CP-generating Waveguide Polarizer Using Multi-Staged Elliptical Cross Sections

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Abstract

In this paper, CP-generating circular cylindrical waveguide polarizer using stepped discontinuities of elliptical interface between two waveguides is investigated and studied in terms of electrical performances such as return loss, radiation pattern, axial ratios, and cross polarization dealing with the purity level in circular polarization. By considering the interconnection of multi-staged waveguides, impedance matching and phase differences of vertical and horizontal electric field inside waveguide have been accomplished with a reasonable generation of circular polarization. The proposed polarizer in this paper is designed to cover the X-band frequency including the link frequency of 8.13GHz in satellite communication. The obtained simulated results show that the proposed polarizer has good characteristics of return loss, axial ratios, and X-polarization level over wide bandwidth.

Keywords : Circular Polarization, Waveguide, Polarizer, Discontinuity

1. Introduction

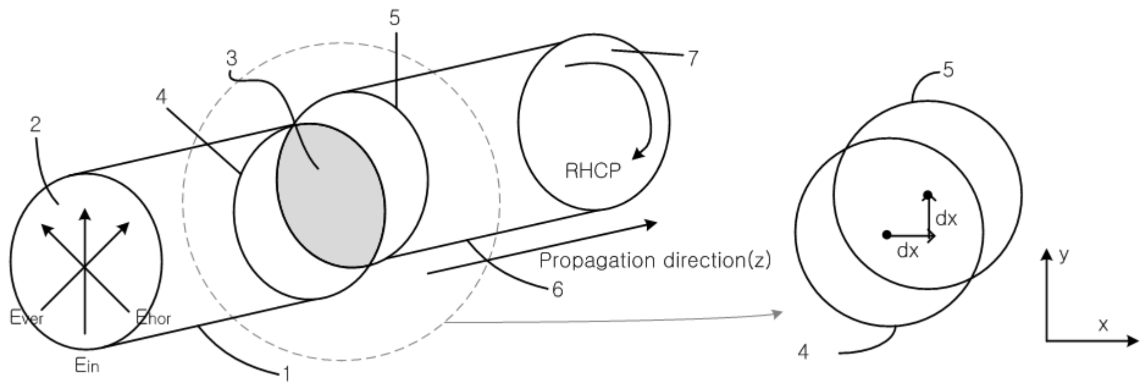
In general, it is well known that antennas suitable for satellite communication have disadvantages of path loss and polarization loss caused by wave diffraction effects of ionosphere and polarization mismatch between transmitting and receiving antennas in a long-distance communication, respectively. In order to avoid the losses mentioned above, high-purity circular polarized antenna is essential for satellite communication antenna. In particular, in high frequency regimes, waveguide-typed antenna is mostly used for high gain, transmission of high power with a small loss, and minimization of radiation loss. From the same reasons, CP-generating waveguide polarizer has been developed by many researchers and various types of septum polarizers having step ridges inside waveguide have been designed and studied by considering the proper combination of TE10- and TE01-modes in rectangular waveguide [1]. In other papers dealing with rectangular waveguide, a bandwidth enhancement and dual band application have been reported by inserting iris discontinuities continuously inside waveguide [2-3]. However, for an application to feeding structure of circular radiator such as circular horn, a transition part with a low loss is required for a smooth power transmission. In addition, manufacturing tolerance of waveguide polarizer adopting a septum is very sensitive to electrical performances as a disadvantage. In order to complement this shortcoming, a study on the CP-generation using circular ridged waveguide has been carried out [4]. According to the other studies, it seems that circular polarization can be generated by inserting an elliptical waveguide with 45-degree rotation between two circular waveguide [5-6]. In this paper, it is verified that an elliptical discontinuity surface can be formed by directly connecting two circular waveguide with a separated distance between the central points of two waveguide and can generate a phase difference of 90 degree between vertical and horizontal electric fields, which leading to a circular polarization in radiation pattern.

2. Design of a Novel Circular Waveguide Polarizer

2.1. In Single Stage

Fig. 1 shows the structure of single-staged circular polarizer having a elliptical cross section at the interface between cascaded two waveguides. The electric field, E_{in} is excited and incident on the input part (denoted by number "2" in Fig. 1) of the first waveguide. Along the waveguide, the incident electric field is modified and affected by the elliptical cross section (denoted by number "3" in Fig. 1) at the interface and transformed into the combination of vertical and horizontal electric fields with a phase difference of 90 degrees leading to a circular polarization. At this time, the central point of the first waveguide (marked by number "4" in Fig. 1) on the elliptical interface has separated distances with that of the second waveguide in x- and y-directions.

