

Sept. 9, 1958

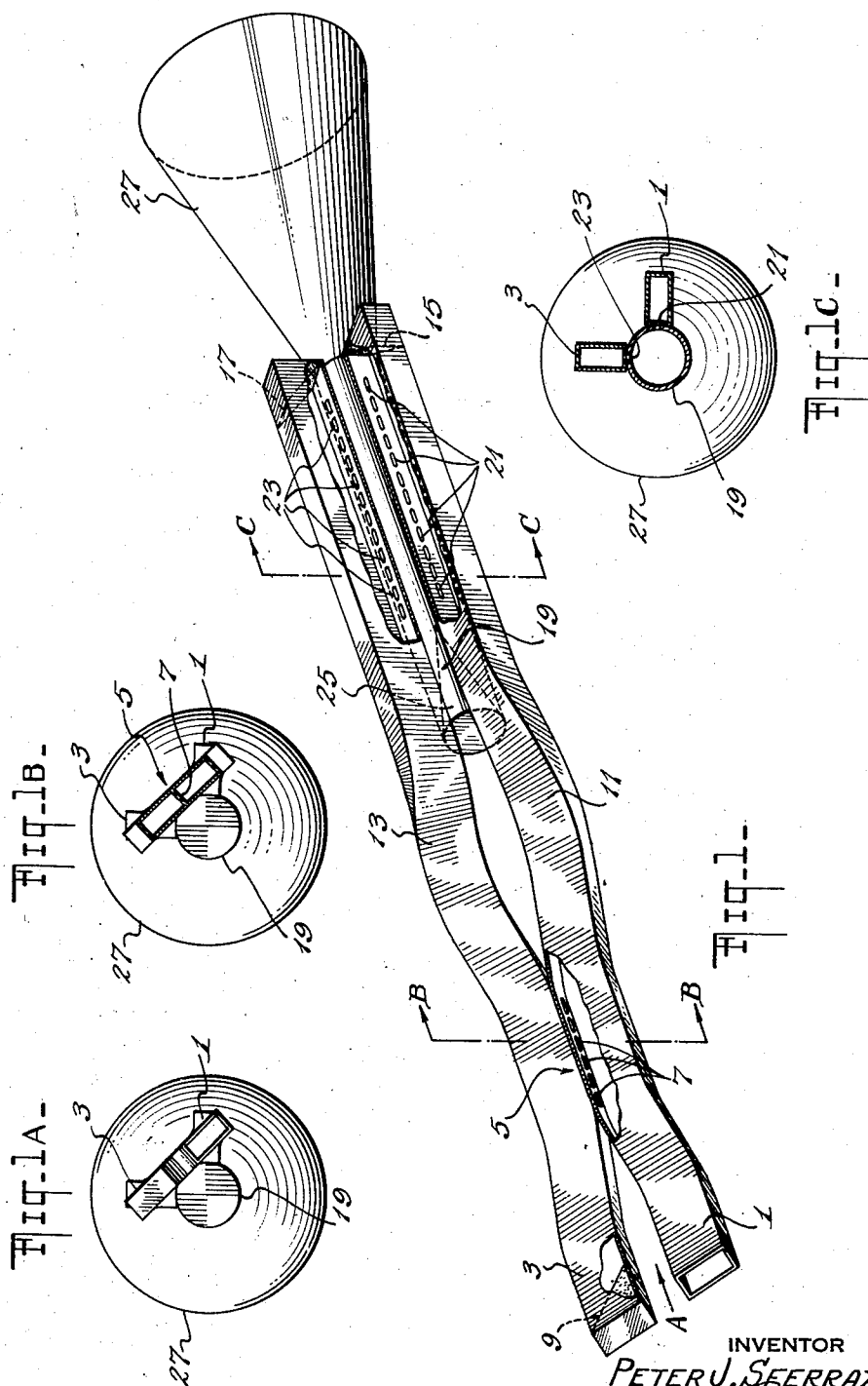
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2,851,687

