

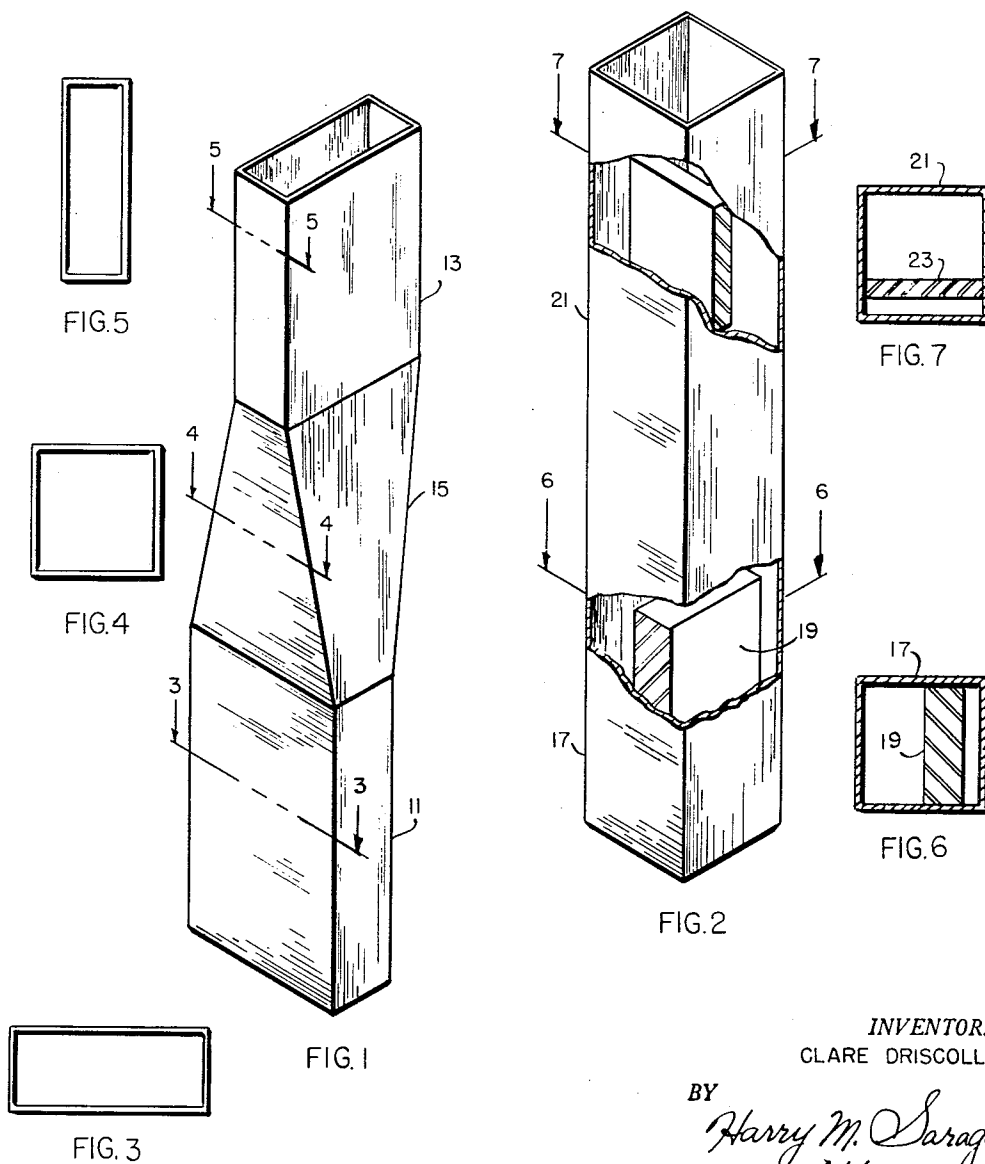
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MICROWAVE APPARATUS FOR CIRCULAR POLARIZATION

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MICROWAVE APPARATUS FOR CIRCULAR POLARIZATION

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This invention relates in general to microwave waveguides and is particularly directed to a broad band transformer for converting plane polarized waves to waves of circular polarization.

An electrical wave is said to be circularly polarized when the field thereof can be resolved into two equal components 90° apart in space and 90° apart in time. If the two vectors are not of equal amplitude, or if the time difference between them is other than 90°, the wave is said to be elliptically polarized; in the special case in which the time phase angle reduces to zero, the wave is linearly polarized. Thus, both linear polarization and circular polarization can be looked upon as special cases of elliptical polarization.

The equation of this ellipse may be expressed as follows:

$$\frac{E_x^2}{A^2} + \frac{E_y^2}{B^2} - \frac{2E_xE_y \cos \epsilon}{AB} = \sin^2 \delta$$

where E_x and E_y are the two components of the field, A and B are their respective coefficients denoting amplitude, and δ is the time phase angle of the two components.

