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LOW LOSS TRANSMISSION THREE-LAYER CIRCULAR POLARIZER BASED ON CROSS-METALLIC STRIPS

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ABSTRACT

A low loss transmission three-layer circular polarizer is presented to realize linear-to-circular polarization and minimize the transmission loss at resonance frequencies. The transmission characteristics of double- and three-layer polarizer has been comprehensively investigated and improved at frequency bands. The new approach of designed three-layer circular polarizer is introduced for Ku-band applications. The circular polarization purity and transmission loss has been important issue for the researchers in the field of microwave; therefore significant techniques are employed to improve the transmission loss with good circular polarization at resonant frequencies. The infinitely unit cell of three-layer polarizer is composed of three metallic strips, which are tilted at and angles at xoy-direction respectively. The simulation results demonstrate that the transmission loss of -0.06 dB is obtained at 14.11 GHz.

Key Words: Circular Polarization, Fabry-Perot Interferometer, Frequency Selective Surface (Fss), Double- And Three-Layer Circular Polarizer, Quarter Wave Plate.

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1. INTRODUCTION

Polarization is a basic characteristics of microwaves because of the inherent polarization sensitivity, which attracts more interest of researchers (Hao J,et.al, 2007). Now a days, circular polarization have lot of applications in field wireless and microwave devices because of the unique characteristics e.g., atmospheric absorption, multipath and lower susceptibility. The polarization conversion transmission is highly desirable for the researchers in the practical application.

Quarter wave plate is an efficient approach that converts linear-to-circular polarized wave or vice versa (D. Lerner.ety, al, 1965 Frequency selective surfaces (FSSs) are also employed linear-to circular polarization converter and filter (B. A. Munk, et.al, 2000). FSSs are considered as EM filter that transmit circularly polarized wave over desired frequency bands under the projection of EM wave (B. A, et.al, 2000).].Moreover, many other approaches are adopted to convert linear-to-circular polarization state and cross-polarization conversion reported in (P. Ginzburg, 2013).

The important issue of transmission loss and circular polarization purity of polarizer converter has aroused the attention of the researchers; for instance, it can be noted in the reported published work (G. I. Kiani,2010), the low loss transmission of structure was demonstrated 6 dB at 75 GHz for different applications. The previous an efficient approach of Fabry-Perot Interferometer was introduced to construct double-layer FSS circular polarizer for improving the transmission loss (A. C. De, C. Lima and E. A. Parker, 1996). Another recent approach is adopted to improve transmission loss of circular polarizer which has minimized 0.3 dB at 70 GHz (Gaffer Kiani, 2012). Currently, most of structures possess poor transmission efficiency with narrow bandwidth performance at operated frequencies. Therefore, research is needed to improve transmission loss with circular polarization purity and overcome presented issues.

In this paper, the proposed structures using single- double- and three periodic metallic strips (PECT) demonstrate linear-to-circular polarization conversion. The presented approach is adopted to realize circular polarization with low loss transmission at operated frequencies. (N. Yu, et.al, 2012). The incident x-linearly polarized wave is applied normally as excitation source along +z direction, which can be decomposed into two orthogonal vector components propagating with different velocities. The designed structures with different periodic parameters and dimensions in each layer are employed to transmit linear-to-circular polarization at distinct resonant frequencies (A. C. De, C. Lima and E. A. Parker, 1996).

The transmitted decomposed linearly polarized wave has nearly equal magnitudes and phase difference is satisfied around resonance frequencies. In this study, the designed techniques to construct various proposed structures are well described. The numerical simulation results are comprehensively analyzed and demonstrated the characteristics of structures. Our designed structures have several advantages compared most of the reported structures, such as, easily designing process, minimum transmission loss, circular polarization purity, simple structure(L. Wang,et.al,2014).

2. DESIGN AND PROCESS

The design structures of circular polarizer's that is composed of single, double, and three- layers are shown in Fig.No.1, 2 and 3. The unit cell configuration are slanted 45^o and - 45^o along XOY plane. The length of single strip is l and wide w. The periodic boundaries conditions are $p_x$and p_y respectively.

