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Bandwidth-Enhancement of Low Profile Frequency Selective Surface Dual Layer Circular Polarizer

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Abstract This paper presents a low profile transmission type dual layer circular polarizer to obtain circular polarization for X-band applications. The FSS Polarizer is composed of two layers tilted at 45^0 along x, y-directions. In this research, significant technique is employed to obtain optimal bandwidth around resonant frequencies. Bandwidth widening with low loss transmission through the polarizer have been an important issue for researchers; therefore significant technique is employed to improve bandwidth widening of polarizer at operated frequencies. The simulation result shows that a right handed circular polarization (RHCP) and a left handed circular polarization (LHCP) are achieved at the resonant frequencies of 9.28 GHz and 11.23 GHz. The proposed structure achieves good circular polarization with low loss transmission and AR axial ratio is found between 9.14 GHZ and 11.58 GHZ i.e. 23.55% bandwidth.

Keywords: circular polarization, dual layer polarizer, Frequency selective surface (FSS), quarter wave plate, resonance

1. INTRODUCTION

The microwave communication system, radar, tracking system and wireless communication system circular polarization have great importance because a circular polarization possesses the lower susceptibility to the reflection effects, atmospheric absorption and multipath. The circular polarization of waves is widely used in Satellite Communications Systems, Global Positioning System (GPS), and Radio Frequency Identification (RFID). There are several techniques existing to generate circular polarizations (Balanis, 2005). Frequency selective surfaces (FSSs) are also used as polarizers, polarization transformer, filters, band-pass hybrid radomes for radar cross section (RCS) controlling (Carl and Grbic 2013), (Munk, 2000). (Kiani, *et al.*, 2006.) (Kiani, *et al.*, 2007) (Strikewerda 2009) (Karkkainen, and Stuchly, (2002) due to contributing overall stable performance for different incidence angles, polarization states and offering the simple fabrication. FSSs are known as spatial electromagnetic filters which show transmission over a required frequency band to an incident electromagnetic wave (Winkler, *et al.*, 2009). The previous FSS polarizers were designed on the basis of cross dipole structures and fabricated for high frequency applications.

The bandwidth widening through the polarizer is an important issue in the field of wireless communication system. Euler achieved axial ratio bandwidth of 0.5% with -3.2 transmission loss of polarizer (Euler *et al.*, 2006). Masa-Campos used the double-layer polarizer approach to obtain circular polarization in order to operational bandwidth of 5.7% Masa *et al.*, 2009 observed the transmission loss 6 dB with narrow band and 1.0 axial ratio through polarizer at 75 GHz Kiani *et al.*, 2009. introduced single layer transmission polarizer with Jerusalem cross FSS design in which bandwidth performance of 3.4% and transmission loss 3.1 dB was found at 17.8 GHz (Irfan *et al.*, 2013) Currently, the FSS circular polarizers have narrow bandwidth performance with poor efficiency of transmission; therefore research is needed to improve the bandwidth performance with low loss transmission of polarizer to achieve perfect circular polarization.

In this study, the innovative technique of low profile dual layer FSS circular polarizer is proposed that is quite different from previous several published contribution. The most significant feature of this proposed designed model by using optimization techniques to achieve the best results of FSS circular Polarizer. The proposed designed model has several advantages over at present available dual layer circular polarizes, such as, large bandwidth, good circular polarization, simple structure, high polarization efficiency, low loss transmission, and easily fabrications.

