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ANALYSIS OF A CYLINDRICAL WAVE GUIDE CONVERTER FOR CIRCULAR POLARIZATION

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Abstract

The circularly polarized wave have gained popularity due to their use as the principal propagation mode in satellite communications. To realize the multiplexing of the transmitting system in satellite communications. It is necessary to supply the waves instantly to the devices. Therefore, to know the transient characteristics of the devices, time domain analysis is important. The transient charactertistics of two types of converters to generate a circularly polarized wave from a lineraly polarized one has been analyzed. The cutoff wave lengths are obtained from the frequency response by applying the fourier transform. The phase shift constants and guide wave lengths are obtained by the spatial and time variation of the electric field distribution. The whole distribution of fields can be to provide detailed information on the field properties, such as the local field concentration. The process of generating either a circularly or an elliptical polarized wave from a linearly polarized wave is shown by time domain analysis.

Introduction

Recently, the circularly polarized wave have gained prominence due to its use as the principal propagation mode in satellite communications. This utilization is a consequence of its stability in long-range propagation through the ionosphere and the air. Such a circularly polarized wave may be represented as the sum of two equal amplitude, linearly polarized wave perpendicular in direction and separated 90 degrees in phase.

Many kinds of converters for generating a circularly polarized wave from a linearly polarized one have been proposed. To produce such a phase difference, a change in propagation characteristics is indispensable; this is realized by either the medium condition or the structure in the wave guide. To utilize the medium condition, a dielectric plate can be loaded into the wave guide [1]. In satellite communication to utilize the multiplexing of the sending system, it is necessary to supply the waves instantly to the converters. Therefore, to know the transient characteristics of the devices, time-domain analysis is important. Further more, the transient analysis of an electromagnetic field not only clarifies the variation of the field in time; it also provides information on the mechanism by which the distribution of the eletromagnetic field in the stationary state is brought. This method is based on the equivalent circuit of Maxwells equation. The transient characteristics of two types of converters are analyzed: those loaded with metal plates in the cylindrical wave guide and those loaded with a fin. The mechanism for generating circularly polarizing wave is obtained by the spatial and time variations of the fields.

Boundary Conditions of a Conductor

The electromagnetic field is expressed in terms of the equivalent circuit of a network of the type shown in Fig 1. In this network, each set of equations expressing waves in their respective .plane is assumed at each node and the lines connecting them. The lines between nodes are one dimensional transmission lines and the node is the point where the continuity of currents is assumed. Here Δ d is the internal between adjacent nodels in the equivalent circuit [2]. The dark circles (.) Stand for an electric node at which the electric field component is treated as a voltage variable, while the empty circle (0) stand for a magnetic node at which magnetic field component is treated as a voltage variable.

At each node, the related electromagnetic field variables are associated with those of voltage and current. The medium conditions are represented by lumped circuit elements and formulated by the trapezoidal rule. Nodal equations with medium conditions can thus be uniquely formulated in terms of the equivalent circuit in the time-domain. The correspondence between the variables in the equivalent circuit and those in the field are shown at each node (A,B,C,D,E and F) in the network. The asterisk identifies the variables at the magnetic nodes due to the duality of their physical meaning, as compared with their interpretation at the electric nodes. The conductors are assumed perfect. Hence, the tangential electric field and the normal magnetic field becomes zero on the conductive surface. The boundary conditions at each node for the perfect conductor preclude the following two conditions:

(1) When the node at which the tangential electric field becomes a voltage function or current function, the node must be either short or open.

(2) When the node at which the normal magnetic field becomes a voltage function or a current function, the node must again be either short or open.