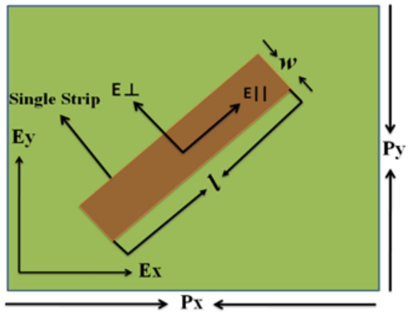


Figure 1: The schematic of single-layer circular polarizer

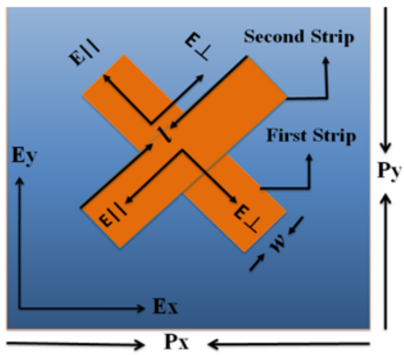


Figure 2: The schematic view of double-layer circular polarizer

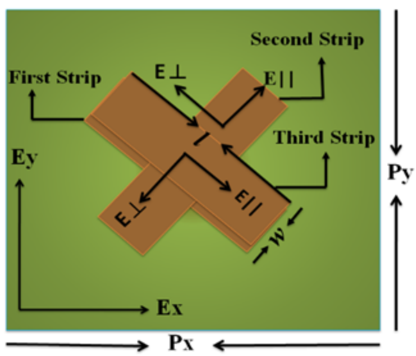


Figure 3: The schematic view of three-layer circular polarizer

3. SIMULATION OF MODELS

The proposed structures convert linear-to-circular polarized wave when structures are illuminated by x- polarized wave along +z direction. The periodic boundaries are selected in xoy sides. Thelinearly polarized wave is applied for cross polarization conversion transmission. The numerical simulation process of single-, double and three-layer circular polarizers are mentioned in Figure.4, 5 and 6, respectively.

The geometrical parameters of constructed structures are as follow. The single-layer structure parameters arew = 3.6 mm, $l = \lambda/4$ = 7.5 mm, p_x = 13 mm and p_y = 13 mm. The structure parameter of double-layer polarizer are to bew = 3.6 mm, $l = \lambda/4$ = 7.5 mm, r = 7.4 mm, p_x = 16.3 mm and p_y= 16.3 mm. The each strips parameter of three-layer circular polarizer's are selected asw = 3 mm,r = 9.3 mm, $l = \lambda/4$ = 7.5mm, and p_x = 30 mm and p_y = 30 mm.

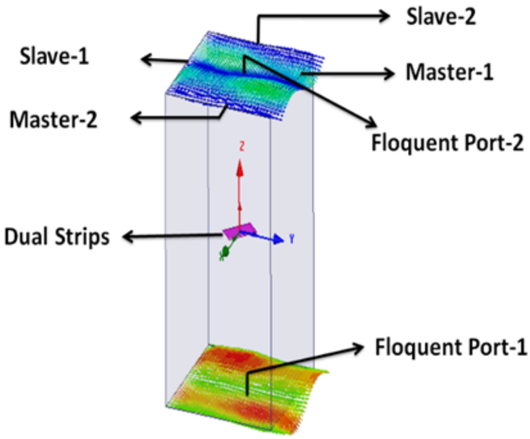
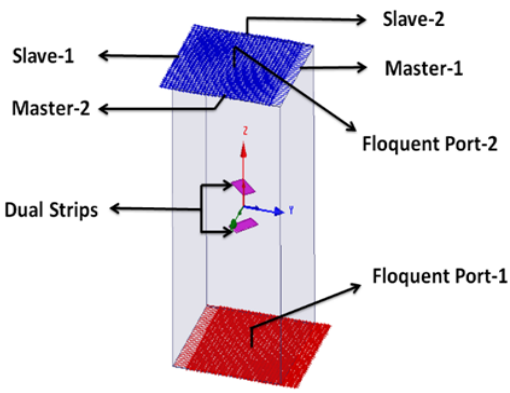


Figure4: Simulation model of single-layer circular polarizer



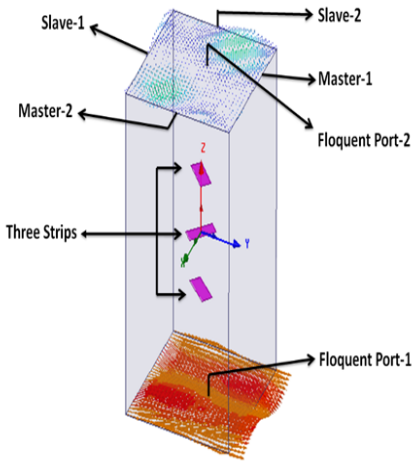


Figure6: Simulation model of three-layer circular polarizer

4. RESULTS & ANALYSIS

In this communication, the proposed circular polarizer's based on single- double- and three-layer periodic metallic strips are efficient in polarization transformation. In addition, the presented novel design of three-layer circular polarizer performs more efficiency of polarization transformation and has great characteristics of low loss transmission at frequency bands.