If

$$\delta = \frac{\pi}{2}$$

and $A=B$ so that the components are 90° apart in time phase and are of equal amplitude the equation of the ellipse reduces to

$$E_x^2 + E_y^2 = A^2$$

which is the equation of a circle. The wave is then circularly polarized. If $\delta=0$ or π (components in phase or 180° out of phase), the equation becomes that of a straight line and the wave is linearly polarized.

Various methods may be used to produce a field having components of substantially equal amplitude 90° apart in space in a square or rectangular waveguide. For example the two components may be separately introduced into the waveguide or they may be generated by applying a linearly polarized wave to the waveguide having an electric vector rotated approximately 45° with respect to either of the two pairs of sides of the square or substantially square waveguide, so that the electric vector will have substantially equal components perpendicular to each pair of sides.

It is necessary, in order to produce a circularly polarized wave, to create a phase shift in time of 90° in the two components of the wave in space quadrature. This has been previously accomplished by utilizing a rectangular waveguide of asymmetric proportions or, in a square waveguide, by the introduction of a longitudinal dielectric slab inserted parallel to one pair of sides of the waveguide.

The dimensions of the waveguide or of the dielectric slab are chosen so as to produce the desired time phase-shift at the center of the desired frequency band. At frequencies above and below the center frequency, however, the time phase-shift will vary from the desired 90° time phase-shift, causing the polarization to deviate from circular polarization at these frequencies. The frequency

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band in devices of this nature is, therefore, restricted by the limits of ellipticity which are considered satisfactory.

It is consequently an object of this invention to provide apparatus which overcomes the limits of the prior art by reducing the deviation from circular polarization over a given frequency range.

It is a specific object of this invention to provide improved apparatus for producing circular polarization within desired limits of ellipticity over a broad frequency range.

In accordance with this invention two wave guide transformers are connected in series to produce a total time phase shift between the transformers which is subject to less variation with change in frequency than would occur through the use of a single waveguide transformer. One transformer is designed to produce a time phase shift which is greater than the desired phase shift. The other transformer is designed to produce a correcting phase shift which reduces the total phase shift to approximately the desired value over a broad frequency range.

The foregoing and other objects of the invention will be best understood from the following description of specific embodiments thereof, reference being had to the accompanying drawings, wherein:

Fig. 1 is an isometric view of one embodiment of the invention;

Fig. 2 is an isometric view of another embodiment of the invention;

Figs. 3, 4 and 5 are cross sectional views of the arrangement of Fig. 1; and

Figs. 6 and 7 are cross sectional views of the arrangement of Fig. 2.

Referring now to Fig. 1, a view of a device for converting a linearly polarized wave propagated in space quadrature into a substantially circularly polarized wave is shown, said device comprising a rectangular waveguide section 11 of constant cross section, as shown in Fig. 3, having a pair of long sides and a pair of short sides. A second section 13 of rectangular waveguide of constant cross section, as shown in Fig. 5, is provided having a length and a dimension ratio of long side to short side which differ from the length and dimension ratio of sides of section 11. The dimensions of the narrow walls of the sections 11 and 13 are, of course, large enough to support propagation in which the electric field voltage vectors are perpendicular to the narrow walls for otherwise a circularly polarized wave would not be produced by the waveguide.

The long sides of section 11 are joined to the short sides of section 13 and the short sides of section 11 are joined to the long sides of section 13 by tapered waveguide section 15. Waveguide section 15 changes in cross sectional dimension along its length from the dimensions of section 11 shown in Fig. 3 through a square cross section shown in Fig. 4 to the dimensions of section 13 shown in Fig. 5.

A wave propagated into the open end of waveguide section 11 in space quadrature may be derived from any desired source (not shown) in a conventional manner. This wave has a composite electric vector lying in the cross sectional plane of the waveguide and inclined at an angle of approximately 45° to both pairs of sides of the rectangular waveguide. This electric vector can be resolved into two components E_x and E_y , each perpendicular to a separate pair of sides of the waveguide.

At the open end of waveguide section 11 E_x and E_y are still in time phase and the resultant is a linearly-polarized wave. In order to satisfy the condition for a circularly polarized wave the two components must also have a time phase of 90° or 270°.

The waveguide section 11 as seen by the component E_x

is different in width from that seen by E_y . Therefore their velocities of propagation are somewhat different, and in the passage of the components through section 11 the phase angle between E_x and E_y progressively departs from zero and the wave becomes elliptically polarized. This progressive increase in time phase angle continues with the passage of the wave into the tapered waveguide section 15 up to the point in section 15 where the dimensions of the two pairs of sides become equal. At this point, indicated by the cross sectional view of Fig. 4, the components E_x and E_y see equal dimensions, and past this point in section 15 and in waveguide section 13, it is apparent that components E_x and E_y see a reversal in proportionate waveguide widths. The time phase shift is consequently reversed in the waveguide section 15 and the time phase angle is progressively decreased in waveguide section 13.

