

March 4, 1952

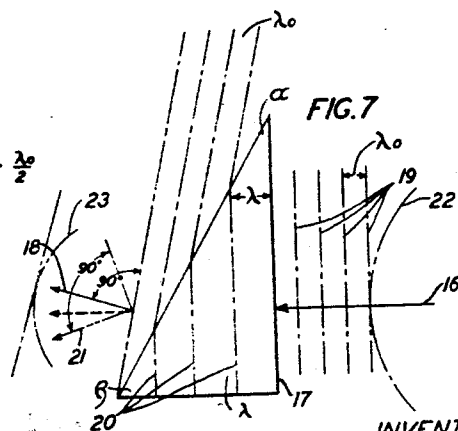
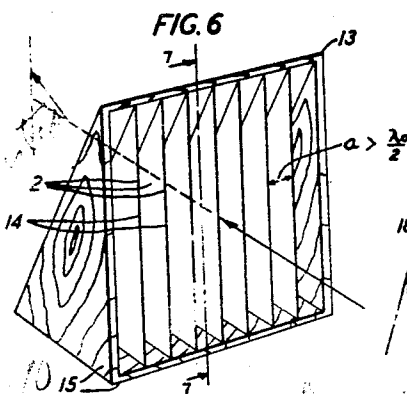
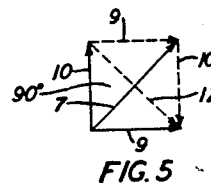
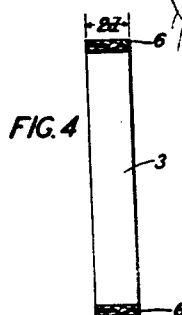
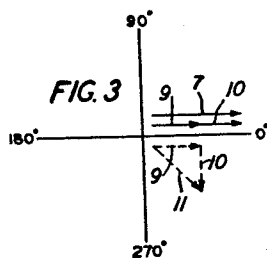
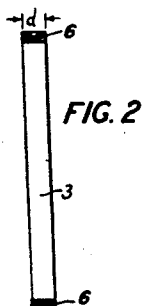
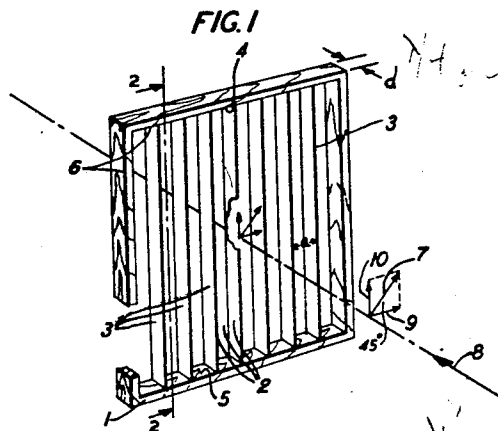
W. E. KOCK