The proposed three-layer circular polarizer is based on three-layers periodic metallic strips oriented along xoy direction. The presented novel design of three-layer circular polarizer is excited by x-linearly polarized wave along floquent port-1 and linearly polarized wave decomposed in to two orthogonal vector components with equal amplitudes with phase difference is satisfied between two transmitted wave. Our designed structures realize the conversion of linear-to-circular polarization under normal incidence on the surface of structures along +z direction. The fractional axial ratio expression follows as expression.

$$\text{Minor Axis} = \sqrt{\frac{1}{2}\left[E^2_X + E^2_Y + \sqrt{E^4_X E^4_Y + 2E^2_X E^2_Y Cos2\phi}\right]} \quad (1)$$

$$\text{Major Axis} = \sqrt{\frac{1}{2}\left[E^2_X + E^2_Y - \sqrt{E^4_X E^4_Y + 2E^2_X E^2_Y Cos2\phi}\right]} \quad (2)$$

Where ϕ is phase difference and the axial ratio $= \frac{\text{Minor Axis}}{\text{Major Axis}}$

The outcome two orthogonal linearly polarized wave of E_x and E_y with equal magnitudes ca be expressed as.

$$E^T(t) = \hat{x}\, E_x^T(t) + \hat{y}\, E_y^T(t) \quad (3)$$

$$E_y(t) = \hat{M}y \cos(\omega t - Kz + \delta) \quad (4)$$

$$E_x(t) = \hat{M}x \cos(\omega t - Kz) \quad (5)$$

The designed structure realizes the circular polarization with efficiency of polarization transmission because the orientations and distance between implemented periodic metallic strips are efficiently adjusted. The simulation process is used to analysis the characteristics of structures and calculated the axial ratio corresponding to phase differences of transmitted waves.

The calculated axial ratio between transmitted wave Ex and Ey of single-layer circular polarizer is 1.0 at the 14.03 GHz as shown in Fig.7. The pass band is extended from 13.96-14.19 GHz.

$$\Delta\phi = \phi_y - \phi_x = \begin{cases} +\left(\frac{1}{2} + 2n\right)\pi, n = 0,1,2,\ldots\ldots \\ -\left(\frac{1}{2} + 2n\right)\pi, n = 0,1,2,\ldots\ldots \end{cases} \quad (6)$$

The calculated axial ratio of single-layer circular polarizer is 1.0 at the 14.03 GHz as shown in Fig.7 that is equal to the phase difference between transmitted wave Ex and Ey. The pass band is extended from 13.96-14.19 GHz.

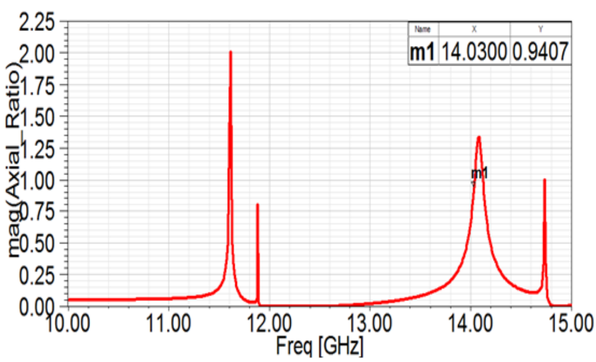


Figure 7: Simulated axial ratio versus frequency of single-layer.

The polarization transmission loss can be observed of single layer polarizer where the transmitted orthogonal components are same at the 14.03 GHz and transmission achieved about -3.6 dB as denoted in Figure.8.

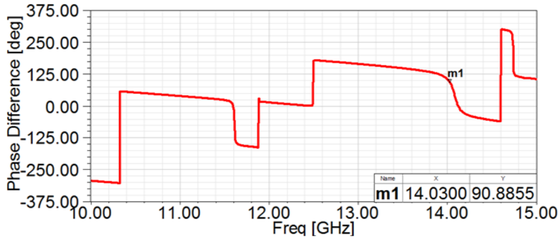


Figure 8: Transmission Loss of E-field versus frequency of single-layer circular polarizer.

