Sindh Univ. Res. Jour. (Sci. Ser.) Vol.49(2) 421-424 (2017)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Compact Four-Band Asymmetric Bi-Layer Circular Polarizer

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Received 10th April 2016 and Revised 12th December 2016

Abstract: A compact four-band Asymmetric bi-Layer circular polarizer is presented based onH-shape split ring resonator. The proposed structure exhibits the four-band asymmetric transmission (AT) of circular polarization with low loss transmission. Compact four-band Asymmetric bi-layer circular polarizer converts impinged x-polarized wave to obtain left-handed circular polarized (LHCP) waves at 32.80 GHz and 37.52 GHz and right-handed circular polarized (LHCP) waves at 34.40 GHz and 39.50 GHz. The proposed structure rigorously satisfies the AT and realizes the cross-polarization conversion with high efficiencies at distinct resonant frequency bands.

Keywords: Circular Polarization, Bi-Layer Circular Polarizer, Electric Field, Magnetic Field,

1. INTRODUCTION

Controlling and manipulating electromagnetic polarization state has long been a concern in many applications Wu *et al.,* 2014) Polarization is highly desirable in reflection, transmission, and absorption of EM waves. Circular polarization (CP) has always attracted the considerably great interest of researchers in wireless and satellite communication. Currently, research is carried on polarization rotation and designing of different types of cross-polarization convertors.

The structure was proposed to improve the bandwidth from 4.6% to 7.2% at operating frequencies (Xi-Cheng *et al.,* 2014) The chiral met material based on bi-layer structure was introduced to achieve triple-band asymmetric transmission (Zhimou and Yang, 2015)

The three-layer of periodic array design based on the frequency-selective surface was proposed (Mingbao *et al.*, 2016). The new design of tri-band cross-polarization converter was presented to achieve tri-band cross-polarization conversion (Shi, *et al.,* 2014). Another concept of the bi-layeredstructure was introduced to realize the asymmetric transmission. The structure constructed of double-gap split- ring resonator was introduced to possess the large extension ratio of 18 dB at four bands (Yuan, *et al.*, 2014) . The designed dual-band structure was introduced to feature high conversion efficiency (Yong *et al.,* 2014). A circular polarizer composed of bi-layered asymmetrical split ring resonator to convert RHCP wave and LHCP wave (Cheng, *et al.,* 2014) The bi-layer twisted circular polarizer was proposed to achieve ultra-wide band transparent polarization conversion (Hongya *et al.,* 2016) . Recently, the reported structure based on non-twisted Q-shape transforms RHCP wave and LHCP wave (Hailin *et al.*, 2016) . In this paper, a compact four-band asymmetric circular polarizer based on bi-layer H-shape split ring resonator is presented to achieve four broadband at resonance frequencies. The transmission efficiency of co- and cross- polarization is investigated at distinct resonance frequencies. To understand the mechanism of strong circular dichroism (CD) effect and behavior of asymmetric transmission, the surface currents distribution on the both sides of the structure is illustrated. The surface currents distribution is illustrated to demonstrate the high polarization conversion efficiency. In addition, our designed structure transforms the RHCP waves and LHCP waves after the incidence of the electric field. The good advantages of this design are obtained, such as easy fabrication, compact size, simple structure and high transmission efficiency. The proposed structure is very advantageous in many applications such as compact size sensors and electrically small antennas.