Experimental Details

Two models of the circularly polarized wave converter are considered. The first analyzed is shown in Figure 2. Two equal and diametrically opposite metal plates are loaded into a cylindrical wave guide. The radius of the wave guide, r is 15 Δ d and the longitudinal length in the Z direction, l, is 170 Δ d. The curvature of the wave guide is approximated in step form as this model is expressed in the three dimensional lattice network. The boundary condition of the wall of the wave guide is assumed to have perfect conductivity. For simplicity of a TE_{11} mode in the cross section of the input ABD plane. The electric field component in the Y direction (E_y) of the TE_{11} mode is applied at node A_k with the amplitude distribution corresponding to the mode. The component in the X-direction (E_x) is similarly applied at node D_k , as shown in Figure 3 (a). The input and output planes are terminated by the characteristic impedance of the TE_{11} mode to approximate the matching condition. Figure 3(b) shows the instantaneous pattern of electric field distribution of the TE_{11} mode in the X-Y plane, titled at an angle of 45 degrees with respect to the Y axis.

Figure (4) shows the curves of the cutoff wave length λ_{c_x} and λ_{c_y} as a function of plate depth d with both coordinates normalized to radius r of the cylindrical wave guide. To calculate this characteristic the raised cosine wave is applied and the transmitted response of the wave through the parallel-plate structure is obtained in the time domain. The cutoff wave lengths can thus be computed from the frequency response by normalized phase shift $\gamma\,[\beta_y - \beta_x]$ for the parameters of the normalized wave length λ/λ_c as a function of the normalized plate depth d/r. Good agreement with previous result is obtained.

To clarify the fundamental mechanism of generating a circularly polarized wave from a linearly polarized wave. The spatial and time variations are presented [3] Figure (6a] shows the instantaneous spatial distribution of the two components Ex and Ey of the electric field vector E. The free space wave length of the input wave, λ_O, is 40 Δ d and the observation time is t = 8.0 T. T-being the period of input wave. Time is set at r = 0 when the wave is applied to the input plane. From this figure, the phase difference between the components E_x and E_y can be seen. The resultant, composite electric field vector is shown in Fig 6.(b). Fig 7 (a) gives the time response of the electric field component E_x and E_y at the observation point P on the central axis of the wave guide. the phase of E_y lags 90 behind that of E_x. Fig 7 (b) shows the clock wise rotation of the electric field vector E at the same observation point over o e period of the input wave. Fig 8 shows the frequency characteristics of the phase shift constant [$\beta y - \beta x$] with a plate penetration depth of 3 Δ d. To demonstrate the complicated characteristics of the variation of the electric field vector in wave propagation. Fig (9) shows the instantaneous spatial distribution of the electric field vector on the central axis of the wave guide.

The second analyzed model, containing a metal fin of height h is shown in fig 10. The width of the fin, ω, is 6 Δ d. The radius and longitudinal length of the wave guide are the same as that the previous model shown in Fig 2. The guide wave lengths, of the electric fields E_x and E_y, as a function of height h, are shown in Fig 11. The input free space wave length, λ_O is 42 Δ d.

The left hand side of Fig 12 shows the time response of the electric field components E_x and E_y at each observation point on the central axis of the wave guide indicated in Fig 10. The right hand side of the figure shows the rotation of the electric field vector E at the same observation point over one period of the input wave. The input free space wave length λ_O is 42 Δ d. In the case of (a) and (c), elliptically polarized waves are generated from the phase differences of 45° and 135° respectively. In the case of (b) as the phase difference between E_x and E_y is 90° and the amplitudes are equal, a circularly polarized wave is generated, In the case of (d), a linearly polarized wave is regenerated because the phase difference is 180°. However, its direction of polarization is rotated 90° with respect to that of the input wave.

Fig 13 is the time variation of the instantaneous pattern of the electric field distribution in the x-y plane for case (b) as shown in Fig 12. It is observed that every quarterly period of the input wave. From this figure we can see that the TE_{11}

mode distribution of the field is almost conserved despite the application of the fin in the wave guide. A field concentration is observed near the edge of the fin. Thin phenomenon yields discharge and local over heating and can result in destruction of the converter in high power operation. In addition, the distribution pattern can be seen to rotate 90° in a clock wise direction per observation.