The phase difference between two linearly transmitted waves is required to achieve perfect circular polarization. Whereas, the phase shift of two orthogonal components Ex and Ey is at the 14.03 GHz as depicted in Fig. 9

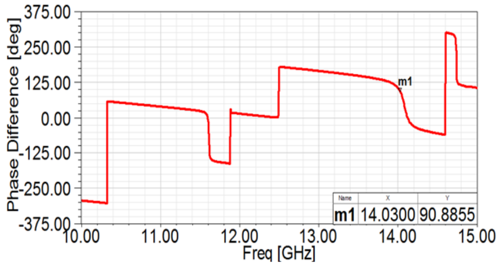


Figure 9: Phase difference of E-field versus frequency of single-layer circular polarizer

The single-layer circular polarizer composed of single metallic strip tilted at 45^{o} is -3.6 dB at 14.03 GHz as denoted in Fig. 8. While, the calculated fractional axial ratio of 1.0 with respect to phase shift at 90.8^{o} transmitted frequency. Meanwhile, it is possible to improve transmission loss of single layer polarizer by adding another strip by increasing the width w = 2 mm of each strips at angle at the distance -9.3 along xoy-direction respectively.

The double-layer combination of circular polarizer transmits circularly polarized wave under the incidence of linear polarized wave in order to improve the transmission loss at 14.03 GHz. The calculated fractional axial ratio is achieved of 1.1 at 12.7 and 1.3 at 14.07 GHz as shown in Fig. 10. The pass band extended from 12.70-12.80 GHz and 13.92-14.16 GHz.

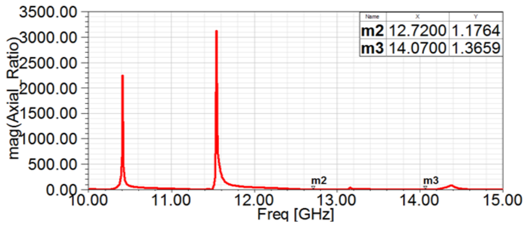


Figure 10: The axial ratio of transmitted wave versus frequency of dual-layer circular

polarizer

The transmission coefficients of double-layer circular polarizer are presented in Fig. 11. The structure generates the transmission of co- and cross-polarization under the normal incidence. The transmission magnitude from the dual layer polarizer indicates the transmission loss of -3.7 dB at 12.7 GHz, and -1.8 at 14.07 GHz as mentioned in Fig.11 which has been minimized as compare to single layer polarizer.

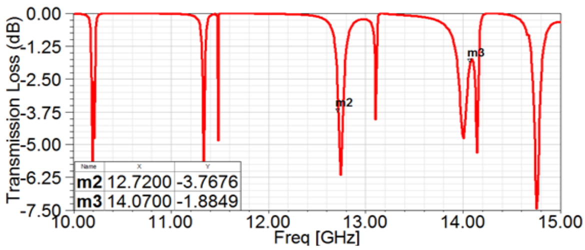


Figure 11: Transmission loss of E-field versus frequency of dual- layer circular polarizer

The phase difference of is noticed at 12.7 and at 14.07 GHz corresponding to fractional axial ratio of double-layer polarizer as denoted in Figure.12.

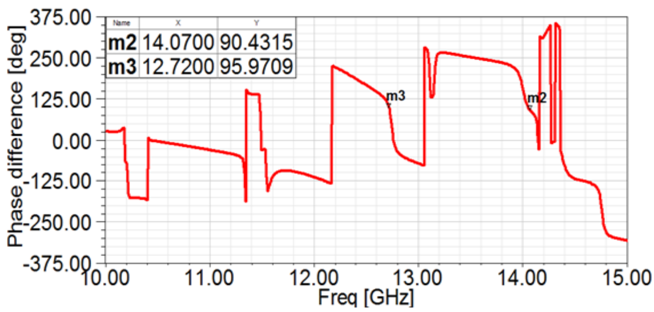


Figure 12: Phase difference of E-field versus frequency of dual- layer circular polarizer.

The low loss transmission and passband of three-layer circular polarizer has been improved significantly by changing some parameter as discussed in previous section [4]. Three layer strips combination operates good circular polarization at transmitted frequency. The fractional axial ratio is calculated as 1.5 corresponding to phase difference of at 14.11GHz and pass band ranging from 13.71–14.13 GHz which is better than single and dual layer polarizer as denoted in Figure 13.

