TRI-BAND LINEAR T-CIRCULAR POLARIZATION CONVERTOR FOR KU BAND APPLICATIONS

Farman Ali Mangi, Deedar Ai Jamro, Memon Imran, Qasim Ali Arain, Ghulam Fatima Kake poto

Abstract-A tri-band linear-to-circular polarization convertor is proposed which is composed of 3x3 metallic strips array printed on both sides of the dielectric substrate. The linear-to-circular polarization conversion is obtained by decomposing the linearly incident x-polarized wave into two orthogonal vector components of equal amplitude and 90° phase difference between them. The simulation results demonstrate that proposed structure can work at 12.62 GHZ, 15.03 GHz and 16.25 GHz with low loss and high polarization conversion ratio. Proposed structure achievesa right circularly polarized (RHCP) wave from 14.01GHz-15.25GHz and 16.25GHz-16.45GHz. The accumulative axial ratio bandwidth of 10.25% is obtained ranging from 12.0 GHz-18 GHz.

IndexTerms- Axial ratio (AR), single-layer polarizer, circular Co and cross-polarization, quarter wave plate, met material

I. INTRODUCTION

Polarization is an important property of electromagnetic (EM) waves, which is widely used in various electromagnetic waves applications.

The circularly polarized wave has been widely used in satellite communications systems and remote sensing because it achieves the lower susceptibility.Polarizer is an important method to realize required polarization wave.

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Circular polarizer can transfer the linearly polarized wave into circular polarized wave under the normal incidence of plane wave. According to existing research, circular polarizer can be designed by employing photonic [1-3], chiral structures [4-8], metasurface, metamaterials[9], meander-line [10], slots of different structures [11,12], waveguide [13,14], grating structures [15,16], quarter wave plate [17-18], etc.

Widening bandwidthis an important issue in polarizer research.However, lots of polarizers, such as the metamaterial polarizer, usually operate over narrowband. The circular dichroism was obtained across a narrow band at resonance frequencies [19].The polarization characteristics of transmitted wave of dual-band asymmetry chiral metamaterial structure was demonstrated in [20, 21]. In [22-25], the gold helix MMs and the stacking multiple polarizerswere presented to broadened the bandwidth. Another way of improving bandwidth is to employ the substrate with low thickness and low permittivity and use multi-layer periodic arrays structure [26-28].

In this paper, a broadband single-layer circular polarizer is presented based on metallic strips array printed on both sides of dielectric substrate. The transmission characteristicsof the proposed circular polarizer have been investigated on the operation frequency bands. The designed structureachievesRCP wave at broadband. The significantadvantages of this proposed structure compared with reported circular polarizers are such as; the unit cell of structure is small, simple and easy fabrication. Eventually, the broadband circular polarizer is fabricated and the measured results are in very good agreements to numerical simulation results.

II. DESIGNE OF STRUCUTRE

Figure 1 depicts the unit cell of tri-band linear-to-circular polarization convertor. The two metallic strips with same size are printed on the both sides of single layer with different directions in XOY plane. The top printed strip is tilted at 45^o and the bottom strip is slanted at 90^o along XOY plane, respectively. The substrate is chosen with relative permittivity$\mathcal{E}r$and thickness *t*. The length and the width of the metallic strips are represented by *l* and *w*, respectively, whereas, the thickness of strips is assumed to be negligible. The periods of the unit

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cell are represented by p_x and p_y in x and y directions, respectively.

Figure 1 depicts the schematics of unit cell geometry of bi-layer cross shaped circular polarizer. The two metallic strips with same size are printed on both sides of single layer with different directions in XOY plane. The top printed strip is tilted at 45^o and the bottom strip is slanted at 90^o along XOY plane, respectively. The substrate is chosen with relative permittivity and thickness *t*. The length of strips is *l* and width is *w*, respectively, and thickness of strips is assumed to 0.01 comparing to operational wavelength. The periods of the unit cell are represented by *px* and *py*, respectively. The dielectric substrate Roger RT/duroid5880 is employed in this design. The selected parameters are as =2.2 with loss tangent of 0.0009, *t* = 0.787 mm, *l* = 8 mm, *w* = 3 mm, *px* = 14mm and *py* = 14mm, respectively.