2,588,249

WAVE POLARIZATION SHIFTER SYSTEMS

Filed Jan. 22, 1946

2 SHEETS—SHEET 1



INVENTOR
W. E. KOCK
BY *A. J. Zerbarini*

ATTORNEY

BRITISH 655,936 8/8/51

NORWAY 78078 2/12/51

March 4, 1952

W. E. KOCK

2,588,249

WAVE POLARIZATION SHIFTER SYSTEMS

Filed Jan. 22, 1946

2 SHEETS—SHEET 2

FIG. 8

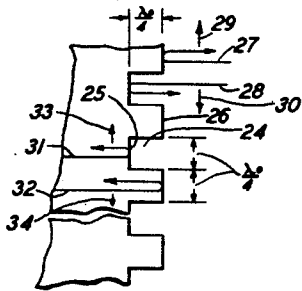


FIG. 10

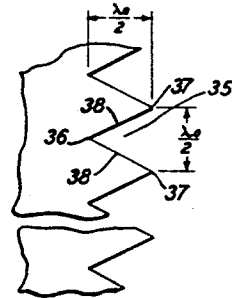


FIG. 9

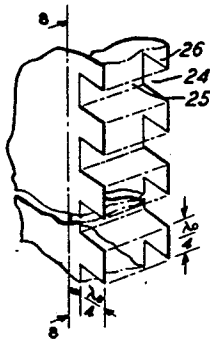


FIG. 11

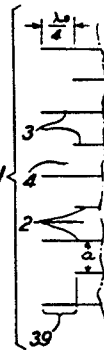


FIG. 13

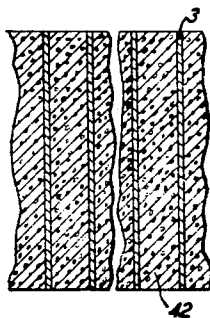
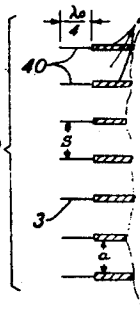


FIG. 12



INVENTOR
W. E. KOCK
BY
A. J. Zerbarini

ATTORNEY

UNITED STATES PATENT OFFICE

2,588,249

WAVE POLARIZATION SHIFTER SYSTEMS

Winston E. Kock, Middletown, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application January 22, 1946, Serial No. 642,722

8 Claims. (Cl. 250—33.63)

1

This invention relates to wave transmission systems and particularly to passive dielectric means for refracting or otherwise modifying guided and unguided radio waves.

As is known, dielectric guides comprising a metallic rectangular tube which completely surrounds the dielectric medium, such as air, are widely used for conveying radio waves. Also, various devices and systems have been suggested for changing a characteristic, such as the plane (vertical or horizontal) of polarization, the type (linear or circular) of polarization, or the propagation direction, of the guided waves. In addition, as disclosed in the copending application of A. C. Beck, Serial No. 574,335, filed January 24, 1945, which matured into Patent 2,495,219, granted January 24, 1950, a passive or secondary antenna member comprising air dielectric linear channels, each comprising two parallel metallic elements spaced less than a half wavelength apart and each having two open sides, has been proposed for changing or reversing the propagation direction of a so-called "space" wave, that is, a wave traveling in the ether medium. Since the spacing between the elements is smaller than a half wavelength, the incoming wavelets are rejected by the dielectric channels and the passive member functions as an antenna reflector.

In general, and with the possible exception of the reflector of the Beck application, the systems mentioned above comprise conventional structures such as wires, solid metallic deflectors and refractors of homogeneous solid dielectric material. These conventional structures often introduce excessive energy losses and ordinarily are complicated in construction and difficult to manufacture. Moreover, these structures are not always suitable for altering a characteristic of an unguided or space wave and are otherwise not always entirely satisfactory. Accordingly, it now appears desirable to utilize simple, easily constructed structures for changing the characteristics of guided and space waves. In particular, and in accordance with the invention, it appears highly advantageous to employ passive structures comprising air dielectric channels, each channel comprising parallel conductive plates spaced apart a half wavelength or more, for altering the space waves. In contrast to the system of the Beck application, the incoming wavelets are received or accepted by the dielectric channels, since the spacing between the plates is greater than a half wavelength, and are thence refracted or otherwise altered in the channels.

2

It is one object of this invention to alter, with substantially no energy loss, a characteristic of a rectilinearly propagated wave.

It is another object of this invention to refract rectilinearly propagated waves without loss.

It is another object of this invention to deflect waves of a single frequency, and to disperse waves of different frequency, without loss.

It is another object of this invention to shift the plane of linear polarization of a space or guided wave.

It is another object of this invention to convert, without loss, a fixed linear wave polarization to a rotating linear or so-called "curvilinear" polarization, or vice versa.

It is a further object of this invention to utilize a simple, economical and easily constructed wave changer for altering, without loss, a characteristic of guided or unguided waves.

It is still another object of this invention to eliminate reflection at the surface of the wave changer mentioned above.