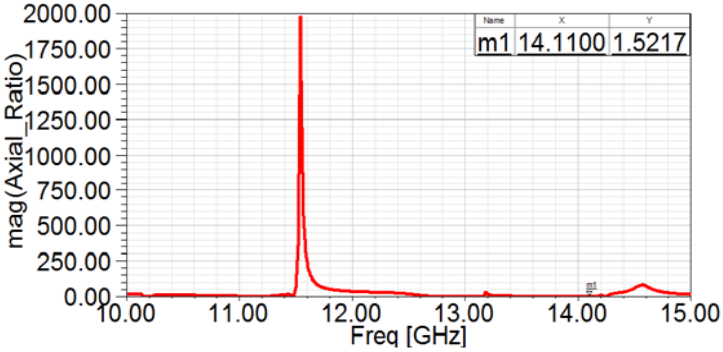


Figure 13: The axial ratio versus frequency of three-layer circular polarizer.
It is noticed that the transmission loss and pass band of three layer polarizer has been improved than single and dual layer polarizer by adding three layer of strip. The structure demonstrates the transmission loss of -0.06 dB at the 14.11 GHz which is better than reported work as represented in Figure 14.

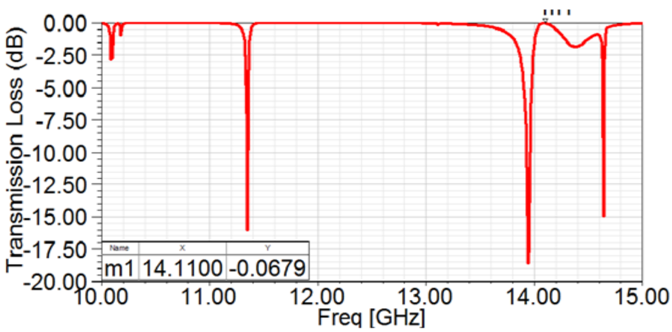


Figure14: Transmission loss of E-field versus frequency of three- layer circular polarizer.
The phase shift between transmitted wave E_X and E_y is to be 900.3 at the 14.11 GHz to realize linear-to-circular polarization as depicted in Figure 15.

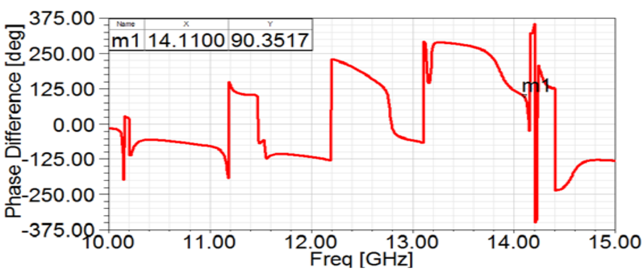


Figure 15: Phase difference between transmitted waves versus frequency of three-layer

circular polarizer

5. DISCUSSION

The polarization transmission of single-, double- and three-layer circular polarizers is comprehensively analyzed and investigated the linear-to-circular polarization transmission at frequency bands. In Fig.8, the transmission loss is noticed -3.6 dB at transmitted frequency of 14.03 GHz and pass band extended from 13.96-14.19 GHz as shown in Fig. 7. Meanwhile, when we extended other layer of mantellic strip in Fig. 11. As we can observe that the improvement of transmission loss which has been minimized -1.8 dB at 14.07 and band pass extended from 13.92-14.16 as shown in Figure 10.

Observing the optimal performance and transmission amplitude for circularly polarized waves of three layer structure and comparative analysis is presented. In Fig. 14, the transmission loss of three layer structure is observed -0.06 dB at 14.1 GHz and pass band is also improved which extended from 13.71–14.13 GHz which is quite better than single and dual layer structures. The interesting features of designed structure of three-layer of circular to realize linear-to-circular polarization. The presented structure demonstrates the transmission of outcome linearly polarized wave that are obtained same at 14.11 GHz. The phase difference between transmitted are to be and purity of circular polarization is obtained with low loss polarization transmission -0.06 dB.

CONCLUSION

In summary, the various designs of single- double- and three-layers structures are constructed to realize linear-to-circular polarization. Whereas, the presented three-layer circular polarizer demonstrates the transmission characteristics. The efficient design techniques are introduced to design simple structures of circular polarizer's for microwave applications. The pronounced techniques are introduced to construct linear-to-circular polarization converters for desired micro wave applications. Furthermore, the introduced efficient techniques can be used to improve the bandwidth and low loss transmission of structures by varying significant parameters, e.g., length and width of periodic strips, by using multi-layers of strips, thickness and adjustment of distance between layers.

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