2. DESIGN AND GEOMETRY OF STRUCTURE

(Fig. 1) shows the designed structure of four-band asymmetry bi-layer structure. It is composed of two same size metallic layers which are patterned on the both interfaces of the substrate. The top and bottom printed metallic layers are tilted at 45º in opposite direction along xoy directions. The substrate Roger RT/duroid 5880 is selected with relative permittivity ε_r

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and thickness. The length and the width of the structure are represented by l_1, l_2, l_3 and w_1, w_2. The gap is denoted by g_1, g_2, g_3. The px and pyare periods in x and y sides. The selected parameters are as ε_r=2.2 with loss tangent of 0.0009, t = 0.787 mm, g_1 = 0.14mm, g_2 = 0.23mm, g_3 =0.07 mm, l_1 = 1.13 mm, l_2 = 2.26 mm, l_3 = 1.41 mm, w_1 = 0.35 mm, w_2 = 0.35 mm, px = 5mm and py = 5 mm. The unit cell boundaries and floquet ports are assigned. The controlling operating resonance frequencies depend on the geometry scalability of the structure. The thickness of the substrate is an important parameter in coupling between two SRR. Here, the selected thickness 0.787mm is carefully assigned with a combination of gap and size of the printed metallic layers which control the resonance frequencies of the polarizer.

The designed structure is composed of 3x3 arrays as shown in **(Fig. 1(b)).** The overall area occupied by the structure of 15mm × 15mm. The periodic boundary conditions are applied to the designed model.

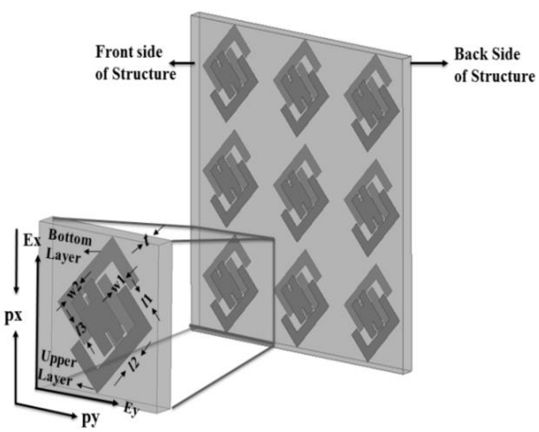
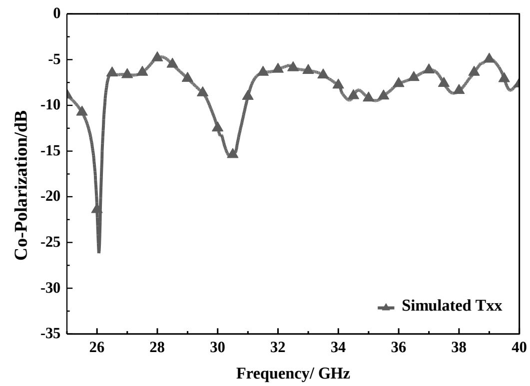


Fig. 1. Geometry of the unit cell and compact four-band circular polarizer based on 3x3 array

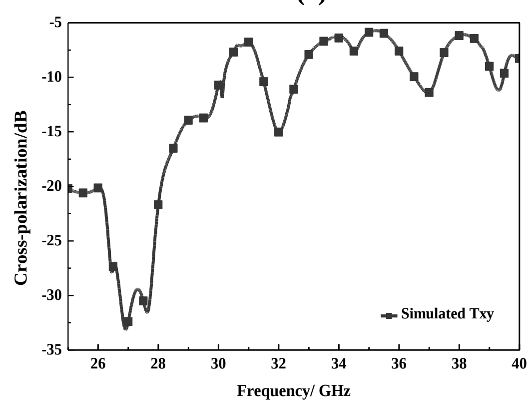
3. RESULT AND DISCUSSION

We simulated to characterize the efficiency of proposed structure, the co- and cross- polarization transmissions are simulated by using ANSYS HFSS. The structure is excited by floquet port with impinged of the polarized wave along the-direction. **(Fig 3(a) and (b))** show the transmission coefficients of co- and cross-polarizations. The transmission of T_{xx} are 6.11 dB (f_1 = 32.80GHz), 9.40 dB (f2 = 34.40GHz), 7.72 dB (f3 = 37.52 GHz) and 7.10 dB (f4 = 39.50GHz). The transmission of T_{xy} are to be 8.89 dB (f1), 7.22 dB (f2), 7.60 dB (f3), and 9.64 dB (f4).