As used herein the term "polarization" refers to the electric polarization. The term "fixed linear" polarization refers to a wave having cophasal perpendicularly related polarization components and the terms "curvilinear" or "rotating" polarization signify a wave in which the perpendicular components are in phase quadrature.

In accordance with one embodiment of the invention, a passive polarization circularizer comprises a plurality of parallel dielectric guides of channels of rectangular cross section. Each channel is open at the front and rear and must be free of any conductive material which would impede the transmission of the electromagnetic waves through the structure in a direction parallel to the sides of the channel and perpendicular to the longer dimension of the channel. Each channel comprises a pair of rectangular plates or side walls spaced at least a half wavelength apart and the air dielectric included therebetween. The plates extend with their corresponding front and rear longitudinal edges parallel to each other, respectively, and these longitudinal edges are at an angle of 45 degrees to the polarization of the incoming wave, and the channel depth, taken parallel to the wave propagation path, is constant. As measured in wavelengths in the dielectric channels, the depth for waves or wave components, the polarization of which is parallel with the plates, is a quarter wavelength, or an odd multiple thereof, smaller than the same depth if expressed as being meas-

3

ured in terms of wavelengths in free space. Since the wavelength in the guide or dielectric channel for waves, or wave components, the polarization of which is parallel with the plates, is greater than the wavelength of the same wave in free space (because the velocity of such waves or wave components is increased in the dielectric channel), the numerical result obtained by measuring the above-mentioned depth in terms of wavelengths in the guide of parallel polarized waves, will, of course, be smaller than when the same depth is measured in terms of free space wavelengths. On the other hand, for waves, or wave components, the polarization of which is perpendicular to the plates, no change in velocity or wavelength as compared with that in free space takes place during passage through the polarizer. In order that the device just described be a passive polarization circularizer, it is necessary that the parallel polarized wave component be advanced by a quarter wavelength, or an odd number of quarter wavelengths, relative to the perpendicularly polarized component which, of course, requires that the difference between the numerical result obtained by measuring the distance or depth in guide wavelengths for parallel polarized waves be one-quarter wavelength, or an odd number of quarter wavelengths, smaller than the numerical result obtained by measuring the same distance or depth in free space wavelengths, as will be apparent from the following explanation of the operation of the device. In operation, the wave polarization component perpendicular to the plates passes through the circularizer without alteration in phase velocity or wavelength, whereas the component parallel to the plates is changed a quarter wavelength, or 90 degrees, relative to the perpendicular component, whereby the emergent perpendicular components are in phase quadrature and, assuming the components are of equal intensity, a circularly polarized resultant wave is obtained.

In accordance with another embodiment, a polarization shifter or rotator comprises a wave changer as described above except that the channel depth, as measured in channel or guide wavelengths, is a half wavelength, or an odd multiple thereof, smaller than the same depth as measured in "space" wavelengths. In effect, the shifter comprises two contiguous circularizers positioned one in front of the other. The perpendicular component passes through the shifter substantially unaffected whereas the phase angle of the parallel component is advanced 180 degrees relative to that of the perpendicular component. By reason of the phase angle change just mentioned the polarity of the parallel component is reversed and, assuming the components are of equal intensity, the polarity of the resultant outgoing wave is perpendicular to the original polarity of the incoming wave.

In accordance with still another embodiment, a heterogeneous non-focussing refractor or prism comprises a wave changer similar in certain aspects to those described above, the primary difference being that the plates are triangular, instead of rectangular. In other words, the channel depth or thickness is tapered instead of constant. Since the dielectric medium is air, the phase velocity characteristic of the channels for waves polarized parallel to the plates is greater than that of free space. In operation, the propagation direction of an incoming wave is, by reason of the increased phase velocity and by virtue of the tapered channel depth or path, bent or re-

4

fracted toward the thinner portion of the prism. The amount or angle of deviation in the wave direction is a function of the frequency of the incoming wave, and a dispersive effect is obtained when waves of different frequencies are propagated through the prism. In each of the embodiments described above, the longitudinal edges of each plate may, in accordance with the invention, be shaped in a manner such that reflection losses at the front and rear faces of the wave changer are substantially eliminated.

