4. A combination as set forth in claim 3 wherein said index of refraction is substantially unity for a single given electric-field vector orientation.

5. In a high frequency antenna system for linearly polarized electromagnetic waves, wave transmission means having different electrical path lengths measured in the direction of propagation for different transverse incremental portions of the wave front of said waves refracting the front of said waves and thereby changing its direction of propagation, said transmission means having different electrical path lengths measured in the direction of propagation for orthogonally polarized waves, whereby waves of orthogonal polarization are refracted by different amounts, and means for rotating the polarization of said waves between said orthogonal polarizations to vary the direction of radiation of said antenna system.

6. A high frequency antenna system comprising means for supporting electromagnetic waves, means for rotating the electric-field vector of said waves, means for radiating said waves in space, and an anisotropic refracting means located in the path of said radiated waves, whereby the angle of refraction of said waves through said anisotropic refracting means varies with the rotation of said electric-field vector.

7. A combination as set forth in claim 6, and means for controlling said polarization rotating means to confine said vector rotation to discrete 90-degree oscillatory variations, the variation of said vector orientation versus time describing a square wave function.

8. A combination as set forth in claim 6, wherein an elongated ferrite element is located within said polarization rotating means.

9. A combination as set forth in claim 8, wherein said ferrite element is subject to a magnetic field whose intensity varies with time as a square wave.

10. A combination as set forth in claim 6 wherein said electric-field vector rotating means comprises at least one thin 180-degree differential phase shifting dielectric vane, whereby rotation of said vane about the longitudinal axis of said supporting means defines a directly proportional rotation of the electric-field vector of said waves.

11. A combination as set forth in claim 6, wherein said refracting means is constrained by means maintaining the axes of said refracting means in a constant

angular position relative to a given direction and sense of said electric-field vector.

12. A combination as set forth in claim 6, wherein said anisotropic refracting means comprises ferromagnetic material subject to a variable magnetic field.

13. A combination as set forth in claim 6, wherein said radiating means comprises an outwardly flaring horn ending in a parabolic deflector, whereby waves propagated through said horn are incident upon said deflector and thus radiated in space in other than said incident direction.

14. A combination as set forth in claim 6, wherein said anisotropic refracting means comprises a dielectric prism.

15. A combination as set forth in claim 6, wherein

a source of electromagnetic wave energy is coupled to said supporting means.

16. A combination as set forth in claim 6, wherein a means for receiving electromagnetic wave energy is coupled to said supporting means.

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