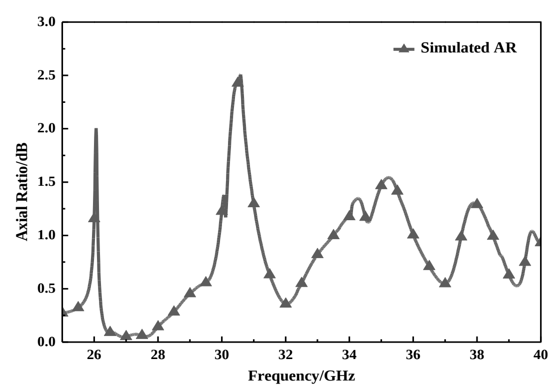
In order to pure circular polarization, the amplitude of the T_{xx} and T_{xy} coefficients should be approximately equal to each other and the phase difference between them must be $n\pi/2$. The axial ratio between transmitted waves is 0.72, 1.2, 1.0, and 0.74. The calculated phase differences are to be 258.70º (f1), -131.13º (f2), 250.17º (f3) and -93.46º (f4).The axial ratio bandwidth is achieved from 25GHz-40GHz, which are broader at 32.40–32.88GHz, BW= 1.47%, 32.89–35.12GHz, BW = 6.86%, 36.97–38.80GHz, BW = 3.16% and 39.11–40.0GHz, BW = 2.73%. The axial ratio bandwidth of 14.24% is achieved at four resonance frequencies. The RHCP waves are transformed at 32.40-32.88 GHz, 36.97-38.0 GHz and LHCP wave are transformed at 32.89-35.12 GHz, 39.11- 40.0GHz.



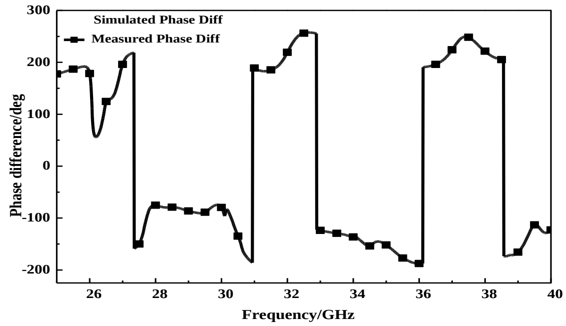
(a)



(b)



(c)

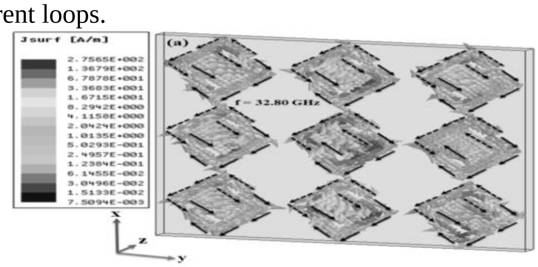


(d)

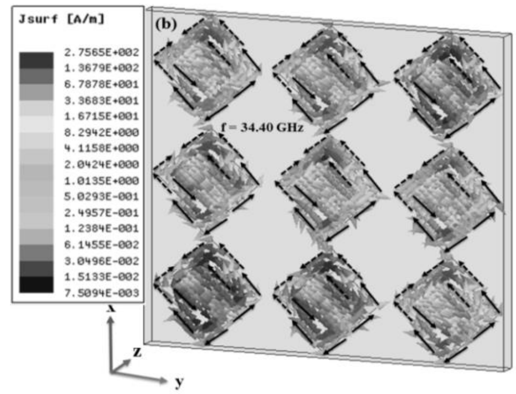
(Fig. 2 (a) and (b)) indicate the transmission coefficients of T_{xx} and T_{xy} versus frequency (c) represents the phase difference versus frequency and (d) denotes the axial ratio versus frequency.