The invention will be more fully understood from a perusal of the following specification, taken in conjunction with the drawing, on which like reference characters denote elements of similar function and on which:

Figs. 1 and 2 are, respectively, a perspective view and a sectional elevational view of a polarization circularizer constructed in accordance with the invention;

Fig. 3 is a phase diagram used in explaining the circularizer of Figs. 1 and 2;

Fig. 4 is a sectional elevational view of a polarization shifter of the invention;

Fig. 5 is a polarity diagram used in explaining the shifter of Fig. 4;

Figs. 6 and 7 are, respectively, a perspective view and a sectional side view of a non-focusing refractor of the invention;

Fig. 8 is a partial side view, and Fig. 9 is a partial perspective view, of a pair of notched or stepped metallic plates designed in accordance with the invention for matching impedances and eliminating reflection, and suitable for use in the devices of Figs. 1, 2, 4 and 6 in place of the rectangular plates;

Fig. 10 is a partial side view of a serrated plate constructed in accordance with the invention and also suitable for use in the devices of Figs. 1, 2, 4 and 6;

Fig. 11 is a partial plan view of a wave changer in which the adjacent plates are, in accordance with the invention displaced for the purpose of eliminating reflection;

Fig. 12 is a partial plan view of a wave changer comprising relatively thick metallic plates and thin impedance matching transformer plates, and

Fig. 13 is a front view of a wave changer constructed in accordance with the invention and in which the metallic plates are held in position by a solid dielectric medium having a dielectric constant substantially the same as the dielectric constant, unity, of air.

Referring to Figs. 1 and 2, reference numeral 1 denotes a wave changer of the polarization circularizer type comprising a plurality of parallel dielectric channels 2 each comprising the oppositely facing surfaces of two parallel adjacent metallic plates 3 and the air dielectric medium included therebetween. The top and bottom sides 4, 5 of each channel are open; and the plates are held in position by the rectangular wooden frame 6. The longitudinal dimensions of the several plates are at an angle of 45 degrees relative to the polarization 7, and the plate width or channel depth dimension d is parallel to the propagation direction 8, of the incoming wave. The plates have a negligible thickness and are spaced apart a distance a equal to at least a half of the wavelength of the incoming wave. Since the dielectric medium is air, with a dielectric constant of unity, the phase velocity v and the wave length λ , in each channel of waves polarized parallel to the plates are greater, respec-

5

tively, than the phase velocity v_0 and the wavelength λ_0 of waves in free space. It should be noted particularly, however, that, as pointed out above, waves which are polarized perpendicularly with respect to the plates will pass through the polarization circularizer without any change in wavelength, i. e., they will retain during transit through the circularizer the same velocity and wavelength as for transmission through free space.

On the other hand, a wave, the direction of polarization of which is at an acute angle with respect to the plates of the polarization circularizer can be considered as being the vector sum of two component waves, one of which has its polarization parallel to the plates and the other of which has its polarization perpendicular to the plates. The parallel component will be speeded up in the polarizer, as noted above, and consequently, its wavelength will be increased. The perpendicular component will pass through the polarizer with no change in velocity or wavelength. If the acute angle, mentioned above, is 45 degrees, the two components will be equal and the wave at the output side of the plates will be circularly polarized provided the parallel component has been speeded up by a quarter wavelength, or an odd multiple of quarter wavelengths, relative to the perpendicular component, in passing through the polarizer. If the acute angle is other than 45 degrees, the emerging wave will, of course, be elliptically polarized. These relations will become apparent during the following detailed description of specific examples. As measured in wavelengths in the channels, for a wave having its polarization parallel with the plates, the value of d is a quarter wavelength, or an odd multiple thereof, smaller than the value of d if expressed as being measured in terms of wavelengths in free space. In one practical embodiment, for example, designed for a wave having in free space a wavelength λ_0 equal to 3.4 centimeters, and assuming that, as was the case in this embodiment, the wavelength in the wave guiding structure is four-thirds of the wavelength in free space, i. e. $1.0\lambda_0$ equals 0.75λ , and assuming further, as was also the case in this embodiment, that the depth of the structure parallel to the direction of propagation is to be three-quarters of the wavelength in the guide i. e. d is to be

$$\frac{3}{4}\lambda$$

then d equals 3.4 centimeters and a can, for example, be made 2.57 centimeters.