2. DESIGN PROCESS & SIMULATION

The schematics structure of dual layer polarizer is composed of two metallic strips grounded on two dielectric substrates and oriented at 45^0 along the x-y direction, respectively separated at the distance $\boldsymbol{r}$ from each other. The length of single layer structure $\boldsymbol{l}$ and wide

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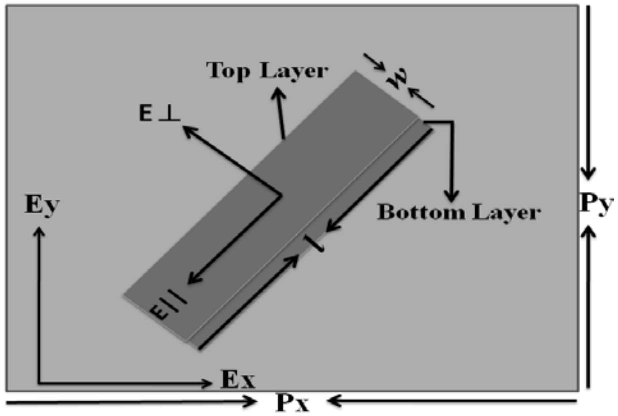

Fig. 1. The dimensions of the dual layer with electrical field orientation.

w. The thickness and relative permittivity of the dielectric substrate are t and ξ_r respectively. Whereas, perfect electric conductor (PEC) is assigned to the strips. The periods in x- and y- direction are P_x and P_y, respectively.

In simulation setup, x-polarized wave incidents on metallic strips as excitation source through floquent port one and unit cell boundary conditions are applied. Unit cell of dual layer structure is composed of two rectangular PEC strips that are grounded on dielectric substrate. In **(Fig. 2),** the dielectric substrate Roger RT/Duriod 5880(tm) with relative permittivity 2.2 is assigned for two substrate sheets on which couple of layer is mounted. The structure parameters of polarizer are selected as ***l*** = 11 mm, ***w*** = 3.74 mm and **P*x*** = 22.6 mm and **P*y*** = 22.6 mm, t =0.508 mm and ξ_r =2.2 respectively.

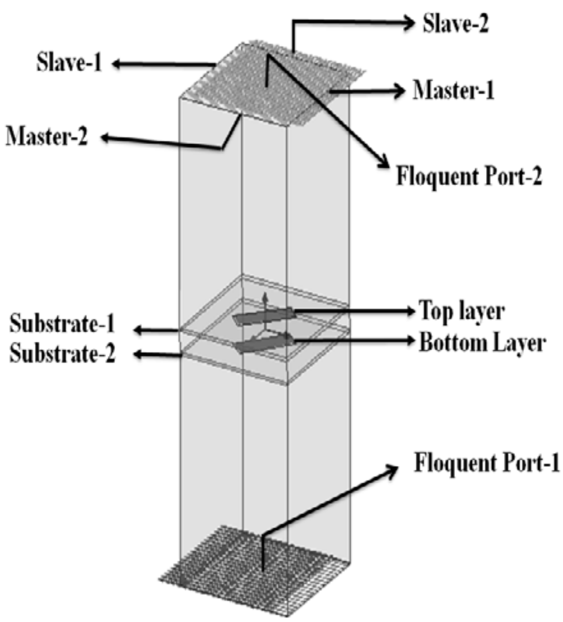

Fig. 2. Simulation model of dual layer polarizer

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3. RESULTS AND DISCUSSION

The transmitted output E field through the strips can be decomposed in to two orthogonal linear electric field vector components (E|| and E⊥) with equal magnitude. After EM waves passing through polarizer, the phase difference 90^0 and axial ration 1.0 between two **t**ransmitted orthogonal components (E^T|| and E^T⊥) can be produced and satisfied with perfect circular polarization.

$$\Delta\phi = \phi y - \phi x = n\pi, \text{ Where n = 0, 1, 2} \quad (1)$$

The E field decomposed in two orthogonal components of Ex and Ey having equal magnitude.

$$\mathrm{E}(t) = \hat{x}E_X(t) + \hat{y}E_Y(t) = \tilde{E} = \hat{x}\tilde{E}_X + \hat{y}\tilde{E}_Y \quad (2)$$
$$E_x(t) = mx\cos(\omega t - Kz)$$
$$E_y(t) = my\cos(\omega t - Kz + \delta)$$