To understand the physics of strong CD effect and optical activity of proposed design, the surface current distributions are illustrated on the interface of both sides of layers of as depicted in Fig. 4. The mechanism of strong CD effect can be interoperated by the coupling of the electric and magnetic field. In order to the direction of current distribution, the solid line arrows show the top surface currents with electric field direction and dash line arrow illustrates the bottom surface currents. The two current modes are possible in each H-shape SRR. One is dipole mode and another mode is loop mode which occurs on the top and bottom metallic layers under the incident of the electric field along the +z direction. The current loop mode occurs on both sides of the structure at the low frequency of 32.43 GHz. Meanwhile, the dipole current mode appears on the top and bottom metallic layers at 34.40 GHz, 37.52 GHz, and 39.50 GHz, respectively.

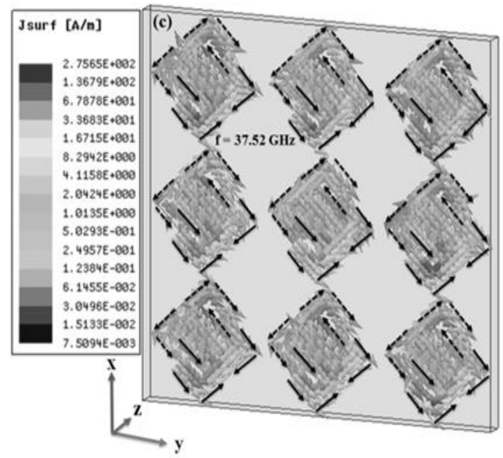
The surface currents distribution moves in same directions on top and bottom metallic layers at 32.43 GHz but overall structure possess the asymmetric transmission at 32.43GHz. The currents on both layers move antiparallel at 34.40 GHz, 37.52 GHz and 39.50 GHz which attribute to an asymmetric resonance mode. The currents determine the excitation of strong CD effect result from the dipole resonance at four distinct frequencies. Based on the direction of surface currents distributions on top and bottom layers, the antiparallel currents at all resonance frequencies show the effective current loops.



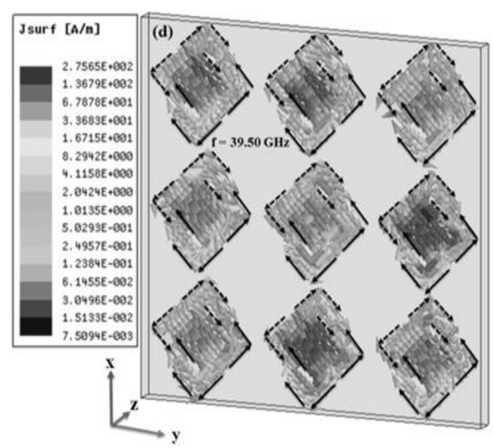
(a)



(b)



(c)



(d)

(Fig. 4 (a) and (b)) shows currents distribution on top and bottom structure at (a) f_1 = 30.24 GHz, (b) f_2 = 33.90 GHz, (c) f_3 = 35.40 GHz, and (d) f_4 = 38.82 GHz.

The currents move antiphase between layers as shown in **(Fig. 4 (a) and (b)).** The inphase and antiphase currents represent the electric and magnetic response (Singh, *et al.,* 2011). (Shi, *et al.,* 2012) (Huang, *et al.,* 2013) The incident wave produces the current loops in printed layers which create the magnetic dipole moment. The response of electric and magnetic field exist no only on the metallic surface but also between two layers due to strong coupling effect (Ye and He, 2010) (Huang, *et al.,* 2013).

4. CONCLUSION

The compact four-band asymmetric circular polarizer based on H-shape SRR structure. The simulation results have demonstrated that 90^{o} polarization rotation is obtained at four bands. The surface current distribution is illustrated to understand the strong CD effect at operated frequency bands. The compact four-band asymmetric circular polarizer is assessed with HFSS simulation. The designed structure has good advantages such as easy fabrication, compact size, simple structure, high transmission efficiency and compact size.