In operation, referring to Figs. 1 and 3, the polarization vector 7 of the incoming fixed, or so-called linearly polarized wave, comprises a component 9 perpendicular to the plates 3 and a component 10 parallel to the plates 3, these components being in phase, as shown by the full line vectors 7, 9 and 10 in the phase diagram of Fig. 3. Assuming d equals λ_0 , component 9 undergoes in the polarizer a phase angle change of 360 degrees, whereas the component 10 undergoes a phase angle change of 270 degrees, as shown by the dotted line vectors 9 and 10 of Fig. 3. Hence, the perpendicular components 9 and 10 of the wave emerging from the polarizer 1 are in phase quadrature, and the resultant linear polarization vector 11 therefore rotates, like a spoke in a wheel. If the components 9 and 10 are of equal intensity a so-called circularly polarized wave is obtained, whereas if

6

they are of different intensities a so-called elliptically polarized wave is secured. In short the circularizer changes or modifies the wave by converting its fixed, non-rotating or so-called linear polarization, to a rotating linear, or so-called curvilinear, polarization. It should be observed that the polarities of components 9 and 10 are not changed in passing through the circularizer.

The polarization shifter, Fig. 4, is the same as the polarization circularizer, Fig. 2, except that the width of the plates corresponding to the channel depth is $2d$. A perspective view of the shifter would in general be similar to the perspective view, Fig. 1, of the polarizer, and reference to Fig. 1 will be made below in describing the shifter operation. More specifically the depth $2d$ of the dielectric channels, as measured in channel wavelengths, is a half of a wavelength, or an odd multiple thereof, smaller than the same depth $2d$ as measured in space wavelengths. In an actually tested embodiment of the shifter the depth $2d$ was equal to $2.0\lambda_0$ and equal to 1.5λ . As stated previously, the shifter in a sense comprises two contiguous circularizers positioned on the wave path, one in front of the other.

In operation, referring to Figs. 1 and 5, and assuming $2d$ equals $2.0\lambda_0$, the perpendicular polarization component 9 entering the shifter undergoes a phase angle change of 720 degrees corresponding to two wavelengths in the shifter and the parallel polarization component 10 undergoes a phase angle change of 540 degrees corresponding to 1.5 wavelengths or 3 half wavelengths. Hence, in effect, the phase of component 9 outgoing from the shifter is the same as the phase of this component incoming to the shifter, whereas the phase of the outgoing component 10 is opposite that of the incoming component 10. By reason of the phase reversal of component 10, the polarity of this component is reversed whereby, assuming the components are of equal intensity, the polarity of the outgoing resultant wave is perpendicular to the polarity 7 of the original incoming resultant wave. Thus, as shown in the polarity diagram of Fig. 5, the polarities of the incoming perpendicular component 9 shown in full line and of the outgoing perpendicular component 9 shown in dash line are the same, whereas the polarities of the incoming and outgoing components 10 shown in full and dash lines, respectively, are opposite; and the polarity 12 of the outgoing resultant is perpendicular to the polarity 7 of the incoming wave. Hence, if the polarization of the incoming wave is vertical and at an angle of 45 degrees to the plates 3, the outgoing wave is horizontally polarized, and vice versa. If the components 9 and 10 are unequal in intensity the polarization is shifted through an angle differing from 90 degrees. Hence the shifter changes or modifies the wave by changing the plane or orientation of the wave polarization.