CIRCULARLY POLARIZED ANTENNA

Filed May 10, 1955

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

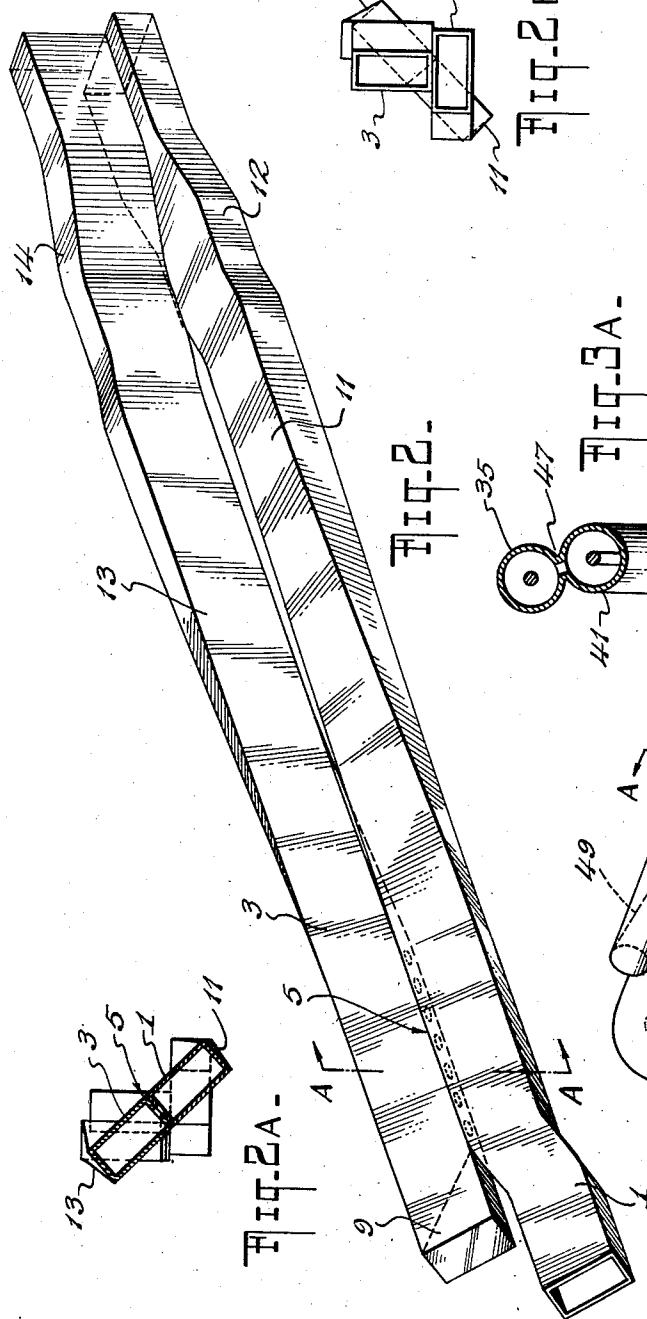


FIG. 2B-

FIG. 2A-

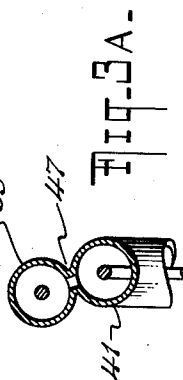


FIG. 3A-

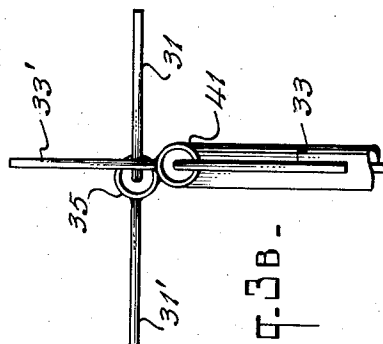


FIG. 3B-

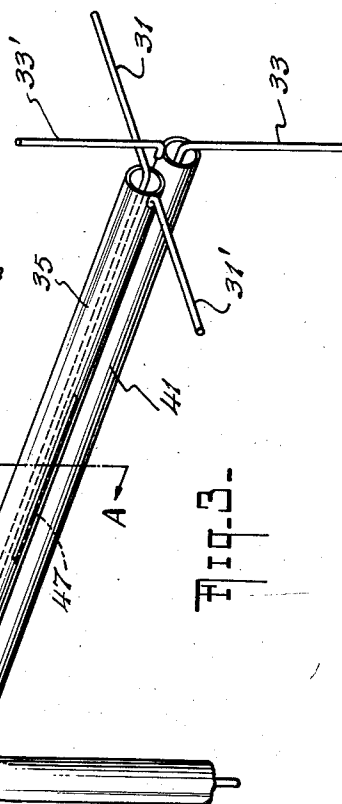


FIG. 3-

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1

2,851,687

CIRCULARLY POLARIZED ANTENNA

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Application May 10, 1955, Serial No. 507,320

12 Claims. (Cl. 343—850)

This invention relates to high frequency radio antenna systems, and more particularly to improvements in antennas for circularly polarized waves.

A circularly polarized wave can be considered as the resultant of two plane polarized waves in space and time quadrature. Since most simple coupling elements and radiator elements are plane polarized devices, antennas for circular polarization generally include polarization converter means for changing plane polarized waves to circularly polarized waves to be radiated, and/or circularly polarized waves to plane polarized waves to be utilized by way of conventional coupling elements. All such polarization converters include some kind of phase shifter to provide for the requisite 90° phase relationship between the plane polarized components of the circularly polarized wave.

Various types of phase shifters have been used in prior art circular polarizers. The most of these operate by providing electrical paths for the two components that differ in their effective lengths by one quarter wavelength. For example, the so called quarter wave plates that are used at microwave frequencies are designed to resolve the wave into two components at right angles, one being "guided" through a group of conductors parallel to its electric field at a phase velocity that depends on the spacing between the conductors, and the other being "unguided," i. e. passing through the conductors, with its electric field perpendicular to the conductors, and hence with a phase velocity independent of the conductor spacing. The widths of the conductors in the direction of propagation are such that the phase shift between the guided and unguided components is 90°. It will be apparent that such converters can operate ideally only at the design frequency; at other frequencies the relative phase shift is not 90° and the polarization is elliptical instead of circular.