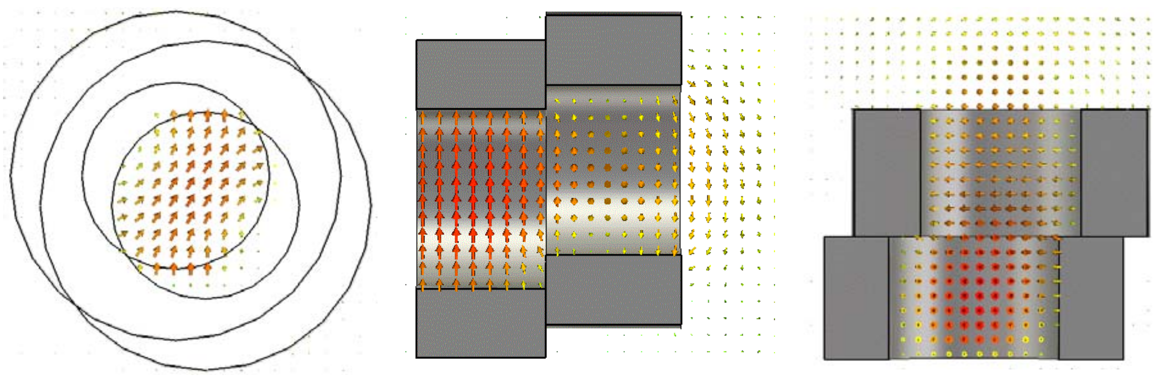
The polarizer shown in Fig. 1 is designed for the bandwidth including the 8.13GHz as a operating frequency and the diameter of the waveguide has been set to be 26mm for the existence of only TE11-mode propagation inside circular waveguide. Especially, an elliptical discontinuous surface is formed by directly connecting two circular waveguide as shown in Fig. 1(a) and (b).



(a) Perspective view of the entire polarizer **(b) Step discontinuity at the interface**

Fig. 1. The inside structure of single-staged circular waveguide polarizer

Fig. 2 depicts the electric field distributions inside circular waveguide-typed polarizer. Especially, Fig. 2(a) shows the field distribution on the elliptical interface with a transparently perspective view. It is observed from Fig. 2(a) that the TE11-mode generated in the input waveguide is rotating in the right-handed direction with 90 degrees of phase difference in the vertical and horizontal electric field due to the abrupt change of waveguide cross section on the interface between two waveguides. For a better impedance matching condition at the operating frequency, the design parameters, dx and dy showing the shifts from the center point into the x- and y-directions on the interface have been optimized. In addition, Fig. 2(b) and (c) show the circular polarized wave propagating along the polarizer at yz- and xz-planes as cutting plane, respectively.



(a) at the interface (b) at the yz-plane (c) at the xz-plane

Fig. 2 Electric field distributions

2.2 In Multi Stage

In section 2.1, we have dealt with the design and field distribution of single-staged circular waveguide polarizer. Even though the designed single-staged polarizer shown in Fig. 1 has a small size of length 34mm relative to the previously designed other polarizers and is not so sensitive to the manufacturing tolerance, the simulated results show a characteristic of the narrow bandwidth. To overcome this problem, the number of discontinuity stage has been increased with a target frequency remained as shown in Fig, 3. For a structural and mechanical stabilization, the entire configuration of the designed multi-staged polarizer has been approximated to a symmetrical structure.