Referring to Figs. 6 and 7, the prism 13 comprises a plurality of dielectric channels 2 each comprising the air dielectric medium and a pair of metallic right triangular plates 14. The plates 14 are mounted in the wooden frame 15 and are spaced apart a distance a equal to at least a half wavelength of the incoming wave. The acute angles of the plates are denoted by α and β . Since the plates are triangular, the depth of each channel is tapered uniformly from a minimum value at one extremity, such as the top extremity, to a maximum at the opposite or bot-

7

tom extremity. As in the circularizer and shifter described above, the channel phase velocity v and the channel wavelength λ are greater respectively than the free or space phase velocity v_0 and the space wavelength λ_0 . The ratio, denoted n , of the space phase velocity to the channel phase velocity is the index of refraction and is less than unity. That is,

$$\frac{v_0}{v} = n < 1 \quad (1)$$

In operation, assuming an incoming wave having an electric polarization parallel to the plates 14 and a propagation direction 16 perpendicular to the front face 17 of the refractor 13, enters the refractor, the wave direction is bent or refracted toward the thinner portion of the refractor, as indicated by the outgoing wave direction 18. For a given value of n , the angle between directions 16 and 18 is a function of α or β . More specifically, assuming the incoming wave has a plane front and the dash-dot lines 19 represent successive cophasal or in-phase fronts spaced λ_0 apart in the ether medium, the spacing λ between the successive fronts 20 in the refractor 13, Fig. 7, is greater than λ_0 . On emerging from the refractor the wave fronts assume their ether spacings, whereby the propagation direction is refracted. If n were greater than unity, as in optical prisms and prior art radio prisms, the wave direction would be bent towards the thicker portion of the prism, as shown by the dotted arrow 21. Also, as shown by the circular lines 22 and 23, the incoming and outgoing waves may have a curvilinear, instead of a plane, wave front as, for example, a circular front. The prism of Fig. 6 is not isotropic since it does not refract waves of all polarizations. It may, however, be made isotropic by utilizing plates perpendicular to the plates shown, thereby obtaining a prism having a cellular construction.

In the wave changers described above and illustrated by Figs. 1, 2, 4 and 6, some reflection occurs at the front and at the rear surfaces of the changers. Accordingly, the front and rear longitudinal edges of each metallic plate in these devices are preferably notched, as shown in Figs. 8 and 9, for the purpose of eliminating or at least minimizing the reflection at these surfaces. The notches 24, Figs. 8 and 9, are a quarter wavelength deep and a quarter wavelength long and, considering the edge of one plate, the number of notched or recessed sections equals the number of protruding or non-recessed sections.

In operation, considering a pair of adjacent plates, the air dielectric surface 25 extending between the inner or bottom quarter wave edges of any pair of corresponding notches constitutes one reflective surface, and the air dielectric surface 26 extending between the outer quarter wave edges adjacent the aforesaid corresponding notches constitutes another reflective surface. Since the two surfaces are displaced a quarter wavelength on the wave propagation path, waves impinging on these surfaces and reflected thereby mutually cancel. Thus, assuming Figs. 8 and 9 illustrate the front edges of the wave changer plates, the components 27 and 28, Fig. 8, of an incoming wave are reflected in opposite phase, as shown by the vectors 29 and 30. Assuming Figs. 8 and 9 illustrate the rear edges of the plate, the outgoing wavelets 31 and 32 are reflected in opposite phase, as shown by the vectors 33 and 34. Since the total area of the reflective areas 25 equals the total area of the reflective surfaces

8

26 complete reflection cancellation is obtained or, stated differently, the impedance of the wave changer and the impedance of the ether path are matched for both the incoming and the outgoing waves.

The plates of the wave changers may have serrated longitudinal edges, as shown in Fig. 10, instead of the notched edges shown in Figs. 8 and 9. In Fig. 10, the V-shaped recessed portions 35 are a half wavelength deep at their vertex 36 and a half wavelength long, the average depth of the V-shaped section being a quarter wavelength. In operation, the V-shaped reflective surface of one recessed section is comparable in function to a quarter wave recessed surface 25, Fig. 8, and an adjacent protruding surface 26. In more detail, according to one explanation, the wavelets reflected by the vertex area 36 and by the outer dielectric areas adjacent to points 37 are cancelled by the wavelets reflected by the intermediate dielectric areas adjacent the mid-points 38, whereby impedance matching is obtained.