Other polarization converter systems use transmission line or wave guide networks in which the relative phase shift is obtained by means of different line lengths for the two components, or by devices such as bodies of dielectric material of prescribed dimensions placed in the wave guides. These systems are likewise frequency-dependent, and may also be subject to undesirable reduction in power-handling capability owing to the presence of regions of high electric field concentrations, particularly in phase shifters of the dielectric slab type.

The principal object of the present invention is to provide polarization converters for circularly polarized antenna systems and the like which operate substantially independently of frequency throughout relatively broad bands.

Another object is to provide devices of the above mentioned type wherein the phase and amplitude relationships between the wave components are substantially independent of frequency.

A further object is to provide systems of the described type in which impedance mismatches between the various

2

components are minimized over relatively broad frequency bands.

Another object is to provide systems for circular polarization wherein the power handling capability is limited substantially only by that of the component wave guides or transmission lines.

According to the present invention, a directional coupler is used to connect two orthogonally disposed radiators or coupling elements to a common source or utilization device. Directional couplers can be designed in well-known manner to provide 3 db coupling (i. e. 50 percent power transfer) throughout wide frequency bands. Thus the requirement of equal amplitudes in the two perpendicular field components may be satisfied. Furthermore, it is characteristic of directional couplers in general that the coupled wave, i. e. the wave that is transferred through the coupler from one line to another, is shifted in phase by 90° with respect to the wave that continues past the coupler along the first line. This characteristic is utilized to provide the required quadrature phase relationship between the two field components.