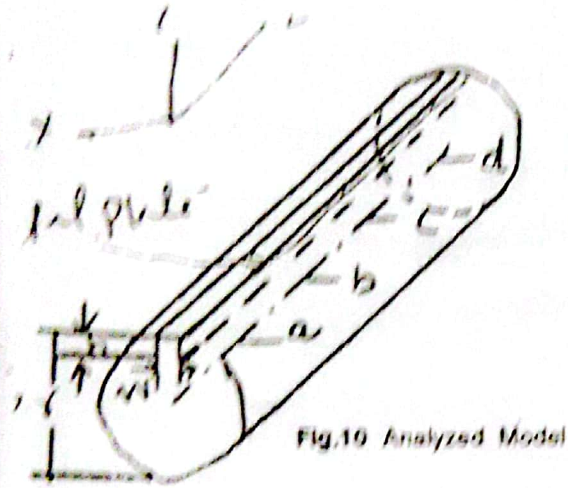


Fig.10 Analyzed Model

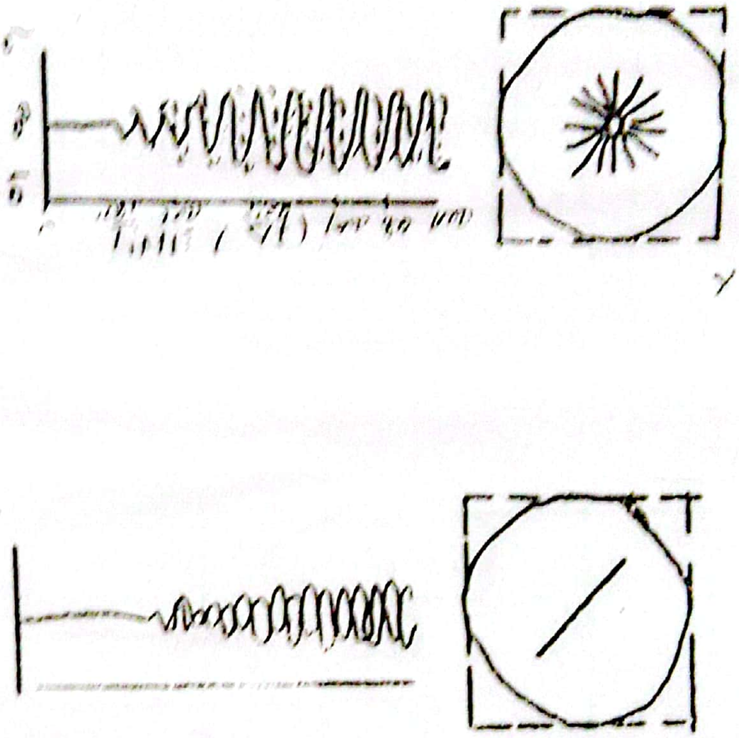


Fig.12 Time response of the electric field components E_x and E_y and the rotation of the electric field vector E.

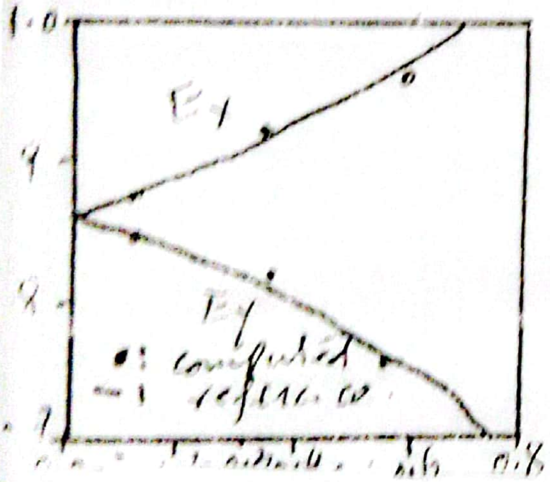
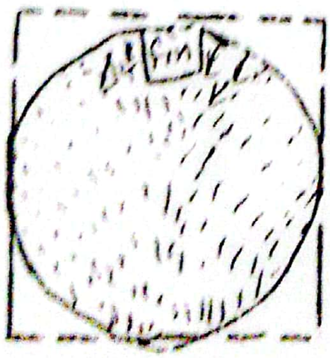


Fig.11 Guide wave lengths of the electric field components E_x and E_y as a function of height.