In the alternative impedance matching arrangement illustrated by Fig. 11 the plates have linear front and rear longitudinal edges. Each plate in one set of alternate plates extends a quarter wavelength beyond the adjacent plate in the other set of alternate plates. In operation, the two extended portions 39 of any pair of adjacent plates in the first mentioned set of alternate plates, constitute a quarter wave transformer for matching the impedance of two dielectric channels 2 to the free space impedance.

In Fig. 12, the plates 3 are relatively thick and each longitudinal plate edge is equipped with a thin metallic strip 40 having a depth or width equal to a quarter wavelength. The spacing s between the strips 40 is greater than the spacing a between the plates 2 and such that each pair of adjacent strips 40 constitutes a quarter wave impedance matching transformer for matching the impedance of the associated dielectric channel 2 to the impedance of free space, whereby reflection is prevented.

The wave changers as described so far utilize air as the dielectric medium and require a supporting structure such as the wooden frame 6, Fig. 1. If desired, and as shown in Fig. 13, the wooden frame in each of these devices may be omitted and the air dielectric may be replaced by polystyrene foam 42 or other similar plastic material, having a dielectric constant nearly equal to unity. The foam may be bonded to the plates 3 which are of heavy metal foil; and the foam functions both as a dielectric medium and as a means for maintaining the spaced relation of the plates. Since the dielectric constant of the foam is substantially the same as that of air, the refractive index n , for a given value of the channel width a , of the foam channel will be substantially the same as that of the air channel.

As is known, the attenuation in the dielectric channel, as in a conventional dielectric guide, is inversely proportional to the E-plane or b dimension and directly proportional to the axial length, of the channel and, assuming the axial length, taken in the wave propagation direction, is long and the b dimension is greater than a half wavelength, second and higher order modes may be established. In so far as these modes are concerned, the axial length or thickness of the metallic wave changer of the invention, such as the prism, is exceedingly small and, in fact so small that these modes are not present or at least

not significant. Hence in these metallic wave changers, the necessity of limiting the maximum value of the *b* dimension is obviated; and the *b* dimension may be, and preferably is made, many wavelengths long. Since the axial length or thickness of the wave changers is small, and the *b* dimension is large, it follows that the attenuation is exceedingly low and negligible.

Relative to the above, while the dielectric passages in the non-focusing refractor of the invention are preferably electrically open at the short ends, to wit, the top and bottom ends, they may be electrically closed. More particularly, although the top and bottom horizontal supporting members in the prism are preferably made of wood, or other insulating material, they may be formed of conductive material as for example, metal. If metallic members are used, the refracting operation would not be affected, and the reflective effects would not be of consequence, inasmuch as the wave polarization is perpendicular to these members. It may be observed that, whereas the prior art solid dielectric prisms including optical and radio prisms are homogeneous, the metallic prism of the invention and the combined foam-metallic prism of the invention are heterogeneous since they each contain conductive elements and dielectric elements. It may be added that the dielectric element in the prism of the invention may be a vacuous space or a gaseous, liquid or solid dielectric substance.

Although the invention has been explained in connection with certain embodiments it is to be understood that it is not to be limited to the embodiments described inasmuch as other apparatus may be employed in successfully practicing the invention.

What is claimed is:

1. An electromagnetic wave prism for refracting an electromagnetic wave having a substantially plane wave front, a predetermined linear electric polarization, a given wavelength and a given direction of propagation, said prism comprising at least a pair of like flat conductive plates, said plates being of triangular shape, the shortest edge of each of said plates being several wavelengths of said wave in length, the other two edges of each of said plates being several times as long as said shortest edge, said plates being positioned side by side with their corresponding edges parallel to each other, the spacing between said plates being at least one-half wavelength of said wave, the space between said plates being substantially free from conductive material and being substantially free of conductive obstructions, for the passage of waves in a direction parallel to the plane of the plates, one of the sets of parallel longer edges of said plates being substantially parallel to the polarization of said wave, and the set of shortest parallel edges of said plates being substantially parallel to the direction of propagation of said wave.