A single waveguide section similar to section 11 in Fig. 1 may be designed to produce a 90° time phase shift between the two components E_x and E_y at a center frequency f_0 . Where the frequency range is to be $f_0 + \Delta f$ to $f_0 - \Delta f$ this wave guide may have the following characteristics:

Frequency:	Phase shift, degrees
f_0 -----	90
$f_0 + \Delta f$ -----	75
$f_0 - \Delta f$ -----	110

In order to narrow the time phase shift over the desired frequency range the length of this waveguide section may be doubled so as to produce a time phase shift of 180° at its center frequency. This wave guide will have the following characteristics:

Frequency:	Phase shift, degrees
f_0 -----	180
$f_0 + \Delta f$ -----	150
$f_0 - \Delta f$ -----	220

This phase shift may be compensated by a shorter series connected waveguide section corresponding to section 13 of Fig. 1 having different cross sectional dimensions and therefore a different ratio of phase shift to frequency variation. This section can be designed to have the following characteristics:

Frequency:	Phase shift, degrees
f_0 -----	minus 90
$f_0 + \Delta f$ -----	minus 55
$f_0 - \Delta f$ -----	minus 125

The total phase shift of these two sections connected in series would be:

Frequency:	Phase shift, degrees
f_0 -----	90
$f_0 + \Delta f$ -----	95
$f_0 - \Delta f$ -----	95

This is a substantial improvement over the phase shift variation over the same frequency range obtainable from a single waveguide section.

It should be noted that in the particular construction disclosed in Fig. 1 the tapered section 15 will also produce a shift in the time phase angle. This must be taken into consideration in the design of sections 11 and 13. This phase shift will be first in one direction and then in the other, reversing at the plane in which the cross section of the taper is symmetrical. Section 15 can be considered as two guide sections, each section of which can be considered as having a taper to a symmetrical end which is mated with the facing end of the other sections. Carrying this point of view to its limit, none of the waveguide sections would be uniform throughout its complete length and the entire polarization process could be carried out in a properly dimensioned taper with no straight section.

Fig. 2 shows a view of a second embodiment of the

invention particularly applicable to square waveguides. No time phase shift will be created between the components E_x and E_y of the space quadrature wave introduced into the square wave guide by reason of the dimensions of the guide inasmuch as E_x and E_y see equal dimensions. The desired initial phase shift may be obtained in a first section 17 of Fig. 2 by inserting a longitudinal slab of dielectric 19 parallel to a first pair of sides of the waveguide. The second phase shift may be obtained by placing a second longitudinal dielectric slab having different dimensions in a succeeding section 21 of the waveguide parallel to the second pair of sides. By selecting the dimensions and the dielectric constant of the slabs a variation of phase shift over the desired frequency range may be obtained which is similar to that previously described for the structure illustrated in Fig. 1.

While there have been described what are presently considered to be preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention.

What is claimed is:

1. A device for introducing in a band of frequencies a substantially 90° time phase displacement between the space quadrature components of the plane-polarized waves of said band of frequencies comprising first hollow waveguide means for increasing the relative time phase angle between the space quadrature components of the center frequency of said band of frequencies by a given amount greater than 90° and shifting the relative time phase angle between the space quadrature components of the other frequencies of said band by amounts which differ from said given amount as a function of the extent and direction of the deviation of said other frequencies from said center frequency, and second hollow waveguide means coupled to the output of said first means and having a ratio of relative time phase shift with frequency variation which differs from that of said first waveguide means for reducing the shift in relative time phase angle between the space quadrature components of the output waves of said first waveguide means of all frequencies in said band to substantially 90° .

2. A device as claimed in claim 1 wherein said first means comprises a waveguide section having asymmetrical dimensions and said second means comprises a waveguide section of asymmetrical but different dimensions than said first waveguide means.

3. A device as claimed in claim 1 wherein said first means comprises a waveguide rectangular in cross section and having relatively greater spacing between its side walls than the spacing between its top and bottom surfaces, said second means comprises a waveguide rectangular in cross section and having relatively greater spacing between its top and bottom surfaces than the spacing between its side walls, and further including a waveguide component formed to join the opposing short walls of each rectangular waveguide section with the opposing long walls of the other rectangular waveguide section.

4. A device as claimed in claim 1 wherein said first and second waveguides are square in cross section and further including a first dielectric slab mounted within said first waveguide parallel to the walls thereof and a second dielectric slab mounted within said second waveguide perpendicular to said first dielectric slab and spaced therefrom.

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