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

Fig. 1 is a perspective view of a presently preferred embodiment of the invention,

Fig. 1A is an end view looking in the direction of the arrow A of Fig. 1,

Figs. 1B and 1C are cross sections of the structure of Fig. 1 as indicated by the lines B—B and C—C in Fig. 1,

Fig. 2 is a perspective view of a modified form of the invention,

Fig. 2A is a cross section of the structure of Fig. 2 as indicated by the lines A—A in Fig. 2,

Fig. 2B is an end elevation of the structure of Fig. 2,

Fig. 3 is a perspective view of another modification of the invention,

Fig. 3A is a cross section of the structure of Fig. 3 as indicated by the line A—A in Fig. 3, and

Fig. 3B is an end view of the structure of Fig. 3.

Referring to Fig. 1, two rectangular wave guides 1 and 3 are joined at a region intermediate their ends by a directional coupler 5. Preferably the coupler 5 is formed as shown, by merging respective narrow walls of the guides 1 and 3 to form a common wall, which is provided with a series of coupling apertures 7. The number and sizes of the apertures 7 are selected in accordance with known design procedure to provide 3 db coupling between the guides 1 and 3.

The left hand end of the guide 1 may be coupled to a radio-frequency source or other device, for example a radar transmitter-receiver system. The corresponding end of the guide 3 is provided with a matching termination 9 such as a wedge of resistive material.

To the right of the coupler 5, the guides 1 and 3 are each twisted 45 degrees as at 11 and 13, but in opposite directions. Beyond the twists the two guides extend along parallel axes, with their cross sections at right angles to each other. The right hand ends of the guides 1 and 3 contain terminations 15 and 17, similar to the termination 9.

A circular wave guide 19 is disposed parallel to and partially between the perpendicular portions of wave guides 1 and 3, so that the respective narrow walls of the guides 1 and 3 are substantially tangent to the circular guide, as shown best in Fig. 1C. A series of coupling apertures 21 is provided along the line of tangency between guides 1 and 19. The number and the sizes of apertures 21 are such as to provide substantially 100 percent coupling between the guides 1 and 19. The guide 3 is similarly coupled to the guide 19 by a series of apertures 23.

The left hand end of the circular guide 19 contains a

3

termination 25 which may be a conical body of resistive material. The right hand end of guide 19 is connected to a circular horn 27. The horn 27 constitutes a directive beam-forming or collimating device which may be directed toward a further collimating device such as a lens or reflector, not shown, or may be used alone. It will be apparent without further illustration that the horn 27 could be omitted, and the open end of the guide 19 used as a radiator and directed toward an external lens or reflector if desired.

For transmission of circularly polarized waves, microwave power is supplied to the left hand end of the guide 1. The power is divided at the directional coupler 5, one half of it flowing into the guide 3 and the other half continuing along the guide 1. If the coupler 5 were of infinite directivity, all of the coupled power would flow to the right in guide 3, and none would flow to the left. As a practical matter, however, a relatively very small portion of the coupled energy will ordinarily flow to the left, to be absorbed in the termination 9.

The power flowing to the right in the guide 3 is substantially equal in magnitude to but is 90° out of phase with that remaining in the guide 1. Substantially all of the power flowing in the guide 1 is transferred into the circular guide 19, by way of the coupling apertures 21. There it excites a vertically polarized wave, with the electric field vector directed between the top and bottom of the guide 19. Similarly substantially all of the power in the guide 3 is transferred through the apertures 23 to the guide 19, where it excites a horizontally polarized wave with the electric field vector directed from side to side of the guide 19.

The phase of the horizontally polarized wave is delayed with respect to that of the vertically polarized wave by 90° degrees, owing to the phase shift in the directional coupler 5. Thus the two components in the circular guide 19, being of equal amplitudes and in space and phase quadrature, constitute a circularly polarized wave.

Since the groups of apertures 21 and 23 act as directional couplers, substantially all of the power that is transferred to the guide 19 flows to the horn 27 and is radiated. The relatively small amount of power that flows to the left in the guide 19 is absorbed by the termination 25.

In the reception of waves arriving at the horn 27, any vertically polarized component is transferred through apertures 21 from the circular guide 19 to the rectangular guide 1. Substantially all of the power that is transferred through the apertures 21 flows to the left in the guide 1, the relatively small amount that flows to the right being absorbed in the termination 15. None of this component propagates in the wave guide 3 because that guide is beyond cutoff for vertically polarized waves.