Where k is the wavenumber, ω is the frequency, t is time, and δ is the phase offset between the two waves.

$$\mathrm{q} = |E_x|/|E_y| \text{ In other word}$$
$$|E_x|\,.\,\mathrm{T}^x = |E_y|\,.\,\mathrm{T}^y \quad (3)$$

Here, axial ratio q = ⊂ [1] and T^X and T^Y are transmitted amplitude of E_X and E_Y which explains the minor to major axis ratio of the circular polarization

$$\lceil ang\,(E_y) + ang\,(T^y)\rceil - \lceil ang\,(E_x) + ang\,(T^x)\rceil = \pm\frac{n\pi}{2} \quad (4)$$

Where n = 1, 2, 3,

It is assumed that the transmission of E field Ex and Ey components possess equal phase and magnitude that need for the circular polarization

$$|\mathrm{T}^x| = |\mathrm{T}^y| \quad (5)$$
$$\lceil ang\,(T^y)\rceil - \lceil ang\,(T^x)\rceil = \pm\frac{n\pi}{2} \quad (6)$$

Eventually, circular polarization emerges when two orthogonal components of E field $E^T\|$ and $E^T\perp$ having equal magnitude and 90° phase difference to produce circular polarization.The large bandwidth achieving over the operating bands depend on the key parameters in T and LHCP waves transmitted because the orientation of couple layer. he resonance mechanism of proposed layer structures can understand by explaining the surface current distributions on the top and bottom layer. The parallel currents flowing on the single and dual strips which indicated the modes of symmetric current

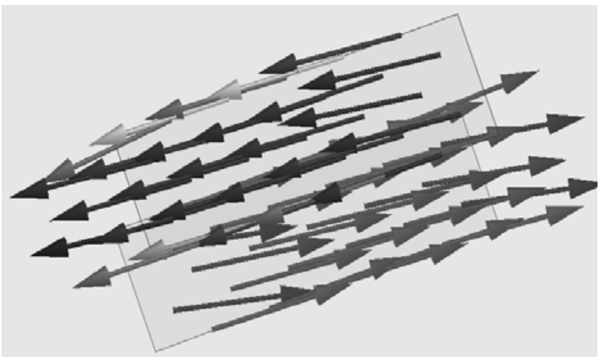


Fig. 3. The surface current distribution of top layer and bottom layer structure at 9.28 GHz for RHCP wave and 11.23 for LHCP wave. The linear arrows represent the surface current distribution and direction of polarized waves

resonance around the transmitted frequencies. The surface current distribution on the top and bottom layer of dual polarizer for RHCP wave at 9.28 GHz and LHCP

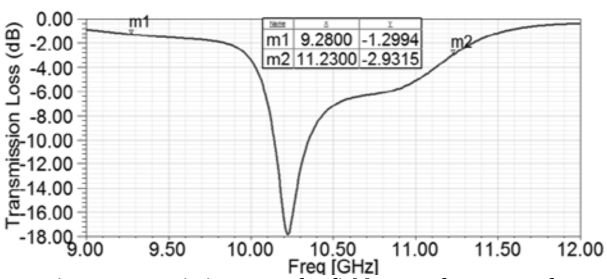


Fig. 4. Transmission Loss of E-field versus frequency of dual layer Polarizer

wave at 11.23 GHz is noticed between 9.14 GHZ and 11.58 GHZ bandwidth, respectively as shown in **Fig 3**.

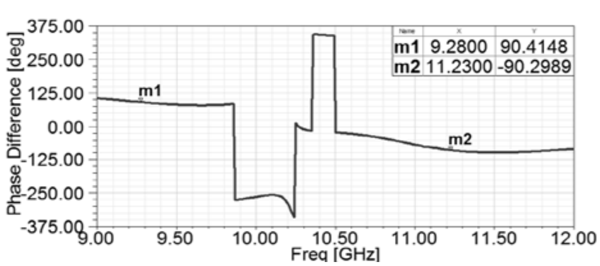


Fig. 5. Phase difference of E-field versus frequency of dual layer Polarizer

The transmission loss of E component of Ex and Ey in dB are -1.2 dB at 9.28 GHz and -2.9 dB at 11.23 GHz is found respectively as shown in **Fig. 4**.