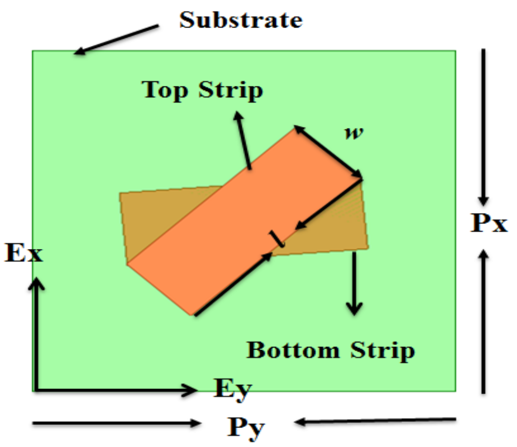

Figure.1: Geometry of the unit cell of Tri-band circular polarizer

I. OPERATING PRINCIPLE

When the linearly polarized incident plane wave E_x^i projects on the polarizer, the transmission *E* field can be decomposed into two orthogonal vector components E_x and E_y. The incident x-linearly polarized wave can be expressed as$\boldsymbol{E}_i = \hat{x}E_0 e^{-ik_z z}$. The transmitted wave can be obtained under the normal incident of electric field and expressed as

$$E_T = \hat{x}T_{xx}E_0 + \hat{y}T_{xy}E_0 \qquad (1)$$

The transmission coefficients of E_x and E_y components can be defined as

$$T_{xx} = t_{xx}e^{i\phi xx}, T_{xy} = t_{xy}e^{i\phi xy} \qquad (2)$$

Where, t_{xx} and t_{xy} are represented as the amplitudes and φ_{xx} and φ_{xy} are represented as the phases of the transmission coefficients T_{xx} and T_{xy}, respectively. In general, realization of circularly polarized wave requires the generation of two orthogonal vector components of approximately equal magnitudes with a 90^o phase shift between two transmitted components E_x and E_y.

Assuming that $T_{xx} = E_x^t/E_x^i$ and $T_{xy} = E_y^t/E_x^i$ represent the transmittance of *x*-to-*x* and *x*-to-*y* polarization conversions through the structure. Meanwhile, under the certain coordinate system, the two decomposed components of transmitted linearly polarized waves E_x^t andE_y^t through the bottom layer can be employed as linearly incident polarized waves E_x^i and E_y^i for another stacked top strip along the +z direction. Thus, the two more pairs of orthogonal vector components can be generated at the other side of stacked layer. Therefore, the strong circular dichroism is achieved at the end of structure which realizes the novel approach of “fission yields vector components of electromagnetic waves”.

II. SIMULATION RESULTS

Figure 2 represents the transmission characteristics of T_{xx} and T_{xy}. The transmission coefficients of T_{xx} are achieved as 13.43 dB at f1, 15.47 dB at f2 and 8.69 dB at f3 the transmission coefficients of T_{xy} are achieved as 19.43 dB at f1, 13.17 dB at f2 and 6.60 dB at f3, respectively. The calculated axial ratio can be seen as 1.4 dB at f1, 0.85 dB at f2 and 0.76 dB at f2, respectively as shown in Figure 3. The corresponding axial ratio bandwidth is achieved at frequency bands ranging from 13.28 GHz – 13.37GHz at f1 = 0.6% BW, 13.51 GHz – 13.65 GHz at f2 = 0.93% BW and 15.26GHz–15.80GHz at f3 = 3.60% BW, respectively. The corresponding phase difference is calculated to be -101.01o at (f1), 90.80o at f2 and 247.39o at f3, respectively as denoted in Figure 4. The accumulative bandwidth of proposed structure is calculated as 5.13% BW, respectively.

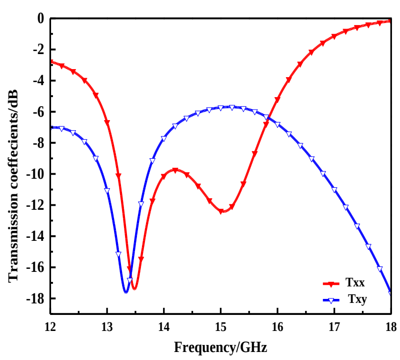

Figure.2: Represents the transmission coefficients T_{xx} and T_{xy} versus frequency

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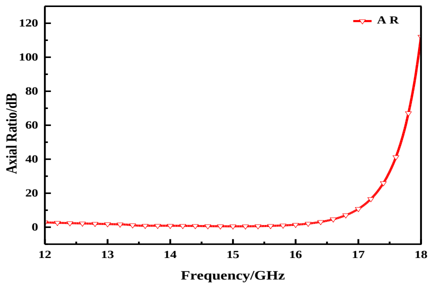

Figure.3: Depicts the axial ratio of transmitted waves versus frequency

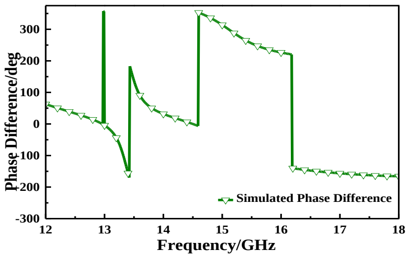

Figure.4: Shows Phase differences between transmitted waves versus frequency

A finite array is used to measure the performance of the proposed structure. Fig. 5 shows the perspective view of polarizer which consists of 3x3 periodic metallic strips array printed on top and bottom sides of the single layer substrate. Thearray occupies an overall area of 42mm x 42mm.