In a similar manner, any horizontally polarized component in the guide 19 is transferred to the guide 3, substantially all of the power flowing to the left. At the directional coupler 5, one half the power flowing in the guide 3 is transferred to the guide 1, undergoing a relative 90° phase delay. One half the power flowing in the guide 1 is likewise transferred to the guide 3, similarly undergoing a 90° relative phase delay.

If either a vertically polarized wave or a horizontally polarized wave alone is received, one half of the power will finally reach the left hand end of the guide 1, where it may be utilized, and the other half will be dissipated in the termination 9 at the end of the guide 3. This is also the case if any purely plane polarized wave is received. If a circularly polarized wave rotating in one screw sense is received, the wave arriving at the coupler 5 in the guide 3 will be 90° in advance with respect to that arriving at the coupler 5 in the guide 1. The power transferred from the guide 3 to the guide 1 will be in phase with that arriving in the guide 1, and the two will add together at the left hand end of the guide 1. The power transferred from the guide 1 to the guide 3 will be 180° out of phase with that arriving at the coupler

4

in the guide 3. These two waves will cancel each other, so that no power flows in the guide 3 from the coupler 5 to the termination 9. Thus substantially all of the energy circularly polarized in the proper screw sense entering the horn 27 reaches the left hand end of the guide 1. Conversely, substantially all incident energy that is circularly polarized in the opposite screw sense will appear at the end of the guide 3 and be dissipated in the termination 9.

Since the paths in the guides 1 and 3 between the coupler 5 and the circular guide 19 are identical, and the 90° relative phase shifts in the coupler 5 are independent of frequency, the quadrature phase relationships necessary to conversion between plane and circular polarization will be maintained throughout the entire operating bandwidth of the system. In addition, the coupler 5 and the coupling apertures 21 and 23 can readily be designed to provide couplings that do not vary significantly over the operating band, which may be the entire band over which rectangular wave guides of the dimensions of guides 1 and 3 are ordinarily used. Side wall couplers of this type have high power handling capacity because they cause a minimum disturbance of the field configurations in the wave guides. Since there are no regions in the system where the electric fields will be appreciably more concentrated than they would be in a straight wave guide run and no dielectric heating effects, the power handling capacity of the polarization converter is substantially the same as that of the wave guides themselves.

Fig. 2 shows a modification of the system of Fig. 1 wherein the circular wave guide and the horn are omitted, the open ends of the rectangular guides 1 and 3 serving as radiator elements. The guides 1 and 3 are coupled at 5 and twisted at 11 and 13, as in Fig. 1. Beyond the twisted regions, the guides are bent as shown at 12 and 14 to place the open end of the guide 3 centrally above and adjacent that of the guide 1, as shown in Fig. 2B. The open ends of the guides lie in the same vertical plane. This arrangement operates substantially like that of Fig. 1. However, since the two radiator elements are not exactly concentric, the polarization will be circular only along the main axis, and increasingly elliptical for increasingly oblique rays. In applications where only the axial rays are of interest, the structure of Fig. 2 is as satisfactory as that of Fig. 1 and has the advantage of being simpler. It will be apparent that a collimating device such as a lens or mirror may be used in front of the radiators if desired.

Figs. 3, 3A and 3B illustrate a circularly polarized antenna system using coaxial transmission lines instead of hollow pipe wave guides, which may be preferable for use at relatively low frequencies that would otherwise require unduly large wave guides. The radiator elements in this case are horizontal and vertical dipoles 31, 31' and 33, 33' respectively.

The horizontal radiator elements 31 and 31' are connected to the inner and outer conductors respectively of a coaxial line 35. The lines 35 and 41 are coupled together by a directional coupler 47, which may be of the type described in U. S. Patent 2,657,361 designed with a coupling slot of sufficient length to provide substantially 3 db coupling between the two lines. The line 35 is terminated by a resistive matching device 49, and the line 41 is adapted to be connected to utilization means such as a receiver and/or transmitter.