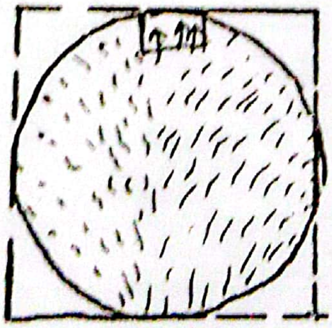


Fig.13 Time variation of the instantaneous pattern of electric field distribution in the x–y plane.

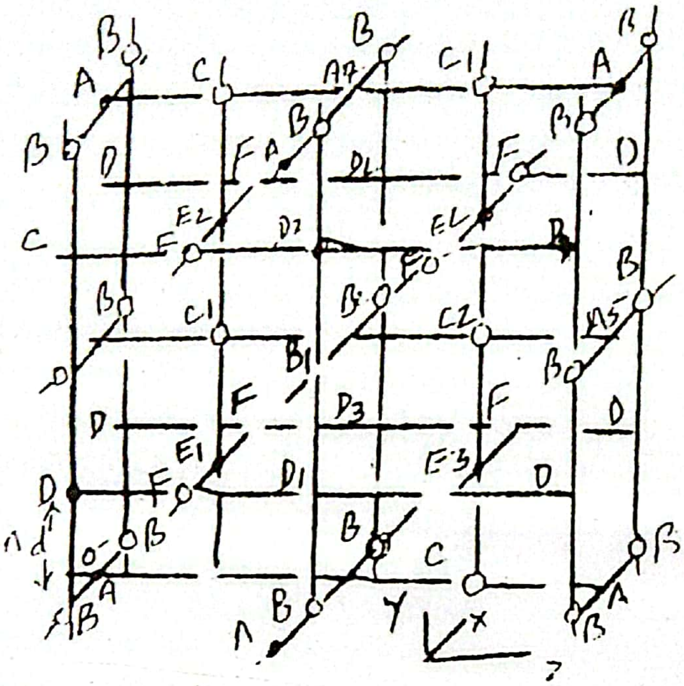


Fig.1 Latice Network

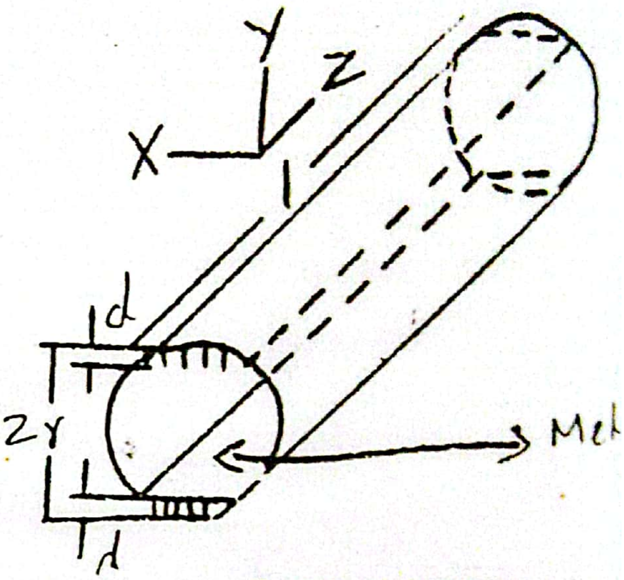


Fig.2 Analyzed Model

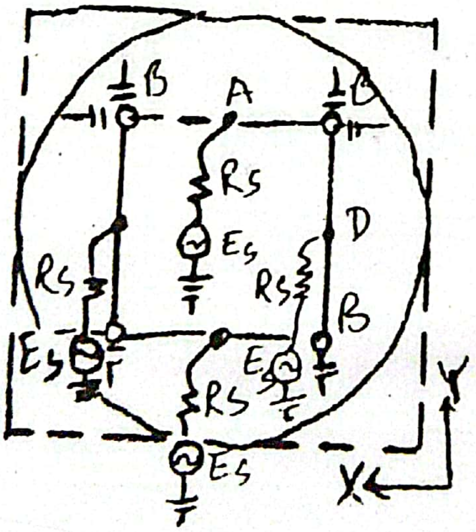


Fig.3(a) Equivalent circuit of the input plane

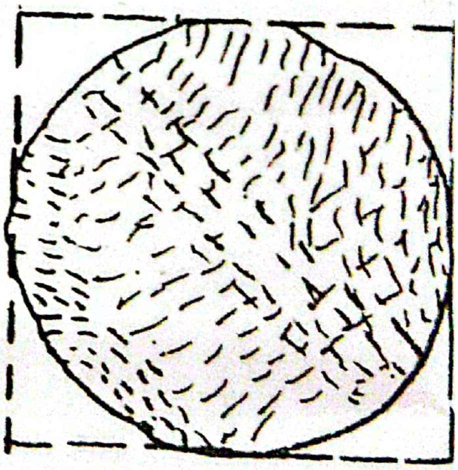


Fig.3(b) Instantaneous Pattern of the Elect
field distribution

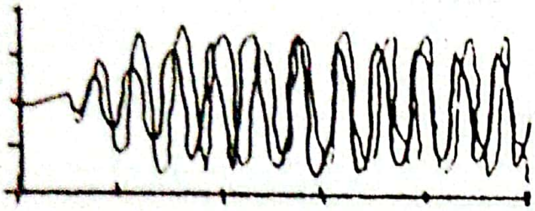