2. The prism of claim 1 and a dielectric medium between said plates.

3. A wave guide device for electromagnetic waves for conveying an electromagnetic wave having a substantially plane wave front, a predetermined linear electric polarization, a given direction of propagation and a given wavelength, said device comprising at least several pair of like, flat, conductive plates, the space between said plates being substantially free from conductive material and being substantially free of conductive obstructions, for the passage of waves in a direction parallel to the plane of the plates,

the longitudinal dimension of said plates is at least several times the maximum lateral dimension of said plates, and several times the wavelength of said wave, the plates being spaced apart at least one-half wavelength of said wave, the corresponding edges of said plates being parallel, one set, at least, of corresponding longitudinal edges of said plates being substantially perpendicular to the said direction of propagation and parallel with at least a substantial component of said electrical polarization, the maximum lateral dimension of said plates being several quarter wavelengths of said wave in said device.

4. The device of claim 3 and a dielectric medium between said plates.

5. A polarization circularizer for an electromagnetic wave having a substantially plane wave front, a predetermined linear electric polarization, a given wave length and a given direction of propagation, said circularizer comprising at least a pair of like flat conductive plates, said plates being of rectangular shape, the space between said plates being substantially free from conductive material and being substantially free of conductive obstructions, for the passage of waves in a direction parallel to the plane of the plates, the length of said plates being several times the width of said plates, and several wavelengths of said wave, said plates being spaced side by side, in parallel planes, the distance between adjacent plates being at least one-half wavelength of said wave, the width of said plates when expressed in terms of wavelengths of a parallel polarized wave propagated through the circularizer being an odd number of quarter wavelengths smaller than when measured in terms of wavelengths of the same wave being propagated in free space, the longitudinal edges of said plates being perpendicular to the direction of propagation and being positioned at an angle of substantially forty-five degrees with respect to the polarization of said wave.

6. The circularizer of claim 5 and a dielectric medium between said plates.

7. A polarization shifter for an electromagnetic wave having a substantially plane wave front, a predetermined linear electric polarization, a given wavelength and a given direction of propagation, said shifter comprising at least a pair of like flat conductive plates, said plates being of rectangular shape, the length of said plates being several times the width of said plates, and several wavelengths of said wave, said plates being spaced side by side in parallel planes, the space between said plates being substantially free from conductive material and being substantially free of conductive obstructions for the passage of waves in a direction parallel to the plane of the plates, the distance between adjacent plates being at least one-half wavelength of said wave, the width of said plates being an odd number of half wavelengths smaller when measured in terms of wavelengths of parallel polarized waves propagated through the shifter than when measured in terms of the same waves being propagated in free space, the longitudinal edges of said plates being perpendicular to the direction of propagation and being positioned at an angle of substantially forty-five degrees with respect to the polarization of said wave.

8. The shifter of claim 7 and a dielectric medium between said plates.

WINSTON E. KOCK.

(References on following page)

11

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
Re. 23,003	Barrow	May 25, 1948
1,898,787	Newcomer	Feb. 21, 1933
2,129,669	Bowen	Sept. 13, 1938

Number

2,129,712
2,405,242
2,411,872
2,415,807
2,416,675
2,437,281
2,442,951
2,479,673

12

Name

Date

Southworth	Sept. 13, 1938
Southworth	Aug. 6, 1946
Feldman et al.	Dec. 3, 1946
Barrow	Feb. 18, 1947
Beck et al.	Mar. 4, 1947
Tawney	Mar. 9, 1948
Iams	June 8, 1948
De Vore	Aug. 23, 1949