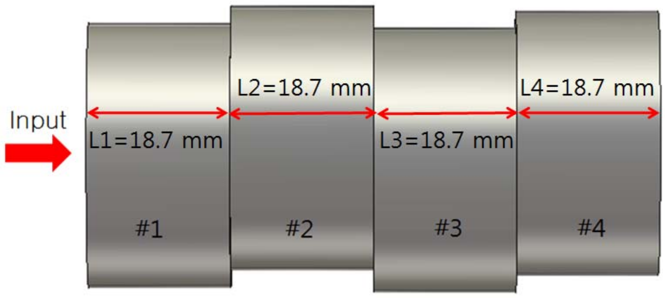
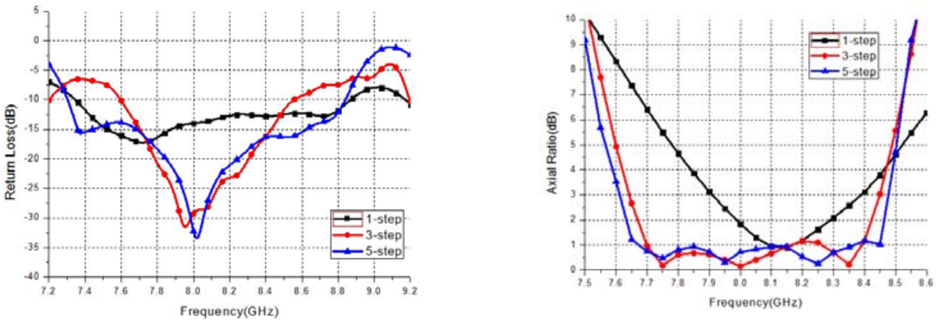


Fig. 3. Side view of three-staged circular polarizer

3. Simulation and Discussion

In a similar way, 5-staged circular cylindrical polarizer has been considered for comparison with a single and 3-staged circular polarizer at the center frequency. Fig. 4 shows the simulated results of return losses and axial ratios in three cases. It is seen from the results that as the stage increases, the electrical performances like return loss and axial ratio become better over wide bandwidth. However, since the difference in performances between three stages and five stages is not so remarkable and the total length of entire polarizer has a size limitation, three staged polarizer has been selected for the target structure.



(a) Return losses according to the number of stages

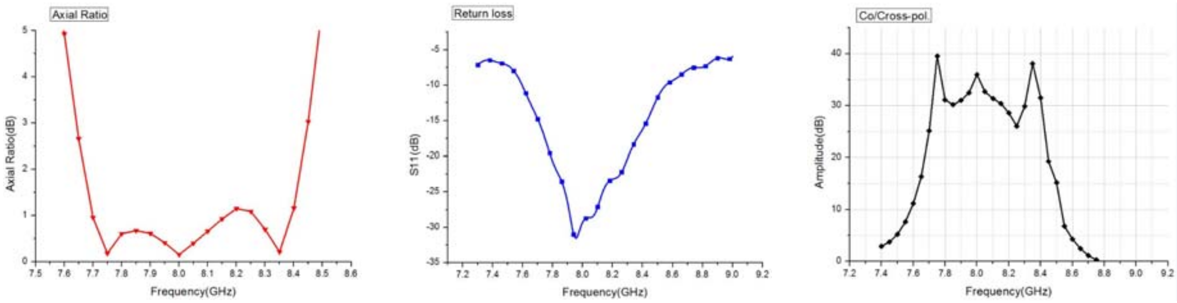
(b) Axial ratios according to the number of stages

Fig. 4 The comparison of polarizer parameters

From Figs. 4 and 5, it is seen that three-staged circular waveguide polarizer has better characteristics in terms of physical size and electrical performances. In Table 1, the optimized parameter values for three-staged polarizer are listed in detail. From Fig. 5, it is observed that the 3dB bandwidth and 15dB bandwidth of axial ratio and return loss are 810MHz covering from 7.64 to 8.45GHz and 730MHz ranging from 7.7 to 8.43GHz, respectively. Lastly, as an excellent characteristic, above 25dB of co/cross-polarization ratio has been achieved within the interested frequency band.

Table 1. The parameter values for multi-staged circular polarizer

Waveguides	Length	Step Discontinuity	dx=dy at the discontinuity surface
#1	18.7 mm	#1 & #2	3 mm
#2	18.7 mm	#2 & #3	3.8 mm
#3	18.7 mm	#3 & #4	2.9 mm
#4	18.7 mm		



(a) Axial ratio (b) Return loss (c) Co/cross-pol. level

Fig. 5. The electrical performances of three staged circular polarizers

4. Conclusion

A novel circular cylindrical waveguide polarizer generating CP has been introduced with a multi-staged section. Especially, the simulated results show that successively loaded elliptical interfaces between waveguides can be used for stably electrical performances over wide bandwidth and easy fabrication in mechanical design. From the return loss, axial ratio, and X-polarization level, it is expected that the proposed polarizer can be adopted for the feeding structure in satellite communication system and the cost reduction can be achieved through an easy design scheme in antenna system.

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