Fig.7(a) Time responses of the electric field components E_x and E_y

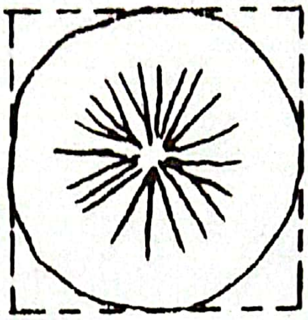


Fig.7(b) Rotation of the electric field E.

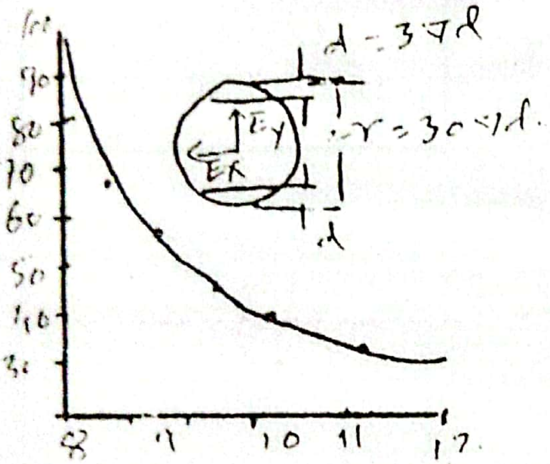
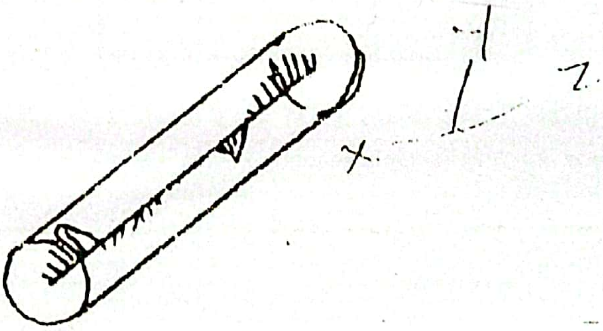


Fig.8 Phase shift constant $(\beta_y - \beta_x)$ for



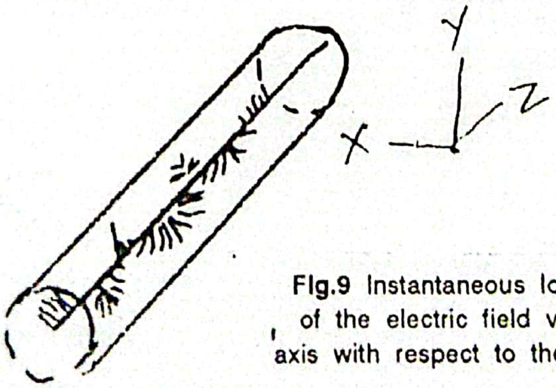


Fig.9 Instantaneous longitudinal distribution of the electric field vector on the content axis with respect to the change of frequency.