The operation of the system of Fig. 3 is basically the same as that of the systems of Figs. 1 and 2. The directional coupler 47 provides the necessary quadrature phase and amplitude equality between the power that flows in the lines 35 and 41. As in the systems of Figs. 1 and 2, the radiator elements may be used alone or in connection with beam-forming means such as reflectors or lenses.

Since many changes could be made in the above construction and many apparently widely different embodi-

5

ments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An antenna for circularly polarized waves, comprising radiator means including orthogonally related elements for operation with plane polarized wave components at right angles to each other, two wave guides connected respectively to said elements, and a directional coupler connected between said wave guides to provide substantially 3 decibels coupling therebetween.

2. An antenna for circularly polarized high frequency radio waves, comprising a main wave guide and an auxiliary wave guide, a directional coupler interconnecting said guides, said coupler being designed to provide a coupling of substantially 3 db, and radiator means including orthogonally related elements for operation with respective plane polarized wave components at right angles to each other, said elements being coupled respectively to one end of said main wave guide and to the corresponding end of said auxiliary wave guide.

3. The invention set forth in claim 2, wherein said radiator means includes a circular wave guide and means for coupling said main and auxiliary wave guides to said circular guide at first and second points respectively on the circumference of said circular guide, said first and second points lying in planes that intersect in the axis of said circular guide at right angles to each other.

4. The invention set forth in claim 3, wherein said means for coupling said main and auxiliary wave guides to said circular guide are directional couplers designed to provide substantially 100 percent coupling.

5. The invention set forth in claim 3, wherein said radiator means further includes a collimating device in front of the mouth of said circular wave guide.

6. The invention set forth in claim 2, wherein each of said orthogonally related elements of said radiator means comprises a rectangular wave guide with open ends adjacent each other, and means including respective wave guide sections comprising opposite 45 degree twists connecting said pair of wave guides to said main and auxiliary wave guides.

7. An antenna for circularly polarized waves, comprising a collimating device, two rectangular hollow wave guides, a directional coupler connected between said wave guides to provide substantially 3 decibels coupling therebetween, said wave guides being oriented alike at said directional coupler and extending from said coupler

6

to said collimating device, said wave guides being twisted between said coupler and said collimating device to an angle of 90 degrees with respect to each other.

8. The invention set forth in claim 7, wherein said collimating device is a conductive horn provided with a throat coupled to the adjacent ends of said wave guides.

9. An antenna for circularly polarized waves, comprising radiator means including orthogonally related elements for operation with plane polarized wave components at right angles to each other, two rectangular hollow wave guides, a directional coupler connected between said wave guides to provide substantially 3 decibels coupling therebetween, said wave guides being oriented alike at said directional coupler and extending from said coupler respectively to said orthogonally related elements of said radiator means, said wave guides being twisted between said coupler and said radiator means to an angle of 90 degrees with respect to each other.

10. An antenna for circularly polarized radio waves, comprising a first wave guide adapted to be coupled at one of its ends to a utilization device and provided at its other end with plane-polarized radiator means, a second wave guide, directional coupler means coupling said second wave guide to said first wave guide at a region intermediate the ends of said first wave guide, said directional coupler means providing a coupling of substantially 3 db between said wave guides, said second wave guide being disposed with one of its ends adjacent said other end of said first wave guide and provided at said end with plane-polarized radiator means, the planes of polarization of said radiator means being substantially at right angles to each other.

11. The invention set forth in claim 10, wherein said wave guides are coaxial transmission lines and said radiator means are dipoles.

12. An antenna for circularly polarized high frequency radio waves, comprising a main transmission line and an auxiliary transmission line, a directional coupler coupling said lines, said coupler being designed to provide a coupling of substantially 3 db, first plane-polarized radiator means at one end of said main line, and second plane-polarized radiator means at the corresponding end of said auxiliary line, said first and second radiator means being adjacent each other with their planes of polarization substantially at right angles to each other.

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