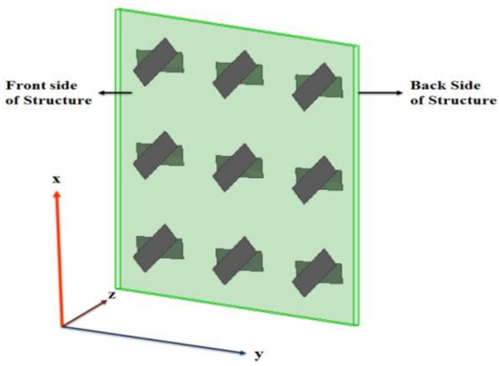

Figure.5: represents the simulation model of circular polarizer based on periodic metallic strips array

In simulation results, the co-polar coefficient are 11.88 dB, at f1 = 12.63GHz, and 16.81 dB at f2 = 15.03GHz and 17.18 dB at f3 = 16.25GHz, respectively and cross polar are 12.16 dB at f1, 9.0 dB at f2 and 10.42GHz at f3, respectively as shown in Fig. 6. The values of axial ratio are 1.0 dB at f1, 0.53 dB at f2 and 0.60 dB at f3, respectively as shown in Fig. 7. The phase differences between cross-co-polarization are presented in Fig. 8. The corresponding phase difference is calculated to be -132.79^{o} at f1, 270.35^{o} and 75.54^{o} at f3 are achieved at distinct frequency bands. Fig. 7 represents the large axial ratio bandwidths ranging from 12GHz-18GHz which are contained at 12.54GHz-12.64GHz, BW = 0.66%, 14.01GHz-15.25GHz, BW=8.26% and 16.25GHz-16.45GHz BW= 1.33%, respectively. The accumulative axial ratio band width is calculated as 10.25%.

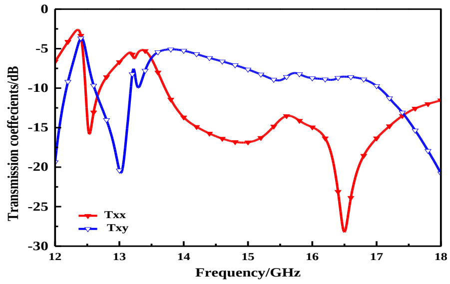

Figure.6: shows results for transmission coefficients of T_{xx} and T_{xy} versus Frequency

Initially, numerical simulation is used to evaluate the performance of the 3x3 metallic strips array. The excitation of port 1 and port 2 is provided with orthogonal waves represent the vertically (E_x) and horizontally (E_y) polarized vector components, respectively. The wave port 1 is excited by *x*-linearly polarized wave along +z direction.The boundary conduction of perfect electric conductor (PEC) and perfect magnetic conductor (PMC) are assigned in *x* and *y* axis direction to support the incident plane wave. In simulation, the transmission coefficients of the polarizer composed of 3x3 metallic strips array is obtained.

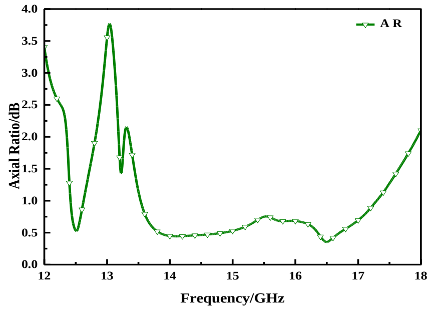

Figure.7: represents the simulated results for axial ratio of transmitted wave versus frequency

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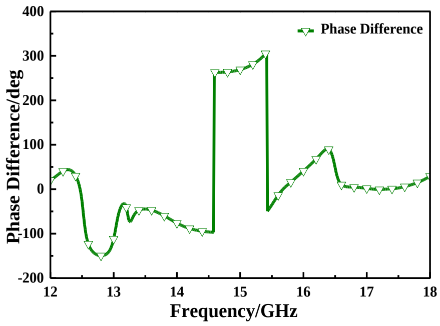

Figure.8: indicates the phase difference versus frequency of designed structure

III. CONCLUSION

In conclusion, we have proposed tri-band linear-to-circular polarization convertor. The designed structure demonstrates strong co- and cross polarization transmission. The object of this research is to evaluate the transmission characteristics of proposed structure at resonance frequencies. The performance of polarizer is computed with HFSS simulation. The proposed structure has good circular polarization efficiency; axial ratio bandwidth of 10.25% is obtained. The designed model is simple and can be easily fabricated. Moreover, it is possible to enhance the bandwidth performance by changing some parameters of structures, such as, size of strips, thickness of substrate and strips, by changing the orientation of strips as well.

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