Fig.4 Curves of the cutoff wave length λ_{c_x} and λ_{c_y}, as a function of the plate depthed.

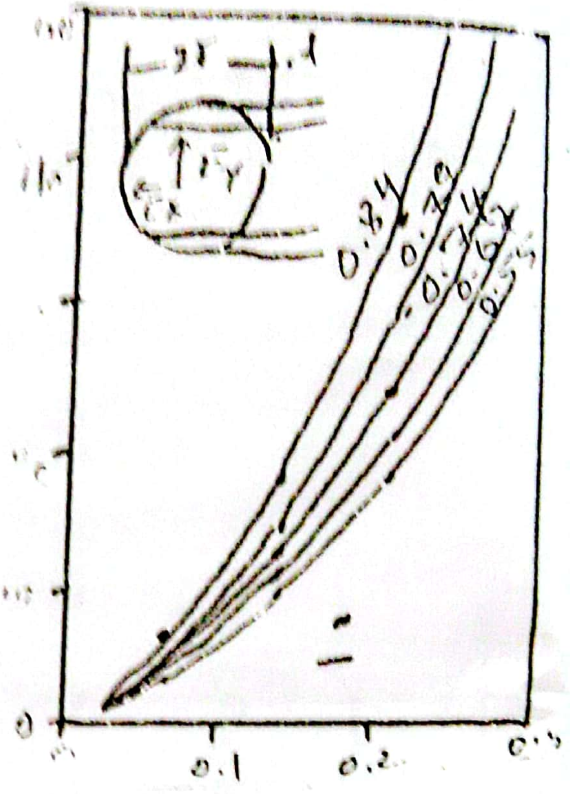


Fig.5 Normalized plate depth (d / r) curves of the shift.

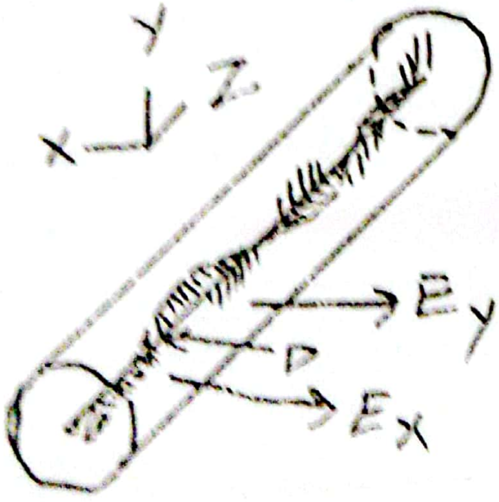


Fig.6(a) Variation of the electric field component E_x and E_y

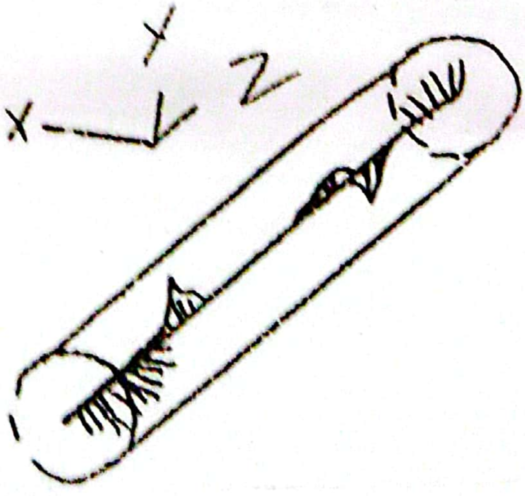


Fig.6(b) Variation of the resultant composite electric field vector E.

Conclusion

Two types of converters to generate a circularly polarized wave from alinearly polarized one were used, those loaded with metal plates in a cylindrical wave guide and those loaded with a fin. The cut off wave length were obtained from the frequency response. The phase shift constants and guide wave lengths were obtained by the spatial and time variations of the electric field distribution. The whole distribution of fields can be seen to provide detailed information on the field properties, such as the local concentration. In particular, the process of generating either a circularly or an elliptically polarized wave from a linearly polarized wave. The fundamental characteristics of the converters agree well with previous analysis.

References

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