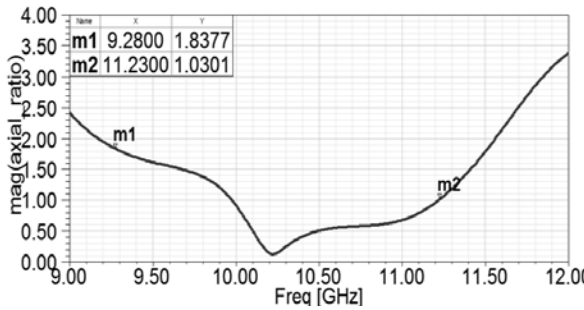


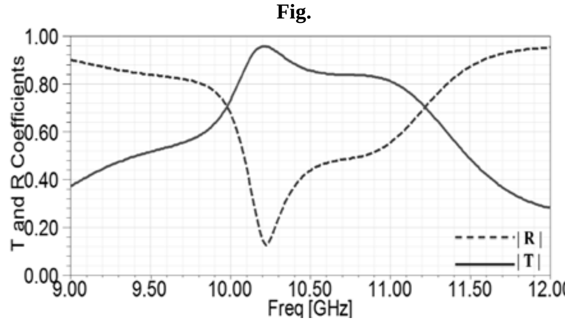
Fig. 5. Phase difference of E-field versus frequency of dual layer Polarizer

The phase shift of E-field is obtained 90^0.4 and -90^0.2 around the resonant frequencies of 9.28 GHz and 11.23 GHz, respectively as shown in **Fig.5.**

The transmission axial ratio between two orthogonal components is achieved 1.8 at 9.28 GHz and 1.0 at 11.23 GHz and bandwidth axial ratio is deduced (9.14 GHZ-11.58 GHZ=3.55% bandwidth) as shown in **Fig. 6**

The reflection and transmission modes of E-field through dual layer polarizer is obtained in order to S11:S21 and S11:S22 as shown in **Fig. 7.**

Fig.



7.

The transmission and reflection efficiency of E-field

The most significant feature of this proposed designed model by using optimization technique to achieve good circular polarization and bandwidth widening with low loss transmission of FSS circular Polarizer.

The simulation results of dual layer polarizer show two transmission resonant frequencies f1= 9.28 GHZ, f2= 11.23 GHZ for RHCP and LHCP wave, respectively. The optimal axial ratio bandwidth is obtained around resonant frequencies 9.14 GHz -11.58 GHz = 23.55% bandwidth as shown in Fig. 6

4. CONCLUSION AND FUTURE RESEARCH WORK

In this paper the research is carried out to investigate the transmission characteristics, broadband and good circular polarization with low loss transmission of dual layer polarizer around the resonant frequencies. The designed model of polarizer is quite simple and can be easily fabricated. By using this efficient technique, circular polarizers can be designed for millimeter, micrometer and terahertz frequencies according to desired applications. In future, the research can be carried out to design and optimize such polarizers based on frequency selective surface to enhance the bandwidth and minimize the transmission loss. Nevertheless, it could possible to improve the bandwidth performance of three layer polarizer by changing some parameters, such as by extending the dipole layers, increasing or decreasing the length of each strips, adjusting the distance between layers and thickness of the layers. design of dual layer polarizer; for instance, the length of strips, small thickness of substrate, orientations of layers and specific boundaries conditions, respectively. When x-polarized wave incident on bottom layer through floquent port one +Z-direction produce resonance on the layer and RHCP

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