REFERENCES:

Cheng, Y., R. Gong, Z. Cheng and Y. Nie. (2014) "Perfect Dual-Band Circular Polarizer Based on Twisted Split-Ring Structure Asymmetric Chiral Metamaterial." Applied Optics, 53, 25 , 5763-5768.

Hongya C., H. Ma, J. Wang (2016) “Ultra-wideband transparent 90^{o} polarization conversion metasurfaces”, Appl. Phys. V. 122: No. 463, 2-5.

Hailin C., J. Liang, X. Wu (2016) “Dual-band polarization conversion based on non-twisted Q-shaped met surface” Optics Communications 370, 311–318

Huang, C., X. Ma, M. Pu, G. Yi, Y. Wang, and X. Luo, (2013) “Dual-band 90° polarization rotaor using twisted split ring resonators array,” Opt. Commun.; 291, 345–348.

Huang, C., X. Ma, M. Pu, G. Yi, Y. Wang, and X. Luo, (2013) “Dual-band 90° polarization rotaor using twisted split ring resonators array,” Opt. Commun.; 291, 345–348.

Lin W., Z.Y. Yang, M. Zhao, P. Zhang, Z. Q. Lu, Y. Yu, S. X. Li, and X. H. Yuan. (2013) "Giant Asymmetric Transmission of Circular Polarization in Layer-by-Layer Chiral Met materials." Applied Physics Letters,; 103, 21903-6.

Mingbao Y., J. Wang, H. Ma, (2016) “A Tri-Band, Highly Selective, Bandpass FSS Using Cascaded Multilayer Loop Arrays” IEEE Transactions on Antennas and Propagation, Vol. 64, No. 5, 2046-2049

Shi H-Yu., L. Jian-Xing, Z. An-Xue, (2014) “Tri-band transparent cross-polarization converters using a chiral met surface” Chin. Phys. B, 23(11), 118101-7

Singh, R., I. A. I. Ai-Naib, M. Koch, and W. L. Zhang, (2011) “Sharp Fano resonances in THz metamaterials,” Opt. Express,; 19, 6312–6319.

Shi, J. H., Z. Zhu, H. F. Ma, W. X. Jiang, and T. J. Cui, (2012) “Tunable Symmetric and Asymmetric Resonances in an asymmetrical split-ring metamatrial,” J. Appl. Phys.; 112, 073522

Wu S., H. Xiao-Jun, X. Bo-Xun, (2014) “Multi-band circular polarizer based on a twisted triple split-ring resonator” Chinese Physics B, 23(12), 01-06.

Xi-Cheng Z., W. Hong, K. Wu (2014) “Design of a Bandwidth-Enhanced Polarization Rotating Frequency Selective Surface” IEEE Transactions on Antennas and Propagation, 62(2): 940-944

Ye. Y. and S. He, (2010) “90° Polarization Rotator using a Bilayered Chiral Metamaterial with giant optical activity,” Appl. Phys. Lett.; 96, 203-501.

Yuan, W., H. Zhang, and Y. Cheng. (2014) "Asymmetric Chiral Met material Multi-Band Circular Polarizer Based on Combined Twisted Double-Gap Split-Ring Resonators." Progress In Electro-magnetic Research C, Vol. 49, 141-147,

Yong Z. C., Y. Nie, Z. Cheng, and R. Z. Gong. (2014) "Dual-Band Circular Polarizer and Linear Polarization Transformer Based on Twisted Split-Ring Structure Asymmetric Chiral Met material." Progress In Electromagnetic Research, Vol. 145, 263-272,

Zhimou Z. and H. Yang, (2015) “Triple-band asymmetric transmission of linear polarization with deformed S-shape Bilayer Chiral Metamaterial”, Appl. Phys. A,, 119, 115–119